ЎЗБЕКИСТОН МИЛЛИЙ УНИВЕРСИТЕТИ
ҲУЗУРИДАГИ ИЛМИЙ ДАРАЖАЛАР БЕРУВЧИ
DSC.03/30.12.2019.FM.01.02 РАҚАМЛИ ИЛМИЙ КЕНГАШ
МИСРНИНГ ЖАНУБИЙ ВОДИЙ УНИВЕРСИТЕТИ

ЭЛ-САИД МОХАМЕД АБО-ДАХАБ ХЕДАРИ

ҚАЙТУВЧИ ВА УЗАТИЛУВЧИ МАГНИТО-ТЕРМОЭЛАСТИК ТЎЛҚИНЛАР ВА СИРТ ТЎЛҚИНЛАРИНИНГ ТАРҚАЛИШ МАСАЛАЛАРИНИ МАТЕМАТИК МОДЕЛЛАШТИРИШ

05.01.07 – Математик моделлаштириш. Сонли усуллар ва дастурлар мажмуи
(физика-математика фанлари)

ИЛМИЙ МАЪРУЗА ШАКЛИДАГИ ФИЗИКА-МАТЕМАТИКА ФАНЛАРИ ДОКТОРИ (DSc) ДИССЕРТАЦИЯСИ

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Диссертация автореферати 2020 йил «____» ноябрь куни тарқатилди.
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КИРИШ (фан доктори (DSc) диссертацияси аннотацияси)

Диссертация мавзусининг долзарблиги ва зарурати. Жаҳон миқёсида олиб борилаётган кўплаб илмий-амалий тадқиқотларда электромагнит майдони, ротация, иссиқлик майдони, фототермик, яримўтказгичлар, бўшлиқлар каби турли жараёнларнинг тўлқин тарқалишига таъсирини эътиборга олувчи термоэластик масалаларга, айниқса қайтарилувчи, узатилувчи (refraction) ва Релей, Стоунли ва Ляв каби сирт тўлқинларини тадқиқ этишга катта эътибор қаратилмоқда. Юқорида зикр этилган тўлқин тарқалиш масалаларини ечиш муҳандислик, геофизика, материалшунослик ва геология соҳалари учун жуда муҳимдир. Шу сабабли буралиш, электромагнит майдон, бошланғич кучланиш, фототермик каби ташқи таъсирларни ҳисобга олган ҳолда тулқин тарқалиш жараёнларининг хоссаларини ўрганиш амалий математика соҳасининг муҳим вазифалардан бири бўлиб қолмоқда.

Ҳозирги кунда жаҳонда муҳандислик масалаларининг математик моделларини яратишга ва уларнинг сифат хоссаларини тадқиқ қилишга катта эътибор қаратилмоқда. Жумладан, қайтувчи ва узатилувчи тўлқинларнинг тарқалиш масаласи, қайтувчи ва узатилувчи тўлқинлар амплитудасини, қайтиш ва синиш коэффициентларини топиш, тўлқинлар хавфсизлигини аниқлаш, ротация, электромагнит майдон, бўшлиқлар, бошланғич кучланиш ва тўлқинлар тарқалиши диффузияси каби ташқи факторларнинг қайтиш ва синиш коэффициентларига ижобий ёки салбий таъсирини аниқлаш, гравитация, электромагнит майдони, ротация, диффузия ва бўшлиқ каби ташқи таъсирларнинг жисм зарраларининг кўчиши ва температурасига ўзаро таъсири масаласини ечиш; “сирт тўлқинлари”, айниқса, зилзила ва вулқонлар ҳамда кўп қатламли муҳитлар хусусиятларининг сирт тўлқинлари тарқалишига таъсирини ўрганиш мақсадли илмий тадқиқотлардан ҳисобланади.

Миср ва Ўзбекистон Республикасида фундаментал фанларнинг илмий ва амалий тадбиқига эга бўлган магнито-термоэластиклик назарияси, туташ муҳитлар механикаси, яримўтказгичлар физикаси каби соҳалардаги ностационар масалаларининг сонли ечиш усулларини яратишнинг долзарб йўналишларига алоҳида эътибор кучайтирилди. Бу йўналишда юқори аниқликка эга сонли ечиш усулларни қуриш ва уларни такомиллаштиришга бағишланган қатор илмий тадқиқотларни амалга оширишда салмоқли натижаларга эришилди. Дифференциал тенглама ва математик физика, динамик тизимлар назарияси ва математик моделлаштириш каби фанларнинг устувор йўналишлари бўйича халқаро стандартлар даражасида илмий тадқиқотлар олиб бориш амалий математика фанининг асосий вазифалари ва фаолият йўналишлари этиб белгиланди[1]. Қарор ижросини таъминлашда буралиш, электромагнит майдон, бўшлиқ, диффузия каби таъсирларни

[1] Ўзбекистон Республикаси Вазирлар Маҳкамасининг 2017 йил 18 майдаги “Ўзбекистон Республикаси Фанлар академиясининг янгидан ташкил этилган илмий-тадқиқот муассасалари фаолиятини ташкил этиш тўғрисида”ги 292-сон қарори.

ҳисобга олган ҳолда термоэластиклик назариясини ривожлантириш муҳим аҳамиятга эга.

Ўзбекистон Республикаси Президентининг 2017 йил 7 февралдаги ПҚ-4947 «Ўзбекистон Республикасини янада ривожлантириш бўйича ҳаракатлар стратегияси тўғрисида»ги; 2017 йил 17 февралдаги ПҚ-2789 «Фанлар академияси фаолияти, илмий-тадқиқот ишларини ташкил этиш, бошқариш ва молиялаштиришни янада такомиллаштириш чора-тадбирлари тўғрисида»ги; 2017 йил 20 апрелдаги ПҚ-2909 «Олий таълим тизимини янада ривожлантириш чора чора-тадбирлари тўғрисида»ги ва 2018 йил 27 апрелдаги ПҚ-3682 «Инновацион ғоялар, технологиялар ва лойиҳаларни амалиётга жорий қилиш тизимини янада такомиллаштириш чора-тадбирлари тўғрисида»ги қарорлари, Ўзбекистон Республикаси Президенти Ш.М. Мирзиёевнинг 2019 йил 24 май куни Ўзбекистон Миллий университетида таълим ва илм-фан соҳаси вакиллари билан бўлиб ўтган учрашувидаги маърузаси, Мисрнинг 2030 йилгача ривожланиш концепцияси ҳамда мазкур фаолиятга тегишли бошқа норматив-ҳуқуқий хужжатларда белгиланган вазифаларни амалга оширишда ушбу диссертация тадқиқоти муайян даражада хизмат қилади.

Тадқиқотнинг республика фан ва технологиялари ривожланишининг устувор йўналишларига боғлиқлиги. Мазкур тадқиқот республика фан ва технологиялар ривожланишининг IV. «Математика, механика ва информатика» устувор йўналиши ва Мисрнинг 2030 йилгача ривожланиш концепциясининг 3-компоненти “Фан, инновация ва илмий тадқиқотлар” доирасида бажарилган.

Диссертация мавзуси бўйича хорижий илмий-тадқиқотлар шарҳи[2]. Магнито-термоэластик умумий назарияси масалаларини ечиш бўйича илмий изланишлар жаҳоннинг етакчи олий таълим муассасалари ва илмий марказлари, жумладан, Cambridge, Manchester, Liverpool, Oxford University of Charleston, Edinburgh, Chester университетлари (Буюк Британия), Orlando ва Florida университетлари (АҚШ), БАА университети (ал-Айн), Султон Қобус университети (Уммон), Martin Loter университети (Германия), South Valley, Al-Azhar ва Assuit университетлари (Миср), Taif University (Саудия Арабистони), Aegean, Karlovassi ва Samos университетлари (Греция), Amsterdam University (Нидерландия), Melbourne, Queensland Universities (Австралия), Russian Institute of Computational Mathematics, Perm Scientific Center of Ural Branch of Russian Academy of Sciences (Россия), Institute of Cybernetics (Украина), Institute of Integrated Informatics Problems of the National Academy of Sciences of Belarus (Белоруссия), Ўзбекистон Миллий университети, Механика институти, Сеймология институти, Бухоро Давлат университети, Самарканд давлат университети, Ургенч давлат универитети,

[2] Диссертация мавзуси бўйича хорижий илмий-тадқиқотлар шарҳи http://www.eriez.com/, http://docs.lib.purdue.edu/, https://www.ihs.com/, http://www.cargocaresolutions.com/, http://www.sciencedirect.com/, http://link.springer.com/, http://www.iccm-central.org/, http://www.university-directory.eu, http://www.digitimes.com/, www.webofknowledge.com, www.scholar.google.com ва бошқа манбалар асосида ишлаб чиқилган.

Тошкент тўқимачилик ва енгил саноат институтларида олиб борилмоқда.

Магнито-термоэластик умумий назарияси масалаларини ечишга оид жаҳонда олиб борилган тадқиқотлар натижасида қатор илмий натижалар олинган, жумладан: тўлқинларни акс эттириш, узатиш, сирт тўлқинларининг тарқалишини ва таъсирини, айниқса, Ралей , Стонелей ва Лов тўлқинларининг физик маъносини ва таъсирини кўрсатиш учун математик моделлаштириш тенгламаларини қуришга қаратилган муҳим натижалар олинган (Oxford University of Charleston, БАА университети, Taif University, Amsterdam University), муҳандислик, астрономия, акустика, геофизика, нефт қазиб олиш каби турли соҳаларда кўп қўлланиладиган масса узатиш, тўлқин тезлиги ва сусайиши коеффициентлари ўрганилган (Russian Institute of Computational Mathematics, Perm Scientific Center of Ural Branch of Russian Academy of Sciences, Martin Loter университети).

Дунёда термоэластиклик назариясининг бир қатор устувор йўналишларида илмий тадқиқот ишлари олиб борилмоқда, жумладан: аналитик кесма тўлқинларининг тарқалиш тезлиги тарқалиш йўналишига, анизотропияга, магнит майдонига, айланишга, гравитацион майдонга, муҳитнинг бир жинссизлигига ва бошланғич зарбага боғлиқлигини асослаш; кесиш тўлқинларининг тезлигини аниқловчи частота тенгламасини ечиш; термоэластиклик назарияси масалалари учун самарали сонли схемаларни ишлаб чиқиш ва асослаш ҳамда ҳисоблаш экспериментлари ўтказишга мўлжалланган дастурий воситалар яратиш.

Муаммонинг ўрганилганлик даражаси. Термоэластиклик назариялари фан, технология, астрономия, геология, нефт қазиб олиш ва акустика каби турли соҳаларда кенг қўлланилади. Термоэластиклик назариясида деформация тезлиги тушунчаси киритилган бўлиб, у Фурье иссиқлик ўтказувчанлик тенгламаси орқали ифодаланади. Динамик боғланган классик назария эса M.A.Biot томонидан киритилган. H.W. Lord, Y.Shulman, A.E.Green ва K.A.Lindsay лар томонидан термоэластикликнинг умумлашган формаси таклиф этилган бўлиб, қаттиқ жисмларда иссиқлик тўлқинларининг чекли тезликда тарқали исботланган. Термал босимнинг умумлашган магнито-термоэластик тўлқинларга таъсири M.A.Ezzat, M.I.A.Othman, A.S.El-Karamany лар томонидан ўрганилган. Аксарият ҳолларда классик ёки термоэластик жараёнларни ўрганиш учун Lameнинг потенциал функцияси кенг қўлланилади. Бироқ L.Y.Bahar, R.Hetnarski, H.Sherief томонидан потенциал функцияларнинг қўлланилишида вужудга келадиган камчиликлар очиб берилган. H.Sherief, M.Anwar, H.M.Youssef, A.A.El-Bary, K.Elsibai каби олимлар томонидан чегараланмаган цилиндрда икки ўлчамли умумлашган термоэластик масаласи ечилган.

Умумлашган термоэластикликнинг турли назариялари нуқтаи назаридан бошланғич кучланиш шароитида чизиқли термоэластикликдаги чегараланмаган изотропик муҳитда ясси тўлқинларнинг қайтиш ва синиш ҳодисалари A.Chattopadhyay, S.Bose, M.Chakraborty, A.Montanaro, M.I.A.Othman, Y.Song, B.Singh, P.J.Chen, M.E.Gurtin, H.M.Youssef, E.A.Al-Lehaibi, M.Schoenberg, D.Censor каби олимлар томонидан ўрганилган.

Айланма ҳаракат қилувчи муҳитларнинг термоэластиклик масалалари P.Puri, S.K.Roy Choudhuri, L.Debnath, A.E.Abouelregal, K.Lotfy, S.Banerjee, A.M.Abd-Alla, A.J.Alqarni, F.Alshaikh, D.Del Vescovo, M.Spagnuolo, F.S.Alzahranilар томонидан; умумлашган муҳитлар учун F.dell'Isola, U.Andreaus, L.Placidi, P.Seppecher, A.Madeo, G.Sciarra, O.Coussy, D.Steigmann, A.Romanoлар томонидан; юқори градиентли ҳолда J.J.Alibert, P.Seppecher, C.Pideri ва F.dell'Isolaлар томонидан; сонли ва экспериментал усулда A.Berezovski, I.Giorgio, A.Della Corte, U.Andreaus, L.Galantucci, A.M.Hamdan, D.Del Vescovo, M.Laudato, L.Manzari, E.Barchiesi, F.Di Cosmo, P.Göransson, E.Barchiesi, M.Laudato каби олимлар томонидан тадқиқ этилган.

Турли назарияларга асосланган тўлқин тарқалиш масалалари S.Kundu, P.Alam, S.Gupta, S.R.Mahmoud, A.M.Zenkour, S.Kundu, P.Alam, N.Das, S.De, N.Sarkar, M.Othman, Y.Song, Х.А.Рахматулин, Т.Буриев, Б.Мардонов, М.Мирсаидов, К.Султонов ва бошқалар илмий изланишларида мунтазам тадқиқ қилинаётган бўлсада, турли муҳитларда тўлқин тарқалишнинг термоэластиклик назарияси бўйича мавжуд ёндошувлар асосидаги назариялар ва унинг амалиётга тадбиқи ҳозирда ўз ечимини топмаган.

Тадқиқотнинг мақсади – муҳандислик, геофизика, биология, материалшунослик ва нефт қазиб олиш соҳалари учун термоэластиклик назарияси асосида тўлқинларнинг қайтиш, узатиш ва тарқалиш жараёнлари математик ва сонли моделлаштириш, ташқи таъсирлар остида тўлқинларнинг тарқалиш тезлиги, амплитудаси ва сўниш коэффициентларини аниқлашдан иборат.

Диссертация мавзусининг диссертация бажарилган илмий-тадқиқот муассасасининг илмий-тадқиқот ишлари билан боғлиқлиги. Диссертация тадқиқоти South Valley ва Assuit (Миср) университетларининг "Магнито-термоэластиклик назарияси масалаларини ечиш" мавзусидаги илмий тадқиқот ишлари режаси доирасида бажарилган.

Тадқиқотнинг вазифалари:

электромагнит тўлқин, буралиш, бўшлиқ ва диффузия каби ташқи таъсирларни ҳисобга олган ҳолда термоэластиклик назариясида янги типдаги тўлқинларни таклиф этиш ва асослаш;

ҳаракат тенгламалари, иссиқлик тарқалиш тенгламаси, диффузия тенгламаси ва бўшлиқлар тенгламаларидан ташкил топган математик моделларни қуриш;

ҳаракат, иссиқлик тарқалиш, диффузия ва бўшлиқ тенгламалари системасини ечиш моделларини ишлаб чиқиш;

ташқи таъсирлар остида тўлқинларнинг тарқалиш тезлиги, амплитудаси ва сўниш коэффициентларини аниқлаш;

ҳаракат, иссиқлик тарқалиш, диффузия ва бўшлиқ тенгламалари системасини сонли ечиш, тарқалиш жараёнлари учун амплитуда, ҳарорат, босим ва ташувчи зичлигини ҳисоблаш экспериментларини ўтказиш.

Тадқиқотнинг объекти - Термоэластиклик назарияси ва Lord-Shulman, Green-Linsay, Tzou, Green-Nagdhi (I, II ва III типлар) назариялари, энергия тарқалиш, электромагнит майдонлари, диффузия жараёнларидан иборат.

Тадқиқотнинг предмети термоэластиклик назариялари учун сонли моделлаштириш усулларини, алгоритмлари ва дастурий мажмуаларни яратишдан иборат.

Тадқиқотнинг усуллари. Диссертацияда ишида термоэластиклик назариялар: классик динамика (CD), Lord-Shulman, Green-Lindsey, Тзоу назарияси, Green-Nagdhi (I, II ва III турлари), математик моделлаштириш, сонли ечиш усулларb, Ляменинг потенциаллар функцияларидан фойдаланилган.

Олинган компонентлар бўйича иссиқлик оқимининг айланиш ва сўниши учун фарқлар график тасвирларда ҳосил қилинган.

Тадқиқотнинг илмий янгилиги:

умумлашган магнит-термоэластик назарияси доирасида кучланиш (shock), термал ташқи кучлар остида бўлган икки ўлчовли ярим текисликда ротация, бўшлиқлар, диффузия, фототермал, яримўтказгичлар каби факторларни ҳисобга олган ҳолда “бошланғич кучланиш” ва икки параметрли температураларни ўз ичига олган термоэластик моделлар яратилган;

термоэластик моделлар учун Ляме потенциаллар усули ёрдамида бир релаксацион вақтли ва тўлқин тезлигининг чексизлигини инобатга олучи Lord-Shulman масаласи ечилган;

икки релаксацион вақтга боғлиқ ҳолда Green-Lindsay, Green-Nagdhi, Dual-Phase-Lag, Three-Phase-Lag термоэластиклик назариялари доирасида чекли тўлқин тезлигини аниқлаш масаласи ечилган;

бошланғич кучланишлар таъсирида термоэластик тўлқинларининг магнитланган қаттиқ-суюқ жисмлар чегарасида қайтиш ва ўтказувчанлик (синиш) масалалари ечилган;

термоэластикликнинг GL ва CT назариялари доирасида магнит майдоннинг, ташқи иссиқлик манбаларининг ва бошланғич кучланишларнинг p, T ва SV тўлқинларнинг тарқалишига таъсири аниқланган;

электромагнит майдон, фототермик, яримўтказгич, гравитацион майдон, ротация ва бошланғич кучланиш каби факторлар таъсирида бир жинсли бўлмаган анизотроп сиқилмайдиган муҳитда кўндаланг тўлқинларнинг тарқалиш масаласи ечилган;

сонли ҳисоблаш эксперименти натижаларининг таҳлиллари асосида кўндаланг тўлқинларининг тарқалиш тезлиги тарқалиш йўналишига, жисмнинг анизотроплик хоссасига, магнит майдонига, ротацион айланишга, гравитацион майдонга, муҳитнинг биржинли эмаслигига ва бошланғич кучланишларга боғлиқлиги кўрсатилган;

кўндаланг тўлқинларининг тезлигини аниқловчи частота тенгламаси олинган ва икки тушувчи p ва SV тўлқинлар учун қайтарувчанлик коэффициентлари топилган;

металлар учун тўлқин тарқалиши масалалари сонли ечилган ва натижалар график кўринишда тақдим этилган.

Тадқиқотнинг амалий натижалари. Муҳандислик, акустика, астрономия, геофизика, саноат ва биология соҳалари учун тўлқин тарқалиш жараёнларини сонли моделлаштириш усуллари ишлаб чиқилган, сонли ечиш алгоритмлари ва дастурлари яратилган.

Тадқиқот натижаларининг ишончлилиги. Олинган натижалар, тасдиқлар ва математик мулоҳазалар қатъий исботланган ва сонли тадқиқотлар натижалари билан тасдиқланган. Сонли натижалар мавжуд эксперимент натижалари билан таққосланган.

Тадқиқот натижаларининг илмий ва амалий аҳамияти. Тадқиқот натижаларининг илмий аҳамияти термоэластиклик назарияси учун янги типдаги математик моделлар қурилганлиги, умумлашган магнит-термоэластик назарияси доирасида кучланиш (shock), термал ташқи кучлар остида бўлган икки ўлчовли ярим текисликда ротация, бўшлиқлар, диффузия, фототермал, яримўтказгичлар каби омилларни ҳисобга олган ҳолда “бошланғич кучланиш” ва икки параметрли температураларни ўз ичига олган термоэластик моделлар яратилганлиги билан изоҳланади.

Тадқиқот натижаларининг амалий аҳамияти муҳандислик, астрономия, акустика, геофизика, нефт қазиб олиш каби соҳаларнинг амалий масалаларини ечишга хизмат қилади.

Тадқиқот натижаларининг жорий қилиниши. Муҳандислик, геофизика, биология, материалшунослик ва нефт қазиб олиш соҳалари учун термоэластиклик назарияси асосида тўлқинларнинг қайтиш, узатиш ва тарқалиш жараёнлари математик ва сонли моделлаштириш, ташқи таъсирлар остида тўлқинларнинг тарқалиш тезлиги, амплитудаси ва сўниш коэффициентларини аниқлашда олинган натижалар асосида:

икки релаксацион вақтга боғлиқ холда Green-Lindsay, Green-Nagdhi, Dual-Phase-Lag, Three-Phase-Lag термоэластиклик назариялари доирасида чекли тўлқин тезлигини аниқлаш масаласини ечиш усулларидан хорижий илмий журналларда (Optics & Laser Technology, Volume 97, 1 December 2017, Pages 198-208; Chaos, Solitons & Fractals, Volume 99, June 2017, Pages 233-242; Applied Mathematics and Mechanics volume 39, 2018, pages783–796) сферик бўшлиққа эга термоэластик чексиз муҳитда бир ўлчовли тўлқин тарқалиш масаласини ечишда фойдаланилган. Илмий натижанинг қўлланилиши фототермик жараёнлар орқали эластиклик ва иссиқлик тўлқинини ҳисобга олган ҳолда тўлқин тарқалиш масаласини ечиш имконини берган.

бошланғич кучланишлар таъсирида термоэластик тўлқинларининг магнитланган қаттиқ-суюқ жисмлар чегарасида қайтиш ва ўтказувчанлик (синиш) масалалари ечимларидан хорижий илмий журналларда (Applied Mathematical Modelling, Volume 78, February 2020, Pages 148-168; J. Heat Transfer. Jul 2019, 141(7): 072002, 7 pages; Journal of Thermal Stresses, Volume 43, - Issue 6, 2020, Pages 667-686) сирт тўлқинлари асосида гидростатик бошланғич кучланишга эга икки ҳароратли умумлашган магнито-термоэластиклик тенгламаларини ечишда фойдаланилган. Илмий натижанинг қўлланилиши Рэле типидаги тўлқинлар учун частота тенгламасини ҳосил қилиш, тўлқин тарқалиш тезлиги ва ютилиш коэффициентини ҳисоблаш имконини берган.

Тадқиқот натижаларининг апробацияси. Тадқиқот натижалари 40 дан ортиқ халқаро илмий-амалий анжуманларда муҳокамадан ўтказилган.

Тадқиқот натижаларининг эълон қилинганлиги. Диссертация мавзуси бўйича Ўзбекистон Республикаси Олий Аттестация Комиссиясининг докторлик диссертациялари асосий илмий натижаларини чоп этиш тавсия этилган илмий нашрларда 100 тадан ортиқ илмий мақола нашр этилган.

Диссертациянинг тузилиши ва ҳажми. Илмий маъруза шаклидаги диссертация 98 саҳифадан иборат.

ДИССЕРТАЦИЯНИНГ АСОСИЙ МАЗМУНИ

Термоэластиклик назарияси фан, муҳандислик, акустика, астрономия, тузилмалар, нефт қазиб олиш ва бошқа турли соҳаларда кўпроқ қўлланилади. Бу ерда хабар қилинган диссертация ишида дастлаб эластиклик, иссиқлик майдони, электромагнит майдон, айланиш, бошланғич кучланиш, бўшлиқлар, фототермик, яримўтказгич ва диффузия орасидаги бир қанча боғланишлар асослаб берилган. Айланиш таъсири, электомагнит майдон, бўшлиқлар, диффузия, яримўтказгичлар ва иссиқлик релаксация вақти тўлқинларнинг тарқалишига (яъни, тўлқинларнинг тарқалишига "акс ва/ёки синиши" ёки сирт Стонелей, Лове ва Райлеигҳ тўлқинлари ўрганилган. Умумлашган магнето-термоэластиклик контекстида ҳаракат тенгламаси, иссиқлик тенгламаси ва воид тенгламасининг илашиш туфайли бу соҳада бажарилган ишлар афсуски, сон жиҳатдан чегараланган. Дунъёвий тенглама бўйича, Стонелей тўлқинлари тезлиги ва магнит майдони, айланиш, бўшлиқлар ва релаксация вақти сифатида ташқи параметрлар сусайтириши коэффициентларига таъсир килади. Олинган компонентлар бўйича иссиқлик оқимининг айланиш ва сўниши учун фарқлар график тасвирларда ҳосил қилинди.

Магнит майдони, бўшлиқлар параметрлари, фототермик, яримўтказгичлар, дастлабки зўриқиш ва термик релаксация вақтларининг таъсири акслантириш ёки/ва рефраксия ҳамда сирт тўлқинларининг тарқалиш ҳодисаларида жуда кўп намоён бўлади, деган хулосага келинаган. Олинган натижалар муҳандислик, тузилмалар, акустика, астрономия, геофизика, нефт қазиб олиш, тармоқлар ва биология соҳалари учун жуда фойдали эканлиги маълум бўлган.

Ушбу диссертацияда термоэластиклик назарияси ва ташқи параметрлар, тўлқинлар ёки сирт тўлқинларининг тарқалиши тахминига кўра термоэластиклик ва магнето-термоэластиклик бўйича баъзи муаммолар мавжуд: электромагнит майдони, иссиқлик майдони, бошланғич кучланиш, бўшлиқлар, фототермик, ярим ўтказгич, айланиш ва диффузия.

Шуни таъкидлаш керакки, ушбу диссертация иши қуйидаги муаммоларни математик моделлаштиришни қамраб олган:

• Магнит майдони ва гидростатик бошланғич кучланиш P ва SV тўлқинларининг умумлаштирилган термоэластик қаттиқ ярим шарнинг акс еттириш ҳодисаларига таъсири.

• P ва SV тўлқинларининг магнит майдон ва гидростатик бошланғич кучланиш таъсири остида кучланишсиз сирт эластик ярим бўшлиқдан энергия тарқалишисиз акс этиши.

• Сферик бўшлиқ билан чегараланмаган жисмда энергия тарқалмасдан ўзгарувчан ҳарорат таъсирида бўлган магнето-термо-вискоэластикликнинг таъсири.

• Айланиш, магнит майдони ва каттиклик таъсири чегараси номутаносиб бўлган термо-эластик диффузия ярим фазода ётадиган эластик қатламда сирт тўлқинларининг тарқалишига таъсири.

• Магнит майдонда ва бошланғич кучланиш ва иссиқлик манбалари шароитида иккита қаттиқ-суюқлик муҳитининг ўзаро алоқасида p-тўлқинларни тарқалиши учун икки термал релаксация вақтининг таъсири.

• Стонли тўлқинларининг магнито-термоэластик материалларда бўшлиқлар ва икки марта бўшашиш вақти билан тарқалиши.

• Электромагнит майдон, айланишсиз ва тортишиш кучи, бошланғич кучланиш таъсири остида бир жинсли бўлмаган анизотропик сиқилмайдиган муҳитда С-тўлқинларини тарқалишининг янги хусусиятлари.

• Бўшлиқлар, айланиш ва электромагнит майдонга эга юқори даражадаги толалар билан мустаҳкамланган анизотропик умумий вискоэластик муҳитдаги сирт тўлқинлари тарқалиши.

• Иссиқлик зарбаси ва бошланғич кучланиш таъсири остида икки ҳароратли умумлаштирилган магнето-термоэластик тўлқинларнинг акс этиши.

• Магнитланган иккита қаттиқ суюқлик муҳитининг иссиқлик манбалари ва дастлабки сиқилишлари билан ва термал вақтлари билан ўзаро алоқада бўлган p-, T-, ва SV тўлқинларининг акс этиши ва синиши.

• Гидростатик бошланғич кучланиш шароитида термал кучланиш билан айланадиган муҳит учун икки ҳароратли умумлаштирилган магнето-термоэластик формуласи.

• GN (ii) модели контекстида айланишнинг йўқлиги сабаб термоэластик магнитланган ярим бўшлиқ масаласи.

• Айланма ҳаракат остида цилиндрда умумлашган термо-эластиклик масаласини ҳал қилиш учун чекли элементлар усули.

Диссертация ўн бир бобдан ташкил топган бўлиб, у қуйидагилардан иборат:

Биринчи бобда эгилувчанлик назариялари ва магнето-термоэластиклик назариялари бўйича тадқиқотларни, шунингдек, диссертация объекти билан боғлиқ баъзи тушунчалар ва параметрларни электромагнит майдон, айланиш, бошланғич кучланиш, бўшлиқлар, диффузия, фототермал ва яримўтказгич каби тадқиқотларни ўз ичига олган кириш қисми тақдим этилган.

Иккинчи бобда Икки ўлчовли ярим фазода термал кучланиш, дастлабки кучланиш ва икки ҳарорат шароитида термоэластиклик масалаларини ечишнинг умумий магнито-термоэластиклик назариясини баҳолаш. Бошқарув тенгламалари Ляме потентсиаллари усули ёрдамида (SD) классик динамик ва (LS) Лорд-Шулман назариялари контекстида ечилади. Чегара шартлари: (i) чегарадаги умумий нормал кучланишлар бошланғич кучланишга тенг; (ii) Уринма кучланишлар чегарада йўқолади; ва (iii) тушиш чегараси термал изоляция қилинган. Қайтиш коэффициентлари иккита ҳодиса p- ва SV-тўлқинлар учун олинган. Қайтиш тўлқинлари учун олинган натижалар тегишли металдан фойдаланган ҳолда сонли ҳисоблаб чиқилган ва график тарзда берилган. Олинган натижалар билан магнит майдони ва дастлабки кучланишнинг йўқлиги ҳоллари билан билан таққослашлар ўтказилган.

Масаланинг қўйилиши.

Муҳит мукаммал электр ўтказгич эканлигини эътиборга олиб ва ўзгарувчан токнинг (SI) йўқлигини ҳисобга олиб, электромагнит майдонни бошқарувчиси сифатида чизиқли Максвелл тенгламаларини оламиз.

$$\begin{aligned} &curl\,\vec{h} = \vec{J} \\ &curl\,\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t} \\ &div\,\vec{h} = 0,\ div\,\vec{E} = 0 \\ &\vec{h} = curl(\vec{u} \times \vec{H}_0),\ \vec{H} = \vec{H}_0 + \vec{h}(x, y, t) \end{aligned} \qquad (1)$$

Унда иссиқлик ўтказувчанлиги тенгламаси қуйидаги кўринишда бўлади

$$K\phi_{,ii} = \left(\frac{\partial}{\partial t} + \tau_0 \frac{\partial^2}{\partial t^2}\right)(\rho C_E T + \gamma T_0 u_{i,j}) \qquad (2)$$

Боғланиш тенгламаси сифатида

$$\sigma_{ij} = \lambda e \delta_{ij} + 2\mu\, e_{ij} - \gamma T \delta_{ij} - P(\delta_{ij} + \omega_{ij}) \qquad (3)$$

олинади. Бу ерда

$$e_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i})\ ,\quad \omega_{ij} = \frac{1}{2}(u_{j,i} - u_{i,j})$$

Ҳаракат тенгламаси

$$\rho \ddot{u}_i = \sigma_{ij,j} + F_i\ . \qquad (4)$$

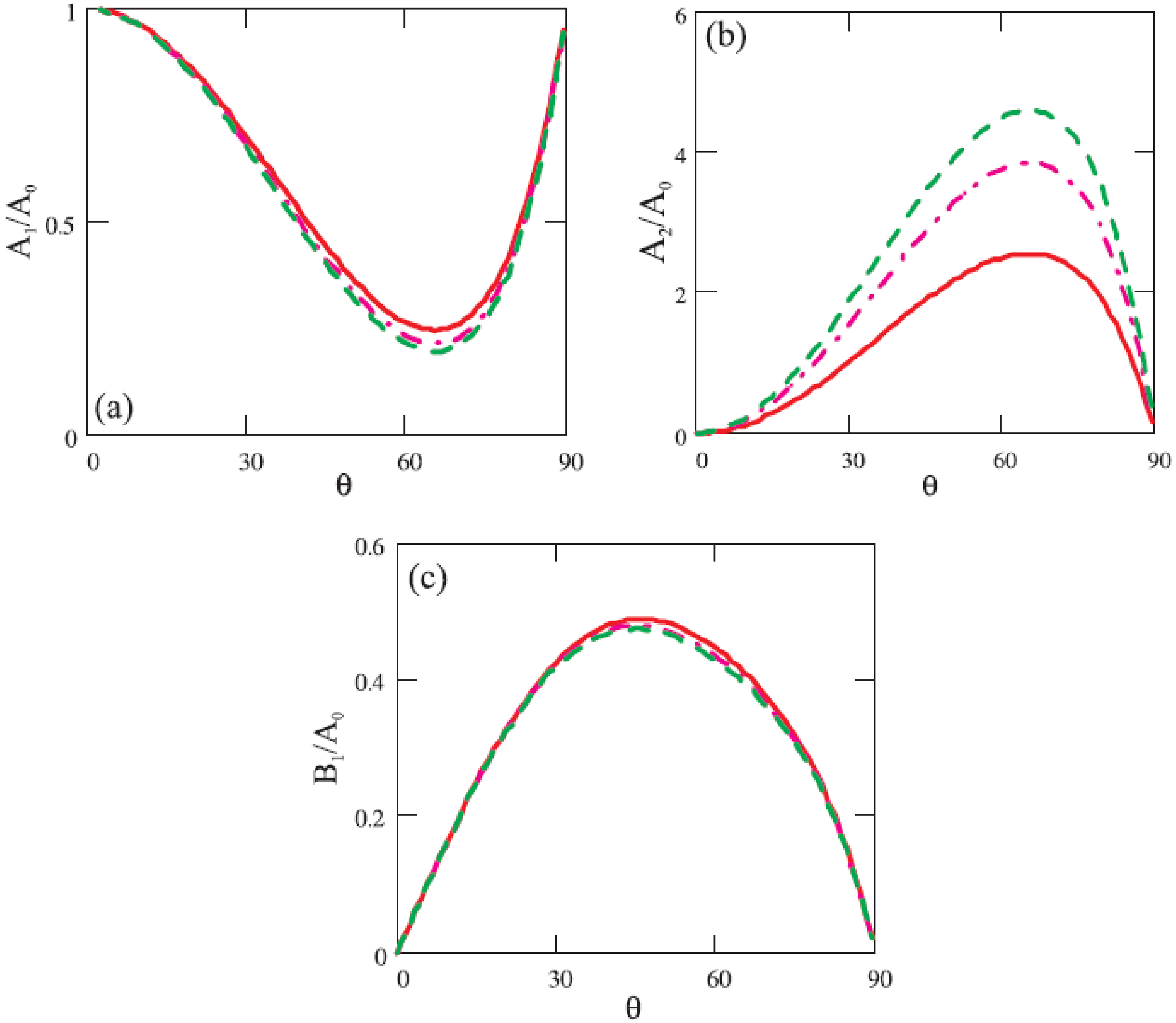
кўринишда бўлади. Бу ерда $\vec{F} = \vec{J} \times \vec{B}$, $\vec{B} = \mu_e \vec{H}_0$

Иссиқлик ўтказувчанлик ва динамик иссиқлик орасидаги муносабат

$$\phi - T = a\phi_{,ii}, \qquad (5)$$

бунда $a > 0$ икки ҳарорат параметри.

Изланишлар натижасида релаксация вақти, бошланғич кучланиш, магнит майдони, икки ҳарорат, иссиқлик кучланиш, ва тушиш бурчаги, металлар, тузилмалар, саноатда, муҳандисликда муҳим аҳамиятга эга акс тўлқинлар ҳодисалар кезишига муҳим таъсири бор, деб **хулоса қилинди.** Қаттиқ жисмларда термоэластик масаласи учун ГЛ назарияси контекстида аналитик ечимлар олинган. Тушувчи SV-тўлқини учун фақат релаксация вақти ва магнит майдони акс эттирилган ва T-тўлқин катталигига таъсир қилиши аниқланган. P-тўлқин учун $|Z_3|<|Z_2|<|Z_1|$, шунингдек, у SV-тўлқин учун $|Z_3|<|Z_2|<|Z_1|$ эканлиги кўрсатилган.



1-расм. Бошланғич кучланишнинг сўнувчи тўлқин коэффициентларини акслантирувчи P= 10^{12}, бўлгандаги таъсири $H0$ =10^5, $\tau_0 = \tau_1 = 0.05, \eta = 1$____$, \eta = 1.2 -.-, \eta = 1.3 ---$

Учинчи бобда магнит майдони эффекти ва бошланғич кучланишнинг p-, T-, ва SV-тўлқинларнинг тарқалишига таъсири ўрганилган. Магнитланган қаттиқ-суюқ интерфейсида дастлабки кучланиш мавжуд бўлганда термоэластик тўлқинларни қайтариш ва синиш муаммоси ўрганиб чиққилган. KT (классик назария) ва GL (Греен Линдсай назарияси) контекстида термоэластиклик нуқтаи назаридан, муаммо ҳал қилинган. Бунда

(i) узликсиз силжиш, (ii) тангенсиал силжишнинг нолга, (iii) нормал кучнинг бошланғич ҳарбир соҳа бирлиги учун узликсизлиги (iv) тангенциал кучнинг бошланғич соҳа бирлиги учун нольга интилиши ва (v) ҳароратнинг узликсизлиги, ҳарбир p-, T ва SV- тўлқинлар учун амплитуда муносабати эътиборга олинган. Тушувчи тўлкинлар ва тасвир тулкинлардан хосил бўладиган коэффицентлар бошлангич кучланиш ва магнит майдони эффекти тасирида сонли таҳлил қилинган.

1) Лоренц кучи мавжудлигини ҳисобга олган ҳолда иссиқлик манбаи йўқлигида бошланғич кучланиш шароитида текисликдаги кучланиш учун айланма ҳаракатнинг динамик тенгламалари

$$\frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \varpi}{\partial y}+F_x=\rho\frac{\partial^2 u}{\partial t^2}$$

$$\frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \varpi}{\partial x}+F_y=\rho\frac{\partial^2 v}{\partial t^2} \qquad (6)$$

бу ерда, $\bar{\omega}=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$, Φ_x ва $\Phi_й$ мос равишда равишда x ва y йўналишдаги магнит майдоннинг таркибий қисмлари.

2) ортиб борувчи изотропия билан кучланиш-деформация муносабатлари деб берилган

$$S_{11}=(\lambda+2\mu+P)e_{xx}+(\lambda+P)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right)$$

$$S_{22}=\lambda e_{xx}+(\lambda+2\mu)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right) \qquad (7)$$

$$S_{12}=2\mu e_{xy}$$

3) орттирма деформация -компонентлар сифатида берилган

$$e_{xx}=\frac{\partial u}{\partial x},\quad e_{yy}=\frac{\partial v}{\partial y},\quad e_{xy}=\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right) \qquad (8)$$

4) модификацияланган иссиқлик ўтказиш тенгламаси

$$K\nabla^2 T=\rho C_e\frac{\partial}{\partial t}\left(1+\tau_0\frac{\partial}{\partial t}\right)T+T_0\gamma\frac{\partial}{\partial t}\left(1+\tau_0\delta_{ij}\frac{\partial}{\partial t}\right)\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right) \qquad (9)$$

5) оқими йўқлигини ҳисобга олган ҳолда, мукаммал электр ўтказувчанликка эга бўлган секин ҳаракатланувчи қаттиқ муҳит учун электромагнит майдонларни бошқарувчи чизиқли Максвелл тенгламалари

$$\operatorname{curl}\vec{h}=\vec{J},\qquad \operatorname{curl}\vec{E}=-\mu_e\frac{\partial\vec{h}}{\partial t}$$

$$\operatorname{div}\vec{h}=0,\qquad \operatorname{div}\vec{E}=0 \qquad (10)$$

бу ерда $\vec{h}=\operatorname{curl}\left(\vec{u}\times\overrightarrow{H_0}\right)$.

Бунда куйидагидан фойдаланилди

$$\vec{H}=\overrightarrow{H_0}+\vec{h}(x,z,t),\quad \overrightarrow{H_0}=(0,0,H)$$

сунгра

$$F_x=\mu_e H^2\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 v}{\partial x\,\partial y}\right)$$

$$F_y=\mu_e H^2\left(\frac{\partial^2 u}{\partial x\,\partial y}+\frac{\partial^2 v}{\partial y^2}\right) \qquad (11)$$

Максвеллнинг кучланиш тенгламасини қуйидагича кўринишда берилган

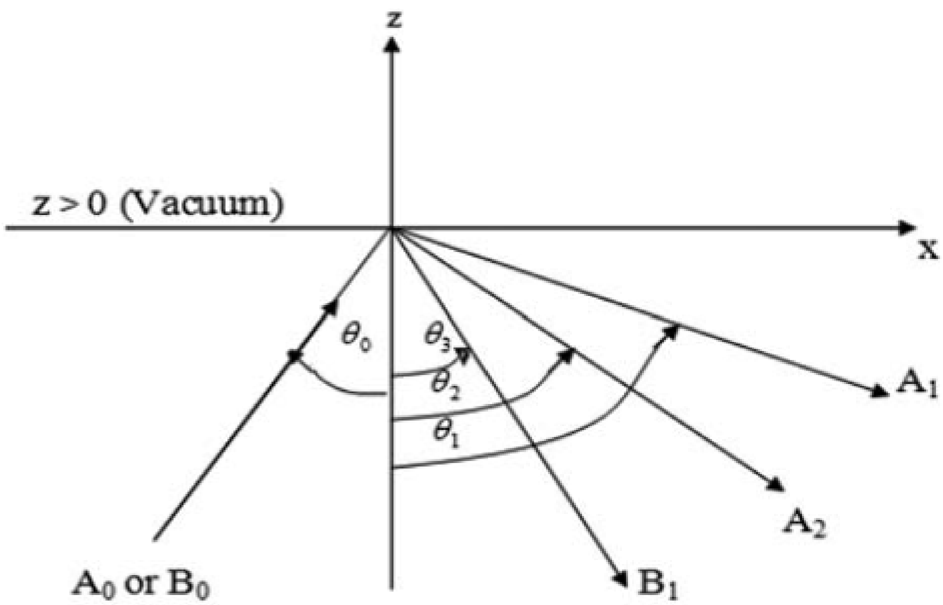
$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij} \right] \tag{12}$$

ва у

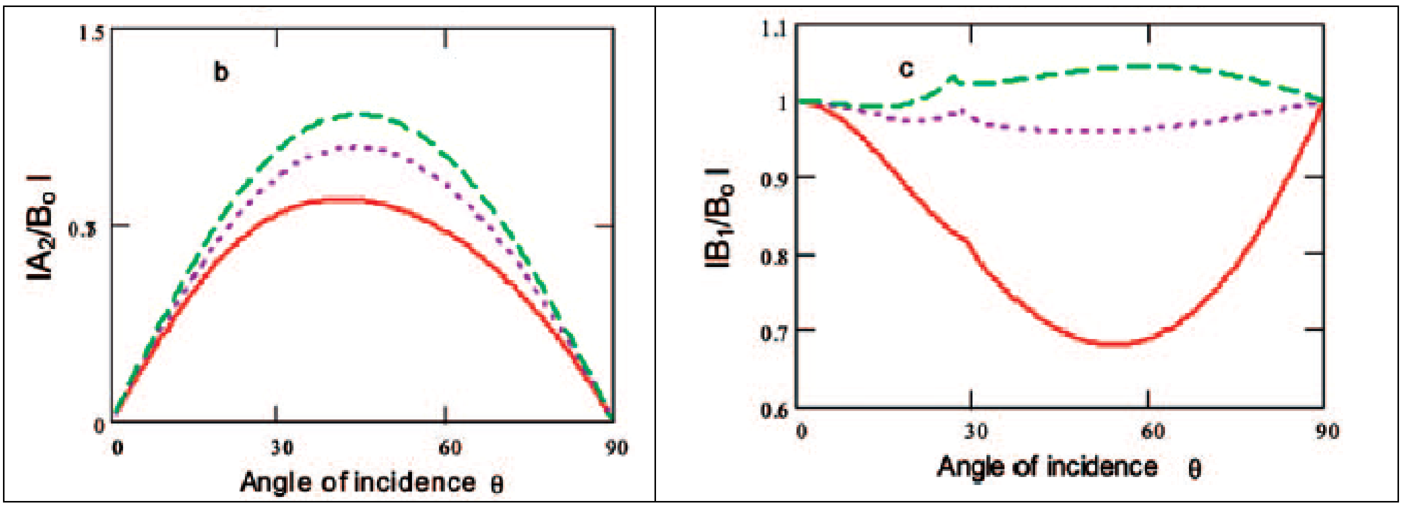
$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right), \quad \tau_{12} = 0.$$

га камаяди

GL ва КТ назариялари нуқтаи назаридан мукаммал чегара шароитида текис суюқлик интерфейсида текислик тўлқинларининг аксланиши ва синиши бошланғич кучланиш ва магнитланганликнинг таъсири аниқ бўлиши аниқланган. Бошланғич кучланиш ва таъсирланиш бурчаги магнит майдони бўлган тўлқинларнинг амплитуда нисбати сонли ўрганилган ва графиклар тақдим етилган GL ва ST моделлари учун олинган.



2-расм. Масаланинг схемавий ифодаси.



Расм 3. Бошланғич кучланишнинг сўнувчи тўлқин коэффициентларини акслантирувчи SV тўлқинларга таъсири, бунда, Ho=10^5,
$\eta = 1, \ h = 3, \ P = 10^{11}, P = 5 \times 10^{11} \ldots\ldots, P = 10^{12}$

Тўртинчи бобда термоэластик тўлқинларининг магнитланган қаттиқ-суюқ интерфейсда акс этиши ва синиши муаммосини бошланғич кучланиш мавжудлигида текширилган. Термоэластикликнинг Gl ва CT назариялари контекстида муаммо ҳал қилинган ва магнит майдоннинг, ташқи иссиқлик манбаларининг таъсири ва p-, T-ва SV-тўлқинларнинг тарқалишига бошланғич кучланиш тахлил қилинган. Кўчиш доимийлиги учун интерфейсдаги чегаравий шартлар, тангенциал кўчишни йўқотиш, нормал куч доимийлиги, тангенциал куч ва ҳароратнинг доимийлиги қўлланилган. Ҳодиса p-, T-, ва SV-тўлқинларининг амплитуда нисбатлари олинган. Ҳодиса тўлқинлари учун дастлабки зўриқиш, иссиқлик манбалари ва магнит майдонининг акс этиши ва узатиладиган коеффициентларга таъсири тахлил қилинган.

1. Иссиқлик манбаи бўлмаганда дастлабки кучланиш шароитида текисликдаги кучланиш учун айланадиган доирадаги ҳаракатнинг динамик тенгламалари қуйидагича берилган:

$$\left.\begin{aligned} \frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \overline{\omega}}{\partial y}+F_1=\rho\frac{\partial^2 u}{\partial t^2} \\ \frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \overline{\omega}}{\partial x}+F_2=\rho\frac{\partial^2 v}{\partial t^2} \end{aligned}\right\} \qquad (13)$$

бунда $\overline{\omega}=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$.

2. Боскичли изотропия билан боглик кучланиш муносабатлари қуйидагича

$$\left.\begin{aligned} &S_{11}=(\lambda+2\mu+P)e_{xx}+(\lambda+P)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right) \\ &S_{22}=\lambda e_{xx}+(\lambda+2\mu)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right) \\ &S_{12}=2\mu e_{xy} \end{aligned}\right\} \qquad (14)$$

3. Ўсувчи кучланиш таркибий кисмлари шаклида берилган

$$e_{xx}=\frac{\partial u}{\partial x},\quad e_{yy}=\frac{\partial v}{\partial y},\quad e_{xy}=\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right) \qquad (15)$$

4. Янгиланган иссиқлик ўтказиш тенгламаси

$$K\nabla^2 T=\rho C_e\left(\frac{\partial T}{\partial t}+\tau_0\frac{\partial^2 T}{\partial t^2}\right)+T_0\gamma\left[\frac{\partial}{\partial t}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+\tau_0\delta\frac{\partial^2}{\partial t^2}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\right] \qquad (16)$$

5. Ўзгарувчан ток йўқлигини ҳисобга олган ҳолда, мукаммал электр ўтказувчанликнинг секин ҳаракатланувчи қаттиқ муҳити учун электромагнит майдонни бошқарувчи чизиқлаштирилган Максвелл тенгламалари қуйидаги кўринишда олиган:

$$\operatorname{curl}\vec{h} = \vec{J}, \quad \operatorname{curl}\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t}, \quad \operatorname{div}\vec{h} = 0, \quad \operatorname{div}\vec{E} = 0 \tag{17}$$

бу ерда $\vec{h} = \operatorname{curl}\left(\vec{u} \times \overrightarrow{H_0}\right), \ \vec{H} = \overrightarrow{H_0} + \vec{h}\left(x, z, t\right), \quad \overrightarrow{H_0} = (0, 0, H)$
кўринишда фойдаланилди ва қуйидагига эга бўламиз:

$$F_x = \mu_e H^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 v}{\partial x \partial y} \right), \quad F_y = \mu_e H^2 \left(\frac{\partial^2 u}{\partial x \partial y} + \frac{\partial^2 v}{\partial y^2} \right) \tag{18}$$

Максвеллнинг кучланиш тенгламасини қуйидаги кўринишда бериш мумкин

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij} \right]$$

Уни қуйидаги кўринишда ёзиб оламиз:

$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right), \quad \tau_{12} = 0 \tag{19}$$

(14)-(18) тенгламалар ёрдамида (13) шаклга эга бўламиз

$$\begin{gathered} \left(\lambda + 2\mu + P + \mu_e H^2 \right) \frac{\partial^2 u}{\partial x^2} + \left(\lambda + \frac{P}{2} + \mu + \mu_e H^2 \right) \frac{\partial^2 v}{\partial x \partial y} + \\ + \left(\mu + \frac{P}{2} \right) \frac{\partial^2 u}{\partial y^2} = \rho \frac{\partial^2 u}{\partial t^2} + \gamma \left(\frac{\partial T}{\partial x} + \tau_1 \frac{\partial^2 T}{\partial x \partial t} \right) \end{gathered} \tag{20}$$

$$\begin{gathered} \left(\mu - \frac{P}{2} \right) \frac{\partial^2 v}{\partial x^2} + \left(\lambda + \frac{P}{2} + \mu + \mu_e H^2 \right) \frac{\partial^2 u}{\partial x \partial y} + \left(2\mu + \lambda + \mu_e H^2 \right) \frac{\partial^2 v}{\partial y^2} = \\ = \rho \left(\frac{\partial^2 u}{\partial t^2} \right) + \gamma \left(\frac{\partial T}{\partial y} + \tau_1 \frac{\partial^2 T}{\partial y \partial t} \right) \end{gathered} \tag{21}$$

Деформациянинг дилатацион ва айланма компонентларини ажратиш учун қуйидаги муносабатлар билан аниқланган кўчиш потенциаллари Φ ва Ψ ни киритамиз:

$$u = \frac{\partial \Phi}{\partial x} - \frac{\partial \Psi}{\partial y}, \quad v = \frac{\partial \Phi}{\partial y} + \frac{\partial \Psi}{\partial x}, \quad \underline{\Psi} = (0, 0, -\Psi) \tag{22}$$

(22), (20) тенгламалардан фойдаланиб, қуйидаги тенгликларга эга бўламиз:

$$\nabla^2 \Phi = \frac{1}{\left(\lambda + 2\mu + P + \mu_e H^2 \right)} \left[\rho \frac{\partial^2 \Phi}{\partial t^2} + \gamma \left(T + \tau_1 \frac{\partial T}{\partial t} \right) \right] \tag{23}$$

$$\nabla^2 \Psi = \frac{\rho}{\left(\mu + \frac{P}{2} \right)} \left[\frac{\partial^2 \Psi}{\partial t^2} \right]. \tag{24}$$

(9) тенглама бу шаклга келади

$$\nabla^2 \Phi = \frac{\rho}{\left(\lambda + 2\mu + \mu_e H^2 \right)} \left[\frac{\partial^2 \Phi}{\partial t^2} \right] + \frac{\gamma}{\left(\lambda + 2\mu + \mu_e H^2 \right)} \left(T + \tau_1 \frac{\partial T}{\partial t} \right) \tag{25}$$

$$\nabla^2\Psi = \frac{\rho}{\left(\mu - \frac{P}{2}\right)}\left[\frac{\partial^2\Psi}{\partial t^2}\right] \tag{26}$$

ва (16) учун

$$K\nabla^2 T = \rho C_e\left(\frac{\partial T}{\partial t} + \tau_0\frac{\partial^2 T}{\partial t^2}\right) + T_0\gamma\frac{\partial}{\partial t}\left(1 + t_0\delta\frac{\partial}{\partial t}\right)\nabla^2\Phi$$

бу ерда $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$.

Gl модел ёрдамида ечиш.

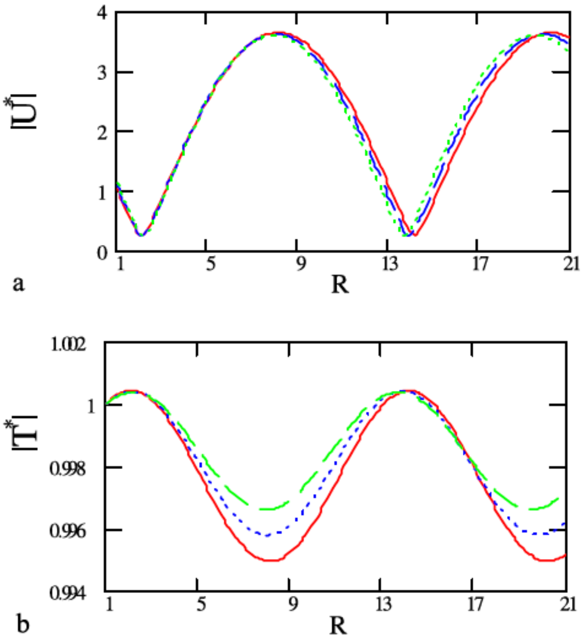
GL назариясида : $\tau_1 \geq \tau_0 > 0$, ва $\delta = 0$,

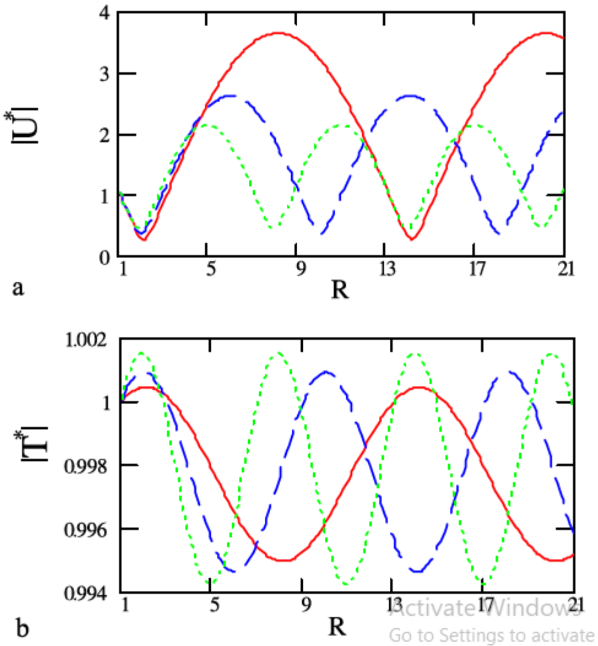
ST модел ёрдамида ечиш.

ST назариясида : $\tau_1 = \tau_0 = 0$ ва $\delta = 0$.

Биз бошланғич кучланиш таъсирини моделлаштирамиз ва текис чегара шароитида текис суюқлик тўлқинларининг тасвири ва синишига Gl ва KT назариялари нуқтаи назаридан мукаммал чегара шароитида. Бошланғич кучланиш ва таъсирланиш бурчаги магнит майдони бўлган тўлқин амплитуда нисбати рақамли ўрганилган ва графикада тақдим етилган Gl ва ST моделлари доирасида олинган. Тасвир ва синиш амплитудалари тушиш бурчаги, бошланғич кучланиш ва магнит майдонга боғлиқ, бу боғлиқликнинг табиати турли-туман акс еттирилган тўлқинлар учун фарқ қилади. Бошлангич кучланиш ва магнитланган муҳит муҳим рол ўйнайди ва акс эттирилган ва узатиладиган тўлқинлар учун тескари тендентцияга эга. Иссиқлик манбалари синган p- ва T-тўлқинларнинг амплитудларига кучли таъсир қилади, аммо бошқа тўлқинларнинг амплитудаларида бироз ўзгаришлар мавжудлиги аниқланган.

Ва ниҳоят, акс еттириш ва синиш коэффициенти жуда кўп қўлланиладиган ҳодисаларда, айниқса сейсмик тўлқинлар, зилзилалар, вулқонлар ва акустикада кучли намоён бўлаётганлиги кўринади.





4-расм. Магнит майдон таъсирида радиус бўйича кўчиш ва харорат абсолют қийматларининг ўзгариши: **Ho** = 10^5 (узлуксиз чизиқ), **Ho** = 2×10^5 (узук чизиқ), **Ho** = 3×10^5 (нуқтали чизиқ).

5-расм: Частота таъсирида радиусга нисбатан кўчиш ва ҳароратнинг абсолют қийматларининг ўзгариши: **ω** = 0.2 (узлуксиз чизиқ), **ω** = 0.3 (узук чизиқ), **ω** = 0.4 (нуқтали чизиқ).

Бешинчи бобда электромагнит майдон, тортишиш майдони, айланиш ва дастлабки кучланишли муҳит таъсирида бир жинсли бўлмаган анизотропик сиқилмайдиган муҳитда сочма тўлқинларининг тарқалиши ўрганилди. Аналитик таҳлил шуни кўрсатадики, тебраниш тўлқинларининг тарқалиш тезлиги тарқалиш йўналишига, анизотропия, магнит майдон, айланиш, тортишиш майдони, муҳитнинг бир ҳил емаслиги ва дастлабки кучланишга боғлиқ. Сочиш тўлқинларининг тезлигини аниқлайдиган частота тенгламаси олинган. Дисперсион тенгламалар олинган ва турли хил ҳолатлар бўйича тадқиқ қилинган. Аслида, бу тенгламалар ўрта изотроп бўлганида мос келадиган классик натижалар билан мос тушаиши кўрсатилган. Олинган натижалар тахлил қилинган ва график шаклида тақдим етилган. Натижалар шуни кўрсатадики, тортишиш майдони, дастлабки кучланиш, магнит майдони, электр майдони анизотропияси ва айланиш таъсири жуда аниқ.

Мос равишда $x-, y-$ йўналишлар бўйлаб дастлабки кучланишлар s_{11} ва s_{22} остида чегараланмаган ноқобил анизотроп жисмни кўриб чиқамиз. Муҳит бироз бузилганда (u,v) орттирма кучланишлар $s_{11,}\ s_{12}$ ва s_{22} ишлаб чиқилади ва орттирма ҳолатдаги ҳаракат тенгламалари

$$\frac{\partial s_{11}}{\partial x}+\frac{\partial s_{12}}{\partial y}-P\frac{\partial w_3}{\partial y}-\rho g\frac{\partial v}{\partial x}+F_x=\rho\left[\ddot{u}+\left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_x+\left(2\vec{\Omega}\times\vec{\dot{u}}\right)_x\right], \tag{28}$$

$$\frac{\partial s_{12}}{\partial x}+\frac{\partial s_{22}}{\partial y}-P\frac{\partial w_3}{\partial x}+\rho g\frac{\partial u}{\partial x}+F_y=\rho\left[\ddot{v}+\left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_y+\left(2\vec{\Omega}\times\vec{\dot{u}}\right)_y\right] \tag{29}$$

бу ерда

$$F_i=\left(\vec{J}\times\vec{B}\right)_i .$$

бунда, Фх ва Фй мос равишда, бошланғич кучланиш $w_3=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right), \rho\ \ z-$ ўқи бўйлаб айланиш қисмларига $P=s_{22}-s_{11}$ ўртача зичликни ифодалайди, g -тортишиш тезлиги, (u,v) деформацияга эга, ва $\vec{\Omega}$ бурилиш бурчаги.

Секин ҳаракатланувчи муҳит учун магнит майдони ва электр майдонининг ўзгариши Максвелл тенгламаси бўйича қуйидаги шаклда берилган:

$$curl\ \vec{h}=\vec{J}+\varepsilon_0\dot{\vec{E}},\quad curl\ \vec{E}=-\mu_e\dot{\vec{h}},\quad div\ \vec{h}=0,\quad div\ \vec{E}=0,$$
$$\vec{E}=-\mu_e\left(\dot{\vec{u}}\times\vec{H}\right),\qquad \vec{h}=curl(\vec{u}\times\vec{H_0}) \tag{30}$$

бу ерда

$$\vec{H} = \vec{H}_0 + \vec{h}(x, y, t), \qquad \vec{H}_0 = (H_0, 0, 0)$$

бу ерда $\vec{B}$ магнит индукция вектори, $\vec{E}$ - электр интенсивлик вектори, $\vec{F}$ - Лоренцнинг жисм кучлари вектори, $\vec{\dot{u}}$ -тезлик вектори, $\vec{h}$ -магнит майдон вектори, $\vec{H}$ -магнит майдон вектори, $\vec{H}_0$ -бирламчи доимий магнит майдон вектори, H_0 -абсолют магнит майдон, $\vec{J}$ -электр ток зичлиги вектори ва μ_e - магнит ўтказувчанлик, ε_0 -электр ўтказувчанлик.

Сиқиб бўлмайдиган муҳит учун кучланишнинг кучайтирувчи муносабати сифатида қабул қилиниши мумкин

$$s_{11} = 2Ne_{xx} + s\,, \;\; s_{22} = 2Ne_{yy} + s \;\text{ and }\; s_{12} = 2Qe_{xy} \tag{31}$$

бу ерда, $s = \frac{s_{11+}s_{22}}{2}$, e_{ij} таркибий қисмлардан иборат, ва N ва Q ўртача даражадаги қаттиқликлар.

Максвеллъ кучланиш тенгламаси

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij} \right]. \tag{32}$$

Сиқилмайдиган ҳолат учун $e_{xx} + e_{yy} = 0$

$$u = -\frac{\partial \phi}{\partial y}, \quad v = \frac{\partial \phi}{\partial x}. \tag{33}$$

(30) ва (31) тенгламаларини (28) ва (29) тенгламаларга қўйсак, қуйидагига эга бўламиз

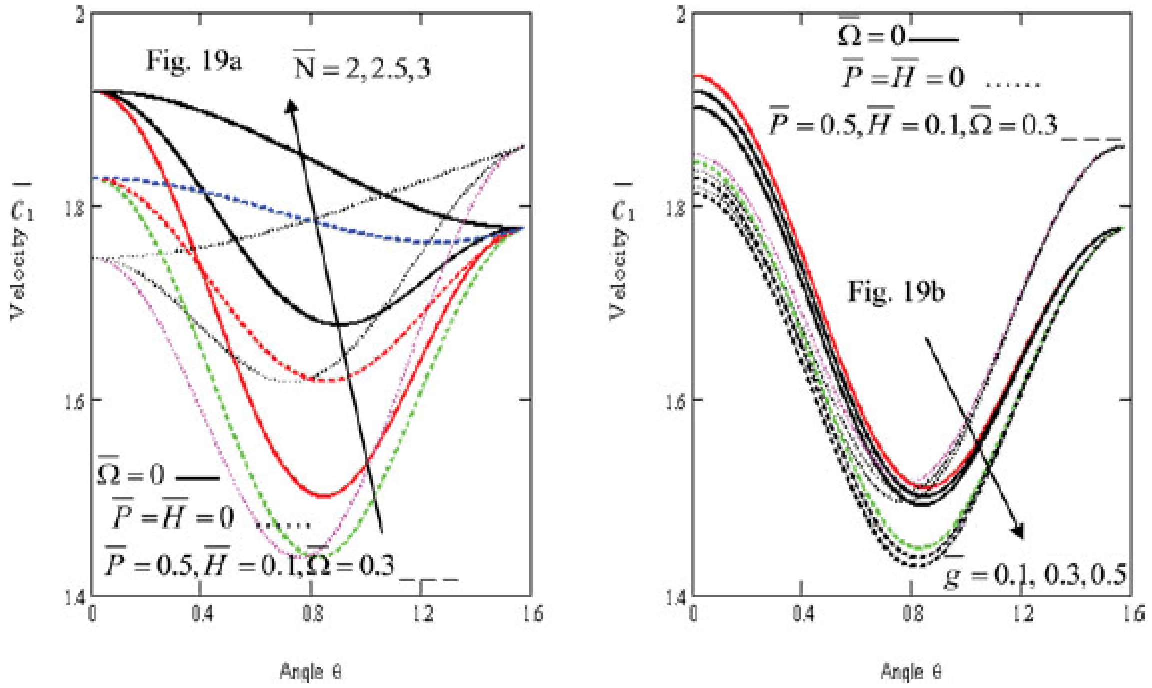
$$\frac{\partial s}{\partial x} - 2N\frac{\partial^3 \phi}{\partial x^2 \partial y} + \frac{\partial}{\partial y}\left[Q\left(\frac{\partial^2 \phi}{\partial x^2} - \frac{\partial^2 \phi}{\partial y^2} \right) \right] - \frac{P}{2}\frac{\partial}{\partial y}\left(\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} \right)$$
$$= \rho\left[g\frac{\partial^2 \phi}{\partial x^2} - \frac{\partial^3 \phi}{\partial y \partial t^2} + \Omega^2 \frac{\partial \varphi}{\partial y} - 2\Omega\frac{\partial^2 \phi}{\partial x \partial t} \right], \tag{34}$$

$$\frac{\partial s}{\partial y} + \frac{\partial}{\partial y}\left(2N\frac{\partial^2 \phi}{\partial x \partial y} \right) + Q\left(\frac{\partial^3 \phi}{\partial x^3} - \frac{\partial^3 \phi}{\partial x \partial y^2} \right) - \frac{P}{2}\left(\frac{\partial^3 \phi}{\partial x^3} + \frac{\partial^3 \phi}{\partial x \partial y^2} \right)$$
$$+ \mu_e H_0^2 \left(\frac{\partial^3 \phi}{\partial x^3} + \frac{\partial^2 \phi}{\partial x \partial y^2} - \varepsilon_0 \mu_e \frac{\partial^3 \phi}{\partial x \partial t^2} \right) = \rho\left[g\frac{\partial^2 \phi}{\partial x \partial y} + \frac{\partial^3 \phi}{\partial x \partial t^2} - \Omega^2 \frac{\partial \varphi}{\partial x} - 2\Omega\frac{\partial^2 \phi}{\partial y \partial t} \right].$$

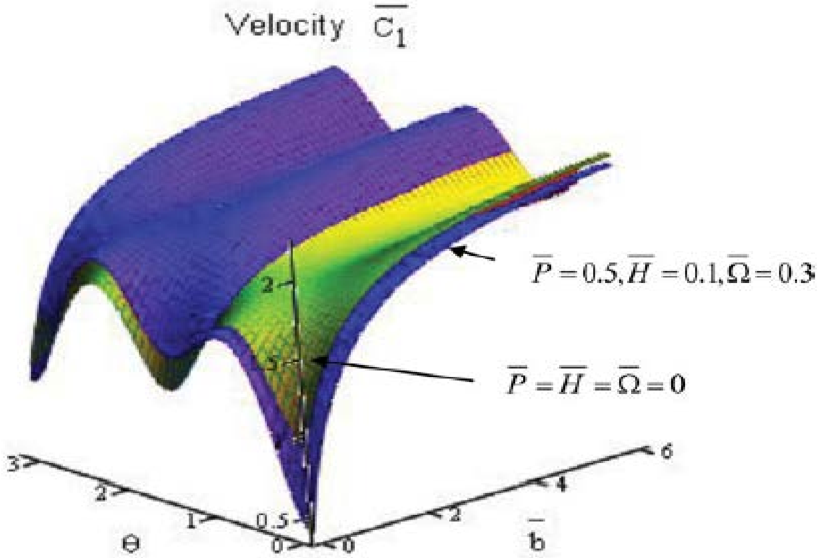
(35)

Бир жинсли бўлмаган ҳолда,

$$\left.\begin{aligned} Q &= Q_0(1 + ay), \\ N &= N_0(1 + by), \\ \rho &= \rho_0(1 + cy) \end{aligned}\right\} \tag{36}$$



6-расм. $\overline{C_1}$ тезикнинг айланиш бурчаги θ ни инобатга олган ҳолда бурилишсиз, бошланғич кучланишсиз магнит майдонда (a) $\overline{N}$ and (b) $\overline{g}$ параметрлар таъсирида ўзгариши.



Бурилишсиз,

7-расм. $\overline{C_1}$ тезикнинг $(\theta, \overline{b})$ магнетик бурилиш ва бошланғич кучланишга боғлиқ ва боғлиқ бўлмаган шаклда ўзгариши.

Аналитик ва сонли график кўринишда олинган натижалардан қуйидаги хулосалар қиламиз:

- тўлқин тарқалиш узунлиги $\overline{b}$,тўлқинлар тезлиги $\overline{C_1}$ га ижобий таъсир қилади;

- тушиш бурчаги θ вақти-вақти билан тезликнинг ошиши ва пасайишига таъсир қилади;

- магнит майдони $\overline{H}$ ва тортишиш кучи $\overline{g}$ тўлқинлар тезлигига халақит беради;

- тўлкинлар тезлиги $\overline{C_1}$ бурчак айланиш тезлигидан, бурчаг айлиниши болмагандаги натижалар учувчи аппаратларда ва самолетларда намоён бўлади, шунингдек улар утилетар жихатлари геофизика, геология, биология, акустика, плазма ва бошқаларда намоён бўлади;

- барча параметрлар тўлқинлар тезлигига $\overline{\zeta}$ дан бошқа барча параметрларга таъсир қилиши кўрсатилган, шу билан бирга $\overline{C_1}$ қиймати бироз пасаяди.

Олтинчи бобда: Греен Линдсай (GL) модели контекстида Стонеси тўлқинларининг магнито-термоэластик материалларда бўшлиқлар билан тарқалишини ва иккита термал релаксиация вақтини ўрганиш учун баҳо берилган. Асосий бошқарув тенгламалари x,z текислигида шакллантирилган ва магнит майдони тўлқин тарқалишига перпендикуляр бўлган *y* - ўқида кўриб чиқилган. Муаммони ҳал қилиш учун Ляме потентциал усулини қўлланилган. Кучларнинг узлуксизлиги ва Максвеллнинг кучланиш компонентлари, жой алмашиш компонентлари, иссиқлик оқими, ҳарорат ва ҳажм фрактцияси соҳалари Стонелей тўлқинларининг муҳитида частота тенгламасини олиш учун иккита бир-бирига ўхшамайдиган ярим бўшлиқлар орасидаги интерфейсларда тасвирланган. Эътибор бермайдиган баъзи бир махсус ҳолатлар: (i) магнит майдони ва (ii) термал релаксация вақти параметрлари ушбу тадқиқотдан алоҳида ҳолатлар сифатида чиқарилиб, сонли натижалар графикада кўрсатилади.

GL назарияси ва майдонларини (иссиқлик, магнит, бўшлиқлар ва эластиклик) ҳисобга олган ҳолда изотропик, бир ҳил эластик қаттиқлик билан умумий термоэластиклик ва тежамкорлик ҳарорати T тавсия этилган харорат тенгламалари бўйича бошқарувчи тенгламалар қуйидагича берилган.

$$\sigma_{ij} = \left(\lambda e_{kk} - \beta \left(1 + \tau_1 \frac{\partial}{\partial t} \right) \Theta + b\Phi \right) \delta_{ij} + 2\mu e_{ij}, \tag{37}$$

$$q_i + \tau_0 \ddot{q}_i = K\Theta_{,i}, \tag{38}$$

$$S_i = \alpha\Phi_{,i}, \tag{39}$$

$$\rho\eta = \beta e_{kk} + \alpha\Theta + m\Phi, \tag{40}$$

$$g = -be_{kk} - \xi\Phi + m\Theta, \tag{41}$$

$$\rho T_0 \dot{\eta} = q_{i,i}, \tag{42}$$

$$e_{ij} = \frac{1}{2}\left(u_{i.j} + u_{j,i} \right), \;\; w_{ij} = \frac{1}{2}\left(u_{j.i} - u_{i,j} \right). \tag{43}$$

Максвеллнинг электромагнит кучланиш тензори τ_{ij}

$$\tau_{ij} = \mu_e \left(H_i h_j + H_j h_i - \left(H_k . h_k \right) \delta_{ij} \right). \tag{44}$$

Ҳаракат тенгламаси

$$\sigma_{ji,j} + F_i = \rho \ddot{u}_i \tag{45}$$

ва

$$\mu u_{i.jj} + (\lambda+\mu) u_{j,ij} - \beta\left(1+\tau_1 \frac{\partial}{\partial t}\right)\Theta_{,i} + b\Phi_{,i} + F_i = \rho \ddot{u}_i . \qquad (46)$$

ГЛ модели бўйича иссиқлик ўтказувчанлик тенгламаси

$$\rho C_e(\dot{\Theta} + \tau_0 \ddot{\Theta}) + \beta T_0 \dot{u}_{k,k} + m T_0 (\dot{\Phi} + \tau_0 \ddot{\Phi}) = K\Theta_{,ii}, \qquad (47)$$

$$\alpha\Phi_{,ii} - b u_{k,k} - \xi\Phi + m\Theta = \rho\chi \ddot{\Phi} \qquad (48)$$

Бу ерда

$$F_i = \left(\vec{J} \times \vec{B}\right)_i . \qquad (49)$$

Муҳит мукаммал электр ўтказгич деб ҳисобланади, ўрин алмаштириш токи (SI) нинг йўқлигини ҳисобга олиб электромагнит майдонни бошқарувчи чизиқли Максвелл тенгламаларига эга бўламиз

$$\left.\begin{array}{ll} curl\,\vec{h} = \vec{J}, & curl\,\vec{E} = -\mu_e \dfrac{\partial \vec{h}}{\partial t}, \\ div\,\vec{h} = 0, & div\,\vec{E} = 0 \end{array}\right\} \qquad (50)$$

бу ерда

$$\vec{h} = curl\left(\vec{u} \times \vec{H}_0\right) \qquad (51)$$

$$\vec{H} = \vec{H}_0 + \vec{h}(x,z,t), \qquad \vec{H}_0 = (0, H, 0). \qquad (52)$$

Икки ўлчовли ҳаракат учун $xz-$ текисликда, (46) - (48) сифатида ёзилган

$$\left(\lambda + 2\mu + \mu_e H^2\right)\frac{\partial^2 u_1}{\partial x^2} + \left(\lambda + \mu + \mu_e H^2\right)\frac{\partial^2 u_3}{\partial x \partial z} + \mu \frac{\partial^2 u_1}{\partial z^2} - \beta\, \tau^1 \frac{\partial \Theta}{\partial x} + b\frac{\partial \Phi}{\partial x} = \rho \frac{\partial^2 u_1}{\partial t^2}, \qquad (53)$$

$$\left(\lambda + 2\mu + \mu_e H^2\right)\frac{\partial^2 u_3}{\partial z^2} + \left(\lambda + \mu + \mu_e H^2\right)\frac{\partial^2 u_1}{\partial x \partial z} + \mu \frac{\partial^2 u_3}{\partial x^2} - \beta\, \tau^1 \frac{\partial \Theta}{\partial z} + b\frac{\partial \Phi}{\partial z} = \rho \frac{\partial^2 u_3}{\partial t^2}, \qquad (54)$$

$$\rho C_e\, \tau^0 \frac{\partial \Theta}{\partial t} + \beta\, T_0 \left(\frac{\partial^2 u_1}{\partial x \partial t} + \frac{\partial^2 u_3}{\partial z \partial t}\right) + m\, \tau^0 T_0 \frac{\partial \Phi}{\partial t} = K\left(\frac{\partial^2 \Theta}{\partial x^2} + \frac{\partial^2 \Theta}{\partial z^2}\right), \qquad (55)$$

$$\alpha\left(\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial z^2}\right) - b\left(\frac{\partial u_1}{\partial x} + \frac{\partial u_3}{\partial z}\right) - \xi\Phi + m\Theta = \rho\chi \frac{\partial \Phi}{\partial t} \qquad (56)$$

бу ерда

$$\tau^0 = 1 + \tau_0 \frac{\partial}{\partial t}, \quad \tau^1 = 1 + \tau_1 \frac{\partial}{\partial t}.$$

u_1 ва u_3 кўчиш компонентлари скаляр ва вектор потенциал функсиялар бўйича φ ва ψ кўринишда қуйидагича ёзилиши мумкин

$$u_1 = \frac{\partial \varphi}{\partial x} - \frac{\partial \psi}{\partial z}, \qquad u_3 = \frac{\partial \varphi}{\partial z} + \frac{\partial \psi}{\partial x}. \tag{57}$$

Магнит майдонинг ва иссиклик релаксация вақтининг Стонелей тўлкинига ва бўшлиққа эга бўлган магнитотермопластик материалларда бу тўлқинлар кийматларининг ошиши йоки камайиши магнит майдонинг майдонинг киймати ошиши ва иссиклик релаксацияси вактига таъсири бу тўлкинларнинг кийматининг ошишига олиб келади.

Умумлаштирилган магнето-термоэластиклик назарияси учун бошқарувчи тенгламаларнинг мураккаблиги туфайли, ушбу соҳада қилинган ишлар, афсуски, сони чекланган. Ушбу ишда қўлланилган усул бундай муаммоларни ҳал қилишда жуда муваффақиятли ёрдам беради. У кўриб чиқилаётган муаммонинг бошқарувчи тенгламаларида пайдо бўладиган ҳақиқий физик катталикларни ҳеч қандай чекловларсиз эластик муҳитда аниқ ечимларини беради.

Ҳодисаларнинг муҳимлиги қуйидаги хулосалардан келиб чиқади.

- Стонелей тўлқинларининг тезлиги ва пасайиш коэффициентлари H йўқлигида тегишли қийматлар билан таққосланадиган магнит майдон мавжудлигида кичик қийматларни олади.

-Стонелей тўлқинларининг тезлиги бўшашиш вақтининг кўпайиши билан H мавжудлиги ёки йўқлиги билан ортади, аксинча пасайиш коэффициентлари учун.

-Стонелей тўлқинлари тезлиги магнит майдони H ва термал вақтлари ортиши билан камаяди, аксинча пасайиш коэффициентига.

Ушбу бўлимда келтирилган натижалар материалшунослик тадқиқотчилари, янги материаллар дизайнерлари, паст ҳароратли физиклар, шунингдек гиперболик термоэластиканинг гиперболик тарқалиш назариясини ишлаб чиқувчилар учун фойдали бўлиши керак. Бўшашиш вақти ва бўшлиқлар атом реакторларидан келиб чиқадиган ва уларнинг ичидаги муҳит билан алмашинуви уларнинг ишлашига таъсир қилади. Бўшашиш вақти ва магнит майдон феноменини ўрганиш мойни олиш шароитларини яхшилаш учун ҳам қўлланилади. Ва ниҳоят, магнит майдоннинг таъсири, бўшлиқлар параметрлари ва иссиқлик бўшашиш вақтлари сирт тўлқинларининг тарқалиш ҳодисаларида жуда аниқдир деган хулосага келишди.

Еттинчи бобда: n-тартибли юқори тартибли бир жинсиз бўлмаган айланувчи толали-мустаҳкамланган вискоэластик анизотропик муҳитда сирт тўлқинларининг тарқалиш тезлигини, шу жумладан тортишиш вақтининг тарқалишини ўрганиб чиқилди. Умумий сирт тўлқинларининг тезлиги айланишнинг сирт тўлқинларига таъсирини ўрганиш учун олинади. Стонелей, Лове ва Райлеигх тўлқинлари учун алоҳида ҳолатлар ўрганилди. Ишда олинган натижалар умумийроқ бўлиб, илгари нашр қилинган баъзи натижалар махсус ҳолатлар сифатида бизнинг натижамиздан олинади. Изланиш натижасида бир хил муҳит учун натижаларини аниқлаш мумкин. Нолинчи тартибли учун бизнинг натижаларимиз толали материалларга яхши мос келади. Шунингдек, мустаҳкамланган эластик параметрларни эътиборга олмасак, натижалар маълум бўлган изотропик муҳитгача келтирилади. Шунингдек, сирт тўлқинлари тез айланувчи муҳитда тарқалиб кетмаслиги кузатилган. Моддий муҳитнинг толали-мустаҳкамланган параметрлари ва йўқлиги, айланиш мавжудлиги ва йўқлигида олинган натижалар билан таққослаш амалга оширилди. Сонли натижалар графикларда берилган ва тасвирланган. Олинган натижалар шуни кўрсатадики, материалнинг тола билан мустаҳкамланган айланиш эффекти ва параметрлари жуда аниқ.

Ўрта иккита бир ҳил бўлмаган анизотропик толали мустаҳкамланган ярим чексиз эластик қаттиқ муҳит M_1 ва M_2 дан иборат бўлиб, турли хил эгилувчан ва мустаҳкамловчи параметрларга эга. Материалнинг бир хил эмаслиги фазовий ўзгарувчига боғлиқ. Бир хил бўлмаганлик аста-секин ўсиб боради ёки пасаяди деб тахмин қилинади. Унинг ўсиш ёки парчаланиш тезлиги ўша вақтдаги қийматига мутаносибдир, яъни.

$\frac{d\lambda}{dx_2} = \alpha\lambda;$ бу ерда λ эластик параметр.

Бу шуни англатади

$$\frac{d\lambda}{dx_2} = m\lambda,$$

бу ерда m доимий эмас, у номутаносибликнинг ўсиши учун ижобий ва емирилиш учун манфий.

Юқоридаги тенглама қуйидагиларни англатади

$$\lambda = \lambda_o e^{mx_2}$$

$m=0$ учун $\lambda = \lambda_o$. Шундай қилиб, $m = 0$ учун муҳит бир хил бўлади.

Иккала муҳит самолёт интерфейсида мукаммал тарзда пайвандланган. Ортогонал Картезиан ўқларини олайлик $Ox_1x_2x_3$ келиб чиқиши билан O. Ox_2 ўрта М($x_2 > 0$) га вертикал равишда юқорига қарайди. Ҳар бир M_1 ($x_2 > 0$) ва M_2 ($x_2 < 0$) $x_2 = 0$ га бўлинади. Иккала муҳит ҳам ўз ўқи атрофида айланади.

Тўлқинлар x_1-ўқининг ижобий йўналиши бўйлаб ҳаракатланади ва ҳар қандай лаҳзада барча зарралар Ox_3 га параллел равишда ҳар қандай йўналишда тенг жой алмашишларига эга деб тахмин қилинади. Ушбу тахминларни ҳисобга олган ҳолда, тўлқинларнинг тарқалиши x_3 дан мустақил бўлади.

Кичик эластик бузилишларнинг тарқалиш тенгламалари қуйидагича:

$$\tau_{ij,j} = \rho\{\ddot{u}_i + \Omega_j u_j \Omega_i - \Omega^2 u_i - 2\varepsilon_{ijk}\Omega_j \dot{u}_k\},$$

бунда ε_{ijk} Леви-Сивита тензоридир, τ_{ij} , τ_{ij} -бу кучланишнинг таркибий қисмлари, ρ-масса зичлиги, u_i эса -жой алмаштириш вектори. Юқоридаги нуқта вақтга ва вергулга нисбатан вақт ҳосилани билдиради, сўнгра индекс координатага нисбатан қисман ҳосилани кўрсатади. Тана бурчакли частота Ω яъни $\mathbf{\Omega} = \Omega(0,0,1)$ билан z-ўқи атрофида айланади, деб тахмин қилинади.

Компонент шаклида ҳаракат тенгламаси кўйидагича олинади

$$
\left.\begin{aligned}
\tau_{11,1}+\tau_{12,2}+\tau_{13,3}&=\rho\{\ddot{u}_1-\Omega^2u_1-2\Omega\dot{u}_2\},\\
\tau_{21,1}+\tau_{22,2}+\tau_{23,3}&=\rho\{\ddot{u}_2-\Omega^2u_2+2\Omega\dot{u}_1\},\\
\tau_{31,1}+\tau_{32,2}+\tau_{33,3}&=\rho\ddot{u}_3.
\end{aligned}\right\} \qquad (58)
$$

Толали мустаҳкамланган чизиқли эластик анизотроп муҳит учун умумий тенглама $\overline{a}=(a_1,a_2,a_3)$ йўналиши қуйидагича.

$$
\tau_{ij}=D_\lambda\varepsilon_{kk}\delta_{ij}+2D_{\mu_T}\varepsilon_{ij}+D_\alpha(a_ka_m\varepsilon_{km}\delta_{ij}+\varepsilon_{kk}a_ia_{j)+}2(D_{\mu_L}-D_{\mu_T})(a_ia_k\varepsilon_{kj}+a_ja_k\varepsilon_{ki}))+
$$
$$
+D_\beta(a_ka_m\varepsilon_{km}a_ia_j),
$$

Бу ерда кучланиш тензори $\varepsilon_{ij}=\frac{1}{2}(u_{i,j}+u_{j,i})$ ва $\mathrm{D}_\lambda, D_{\mu_T}$ - эластик параметрлар. D_α, D_β ва $(\mathrm{D}_{\mu_L}-D_{\mu_T})$ юқори тартибдаги мустаҳкамланган анизотропик вискоэластик параметрлардир.

Ушбу муаммода биз бир ҳил бўлмаган материални экспонента сифатида парчаланишини кўриб чиқамиз. Демак, зичлик, эластиклик модули ва эластик параметрларни қуйидаги шаклда олиш мумкин.

$$
\rho=\rho_o e^{-mx_2}
$$
$$
D_\lambda=\lambda_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_\mu=\mu_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}
$$
$$
D_\alpha=\alpha_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_{\mu_L}=\mu_{L_k}\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}
$$
$$
D_\beta=\beta_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_{\mu_T}=\mu_{T_k}\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}
$$
$$
k=0,1,2...s.
$$

Бунда такрорий индекслар учун Эйнштейн йиғиндиси конвенциясидан фойдаланилади.

Толали йўналишини $\overline{a}=(1,0,0)$, сифатида танласак, кучланишнинг таркибий қисмлари қуйидагича бўлади

$$
\tau_{11}=(\mathrm{D}_\lambda+2D_\alpha+4D_{\mu_L}-2D_{\mu_T}+D_\beta)\varepsilon_{11}+(\mathrm{D}_\lambda+D_\alpha)\varepsilon_{22}+(\mathrm{D}_\lambda+D_\alpha)\varepsilon_{33},
$$
$$
\tau_{22}=(\mathrm{D}_\lambda+D_\alpha)\varepsilon_{11}+(\mathrm{D}_\lambda+2D_{\mu_T})\varepsilon_{22}+D_\lambda\varepsilon_{33},
$$
$$
\tau_{33}=(\mathrm{D}_\lambda+D_\alpha)\varepsilon_{11}+D_\lambda\varepsilon_{22}+(\mathrm{D}_\lambda+2D_{\mu_T})\varepsilon_{33},
$$
$$
\tau_{13}=2D_{\mu_L}\varepsilon_{13},
$$
$$
\tau_{12}=2D_{\mu_L}\varepsilon_{12},
$$
$$
\tau_{23}=2D_{\mu_T}\varepsilon_{23}.
$$

Кучланиш тензоридан фойдаланиб, юқоридаги тенгламалар ва барча ҳосилаларни олиш x_3 нолга тенг.

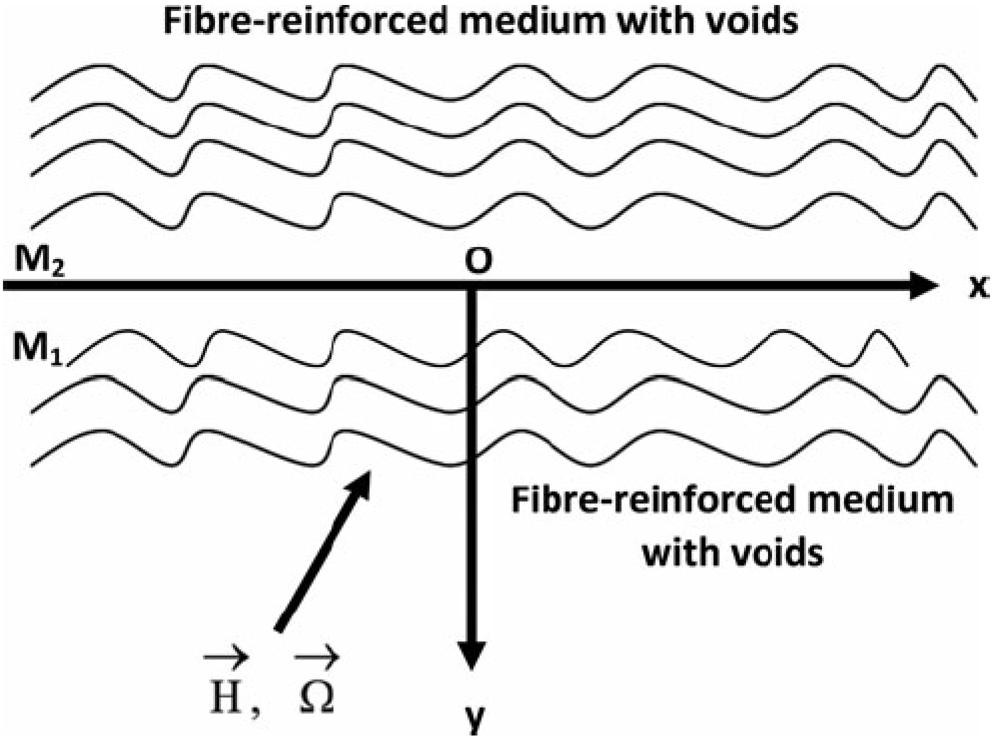
(58) ҳаракат тенгламалари қуйидаги шаклни олади.

$$(D_\lambda + 2D_\alpha + 4D_{\mu_L} - 2D_{\mu_T} + D_\beta)u_{1,11} + (D_\alpha + D_\lambda + D_{\mu_L})u_{2,21} + D_{\mu_L}u_{1,22}$$
$$- mD_{\mu_T}\left(u_{1,2} + u_{2,1}\right) = \rho\{\ddot{u}_1 - \Omega^2 u_1 - 2\Omega\dot{u}_2\}, \tag{59a}$$

$$(D_\alpha + D_\lambda + D_\mu)u_{1,12} + D_\mu u_{2,11} + (D_\lambda + 2D_{\mu_T})u_{2,22} - m\left(D_\lambda + D_\alpha\right)u_{1,1}$$
$$- m\left(D_\lambda + 2D_{\mu_T}\right)u_{2,2} = \rho\{\ddot{u}_2 - \Omega^2 u_2 + 2\Omega\dot{u}_1\}, \tag{59b}$$

$$D_{\mu_L} u_{3,11} + D_{\mu_T} u_{3,22} - mD_{\mu_T} u_{3,2} = \rho\ddot{u}_3, \tag{59c}$$

Худди шундай, биз M_2 ўрта даражасида ρ, D_α, D_λ, D_{μ_L}, D_{μ_T} ва D_β билан алмаштирамиз ρ', $D_{\alpha'}, D_{\lambda'}$, $D_{\mu'_L}$, $D_{\mu'_T}$ ва $D_{\beta'}$.



8-расм. Масаланинг диаграмма кўринишидаги ифодаси.

Қуйидаги хулосалар ўринли:

•бир хил бўлмаган, анизотропик, толали-мустаҳкамланган вискоэластик қаттиқ муҳитда айланиш остида ва н- даражали тартибда юқори тартибда, шу жумладан тортишиш вақтининг тезлиги ўрганилган. Вискоэластик сирт тўлқинларининг айланишига, бир хиллигига, частотасига ва сиқилиш параметрларининг вакт тезлигига таъсир кўрсатиши кузатилади. Ушбу параметрлар тўлқин тезлигига материалнинг характеристикаси ва ёпишқоқлиги билан мос келадиган константаларга боғлиқ. Шундай қилиб, ушбу таҳлил натижалари ушбу таъсирларни эътиборсиз қолдириб бўлмайдиган ҳолатларда фойдали бўлади. Ушбу тезликлар толалар билан мустаҳкамланган баъзи параметрларига боғлиқ бўлиб, бу тўлқинлар муҳитнинг айланишига таъсир қилишини тасдиқлайди;

•бир ҳил бўлмаган муҳитда севги тўлқини; буларга фақат ёпишқоқлик, айланиш, частота, аниқ тартибнинг юқори даражаси, шу жумладан тортишиш тезлиги, муҳитнинг частотаси ва қалинлиги таъсир қилади. Барча майдонлар таъсири бўлмаганда, дисперсия тенгламаси мос келадиган классик натижага тўлиқ мос келади;

• юқори тартибдаги бир хил бўлмаган, умумий вискоэластик қаттиқ муҳитдаги рэлей тўлқинлари, шу жумладан штамм ўзгариши вақтининг тезлиги, тўлқин тезлиги тенгламаси айланиш, частота, номутаносиблик мавжудлиги сабабли тўлқинларнинг айланиш ва частоталар жинсизлик ва ёпишкоклиги туфайли пайдо болади. Натижалар барча майдонлар бўлмаганда тегишли классик натижалар билан тўлиқ мос келади;

•стонелей тўлқинларининг тўлқин тезлиги классик мослашувчанлик назариясига мос келадиган масалага жуда ўхшаш. Тўлқинларнинг тарқалиши, айланиши, фазалар тезлиги, частота ва қаттиқ жисмнинг ёпишқоқлиги билан боғлиқ. Шунингдек, ушбу умумийлаштирилган сирт тўлқинларининг тўлқин тезлиги тенгламаси барча майдонлар бўлмаганда тегишли классик натижага тўлиқ мос келади.

Саккизинчи бобда термоэластикликдаги учта модел учун электромагнит майдон ва дастлабки кучланиш таъсири остида SV тўлқинларининг тарқалишини ўрганилган; жуфтликлар (CD) ва Греен-Линдсай (G-L) назариялари, шунингдек, икки фазали лаг назарияси (DPL). Электромагнит майдонлар ва бошланғич кучланиш мавжуд бўлганда қаттиқ-суюқ интерфейсда термоэластик тўлқинларни акс эттириш ва узатиш муаммоси маълум чегара шароитлари таъсирида ўрганилган. Тушувчи тўлкинлар (SV-тўлқинлар) учун амплитуда муносабатларини топиш учун тегишли ифодалар олинган. Тасвир содир бўлган SV-тўлқинлар учун тасвир ва узатиш коэффициентлари сонли ҳисобланган. Электр майдони, магнит майдони ва бошланғич кучланишнинг таъсири графикларда кўрсатилган. Олинган натижалар билан кўриб чиқилган параметрларнинг мавжудлиги ёки йўқлиги билан таққослаш амалга оширилган ва графикларда намойиш этилган. Олинган натижалар шуни кўрсатадики, электр майдони, магнит майдони ва SV тўлқинларининг таъсири каттик жисмнинг бўлиш чегарасида сезиларли.

1) Лоренц кучи мавжудлигини ҳисобга олган ҳолда иссиқлик манбаи йўқлигида бошланғич кучланиш шароитида текисликдаги кучланиш учун айланма ҳаракатнинг динамик тенгламалари қуйидагича.

$$\begin{aligned} \frac{\partial S_{11}}{\partial x} + \frac{\partial S_{21}}{\partial y} - P\frac{\partial \bar{\omega}}{\partial x} + F_x = \rho \frac{\partial^2 u}{\partial t^2} \\ \frac{\partial S_{21}}{\partial x} + \frac{\partial S_{22}}{\partial y} - P\frac{\partial \bar{\omega}}{\partial x} + F_y = \rho \frac{\partial^2 v}{\partial t^2} \end{aligned} \qquad (60)$$

бунда $\bar{\omega} = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$, F_xва F_y мос равишда x ва y йўналишларда электромагнит майдоннинг таркибий қисмлари.

2) Босқичли изотропия билан боғлиқ заба-шакл алоқалари қуйидагича берилган:

$$S_{11} = (\lambda + 2\mu + P)e_{xx} + (\lambda + P)e_{yy} - \gamma\left(T + \tau_1 \frac{\partial}{\partial t}T\right)$$

$$S_{22} = \lambda e_{xx} + (\lambda + 2\mu)e_{yy} - \gamma\left(T + \tau_1 \frac{\partial}{\partial t}T\right) \qquad (61)$$

$$S_{12} = 2\mu e_{xy}$$

3) Кучланиш деформацияси таркибий бўғинлар томонидан берилган

$$e_{xx} = \frac{\partial u}{\partial x}, \qquad e_{yy} = \frac{\partial v}{\partial y}, \qquad e_{xy} = \frac{1}{2}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) \qquad (62)$$

4) Модифицирланган иссиқлик ўтказувчанлиги тенгламаси

$$K\left(1 + \tau_\Theta \frac{\partial}{\partial t}\right)\nabla^2 T = \rho C_e\left(\frac{\partial T}{\partial t} + \tau_0 \frac{\partial^2 T}{\partial t^2}\right) + T_0\gamma\left[\frac{\partial}{\partial t}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + \tau_0\delta_{ij}\frac{\partial^2}{\partial t^2}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)\right] \quad (63)$$

бу эрда, C_e бу бирлик массасига хос иссиқлик, e_{ij} кучланиш компонентлари, K иссиқлик ўтказувчанлиги, P бошланғич кучланиш, $S_{11}, S_{22,} S_{12}$ кучланишнинг кучаядиган таркибий қисмлари, λ ва μ - Ляме доимийлари, T_0 - бу муҳитнинг табиий ҳарорати, δ_{ij} Кронескер делтаси, T муҳитнинг мутлақ ҳарорати, τ_0 ва τ_1 термал бўшашиш даври, α_t чизиқли термалпексия коэффициенти, u_i-жой алмаштириш векторининг таркибий қисми, ϖ бу маҳаллий айланишнинг катталиги, τ_Θ ҳарорат градиентининг фазавий чегараси.

5) Ўчириш оқими йўқлигини ҳисобга олсак, мукаммал электр ўтказувчанлигига эга, секин ҳаракатланадиган қаттиқ муҳит учун электромагнит майдонларни бошқарувчи чизиқли Максвелл тенгламалари

$$curl\vec{h} = \vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t}, \quad -\mu_e \frac{\partial \vec{h}}{\partial t} = curl\vec{E}, \quad div\vec{h} = 0, \quad div\vec{E} = 0,$$

$$\vec{E} = -\mu_e\left(\frac{\partial \vec{u}}{\partial t} \times \vec{H}_0\right), \quad \vec{h} = curl(\vec{u} \times \vec{H}_0), \quad \vec{F}_i = \mu_e(\vec{J} \times \vec{H}_0)_i \qquad (64)$$

бунда

$$\vec{H} = \vec{H}_0 + \vec{h}(x, y, t), \quad \vec{H}_0 = (0, 0, H).$$

(64) дан фойдаланиб қуйидагини оламиз:

$$F_x = \mu_e H^2\left[\frac{\partial e}{\partial x} - \varepsilon_0\mu_e \frac{\partial^2 u}{\partial t^2}\right]$$

$$F_y = \mu_e H^2\left[\frac{\partial e}{\partial y} - \varepsilon_0\mu_e \frac{\partial^2 v}{\partial t^2}\right] \qquad (65)$$

$$F_z = 0$$

- Бу ерда, $\vec{E}$ электр зичлиги вектори, $\vec{F_i}$ Лорентцнинг танадаги куч вектори, $\vec{h}$ магнит майдон вектори, $\vec{H}$ магнит майдон вектори, $\vec{H}_0$- доимий магнит майдон вектори, $\vec{J}$ электр токининг зичлиги вектори, μ_e магнит ўтказувчанлик , ε_0 электр ўтказувчанлиги.

6) Максвеллнинг кучланиш (кучланиш) тенгламаси қуйидагича берилиши мумкин

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - (\overrightarrow{H_k}.\overrightarrow{h_k})\delta_{ij} \right],\ i, j = 1,2,3 \qquad (66a)$$

бунда, τ_{ij} Максвеллнинг кучланиш тензоридир, бу эса камаяди

$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right),\ \tau_{12} = 0. \qquad (67b)$$

Қуйидаги учта турли назариялар учун юқоридаги асосий тенгламаларни ўрганилган:

(i)Классик ва динамик бирикма назарияси (1956) (CD)

$$\delta_{ij} = 0,\ \tau_0 = 0,\ \tau_\Theta = 0,\ \tau_1 = 0$$

(ii) Греен ва Линдсай назарияси (1972) (GL)

$$\delta_{ij} = 0,\ \tau_1 \geq \tau_0 > 0,\ \tau_\Theta = 0$$

(iii) Икки фазали Lagtheory (DPL)

$$\delta_{ij} = 1,\ \tau_0 > 0,\ \tau_1 = 0,\ 0 \leq \tau_\Theta < \tau_0.$$

(CD), (GL) ва (DPL) моделлар контекстида, бошланғич кучланиш, электромагнит майдоннинг зўр чегара шароитида қаттиқ суюқ муҳит ўртасидаги интерфейсдаги кўзгу ва рефракцияга таъсири тахлил қилинади.

Қуйидаги мулоҳазаларга келинди:

•Кўзда тутилган амплитудалар тушиш бурчаги, бошланғич кучланиш, электромагнит майдон ва термал бўшашиш вақтларига боғлиқ;

•Бошланғич кучланишда электромагнит майдон сезиларли рол ўйнайди, бу акс эттирилган ва узатиладиган тўлқинлар учун тескари томонга бурилади.

•Учта термоэластик назарияларда тасвир ва синиш ҳодисаларига томонлар таъсир қилади.

•DPL моделида $|Z_1| < |Z_4| < |Z_5| < |Z_2| < |Z_3|$ энг кичик $|Z_1|$ га таъсир қиладиган кўринади, аммо энг каттаси $|Z_3|$ га таъсир қилади;

•Кўзгатиш коэффициенти жуда кўп қўлланиладиган ҳодисаларда, айниқса сейсмик тўлқинлар, зилзилалар, вулқонлар ва акустикада кучли намоён бўлиши кузатилган.

•Ушбу бўлимда келтирилган натижалар материалшунослик билан шуғулланувчи тадқиқотчилар, янги материаллар дизайнерлари, паст ҳароратли физика, шунингдек гиперболик тарқалиш назариясини ишлаб чиқувчилар учун жуда фойдали бўлади. Айланиш, магнит майдон ва диффузия феноменини ўрганиш нефть олиш шароитларини яхшилаш учун ҳам қўлланилади.

Тўққизинчи бобда: магнит майдони ва дастлабки кучланиш мавжуд бўлганда қаттиқ-суюқ интерфейсда термоэластик тўлқиннинг қайтарилиши ва синиши муаммоси ўрганилди. Муаммо уч фазали лаг термоэластиклик модели нуктаи назаридан ҳал қилинди. P-тўлқинлар тарқалиши, CV тўлқинлари ва термал тўлқинлар тарқалишининг барча уч ҳолати учун амплитуда нисбатларини топиш учун тегишли тушиш ҳолати ишлаб чиқилган. Аммо акс эттирилган ва синган тўлқинлар амплитудларининг тушувчи тўлқинига нисбати ернинг қобиқ-сув интерфейси учун, фақат p-тўлқин тушуши учун ҳисоблаб чиқилган, бошланғич кучланишни, сиқишни, ҳам сиқилишини этиборга олган ҳолда. Олинган натижалар фазалар, магнит майдони ва дастлабки кучланишларнинг таъсирини кўрсатиш учун график тарзда тақдим этилган.

Қаттиқ ярим бўшлиқ, бир жинсли, изотропик, эластик материал ва T_0 бошланғич ҳарорати бўлган суюқ муҳит ва z йўналишда ҳаракат қилувчи магнит майдон ўртасидаги текислик интерфейсини кўриб чиқилган. Иккала муҳитда ҳам $\vec{H}$ магнит майдони эффекти z йўналишда ҳаракат қилади, аммо қаттиқ бошланғич M фақат бошланғич кучланиш P ҳолатида бўлади. p-, T- ёки SV- тўлқинлар интерфейс текислигидаги ўрта M да содир бўлади. P-тўлқин (дилатацион тўлқин), SV-тўлқин (айланиш тўлқини) ва иссиклик тўлқини. Қолган тўлқинлар бошқа ўрта M' да, синганидан кейин, p-тўлқин ва иссик тўлқини каби давом этади.

y=0 текисликда келиб чиқиши “0” бўлган Картезиан координаталари тизимини қабул қиламиз. Икки ўлчовли муаммони кўриб чиққанимиз сабабли, биз таҳлилимизни *oxy*-теккисликда параллел равишда текисликдаги кучланиш муаммоси билан чеклаймиз. Демак, майдоннинг барча ўзгарувчилари фақат x, y ва t вақтларига боғлиқ.

Фойдаланиш қулайлиги учун биз куйидаги келишувга риоя киламиз: M муҳитдаги барча биқдорлар тўлдирилмасдан тақдим этилади, шу билан мос келадиган микдор (бошланғич кучланиш бундан мустасно) ерланган сифатида тақдим этиладию.

Кучланишнинг бошланғич таркибий қисмлари ўрта M га таъсир қилади, бу эрда θ - текислик тўлқинининг тушиш бурчаги; θ_1 ва θ_2 акс эттирилган тўлқинларнинг бурчаклари; θ_1' ва θ_2' узатиладиган тўлқинлар бурчаги.

$\vec{H}$ - *z*-йўналишда ҳаракат қилувчи магнит майдон вектори; A_1, A_3 ва A_5 ҳодиса тўлқинларининг амплитудлари; A_2, A_4 ва A_6 - акс эттирилган тўлқинларнинг амплитудалари; A_2' ва A_4' - бу T-ва SV -тўлқинларнинг амплитудлари, мос равишда (фақат ўрта M'-да иккита узатиладиган тўлқин мавжуд).

Фараз қилайлик, қаттиқ ярим бўшлиқ, бир жинсли, изотропик, эластик материал ва бошланғич ҳарорати T_0 бўлган суюқ муҳит ва йўналишда ҳаракат қилувчи магнит майдон ўртасидаги текисликни кўриб чиқайлик. Иккала муҳитда ҳам $\vec{H}$ магнит майдони эффекти $z-$йўналишда ҳаракат қилади, аммо қаттиқ муҳит M фақат бошланғич кучланиш шароитида бўлади. P-тўлқин (дилатацион тўлқин), SV-тўлқин (айланиш тўлқини) ва T иссиклик тўлқини. Қолган тўлқин p-тўлқин ва термал тўлқин каби синишдан кейин бошқа ўрта M' бўйлаб юришни давом эттиради.

3. Асосий тенгламалар:

Ҳаракатнинг динамик тенгламалари:

Лоренц кучининг мавжудлигини ҳисобга олган ҳолда иссиқлик манбаи йўқлигида дастлабки кучланиш шароитида текислик учун ҳаракатнинг динамик тенгламалари қуйидагича:

$$\frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \overline{\omega}}{\partial y}+F_x=\rho\frac{\partial^2 u}{\partial t^2}$$

$$\frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \overline{\omega}}{\partial x}+F_y=\rho\frac{\partial^2 v}{\partial t^2} \qquad (68)$$

бунда $\overline{\omega}=\frac{1}{2}\left[\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right]$, F_x ва F_y мос равишда йўналишдаги магнит майдоннинг таркибий қисмлари.

Кучланиш деформация муносабатлари:

Босқичли изотропия билан боғлиқ кучланиш-деформация муносабатлари қуйидагича берилган

$$S_{11}=\left(\lambda+2\mu+P\right)e_{xx}+\left(\lambda+P\right)e_{yy}-\gamma T$$

$$S_{22}=\lambda e_{xx}+\left(\lambda+2\mu\right)e_{yy}-\gamma T \qquad (69)$$

$S_{12}=2\mu e_{xy}$

Ўсувчи кучайиш таркибий қисмлари:

Ўсувчи кучланиш таркибий қисмлари қуйидагича берилган

$$e_{xx}=\frac{\partial u}{\partial x},\ e_{yy}=\frac{\partial v}{\partial y},\ e_{xy}=\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right) \qquad (70)$$

Уч фазали лаг иссиқлик ўтказувчанлиги тенгламаси:

$$K\left(1+\tau_t\frac{\partial}{\partial t}\right)\nabla^2\dot{T}+K^*\left(1+\tau_v\frac{\partial}{\partial t}\right)\nabla^2 T=\left(1+\tau_q\frac{\partial}{\partial t}+\frac{\tau_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left[\rho C_e\ddot{T}+\gamma T_0\left(\frac{\partial \ddot{u}}{\partial x}+\frac{\partial \ddot{v}}{\partial y}\right)\right] \qquad (71)$$

бу эрда K иссиқлик ўтказувчанлиги, K^* бу назариянинг материалдаги доимий характеристикаси, ρ- масса зичлиги, C_e -доимий зўриқишдаги ўзига хос иссиқлик. τ_q,τ_t,τ_v мос равишда иссиқлик оқими, ҳарорат градиенти ва иссиқлик алмашиниш градиентининг фазавий узилишларидир.

Максвеллнинг чизиқли тенгламалари:

Силжиш компонентининг йўқлигини ҳисобга олсак, мукаммал электр ўтказувчанлигига эга секин ҳаракатланувчи муҳит учун электромагнит майдонларни бошқарадиган чизиқли Максвелл тенгламалари мавжуд.

$$curl\,\vec{h}=\vec{J},\quad curl\,\vec{E}=-\mu_e\frac{\partial\vec{h}}{\partial t},\quad div\,\vec{h}=0,\quad div\,\vec{E}=0 \qquad (72)$$

Қуйидагилардан фойдаланамиз

$$\vec{H}=\vec{H}_0+\vec{h},\quad \vec{H}_0=\left(0,0,H\right),\quad \vec{h}=\left(0,0,h\right)$$

сўнгра Лорентц тана кучларининг таркибий қисмлари қуйидагича олинади:

$$F_x=\mu_e H^2\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 v}{\partial x\partial y}\right),\ F_y=\mu_e H^2\left(\frac{\partial^2 u}{\partial x\partial y}+\frac{\partial^2 v}{\partial y^2}\right) \quad (73)$$

Максвеллнинг кучланиш тенгламаси

$$\tau_{ij}=\mu_e\left(H_i h_j+H_j h_i-H_k.h_k\delta_{ij}\right) \quad (74)$$

қуйидагига келтирилади

$$\tau_{11}=\tau_{22}=\mu_e H^2\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right),\tau_{12}=0$$

Уч фазали Лаг модели нуқтаи назаридан мукаммал чегара шароитида текис суюқлик интерфейсида текислик тўлқинларининг тасвирлашиши ва синишининг бошланғич зарби ва магнитланиш таъсирини кўрамиз.

Назарий ва сонли тахлиллардан қуйидаги хулосалар чиқарилиши мумкин: $|Z_1|,|Z_2|,|Z_4|$ва $|Z_5|$ уларнинг максимал қийматларидан $\theta=90^0$ нолга келганда бошланади, лекин $|Z_3|$ $\theta=90^0$да бирликка келади ва магнит майдоннинг ўзгариши ва бошланғич кучланиш билан озгина ўзгаришлар мавжуд бўлади. $\theta=90^0$да $|Z_1|,|Z_2|,|Z_4|$ ва $|Z_5|$нолга тенг бўлган максимал қийматлардан бошланади, лекин $|Z_3|$ бирликка $\theta=90^0$га келади ва фазавий лагларнинг ўзгариши билан озгина ўзгаришлар бўлади.

Ўнинчи бобда: Лорд-Шулман назарияси доирасида нормал режим усули ёрдамида эластик ярим бўшлиқдаги, бир жинсли ва изотропик икки ярим ҳароратли магнит майдон ва иссиқлик майдонининг ўзаро таъсири термал кучланиш ва айланиш билан қаралади. Ўрта текис бурчак тезлиги билан айланади ва у ягона магнит майдон ва гидростатик бошланғич кучланиш орқали ўтади деб ҳисобланади. Биз олган умумий ечим аниқ бир муаммога нисбатан қўлланилади. Горизонтал масофа бўйлаб ҳарорат, динамик ҳарорат, кучланиш ва кучланиш тақсимотлари тегишли сонли мисол ёрдамида ҳисоблаб чиқилган ва график шаклида кўрсатилган.

Шундай қилиб, мухитни энг мукаммал электр ўтказгич деб ҳисоблаймиз, Максвелл тенгламалари, ўзгарувчан ток йўқлигини ҳисобга олиб (SI) қуйидагича шаклланади:

$$\begin{aligned}&curl\,\vec{h}=\vec{J}\\&curl\,\vec{E}=-\mu_e\frac{\partial\vec{h}}{\partial t}\\&div\,\vec{h}=0\ ,\ div\,\vec{E}=0\\&where\ \ \vec{h}=curl(\vec{u}\times\vec{H}_0)\ ,\ \vec{H}=\vec{H}_0+\vec{h}(x,y,t)\end{aligned} \quad (75)$$

Иссиқлик ўтказувчанлиги тенгламаси қуйидагича олинади:

$$K\phi_{,ii}=(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2})(\rho C_E T+\gamma T_0 u_{i,j}) \quad (76)$$

Кучланиш зўриқишининг муносабати қуйидагича:

$$\sigma_{ij}=\lambda e\delta_{ij}+2\mu\,e_{ij}-\gamma T\delta_{ij}-P(\delta_{ij}+\omega_{ij}) \quad (77)$$

бунда, $e_{ij}=\frac{1}{2}(u_{i,j}+u_{j,i})$, $\omega_{ij}=\frac{1}{2}(u_{j,i}-u_{i,j})$.

Ўрта $\underline{\Omega}=\Omega\underline{n}$ бурчак тезлиги билан бир текисда айланаётганлиги сабабли, $\underline{n}$- айланиш ўқининг йўналишини ифодаловчи бирлик вектори. Айланадиган йўналишда ҳаракатланувчи ҳаракатланиш тенгламаси фақат қўшимча вақтга эга, чунки вақт ўзгариши туфайли $\underline{\Omega}\times(\underline{\Omega}\times\underline{u})$ марказлаштирувчи тезлашув ва Сориолис тезлашиши $2\underline{\Omega}\times\underline{\dot{u}}$, бу эрда $\underline{u}$ динамик жой алмашиш векторидир.

Ҳаракат тенгламаси бу кўринишда олинади.

$$\rho[\ddot{u}_i+\{\underline{\Omega}\times(\underline{\Omega}\times\underline{u})\}_i+(2\underline{\Omega}\times\underline{\dot{u}})_i]=\sigma_{ij,j}+F_i \tag{78}$$

бунда, $\vec{F}=\vec{J}\times\vec{B}$, $\vec{B}=\mu_e\vec{H}_0$

Тенглама қуйидагича ёзилган динамик иссиқлик ва иссиқлик ўтказувчанлиги ўртасидаги боғлиқ:

$$\phi-T=a\phi_{,ii}, \tag{79}$$

бунда $a>0$ икки ҳароратли параметрни билдиради.

Эластик бир ҳил ярим бўшлиқни $x\geq 0$ деб тахмин қилиш Ω бурчак тезлиги билан, x ўқи бўйлаб йўналтирилган $\vec{H}_0$ магнит майдони ва (75)-(77) тенгламаларга риоя қилган ҳолда дастлабки сиқишни P мавжудлигида айланади. 2D муҳит учун жой алмаштириш компонентлари қуйидаги кўринишга эга.

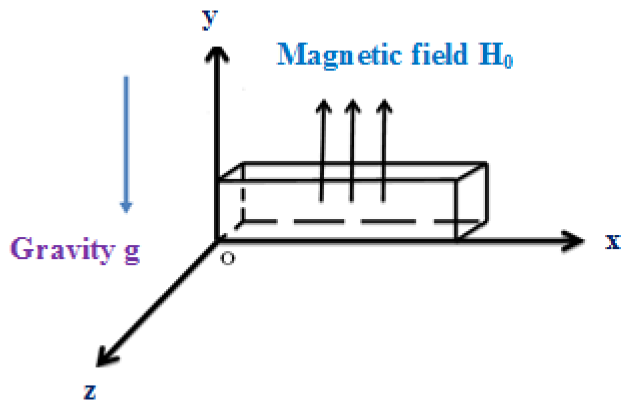
$$u_x=u(x,y,t),\quad u_y=\mathrm{v}(x,y,t),\quad u_z=0. \tag{80}$$

Иссиқлик ўтказувчанлиги тенгламаси қуйидагича олинади

$$K\left(\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}\right)=\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\rho C_E T+\gamma T_0\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right). \tag{81}$$

Ўн биринчи бобда: Ушбу бобнинг асосий мақсади тортишиш кучи, бошланғич кучланиш ва бузилган магнит майдон шароитида икки ўлчовнинг ярим космик муаммосини ҳал қилиш учун умумлаштирувчи шаклда икки ҳароратли термоэластикликни ўрганишдир. Асосий тенгламалар Лорд-Шулман (LS), Греен-Нагди (GN type III) ва янги фазали (3PHL) теоремалар, кучланиш таркибий қисмлари ва ҳароратнинг тақсимланишини ўрганиш бўйича янги математик методларни ҳисобга олган ҳолда ҳал қилинди. Учта назария, яъни (LS), (GN type III) ва (3PHL), тортишиш кучи, магнит майдон ва дастлабки кучланишнинг йўқлиги ва мавжудлигини ҳисобга олган ҳолда олинган натижалар таққосланди. Натижалар сонли ҳисоблаб чиқилган ва ҳодисанинг жисмоний маъноси ва ташқи параметрларнинг таъсирини намойиш этиш учун график равишда намойиш этилган. Йўқлигида олинган натижалар ва ташқи кўриб чиқилган параметрларнинг мавжудлиги ва бошқа тадқиқотчилар томонидан илгари олинган натижалар билан таққослаш амалга оширилди.

Изотроп ярим чексиз эластик қаттиқликни ҳисобга олсак, Oxyz 1-расмда кўрсатилгандек, Картезиан ортогонал координаталар тизими, текисликнинг чегарасининг ҳар қандай O нуқтаси ва Oy пастдан вертикал йўналишда пастга.



9-расм. Муаммонинг шаклланиши кўрсатилган.

Биз муаммонинг фундаментал тенгламасини қуйидагича тузамиз:

(i) Бошланғич кучланишни ҳисобга олган конституцион тенглама (кучланиш-кучланиш нисбати) қуйидаги шаклни олади:

$$\sigma_{ij} = (\lambda\theta - \gamma TP)\delta_{ij} + 2\mu e_{ij} - P w_{ij}, \quad w_{ij} = \frac{1}{2}(u_{j,i} - u_{i,j}) \tag{82}$$

(ii) Учта термоэластик назарияларни оладиган иссиқлик ўтказувчанлигининг тенгламаси қуйидагича

$$\left(K^* + \tau_v^* \frac{\partial}{\partial t} + K\tau_T \frac{\partial^2}{\partial t^2}\right)\nabla^2\varphi = \left(1 + \tau_q \frac{\partial}{\partial t} + \frac{\tau_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left[\rho C_e \ddot{T} + \gamma T_0 \ddot{e}\right], \ \tau_v^* = K + K^*\tau_\upsilon \tag{83}$$

(iii) Тана кучи ва иссиқлик манбаи йўқлиги билан ҳаракат тенгламаси қуйидаги шаклни олади.

$$\sigma_{ji,j} + F_i = \rho \ddot{u}_i, \quad (i, j = 1,2,3) \tag{84}$$

(iv) Суперўтказувчилар ва термодинамик ҳароратнинг ўзаро боғлиқлиги шаклланади.

$$\varphi - T = a\nabla^2\varphi \tag{85}$$

Ўчириш оқими йўқлигини ҳисобга олинг; мукаммал электр ўтказувчанлигига эга қаттиқ, секин ҳаракатланадиган магнит майдонни бошқарувчи чизиқли Максвелл тенгламалари қуйидагича ёзилиши мумкин:

$$\operatorname{curl}\mathbf{h} = \mathbf{J} - \varepsilon_0\dot{\mathbf{E}}, \tag{86a}$$

$$\operatorname{curl}\mathbf{E} = -\mu_e\frac{\partial\mathbf{h}}{\partial t}, \tag{86b}$$

$$\operatorname{div}\mathbf{h} = 0, \tag{86c}$$

$$\operatorname{div}\mathbf{E} = 0, \tag{86d}$$

$$\mathbf{E} = -\mu_e\left(\frac{\partial\mathbf{u}}{\partial t}\times\mathbf{H_0}\right), \tag{86}$$

$$\mathbf{E} = \operatorname{curl}(\mathbf{u}\times\mathbf{H_0}), \tag{86f}$$

$$\mathbf{F_i} = \mu_e(\mathbf{J}\times\mathbf{H_0})_i \tag{86g}$$

Тензори ишлатганмиз

$$\mathbf{H} = \mathbf{H_0} + \mathbf{h}(x, y, t), \quad \mathbf{H_0} = (0, 0, \mathbf{H}).$$

(86) тенгламадан фойдаланиб, қуйидагиларни оламиз:

$$F_x = \mu_e H_0^2 \frac{\partial e}{\partial x}$$

$$F_z = \mu_e H_0^2 \frac{\partial e}{\partial z} \tag{87}$$

$$F_y = 0$$

Максвеллнинг магнит майдонидан ҳосил бўлган кучланиш ыуйидагича шаклланиши мумкин.

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - (\overrightarrow{H_k}.\overrightarrow{h_k})\delta_{ij} \right], \; i, j = 1, 2, 3 \tag{88a}$$

$$\tau_{xx} = \tau_{zz} = \mu_e H_0^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial z} \right), \; \tau_{xz} = 0. \tag{88b}$$

Тенглама (83) бу қуйидагилардан фойдаланиш мумкин бўлган умумий термоэластик қаттиқ тенглама майдони:

i. (LS) фараз: $K^* = \tau_v = \tau_T = \tau_q^2 = 0, \tau_q > 0$

ii. (GN type II) фараз: $\tau_v = \tau_T = \tau_q = 0$

iii. (3PHL) фараз: $\tau_v < \tau_T < \tau_q > 0$

Ўлчовсиз ўзгарувчилар бу шаклни олади:

$$(x', z', u', v') = C_0 \, \eta(x, z, u, v), \qquad (t', \tau_T', \tau_\upsilon', \tau_q') = C_0^2 \eta(t, \tau_T, \tau_\upsilon, \tau_q), \quad h' = \frac{h}{H_0}$$

$$(\theta', \varphi') = \frac{(T, \varphi) - T_0}{T_0}, \; \left(\sigma_{ij}', \tau_{ij}' \right) = \frac{\left(\sigma_{ij}, \tau_{ij} \right)}{\rho C_0^{\,2}}, \quad g' = \frac{g}{C_0^3 \, \eta} \tag{89}$$

бунда $\eta = \dfrac{\rho C_e}{K}$, $C_2^2 = \dfrac{\mu}{\rho}$ ва $C_0^2 = \dfrac{\lambda + 2\mu}{\rho}$.

(89) тенгламадан алмаштир натижасида (83)-(85) дан қуйидагини оламиз:

$$\left(C_k + C_\upsilon \frac{\partial}{\partial t} + C_T \frac{\partial^2}{\partial t^2} \right) \nabla^2 \varphi - \left(1 + T_q \frac{\partial}{\partial t} + \frac{T_q^2}{2} \frac{\partial^2}{\partial t^2} \right) (\ddot{\theta} + \frac{\gamma}{\rho C_e} \ddot{e}) \tag{90}$$

$$\varphi - \theta = \beta \, \nabla^2 \varphi \tag{91}$$

$$C_k = \frac{K^*}{\rho C_e C_0^2}, \;\; C_v = \frac{\tau_v^*}{\rho C_e C_0^2}, \;\; C_T = \frac{K \tau_T \eta}{\rho C_e}$$

Бунда ҳаракат ёндашувининг тенгламалари:

$$a_1^* \nabla^2 u + a_2 \frac{\partial e}{\partial x} - a_0 \frac{\partial \theta}{\partial x} + g \frac{\partial w}{\partial x} = \beta \, \ddot{u} \tag{92}$$

$$a_1^*\nabla^2 w + a_2\frac{\partial e}{\partial z} - a_0\frac{\partial \theta}{\partial z} - g\frac{\partial u}{\partial x} = \beta\,\ddot{w} \qquad (93)$$

бунда

$$\varepsilon = \frac{\gamma}{\rho C_e},\; a_1^* = \frac{2\mu - P}{2\rho C_0^2},\; a_2 = \frac{2\lambda + 2\mu + P + 2\mu_e H_0^2}{2\rho C_0^2},\; a_0 = \frac{\gamma T_0}{\rho C_0^2},\; \beta = 1 + \frac{\varepsilon_0\mu_e H_0^2}{\rho}.$$

П ва ψ скаляр потенциал ва вектор потенциал функцияларини фараз қилиш:

$$u = \frac{\partial \Pi}{\partial x} - \frac{\partial \psi}{\partial z}, \qquad w = \frac{\partial \Pi}{\partial z} + \frac{\partial \psi}{\partial x}. \qquad (94)$$

Тенгламани (94) тенгламага алмаштириб. (92) ва (93) ни оламиз,

$$\left(\nabla^2 - \beta^* \frac{\partial^2}{\partial t^2}\right)\Pi - a_3^*\frac{\partial \psi}{\partial x} - a_0^*\theta = 0 \qquad (95)$$

$$\left(\nabla^2 - \beta^{**} \frac{\partial^2}{\partial t^2}\right)\psi + a_4\frac{\partial \Pi}{\partial x} = 0 \qquad (96)$$

бунда

$$R_H^2 = \frac{\mu_e H_0^2}{\rho C_0^2},\; \beta^* = \frac{\beta}{1+R_H^2},\; a_0^* = \frac{a_0}{1+R_H^2},\; a_3^* = \frac{g}{1+R_H^2},\; a_4 = \frac{g}{a_1^*},\; \beta^{**} = \frac{\beta^*}{a_1^*}.$$

Шу ишда, потенциалга асосланган аналитик ечимни тақдим этдик ва қаттиқ муҳитдаги термоэластик муаммони нормал режим техникаси ишлаб чиқилган ва графиклар орқали таққосланган. Греен-Нагди назариясининг (GN) кучли таъсири Лорд-Шулман (LS) ва уч фазали лаг (3PHL) моделлари ўртасидаги энгил таъсирга нисбатан. Физик миқдорлар z масофасининг ошиши ва кўриб чиқилаётган чегара шартларини қондириш билан нолга айланади. Жисмнинг деформацияси қўлланиладиган ташқи кучларнинг табиатига (электромагнит майдон, икки ҳароратли, бошланғич кучланиш ва тортишиш кучи), шунингдек термоэластик назарияларнинг турига ва чегара шароитларига боғлиқ. Вақт параметри, шунингдек, релаксация вақти, тортишиш кучи ва электромагнит майдон кучли таъсирга эга бўлиб, олинган барча жисмоний миқдорларда кучланишлар, жой алмашиш компонентлари ва ҳарорат пасаётган ёки тобора ортиб борадиган даражада муҳим рол ўйнайди. Шунинг учун ушбу моделда электро-магнит, тортишиш кучи, икки ҳароратли, бошланғич кучланиш ва релаксация вақти майдонининг мавжудлиги катта аҳамиятга эга. Кўриб чиқилган усул жуда қизиқ ва термодинамика, термоэластиклик ва магнито-термоэластикликдаги кўплаб ҳодисаларга тегишли. Электромагнит майдони ўзгарувчиларининг вақтинчалик хатти-ҳаракатлари батафсил ўрганилиб, майдон ўзгарувчисидаги ўзгарувчанликларнинг бир-бирларига таъсири ўрганилган. Шундай қилиб, улар ушбу тажриба майдонида тўлқин тарқалишида ишлайдиган амалий олимлар: технологлар, тадқиқотчилар, сейсмологлар, муҳандислар учун фойдали маълумот беради. Ушбу бобда тортишиш кучи, бошланғич кучланиш, электромагнит майдон ва иккита ҳарорат ўзгариши таркибий қисмларига, ҳароратга ва кучланиш таркибий қисмларига боғлиқлиги кўрсатилган, бу уларга сезиларли таъсир кўрсатмоқда. Ва ниҳоят, натижалар магнито-иссиқлик электр ўтказувчан материалларини янги қўлланиладиган электро-магнето-иссиқлик электродлари синфи сифатида ўрганишга муҳим туртки беради ва материалшунослик тадқиқотчилари, янги материаллар дизайнерлари, физиклар, муҳандислар ва бошқалар учун фойдали бўлиши керак. Электро-магнето-термоэластикликнинг ривожланиши ва амалий вазиятларда, айниқса геомагнит, геофизика, акустика, оптика ва нефт қидирув ишларида.

•**Ўн иккинчи бобда:** касрли экспонентацион функция усули ёрдамида каср тартибни ҳисобга олган ҳолда электромагнит ва тортишиш майдонларининг таъсирида қаттиқ эластик ярим бўшлиқдан бўйлама гармоник тўлқинларнинг аксини ўрганилган. Акс амплитуда нисбати учун зарур бўлган тушунтиришлар (яъни, акс эттирилган тўлқинлар амплитуда нисбати тушувчи тўлқинининг амплитудасига нисбати). Олинган натижалар аналитик усулда ҳисоблаб чиқилган ва ҳодисанинг физик маъносини тахлили графиклар орқали кўрсатилган. Касрли ва бутун сонларни ҳосилалари ўртасида таққослаш амалга оширилди. Ушбу бобнинг натижалари кўриб чиқилаётган касрли техниканинг қатъийлиги ва самарадорлигини намойиш этади.

Каср тартибли дифференциал тенгламалар билан боғлиқ ҳисоблашнинг баъзи тушунчалари ва хусусиятларини қуйида келтирамиз.

2.1 Таъриф Риманн-Луивилнинг $\alpha \geq 0$ тартибли касрли интеграл оператори $f \in C\mu, \mu \leq -1$ функцияси қуйидагича:

$$J^{\alpha} f(x) = \frac{1}{\Gamma(\alpha)} \int_0^x (x-t)^{\alpha-1} f(t)dt, \ \ x>0, \ \ \alpha>0 \qquad (97)$$

$$J^0 f(x) = f(t)$$

2.2 Хусусиятлари. $f \in C\mu, \mu \leq -1 \quad \alpha, \beta > 0, \text{ва } \gamma \leq -1$ учун J^{α} оператор учун, қуйидагилар ўринли:

$$1.\ J^{\alpha} J^{\beta} f(x) = J^{\alpha+\beta} f(x)$$

$$2.\ J^{\alpha} J^{\beta} f(x) = J^{\beta} J^{\alpha} f(x) \qquad (98)$$

$$3.\ J^{\alpha} x^{\gamma} = \frac{\Gamma(\gamma+1)}{\Gamma(\gamma+\alpha+1)} x^{\alpha+\gamma}$$

2. 3 Таъриф: $f(x)$ нинг Капуто маъносидаги касрли ҳосиласи, қуйидагича аниқланади:

$$D^{\alpha} f(x) = J^{m-\alpha} D^m f(x) = \frac{1}{\Gamma(m-\alpha)} \int_0^x (x-t)^{m-\alpha-1} f^{(m)}(t)dt, \qquad (99)$$

$$m-1 < \alpha < m, m \in N, x > 0$$

2. 4 Таъриф: $\alpha > 0$ тартибининг Капуто каср ҳосилалари:

$$D^{\alpha} f(x,t) = \frac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}} = \begin{cases} \frac{1}{\Gamma(m-\alpha)} \int_0^t (t-\tau)^{\varepsilon-1} \frac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}} d\tau, & m-1 < \alpha \le m \\ \frac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}}, & \alpha = m \in N \end{cases} \quad (100)$$

2.5 $\alpha > 0$ тартибидаги Капуто каср ҳосилаларининг D^{α} оператори **хусусиятлари**,

$$D^{\alpha} x^{\gamma} = \frac{\Gamma(\gamma+1)}{\Gamma(\gamma-\alpha+1)} x^{\gamma-\alpha},$$

$$.D^{\alpha} e^{t} = t^{-\alpha} \sum_{n=0}^{\infty} \frac{t^{n}}{\Gamma(n-\alpha+1)} \quad (101)$$

Медиада кўрсатилган z-ўқи билан (x, y, z) Картезиан координаталар тизимидаги термо микространчнинг фундаментал тенгламалари кўриб чиқилган. Бирламчи магнит майдон интенсивлиги y ўқига тўғри келади (яъни, $\boldsymbol{H} = (0, H_0, 0)$). Секин-аста ҳаракатланувчи муҳитнинг электродинамикасининг чизиқли тенгламаларини ҳисобга оламиз,

$$\boldsymbol{J} = curl\, \boldsymbol{h} - \varepsilon_0 \frac{\partial^{\beta}}{\partial t^{\beta}} E, \quad (102)$$

$$curl\, \boldsymbol{E} = -\mu_0 \frac{\partial^{\beta}}{\partial t^{\beta}} \boldsymbol{h}, \quad (103)$$

$$\boldsymbol{E} = -\mu_0 \left(\frac{\partial^{\beta}}{\partial t^{\beta}} \boldsymbol{u} \times H \right), \quad (104)$$

$$\nabla . \boldsymbol{h} = 0. \quad (105)$$

Магнит майдон ва тортишиш кучи мавжуд бўлганда ҳаракат тенгламаси:

$$\sigma_{\ell i,\ell} + F_i + G_i = \rho \frac{\partial^{\alpha}}{\partial t^{\alpha}} u_i, \quad (106)$$

$$F_i = \mu_0 (J \times H)_i, \; G_i = \rho g \left(\frac{\partial w}{\partial x}, 0, -\frac{\partial u}{\partial x} \right). \quad (107)$$

Аналитик ва график усулда олинган натижалардан қуйидаги хулосага келинди.

- $\theta = 90^{o}$ даражадаги $|z_1| = 1$ амплитуда нисбати SV тўлқинини кўрсатади, аммо $|z_2| - |z_5|$ нолга тенг.

- Тортишиш майдони $|z_1| - |z_3|$ акс коэффициентларига кучли таъсир қилади, аммо $|z_4|$ ва $|z_5|$ устидаги акс эттириш қийматларини бироз ўзгариши кузатилади.

- Электр ва магнит майдонларнинг таъсири ҳодисаларга кучли таъсир кўрсатадиган акс коэффициентларида деярли бир хил хусусиятга эга.

- Агар магнит майдон бўлмаса, мослиги билан солиштирганда магнит майдоннинг мавжудлиги кучли таъсир килади.

Ўн иккинчи бобда ҳалқали изотроп цилиндр учун битта термик релаксация вақтини ва температуранинг чексиз тарқалишини физик хоссаларга боғлиқ бўлган умумлашган термоэластиклик моделига айланиш ҳаракатини баҳолаймиз. Бу ҳодиса график шаклда олинган компонентлар бўйича айланиш эффективлиги ва сщнувчи иссиқлик оқими остида чекил айирмалар усулидан фойдаланиб сонли ечилади. Сонли ечимлар турли параметрларнинг таъсирини очиш учун тасвирланган. Янги параметрлараэеътиборга олинмаса, бошқалар томонидан олинган олдинги натижалар билан таққослаш мумкин бўлади.

Масаланинг қўйилиши

Температура жисмнинг хоссаларига боғлиқ бўлган изотроп эластик материалдан иборат чексиз узунликка эга бўлган ҳалқасимон цилиндрни кўриб чиқамиз. (r, φ, z)-цилиндрик координаталарни кўрсатамиз, маркази эса цилиндрик қутб координаталар системасидан олинган. Бу ҳодисада ишлатиладиган жисм хоссаларга боғлиқ бўлган барча физик ўзгарувчилар радиал координата r ва вақт t га боғлиқ функциялардир.

Кучланиш ва зўриқиш ўртасидаги муносабат қуйидаги шаклда ифодаланади:

$$\sigma_{ij} = 2\mu e_{ij} + \left(\lambda\Delta - \gamma\overline{\mathrm{T}}\right)\delta_{ij} \tag{108}$$

бунда $\overline{\mathrm{T}} = \mathrm{T} - \mathrm{T}_0$

Изотроп муҳит учун кучланиш-кўчиш муносабати қуйидагича

$$e_{ij} = \frac{1}{2}\left(u_{i,j} + u_{j,i}\right). \tag{109}$$

Харакатнинг асосий тенгламалари қуйидагича ёзилади

$$\sigma_{ij,j} = \rho\left[\vec{\ddot{u}}_i + \left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_i + \left(2\vec{\Omega}\times\dot{\vec{u}}\right)_i\right] \tag{110}$$

Агарда иссиқлик манбаи мавжуд бўлса у ҳолда иссиқлик ўтказувчанлик тенгламаси қуйидаги шаклда бўлади

$$\left(K\overline{\mathrm{T}}_{,i}\right)_{,i} = \frac{K}{\kappa}\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}} + T_0\gamma\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\Delta \tag{111}$$

Бунда жисмнинг хоссалари қуйидагича ифодаланади деб фараз қиламиз

$$\lambda = \lambda_0 f(\mathrm{T}), \quad \mu = \mu_0 f(\mathrm{T}), \quad K = K_0 f(\mathrm{T}), \quad \gamma = \gamma_0 f(\mathrm{T}),$$

Буерда λ_0, μ_0, K_0 *ва* γ_0 константа, ҳамда $f(\mathrm{T})$ -иссиқликнинг ўлчовсиз функцияси.

Бошқа бир ҳолда харорат боғлиқ бўлмаган жисм хоссалари учун $f(\mathrm{T})$, ва $\lambda = \lambda_0$, $\mu = \mu_0$, $K = K_0$, $\gamma = \gamma_0$.

(108)-(111) тенгламалардан қуйидагиларга эга бўламиз

$$\sigma_{ij} = \left[2\mu e_{ij} + \left(\lambda_0\Delta - \gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right] f(\mathrm{T}) \tag{112}$$

$$\rho\left(\ddot{u}_i - \Omega^2 u - 2\Omega\dot{u}\right) = \left[2\mu e_{ij} + \left(\lambda_0\Delta - \gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right]_{,j} f(\mathrm{T}) + \left[2\mu e_{ij} + \left(\lambda_0\Delta - \gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right]\left(f(\mathrm{T})\right)_{,j} \tag{113}$$

$$\left(K_0 \; f(\mathrm{T})\overline{\mathrm{T}}_{,i}\right)_{,i} = \frac{K_0 \; f(\mathrm{T})}{\kappa}\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}} + \gamma_0 \; f(\mathrm{T})T\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\Delta \tag{114}$$

Соддалаштириш учун $f(\mathrm{T})$ни $f(\mathrm{T})=1-\alpha\mathrm{T}$ кўринишида аппрокцимация қиламиз, бунда α-жисм параметри, шунда (112) тенгламадан кусланиш компонентлари учун қуйидагини хосил қиламиз

$$\sigma_{rr}=\left[\left(\lambda_0+2\mu_0\right)\frac{\partial u}{\partial r}+\lambda_0\frac{u}{r}-\gamma_0\overline{\mathrm{T}}\right]\left(1-\alpha\mathrm{T}\right) \tag{115}$$

$$\sigma_{\varphi\varphi}=\left[\left(\lambda_0+2\mu_0\right)\frac{u}{r}+\lambda_0\frac{\partial u}{\partial r}-\gamma_0\overline{\mathrm{T}}\right]\left(1-\alpha\mathrm{T}\right) \tag{116}$$

Цилиндрик шаклда харакат тенгламасини қуйидагича ёзамиз

$$\frac{\partial\sigma_{rr}}{\partial r}+\frac{1}{r}\left(\sigma_{rr}-\sigma_{\varphi\varphi}\right)=\rho\left[\frac{\partial^2 u}{\partial t^2}-\Omega^2 u-2\Omega\frac{\partial u}{\partial t}\right] \tag{117}$$

натижада (115)-(117) дан қуйидагини оламиз:

$$\left(\lambda_0+2\mu_0\right)\left[\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}-\frac{u}{r^2}\right]\left(1-\alpha\mathrm{T}\right)-\left[\alpha\left\{\left(\lambda_0+2\mu_0\right)\frac{\partial u}{\partial r}+\lambda_0\frac{u}{r}-\gamma_0\overline{\mathrm{T}}\right\}+\gamma_0\left(1-\alpha\mathrm{T}\right)\right]\frac{\partial\overline{\mathrm{T}}}{\partial r}$$
$$=\rho\left[\frac{\partial^2 u}{\partial t^2}-\Omega^2 u-2\Omega\frac{\partial u}{\partial t}\right] \tag{118}$$

(114) дан фойдаланиб, соддалик учун ўлчовлик бирликлар ϖ кесикиш экспонентасини киритамиз.

$$\left(\frac{\partial^2\overline{\mathrm{T}}}{\partial r^2}+\frac{1}{r}\frac{\partial\overline{\mathrm{T}}}{\partial r}\right)-\frac{\alpha}{1-\alpha\mathrm{T}}\left(\frac{\partial\overline{\mathrm{T}}}{\partial r}\right)^2=\frac{1}{\kappa}\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}}+\frac{T_0\gamma}{K_0}\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\left(\frac{\partial u}{\partial r}+\frac{u}{r}\right) \tag{119}$$

Масаланинг ечими

Харорат тарқалиши ва кучланиш компоненталарининг сонли ечимларини топиш учун чекли айирмалар техникасидан фойдаландик. Ечимлар сохаси $\{(r,t):R\in[A,B],t\in[0,\tau]\}$ нуқталар тўпаламидан иборат тўр (r_m,t_n) билан алмаштирилди. Бунда танланган соха $r_m=A+mh;m=0,1,...,N$ ва $t_n=nk;n=0,1,...,P,$ бўлакларга ажратилади, $h=(B-A)/N$ -кенглик бўйича, $k=\tau/P$ -вақт бўйича қадамлар орқали қурилади. Шунингдек τ вақтинг охирги қиймати.

Мустақил ўзгарувчилар r ва t га мос қисман дифференциал коеффициентлар учун ошкор сонли айирмали схемаси ва қуйидагича келтирилган:

$$\frac{\partial u}{\partial r}=\frac{u_{m+1}^n-u_{m-1}^n}{2h}+o\left(h^2\right),\qquad \frac{\partial^2 u}{\partial r^2}=\frac{u_{m+1}^n-2u_m^n+u_{m-1}^n}{h^2}+o\left(h^2\right),$$
$$\frac{\partial u}{\partial t}=\frac{u_m^{n+1}-u_m^{n-1}}{2k}+o\left(k^2\right) \tag{120}$$

Ошкор сонли айирмалар тенгламаларидан фойдаланиб, қуйидагини оламиз:

$$u_m^{n+1}=\Gamma_1 u_m^n-u_m^{n-1}+\nu_1\left[\begin{array}{l}\left[1-\beta\left(\theta_m^n+1\right)\right]\left\{\left(u_{m+1}^n-2u_m^n+u_{m-1}^n\right)+\dfrac{h}{2r_m}\left(u_{m+1}^n-u_{m-1}^n\right)-\dfrac{h^2}{r_m^2}u_m^n\right\}\\ -\dfrac{h}{2}\left\{a_1\left[1-\beta\left(2\theta_m^n+1\right)\right]+\beta\left(\dfrac{u_{m+1}^n-u_{m-1}^n}{2h}+\lambda_1\dfrac{u_m^n}{r_m}\right)\right\}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)\end{array}\right] \tag{121}$$

$$\theta_m^{n+1}=\frac{1}{(k+2\tau_0)}\left[\begin{array}{l}4\tau_0\theta_m^n+(k-2\tau_0)\theta_m^{n-1}+2\nu\left\{\left(\theta_{m+1}^n-2\theta_m^n+\theta_{m-1}^n\right)+\frac{h}{2r_m}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)\right\}\\ -\frac{a_2k}{2h}\left\{\left(u_{m+1}^{n+1}-u_{m+1}^{n-1}-u_{m-1}^{n+1}+u_{m-1}^{n-1}\right)+\frac{2h}{r_m}\left(u_m^{n+1}-u_m^{n-1}\right)\right\}\\ -\frac{a_2\tau_0}{h}\left\{\begin{array}{l}\left(u_{m+1}^{n+1}-2u_{m+1}^n+u_{m+1}^{n-1}-u_{m-1}^{n+1}+2u_{m-1}^n-u_{m-1}^{n-1}\right)\\ +\frac{2h}{r_m}\left(u_m^{n+1}-2u_m^n+u_m^{n-1}\right)\end{array}\right\}\\ -\frac{\beta\nu}{2\left[1-\beta\left(\theta_m^n+1\right)\right]}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)^2\end{array}\right]$$

(122)

Кучланишлар қуйидагича

$$\left[\sigma_{rr}\right]_m^n=\left[1-\beta\left(\theta_m^n+1\right)\right]\left[\frac{u_{m+1}^n-u_{m-1}^n}{2h}+\lambda_1\frac{u_m^n}{r_m}-a_1\theta_m^n\right] \quad (123)$$

$$\left[\sigma_{\varphi\varphi}\right]_m^n=\left[1-\beta\left(\theta_m^n+1\right)\right]\left[\frac{u_m^n}{r_m}+\lambda_1\frac{u_{m+1}^n-u_{m-1}^n}{2h}-a_1\theta_m^n\right] \quad (124)$$

Ошкор айирмали схемалар ва бошланғич шартлар асосида

$$\frac{\partial u_m^0}{\partial t}=\frac{u_m^1-u_m^{-1}}{2k}=0,\qquad \frac{\partial\theta_m^0}{\partial t}=\frac{\theta_m^1-\theta_m^{-1}}{2k}=0 \quad (125)$$

(125) даги u_m^{-1} ва θ_m^{-1} учун (121) ва (122) тенгламалардан фойдаланиб u_m^n ва θ_m^n орқали қаноатлантириладиган тенгламаларни қурамиз, унинг биринчи қатлами қуйидагича

$$u_m^1=u_m^0+\frac{\nu_1}{2}\left[\begin{array}{l}\left[1-\beta\left(\theta_m^0+1\right)\right]\left\{\left(u_{m+1}^0-2u_m^0+u_{m-1}^0\right)+\frac{h}{2r_0}\left(u_{m+1}^0-u_{m-1}^0\right)-\frac{h^2}{r_0^2}u_m^0\right\}\\ -\frac{h}{2}\left\{a_1\left[1-\beta\left(2\theta_m^0+1\right)\right]+\beta\left(\frac{u_{m+1}^0-u_{m-1}^0}{2h}+\lambda_1\frac{u_m^0}{r_m^0}\right)\right\}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)\end{array}\right] \quad (126)$$

$$\theta_m^1=\theta_m^0+\left[\begin{array}{l}\frac{\nu}{2\tau_0}\left\{\left(\theta_{m+1}^0-2\theta_m^0+\theta_{m-1}^0\right)+\frac{h}{2r_0}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)\right\}\\ -\frac{a_2}{4h}\left\{\left(2u_{m+1}^1-2u_{m+1}^0-2u_{m-1}^1+2u_{m-1}^0\right)+\frac{4h}{r_0}\left(u_m^1-u_m^0\right)\right\}\\ -\frac{\beta\nu}{8\tau_0\left[1-\beta\left(\theta_m^0+1\right)\right]}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)^2\end{array}\right] \quad (127)$$

$r=A$да чегаравий шартлардан фойдаланиб,

$$\frac{u_1^n-u_{-1}^n}{2h}+\lambda_1\frac{u_0^n}{r_0}-\theta_0^n=0 \quad \text{ва} \quad \theta_0^n=e^{-\varpi t_n} \quad (128)$$

u_{-1}^n ни (128) дан (121) тенгламага алмаштириб, u_m^n билан ифодаланадиган $r=A$ учун ($m=0$ қатламда), қуйидагини хосил қиламиз

$$u_0^{n+1} = \Gamma_1 u_0^n - u_0^{n-1} + \nu_1 \left[\begin{array}{l} \left[1-\beta\left(\theta_0^n+1\right)\right] \left\{ \begin{array}{l} 2\left(u_1^n - u_0^n + h\lambda_1 \dfrac{u_0^n}{r_0} - a_1 h\theta_0^n\right) \\ +\dfrac{h^2}{r_0}\left(a_1\theta_0^n - \lambda_1\dfrac{u_0^n}{r_0}\right) - \dfrac{h^2}{r_0^2}u_0^n \end{array} \right\} \\ -\dfrac{h}{2}\left\{a_1\left[1-\beta\left(\theta_0^n+1\right)\right]\right\}\left(-3\theta_0^n + 4\theta_1^n - \theta_2^n\right) \end{array} \right] \qquad (129)$$

бунда $\Gamma_1 = \dfrac{-\left(2k+\Omega^2k^2\right)}{1+\Omega k}, \qquad \nu_1 = \dfrac{k^2}{h^2\left(1+\Omega k\right)}$

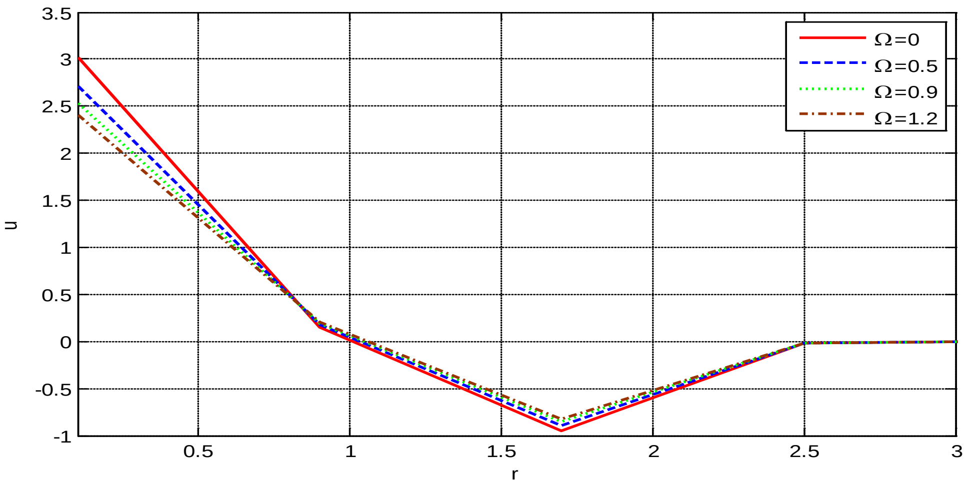
(119)даги чегаравий шартлардан фойдаланиб, (123)да $r = B$ бўлганда

$$\frac{u_{N+1}^n - u_{N-1}^n}{2h} + \lambda_1\frac{u_N^n}{r_N} - \theta_N^n = 0 \quad \text{ва} \quad \theta_N^n = 0 \qquad (130)$$

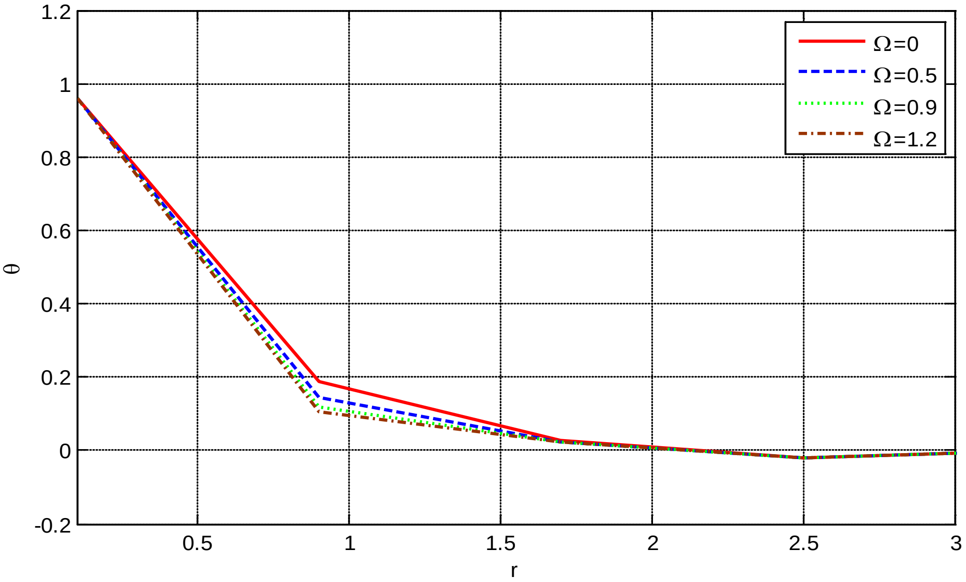
га эга бўламиз. u_{-1}^n ни (130) дан (121) тенгламага алмаштириб, u_m^n билан ифодаланадиган ($m = N$ қатламда), қуйидагини хосил қиламиз

$$u_N^{n+1} = \Gamma_1 u_N^n - u_N^{n-1} + \nu_1 \left[\begin{array}{l} \left[1-\beta\left(\theta_N^n+1\right)\right] \left\{ \begin{array}{l} 2\left(u_{N-1}^n - u_N^n + h\lambda_1 \dfrac{u_N^n}{r_N} + a_1 h\theta_N^n\right) \\ +\dfrac{h^2}{r_N}\left(a_1\theta_N^n - \lambda_1\dfrac{u_N^n}{r_N}\right) - \dfrac{h^2}{r_N^2}u_N^n \end{array} \right\} \\ -\dfrac{h}{2}\left\{a_1\left[1-\beta\left(\theta_N^n+1\right)\right]\right\}\left(3\theta_N^n - 4\theta_{N-1}^n - \theta_{N-2}^n\right) \end{array} \right] \qquad (131)$$

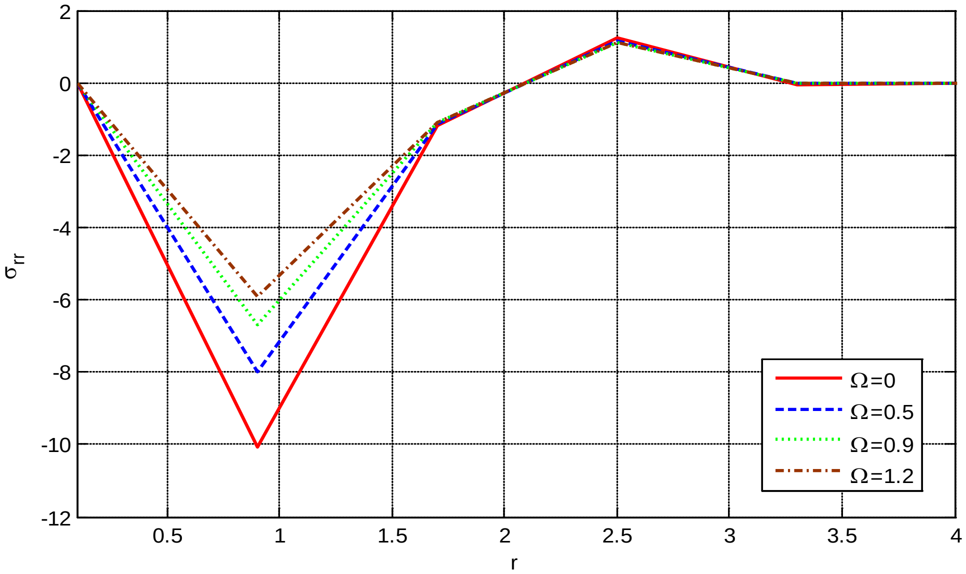
Юқоридаги тенгламалар(121)-(131) ечим соҳасининг $A \le r \le B,\ 0 \le t \le \tau$ турли нуқталарида кўчиш, ҳарорат ва кучланишлар қийматларини белгилаш учун ҳозирги масаланинг чекли айирмали схемаси моделини тасвирлайди . Аппрокциямация хатоси вақт ва масофага нисбатан $O\left(k^2+h^2\right)$да иккинчи тартибли . бу эса $k \to 0$ *ва* $h \to 0$ нолга яқинлашади.



10-расм. Четлашиш u нинг айланиш мавжуд ёки мавжуд бўлмагандаги ўзгариши.



11-расм. Айланиш мавжуд ёки мавжуд бўлмагандаги харорат ўзгариши.



12-расм. Радиал кучланишнинг айланиш таъсирида ўзгариши.

Ҳозирги кўриб чиқилган техника бу турдаги муаммолар билан шуғулланишда улкан муваффақиятларни таъминлайди.

Кўриб чиқилган техника термоэластик муҳитда масаланинг кўриб чиқилган бошқарув тенгламаларида пайдо бўлган физик миқдорларга нисбатан ҳеч қандай чеклаш йўқлигида сонли ечимларни беради.

Шунингдек кўшимча шароитларини яхшилаш учун иссиқлик оқимининг ютилиши ва айланишининг экспонентли ҳодисасини текшириш ҳам фойдалидир.

ХУЛОСА

Илмий ишлардаги олинган натижалардан келиб чиққан ҳолда (CD) Классик Динамик, (LS) Лорд-Шулман, (GL) Греен-Линдсай, Икки фазали-лаг (DPL), Яшил - Нагди (GN type III) ва Уч фазали лаг (TPL) термоэластиклик назариялари (жумлалар узилиб қолиши керак). Магнитланган қаттиқ суюқ суюқлик интерфейсида дастлабки зўриқиш бўлгганда термоэластик тўлқинларни қайтариш ва синиш муаммосини ўрганилди. Терластиклик назарияси GL ва CT нуқтаи назаридан, муаммо ҳал қилинди ва магнит майдони, ташқи иссиқлик манбалари ва p-, T- ва SV тўлқинларининг тарқалишига таъсири кўрсатилган.

Электромагнит майдон, плототермал, яримўтказгич, тортишиш майдони, айланиш ва дастлабки кучланишли муҳит таъсирида бир ҳил бўлмаган анизотропик сиқилмайдиган муҳитда қия тўлқинларнинг тарқалиши ўрганилди.

Аналитик таҳлил шуни кўрсатадики, тебраниш тўлқинларининг тарқалиш тезлиги тарқалиш йўналишига, анизотропия, магнит майдон, айланиш, тортишиш майдони, муҳитнинг бир ҳил эмаслиги ва дастлабки кучланишга боғлиқ.

Сочиш тўлқинларининг тезлигини аниқлайдиган частота тенгламаси олинди ва уни хусусиятлари ўрганилди.

Дисперсион тенгламалар олинган ва у турли хил ҳолатлар бўйича тадқиқ қилинган. Тебраниш бурчаги, электро-магнит майдони ва тортишиш кучи акс эттириш коэффициентларининг амплитудаларига сезиларли таъсир кўрсатадилиши ва бу муҳандислик, геофизика, самолётсозлик, астрономия, нефт қазиб олиш ва ҳоказоларда тажриба синов асосида кўп қўлланилган.

Кўриб чиқилган сонли айирмалар техникаси ушбу турдаги муаммолар билан шуғулланишда катта муваффақиятларни таъминлайди ва термоэластик муҳитда сонли ечимларни беради, чунки бу масаланинг кўриб чиқилган асосий тенгламаларида пайдо бўлган физик миқдорларга нисбатан ҳеч қандай чекловлар қўйилмаган.

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SOUTH VALLEY UNIVERSITY EGYPT

ELSAYED MOHAMED ABO-DAHAB

Mathematical Modeling the Reflection and Transmission of Magneto-Thermoelastic Waves and Propagation of Surface Waves

05.01.07 - Mathematical Modeling. Numerical Methods and Package of Programs (Physical and Mathematical Sciences)

DISSERTATION ABSTRACT OF DOCTORAL DISSERTATION (DSC) ON PHYSICAL AND MATHEMATICAL SCIENCES

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INTRODUCTION (abstract of the DSc thesis)

Actuality and demand of the theme of dissertation. In recent decades, further attention has been paid to the thermoelastic problems, taking into account the influence of different factors, such as electromagnetic field, rotation, thermal field, photothermal, semiconducting, voids, etc. on wave propagations, especially, reflection, refraction (transmission) or surface waves, including the Rayleigh, Stoneley, and Love waves. The aforementioned problems are important for the technical applications related to the wave propagation phenomenon, especially in engineering, geophysics, material sciences, and geology.

The present thesis is devoted to the construction of mathematical modeling equations for the actual and important engineering problems. It consists of the following items: (i) The propagation of waves (reflection or reflection and transmission) related to several scientific and engineering branches due to determining the waves amplitudes for the reflection or refraction (transmission) ratios that has an important role in determining the dangers of waves; (ii) The effect of external parameters, e.g., rotation, electromagnetic field, voids, initial stress, and diffusion on wave propagation to determine whether these parameters make a positive or a negative role in the reflection or refraction coefficients; (iii) Relaxation times and the thermoelasticity theories considered here allow to remove the paradox of infinite speed due to the thermal field to correspond with the practical results; (iv) Interactions between the displacement and temperature with the external fields, such as gravity, electromagnetic field, rotation, diffusion, and voids; (v)The surface waves that have a lot of applications, especially in earthquakes and volcanos and the multilayered properties effect on the surface wave propagation.

Finally, some phenomena were numerically solved considering the finite difference technique under the effectiveness of rotation and decayed heat flux on the obtained components that were graphically drawn. The numerical results were portrayed to unravel the influence of various parameters.

Under the Low of the President of the Republic of Uzbekistan dated February 17, 2017 "On Measures for Further Improvement of the Academy of Sciences, Management and Finance of Research Work, the low published February 8, 2017 with No. PF-4947 and the version of King doom in 2030 and other normative-legal 36 documents relating to these activities, this dissertation research will serve to a certain degree to accomplish the tasks.

Dependence of research to priority directions of development of science and technologies of the Republic. This study was conducted 2010/96 "Actual Sciences" in Egypt and on Scientific-technical programs "Mathematics, Mechanics and Informatics" in the Republic of Uzbekistan.

Review of overseas scientific investigations on topic of thesis. This scientific investigation significantly covers both aspects of the generalized theory of magneto-thermoelasticity, such as the construction the mathematical modeling equations and numerical simulation with some two dimensional half-space problems under the different factors, e.g., thermal shock, rotation, voids, diffusion, photothermal, semiconducting, and initial stress and two temperatures. The thesis problems have more applications in thermoelasticity and magneto-thermoelasticity theory. The thesis corresponds to the highly important investigations that are going on in the leading higher education institutions and research centers, including Cambridge, Manchester, Liverpool, Oxford University of Charleston, Edinburgh, Chester Universities (UK), Orlando, Florida, Universities (USA), University of BAA (Al-Ayn), Sultan Qobus University (Oman), Martin Loter University (Germany), American University of Sharjah (UAE) Yildiz Technical University (Turkey), South Valley University (Egypt), Assuit University (Egypt), Saudi Arabia University (Taif University), Al-Azhar university (Egypt), Aegean, Karlovassi, Samos (Greece), Amsterdam University (Netherlands), Melbourne, Queensland Universities (Australia), Russian Institute of Computational Mathematics (Moscow), Institute of Cybernetics (Ukraine), Perm Scientific Center of Ural Branch of Russian Academy of Sciences (Perm), Institute of Integrated Informatics Problems of the National Academy of Sciences of Belarus (Minsk), National University of Uzbekistan, Institute of Mechanics, Institute of Seysmology Academy of Sciences of Uzbekistan, Urgench State University, Samarkand State University, Bukhara State University (Uzbekistan), and Tashkent textile Institute.

There is a considerable international research effort on the construction of mathematical modeling equations for describing surface wave reflection, transmission, and propagation to show the physical meaning and effects of wave propagation and surface waves, especially the Rayleigh, Stoneley, and Love waves accounting the different external parameters, e.g., rotation, electromagnetic, rotation, initial stress, voids, photothermal, semiconducting. This effort also aims at finding the amplitudes of the reflection and transmission coefficients, as well as the displacement, temperature, stresses, mass transfer, wave speed, and attenuation coefficients that have many applications in diverse fields, such as science, engineering, astronomy, acoustics, geophysics, and petroleum extracting. We consider the new thermoelasticity models, such as the LS, GL, GN (I, II, III), DPL, and TPL.

The analytical results reveal that the velocity of the propagation of the shear waves depends upon the direction of propagation, anisotropy, magnetic field, rotation, gravity field, non-homogeneity of the medium, and initial stress. The frequency equation that determines the velocity of the shear waves was obtained. The dispersion equations were obtained and investigated for different cases. The boundary conditions that: (i)The total normal stresses in the boundary equals the initial stress; (ii) The shear stresses vanish at the boundary; and (iii)The incidence boundary is thermal insulated. The reflection coefficients were obtained for two incident p- and SV-waves. The results obtained for the incident waves were calculated numerically using appropriate metal and were presented graphically. Comparisons were made with the results obtained in the presence and absence of magnetic field, rotation, voids, diffusion, and initial stress.

The degree of the scrutiny of the problem. Theories of thermoelasticity have more applications in diverse fields, such as science, technology, astronomy, geology, petroleum extracting, and acoustics. A numerical simulation was considered concerning the mathematical modeling of the models: (CD) Classical

Dynamical (1952) that considered the coupled theory, (LS) Lord-Şhulman (1967) assuming one relaxation time to determine an infinite speed of thermal signals, (GL) Green-Lindsay (1972) with two thermal relaxation times to determine the origin time for the worth time for wave speed, (GN) Green-Nagdhi (I, II, and III types) [(1991)-(1993)], Dual-Phase-Lag (DPL) (2007), and Three-Phase-Lag (TPL) (2007) theories of thermoelasticity that are much useful in the problems of nuclear boiling, exothermic catalytic reactions, phonon-electron interactions, phonon-scattering, etc., where the time delay. We considered these theories to make numerical simulations with external parameters, such as rotation, voids, photothermal, semiconducting, initial stress, thermal shock, temperature-dependence, diffusion, and electromagnetic field and to show their impact on the wave propagation phenomena. These results will help the researchers to show the results worth for the reflection and transmission and surface waves' propagation and their applications, especially in industries, geophysics, structures, and petroleum extracting. They also help decrease the cost of producing some products that depend on the external effect and release the impact of the parameters, including electromagnetic, initial stress, etc. We considered the finite difference technique under the effectiveness of rotation and decayed heat flux on the obtained components, which was graphically drawn.

The connection of the topic of the thesis with research work of the higher educational institution, in which the thesis is carried out. The dissertation research is carried out by the National University of Uzbekistan "on a thermoelastic magnetized half-space problem in presence and absence of rotation in the context of GN (II) model" (2019-2020), South Valley University, Assuit University, Faculty of Science, Mathematics Department "Solutions of some problems in magneto-thermoelastic theories" (2005-2010).

The aim of the research. The main aim of this work is to model a mathematical technique and make a numerical simulation on wave reflection, and transmission, and propagation, as well as surface waves' propagation, which have a wide range of delay on some phenomenon related with engineering, geophysics, biology, material science, and petroleum extracting for determining its amplitudes, velocities, and attenuation coefficients due to the external parameters. All results were considered under thermoelastic theories, e.g., the (CT), (LS), (GL), (GN types I, II, III), (DPL), and (TPHL).

Tasks of the research work:

To introduce some new types of thermoelasticity theories considering new parameters, such as rotation, electromagnetic, voids, diffusion, etc.

To make mathematical models to solve the system of motion equations, temperature equation, diffusion equation, and voids equation.

To obtain the waves' propagation amplitudes (reflection or reflection and transmission), the amplitudes ratios (reflection or reflection and refraction coefficients) that will be investigated (ii) Concerns the propagation of surface waves, the frequency equation, surface waves velocity, and attenuation coefficients (iii) Respect to the two-time dependence, thermal shock problems considering the normal mode method, displacement components, temperature distribution, stress components, friction due to the voids, and diffusion due to the mass transfer will be pointed out.

To make a numerical simulation for solving the governing equation and to obtain the amplitudes and the physical quantities, such as displacements, temperature, stress, volume fraction, and carrier density.

The research object. Based on the thermoelasticity theory and Lord-Shulman, Green-Linsay, Tzou Theory, Green-Nagdhi (Types I, II and III) theories and taking into account the external factors and objects, such as energy dissipation, electromagnetic field, diffusion, voids, Dual-Phase-Lag, Three-Phase-Lag, volume friction, photothermal, semiconducting, reflection, refraction, and surface waves, the mathematical models and the numerical simulation methods will be investigated.

The research subject. The study is a generation of a numerical simulation, considering mathematical modeling for thermoelasticity theories and making a comparison with their results and applications in sciences and techniques.

Research Methods. In the thesis, we make a numerical simulation and mathematical modeling in the context of thermoelasticity theories: Classical Dynamical, Lord-Shulman, Green-Linsay, Tzou Theory, Green-Nagdhi (Types I, II and III), (DPL), and (THPL). We used Lame's potential, Harmonic, and Normal mode techniques to solve and make simulations for the thesis problem. The finite difference technique under the effectiveness of the rotation and the decayed heat flux on the obtained components was graphically drawn.

The scientific novelty of the research is as follows:

Our research significance covers both aspects of the theory of generalized magneto-thermoelasticity to make mathematical modeling for some problems of two-dimensional half-space under thermal shock, rotation, voids, diffusion, photothermal, semiconducting, initial stress, and two temperatures. The governing equations are solved using the Lame's potentials method in the context of the (CD) Classical Dynamical (1952) that considered the coupled theory, the (LS) Lord-Şhulman (1967) assuming one relaxation time to determine an infinite speed of thermal signals, the (GL) Green-Lindsay (1972) with two thermal relaxation times to determine the origin time for the worth time for wave speed, the (GN) Green-Nagdhi (I, II and III types) [(1991)-(1993)], the Dual-Phase-Lag (DPL) (2007) and the Three-Phase-Lag (TPL) (2007) therories of thermoelasticity that are very much useful in the problems of nuclear boiling, exothermic catalytic reactions, phonon-electron interactions, phonon-scattering, etc. The time delay τ_q captures the thermal wave behavior (a small scale response in time), the phase lag τ_T captures the effect of phonon-electron interactions (a microscopic response in time), and the other time delay τ_v is effective. In the three-phase-lag model, the thermal displacement gradient is considered as a constitutive variable, whereas in the conventional thermoelasticity, it is considered as a constitutive variable. We investigate the problem of the reflection and refraction of thermoelastic waves at a magnetized solid–liquid interface in the presence of initial stress. In the context of GL and CT theories of thermoelasticity, the problem was solved and the effect of magnetic field, external heat sources, and initial stress on p-, T-, and SV-waves propagation were discussed. Shear waves' propagation in a non-homogeneous anisotropic incompressible medium under the influence of the electromagnetic field, photothermal, semiconducting, gravity field, rotation and initially stressed medium was studied. The analytical results reveal that the velocity of the propagation of the shear waves depends upon the direction of propagation, anisotropy, magnetic field, rotation, gravity field, non-homogeneity of the medium, and initial stress. The frequency equation that determines the velocity of the shear waves was obtained. Moreover, the dispersion equations were obtained and investigated for different cases. The boundary conditions that: (i)The total normal stresses in the boundary condition is equivalent to the initial stress; (ii) The shear stresses vanish at the boundary; and (iii)The incidence boundary is thermal insulated. The reflection coefficients were obtained for two incident p- and SV-waves. The results obtained for the incident waves were calculated numerically using appropriate metal and were presented graphically. Comparisons were made with the results obtained in the presence and absence of the magnetic field, rotation, voids, diffusion, and initial stress. We considered the finite difference technique under the effectiveness of rotation and the decayed heat flux on the obtained components, which was graphically drawn.

Practical results of the research. The results obtained are very useful for engineering, structures, acoustics, astronomy, geophysics, industries, and biology. Also, they contribute to petroleum extracting to decrease the extracting cost, industries, acoustics, and technology.

The reliability of the results of the research. Theoretical results are presented within the framework of the theories and are proven accurately. The conditions are taken consistent with reality to make simulation during mathematical modeling. They have more applications in science, engineering, technology, industries, and technology. Therefore, the theoretical part is linked to the process through the results, and the applied part is compared to the theory to obtain the best results assuming numerical simulation.

The scientific and practical significance of the results of the research. The main focus of this thesis is to make mathematical modeling for waves' reflection and transmission, as well as propagation of surface waves and to show the physical meaning and effects of waves' propagation and surface waves, especially the Rayleigh, Stoneley, and Love waves considering the effects of external parameters, such as rotation, electromagnetic, rotation, initial stress, voids, photothermal, semiconducting, etc. They also help find the amplitudes of the reflection and transmission coefficients, displacement, temperature, stresses, mass transfer, wave speed, and attenuation coefficients that have many applications in diverse fields, e.g. science, engineering, astronomy, acoustics, geophysics, and petroleum extracting. We will consider the new thermoelasticity models, such as the LS, GL, GN (I, II, III), DPL, and TPL.

Implementations of the research results. As part of the dissertation research, more than 100scientific articles were published according to the high imperative factor of Scopus and Web of Science database, which made Hirsch index 29 by Scopus database and more 2500 references to scientific articles: from the methods of solving the problem of determining the finite wave velocity in the framework of the thermoelastic theories Green-Lindsay, Green-Nagdhi, Dual-Phase-Lag, Three-Phase-Lag in relation to the two relaxation times in foreign scientific journals Optics & Laser Technology, Volume 97, 1 December 2017, Pages 198-208; Chaos, Solitons & Fractals, Volume 99, June 2017, Pages 233-242; Applied Mathematics and Mechanics volume 39, 2018, pages783–796) used to solve the problem of one-dimensional wave propagation in a thermoelastic infinite medium with a spherical space. The application of the scientific result made it possible to solve the problem of wave propagation by photothermal processes, taking into account the elasticity and heat wave.

From the solutions of problems of return and refraction of thermoelastic waves at the boundaries of magnetic solid-liquid bodies under the influence of initial stresses in foreign scientific journals (Applied Mathematical Modelling, Volume 78, February 2020, Pages 148-168; J. Heat Transfer. Jul 2019, 141(7): 072002, 7 pages; Journal of Thermal Stresses, Volume 43, - Issue 6, 2020, Pages 667-686) used to solve two temperature generalized magneto-thermoelasticity equations with hydrostatic initial stress based on surface waves. The application of the scientific result made it possible to form a frequency equation for relay-type waves, to calculate the speed of wave propagation and the absorption coefficient.

Approbation of the research results. The results of the research have been discussed at more than 40 international scientific conferences.

Volume and structure of thesis. The dissertation is prepared in the form of English scientific lectures and consists of 98 pages.

MAIN CONTENT OF THE DISSERTATION

The thermoelasticity theory has more applications in diverse fields, such as science, engineering, acoustics, astronomy, structures, petroleum extracting, etc. The dissertation work reported here is originally motivated by several connections between elasticity, thermal field, electromagnetic field, rotation, initial stress, voids, photothermal, semiconducting, and diffusion. The effect of rotation, electromagnetic field, voids, diffusion, semiconducting, and thermal relaxation time will be studied on the waves' propagation (i.e., either waves' propagation "reflection and/or refraction" or "surface waves: Stoneley, Love, and Rayleigh"). Due to the coupling of the equation of motion, heat equation, and void equation in the context of generalized magneto-thermoelasticity, the work done in this field is unfortunately limited in number. The secular equation, Stoneley waves' velocity and attenuation coefficients are affected by the external parameters, such as the magnetic field, rotation, voids, and relaxation time. The finite difference technique under the effectiveness of rotation and decayed heat flux on the obtained components was graphically drawn.

It is concluded that the influence of the magnetic field, voids parameters, photothermal, semiconducting, initial stress, and thermal relaxation times is very pronounced in the reflection or/and refraction and also surface waves' propagation phenomena. The results obtained are very useful for engineering, structures, acoustics, astronomy, geophysics, petroleum extracting, industries, and biology.

In this thesis, we will introduce some problems on thermoelasticity and magneto-thermoelasticity under the assumption of waves or surface waves' propagation in the context of thermoelasticity theory and external parameters, such as the electromagnetic field, thermal field, initial stress, voids, photothermal, semiconducting, rotation, and diffusion.

Some points should be noted, that this thesis is devoted to a numerical simulation of considering mathematical modeling equations for the following problems:

- Influence of magnetic field and hydrostatic initial stress on reflection phenomena of P and SV waves from a generalized thermoelastic solid half-space.
- Reflection of P and SV waves from stress-free surface elastic half-space under influence of magnetic field and hydrostatic initial stress without energy dissipation.
- Effect of magneto-thermo-viscoelasticity in an unbounded body with a spherical cavity subjected to a harmonically varying temperature without energy dissipation.
- Rotation, magnetic field and stiffness effect on propagation of surface waves in an elastic layer lying over a generalized thermo-elasticdiffusive half-space with imperfect boundary.
- On magnetic field and two thermal relaxation times for p-waves propagation at interface between two solid liquid media under initial stress and heat sources.
- Propagation of Stoneley waves in magneto-thermoelastic materials with voids and two relaxation times.
- New features on S-waves propagation in a non-homogeneous anisotropic incompressible medium under influences of gravity field and initial stress with and without electromagnetic field and rotation.
- Surface waves in fibre-reinforced anisotropic general viscoelastic media of higher orders with voids, rotation and electromagnetic field.
- Reflection of generalized magneto-thermoelastic waves with two temperatures under influence of thermal shock and initial stress.
- Reflection and refraction of incident p-, T- and SV-waves at interface between magnetized two solid-liquid media with heat sources and initial stress with and without thermal relaxations times.
- A two-temperature generalized magneto-thermoelastic formulation for a rotating medium with thermal shock under hydrostatic initial stress.
- On a thermoelastic magnetized half-space problem in presence and absence of rotation in the context of GN (II) model.
- Finite difference technique to solve a problem of generalized thermoelasticity on an annular cylinder under the effect of rotation.

The thesis consists of twelve chapters. It is presented, as follows:

- **In chapter (One)**, we give an introduction, which covers a survey of the earlier studies of elasticity theories and magneto-thermoelasticity. It also covers some concepts and parameters related to the thesis object, such as the electromagnetic field, rotation, initial stress, voids, diffusion, photothermal, and semiconducting.

•**In chapter (Two)**, we provide an estimation of the theory of generalized magneto-thermoelasticity to solve the thermoelasticity problems for two-dimensional half-space under thermal shock, initial stress, and two temperatures. The governing equations are solved using the Lame's potentials method in the context of the (CD) Classical Dynamical and (LS) Lord-Şhulman theories. The boundary conditions that: (i)The total normal stresses in the boundary equal the initial stress; (ii) The shear stresses vanish at the boundary; and (iii)The incidence boundary is thermal insulated. The reflection coefficients are obtained for two incident p- and SV-waves. The results obtained for the incident waves are calculated numerically using appropriate metal and are presented graphically. Comparisons are made with the results obtained in the presence and absence of the magnetic field and initial stress.

Formulation of the problem

Let us consider that the medium is a perfect electric conductor. We take the linearized Maxwell's equations governing the electromagnetic field, taking into account the absence of the displacement current (SI)

$$\begin{aligned} &curl\,\vec{h} = \vec{J} \\ &curl\,\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t} \\ &div\,\vec{h} = 0,\ div\,\vec{E} = 0 \\ &\vec{h} = curl(\vec{u}\times\vec{H}_0),\ \vec{H} = \vec{H}_0 + \vec{h}(x,y,t) \end{aligned} \tag{1}$$

The heat conduction equation takes the form

$$K\phi_{,ii} = \left(\frac{\partial}{\partial t} + \tau_0 \frac{\partial^2}{\partial t^2}\right)(\rho C_E T + \gamma T_0 u_{i,j}) \tag{2}$$

The constitutive equation takes the form

$$\sigma_{ij} = \lambda e \delta_{ij} + 2\mu\, e_{ij} - \gamma T \delta_{ij} - P(\delta_{ij} + \omega_{ij}) \tag{3}$$

where $e_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i})$, $\omega_{ij} = \frac{1}{2}(u_{j,i} - u_{i,j})$

The equation of motion takes the form

$$\rho \ddot{u}_i = \sigma_{ij,j} + F_i\ . \tag{4}$$

where $\vec{F} = \vec{J}\times\vec{B}$, $\vec{B} = \mu_e \vec{H}_0$

The relation between the heat conduction and the dynamical heat takes the form

$$\phi - T = a\phi_{,ii}, \tag{5}$$

where $a > 0$ two-temperature parameter.

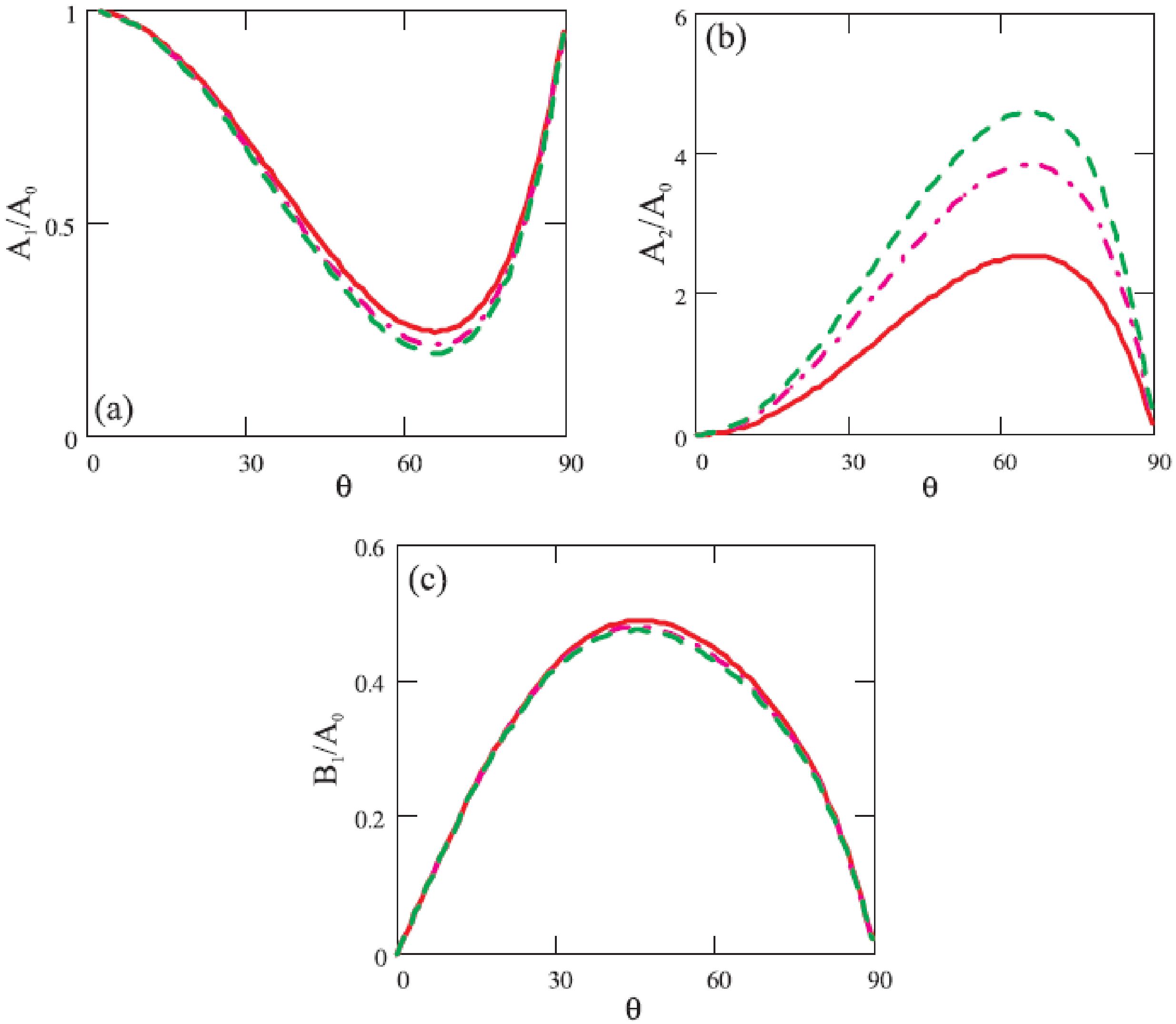


Figure 1. Effect of the initial stress on reflection coefficients for the incident P wave when $P = 10^{12}$, $H_0 = 10^5$, $\tau_0 = \tau_1 = 0.05, \eta = 1$____, $\eta = 1.2$ –.–, $\eta = 1.3$ - - -

We conclude that the relaxation time, initial stress, magnetic field, two temperatures, thermal shock, and angle of incidence have significant effects on the reflection waves' phenomena that have an important role in the engineering of metals, structures, industries, etc. Analytical solutions in the context of GL theory for thermoelastic problem in solids are obtained. For the incidence SV-wave, the relaxation time and magnetic field affect only the magnitude of the reflected T-wave. $|Z_3| < |Z_2| < |Z_1|$ for incidence p-wave. Furthermore, it is shown that $|Z_3| < |Z_2| < |Z_1|$ for incidence SV-wave.

•**In chapter (Three)**, we study the effects of the magnetic field and initial stress on p-, T-, and SV-waves' propagation. We investigate the problem of reflection and refraction of thermoelastic waves at a magnetized solid-liquid interface in the presence of the initial stress. In the context of the CT (Classical theory) and GL (Green Lindsay theory) of thermoelasticity, the problem is solved. The boundary conditions applied at the interface are (i) The displacements' continuity, (ii) Vanishing the tangential displacement, (iii) The continuity of the normal force per unit initial area, (iv) Vanishing the tangential force per unit initial area, and (v) The continuity of temperature. The amplitudes ratios for the incident p-, T-, and SV- waves have been obtained. The reflection and transmission coefficients from the incident waves are computed numerically considering the initial stress and magnetic field effect, and the results obtained are presented graphically.

1) The dynamical equations of motion and the rotating frame of reference for a plane strain under initial stress in the absence of heat source, taking into account the presence of the Lorentz force, are

$$\begin{aligned} \frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \bar{\omega}}{\partial y}+F_x &= \rho\frac{\partial^2 u}{\partial t^2} \\ \frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \bar{\omega}}{\partial x}+F_y &= \rho\frac{\partial^2 v}{\partial t^2} \end{aligned} \tag{6}$$

where $\bar{\omega}=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$, F_x and F_y are the components of the magnetic field in x and y directions, respectively.

2) The stress-strain relations with incremental isotropy are given as

$$\begin{aligned} S_{11} &= (\lambda+2\mu+P)e_{xx}+(\lambda+P)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right) \\ S_{22} &= \lambda e_{xx}+(\lambda+2\mu)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right) \\ S_{12} &= 2\mu e_{xy} \end{aligned} \tag{7}$$

3) The incremental strain- components are given as

$$e_{xx}=\frac{\partial u}{\partial x},\quad e_{yy}=\frac{\partial v}{\partial y},\quad e_{xy}=\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right) \tag{8}$$

4) The modified heat conduction equation is

$$K\nabla^2 T=\rho C_e\frac{\partial}{\partial t}\left(1+\tau_0\frac{\partial}{\partial t}\right)T+T_0\gamma\frac{\partial}{\partial t}\left(1+\tau_0\delta_{ij}\frac{\partial}{\partial t}\right)\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right) \tag{9}$$

5) Taking into account the absence of the displacement current, the linearized Maxwell equations governing the electromagnetic fields for a slowly moving solid medium having perfect electrical conductivity are

$$\begin{aligned} &\operatorname{curl}\vec{h}=\vec{J}, \qquad \operatorname{curl}\vec{E}=-\mu_e\frac{\partial \vec{h}}{\partial t} \\ &\operatorname{div}\vec{h}=0, \qquad \operatorname{div}\vec{E}=0 \end{aligned} \tag{10}$$

where $\vec{h}=\operatorname{curl}\left(\vec{u}\times\overrightarrow{H_0}\right)$.

We use $\vec{H}=\overrightarrow{H_0}+\vec{h}(x,z,t),\quad \overrightarrow{H_0}=(0,0,H)$

Then,

$$\begin{aligned} F_x &= \mu_e H^2\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 v}{\partial x\,\partial y}\right) \\ F_y &= \mu_e H^2\left(\frac{\partial^2 u}{\partial x\,\partial y}+\frac{\partial^2 v}{\partial y^2}\right) \end{aligned} \tag{11}$$

Again, the Maxwell's stress equation can be given in the form of

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij} \right] \tag{12}$$

which reduces to

$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right), \quad \tau_{12} = 0$$

We observe the effect of the initial stress and magnetized on the reflection and refraction of plane waves at a solid-liquid interface under perfect boundary conditions in the context of GL and CT theories. The waves' amplitudes ratios with initial stress and magnetic field with the angle of incidence are obtained in the framework of the GL and CT models investigated numerically and presented graphically.

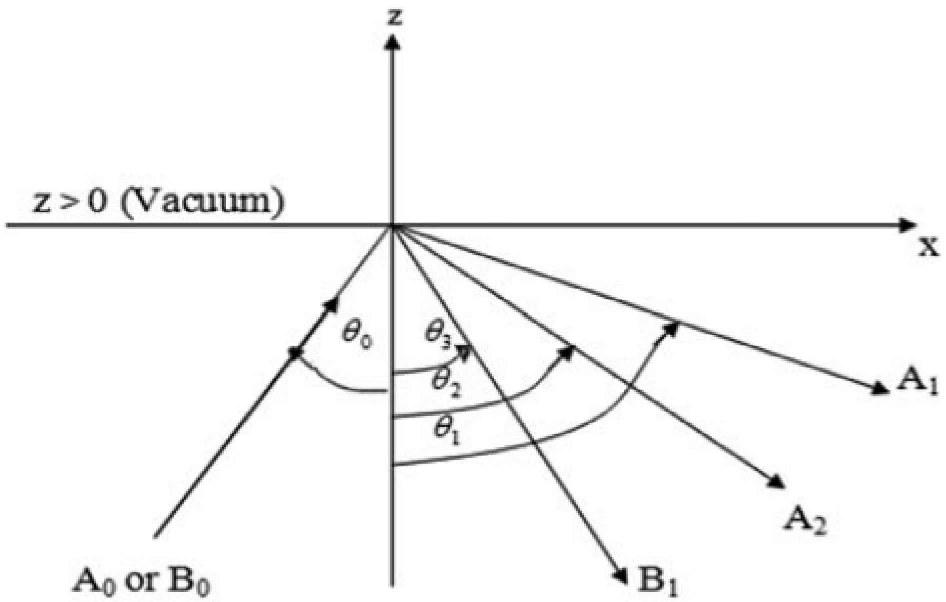
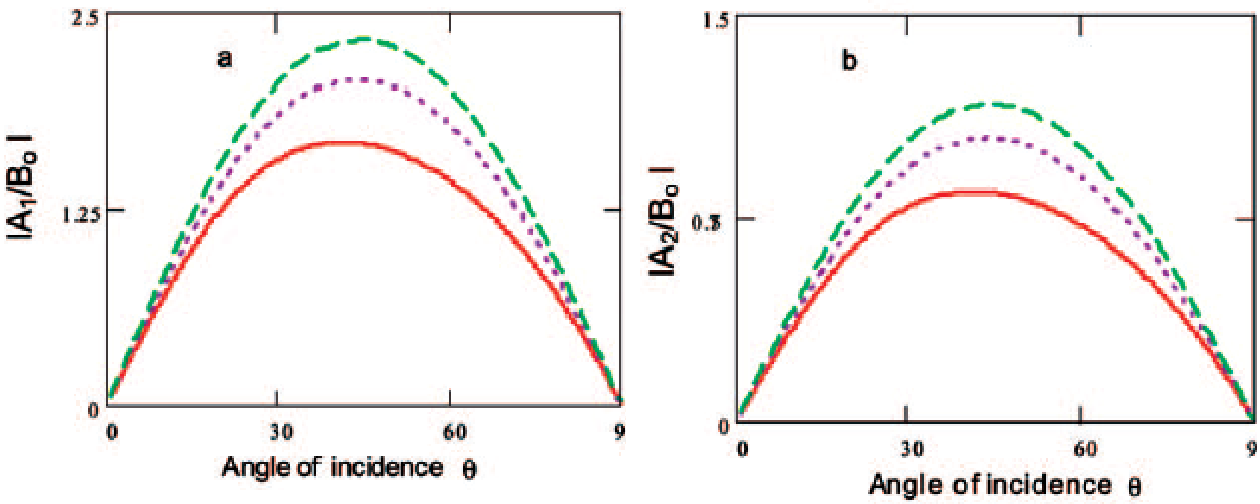


Figure 2: Schematic of the problem



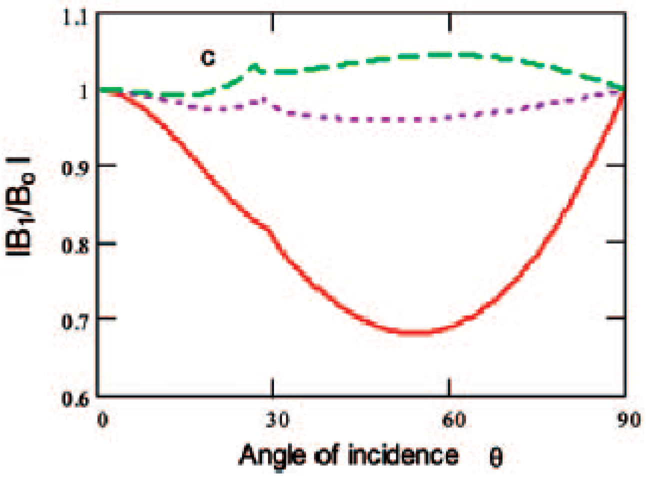


Figure 3. Effect of the initial pressure on reflection coefficients for the incident SV wave, where $H_0=10^5$, $\eta=1, h=3, P=10^{11}$ ____, $P=5\times10^{11}$......., $P=10^{12}$ − − −

•**In chapter (Four)**, we investigate the problem of the reflection and refraction of thermoelastic waves at a magnetized solid-liquid interface in the presence of initial stress. In the context of the GL and CT theories of thermoelasticity, the problem is solved, and the effect of the magnetic field, external heat sources, as well as initial stress on p-, T-, and SV-waves' propagation is discussed. The boundary conditions at the interface for displacement continuity, vanishing the tangential displacement, continuity of normal force, tangential force and continuity of temperature are applied. The amplitude ratios of the incident p-, T-, and SV-waves are obtained. The effect of the initial stress, heat sources, and magnetic field on the reflection and transmitted coefficients for the incident waves is discussed.

1. The dynamical equations of motion in the rotating frame for a plane strain under initial stress in the absence of the heat source can be given as:

$$\left.\begin{aligned}\frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \varpi}{\partial y}+F_1=\rho\frac{\partial^2 u}{\partial t^2}\\ \frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \varpi}{\partial x}+F_2=\rho\frac{\partial^2 v}{\partial t^2}\end{aligned}\right\} \qquad (13)$$

where $\varpi=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$.

2. The stress–strain relations with incremental isotropy are given as

$$\left.\begin{aligned}S_{11}&=(\lambda+2\mu+P)e_{xx}+(\lambda+P)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right)\\ S_{22}&=\lambda e_{xx}+(\lambda+2\mu)e_{yy}-\gamma\left(T+\tau_1\frac{\partial T}{\partial t}\right)\\ S_{12}&=2\mu e_{xy}\end{aligned}\right\} \qquad (14)$$

3. The incremental strain components are given in the form of

$$e_{xx} = \frac{\partial u}{\partial x}, \quad e_{yy} = \frac{\partial v}{\partial y}, \quad e_{xy} = \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) \tag{15}$$

4. The modified heat conduction equation is

$$K\nabla^2 T = \rho C_e \left(\frac{\partial T}{\partial t} + \tau_0 \frac{\partial^2 T}{\partial t^2}\right) + T_0 \gamma \left[\frac{\partial}{\partial t}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + \tau_0 \delta \frac{\partial^2}{\partial t^2}\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)\right] \tag{16}$$

5. The linearized Maxwell equations governing the electromagnetic field for a slowly moving solid medium of perfect electrical conductivity, taking into account the absence of displacement current, are:

$$\operatorname{curl}\vec{h} = \vec{J}, \quad \operatorname{curl}\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t}, \quad \operatorname{div}\vec{h} = 0, \quad \operatorname{div}\vec{E} = 0 \tag{17}$$

where $\vec{h} = \operatorname{curl}\left(\vec{u} \times \overrightarrow{H_0}\right).$

We use $\vec{H} = \overrightarrow{H_0} + \vec{h}(x, z, t), \quad \overrightarrow{H_0} = (0, 0, H)$

Then,

$$F_x = \mu_e H^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 v}{\partial x \partial y}\right), \quad F_y = \mu_e H^2 \left(\frac{\partial^2 u}{\partial x \partial y} + \frac{\partial^2 v}{\partial y^2}\right) \tag{18}$$

Again, the Maxwell's stress equation can be given in the form of

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij}\right]$$

This reduces to

$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \quad \tau_{12} = 0 \tag{19}$$

with the help of Eqs. (14)-(18), Eq. (13) has the form of

$$\begin{aligned} &\left(\lambda + 2\mu + P + \mu_e H^2\right)\frac{\partial^2 u}{\partial x^2} + \left(\lambda + \frac{P}{2} + \mu + \mu_e H^2\right)\frac{\partial^2 v}{\partial x \partial y} + \\ &+ \left(\mu + \frac{P}{2}\right)\frac{\partial^2 u}{\partial y^2} = \rho \frac{\partial^2 u}{\partial t^2} + \gamma \left(\frac{\partial T}{\partial x} + \tau_1 \frac{\partial^2 T}{\partial x \partial t}\right) \end{aligned} \tag{20}$$

$$\begin{aligned} &\left(\mu - \frac{P}{2}\right)\frac{\partial^2 v}{\partial x^2} + \left(\lambda + \frac{P}{2} + \mu + \mu_e H^2\right)\frac{\partial^2 u}{\partial x \partial y} + \left(2\mu + \lambda + \mu_e H^2\right)\frac{\partial^2 v}{\partial y^2} = \\ &= \rho \left(\frac{\partial^2 u}{\partial t^2}\right) + \gamma \left(\frac{\partial T}{\partial y} + \tau_1 \frac{\partial^2 T}{\partial y \partial t}\right) \end{aligned} \tag{21}$$

To separate the dilatational and rotational components of strain, we introduce displacement potentials Φ and Ψ defined by the following relations:

$$u = \frac{\partial \Phi}{\partial x} - \frac{\partial \Psi}{\partial y}, \quad v = \frac{\partial \Phi}{\partial y} + \frac{\partial \Psi}{\partial x}, \quad \underline{\Psi} = (0, 0, -\Psi) \tag{22}$$

Using Eq. (22), Eq. (20) reduces to the following equations

$$\nabla^2 \Phi = \frac{1}{\left(\lambda + 2\mu + P + \mu_e H^2\right)}\left[\rho \frac{\partial^2 \Phi}{\partial t^2} + \gamma \left(T + \tau_1 \frac{\partial T}{\partial t}\right)\right] \tag{23}$$

$$\nabla^2\Psi = \frac{\rho}{\left(\mu + \frac{P}{2}\right)}\left[\frac{\partial^2\Psi}{\partial t^2}\right]. \tag{24}$$

Similarly, Eq. (21) takes the form of

$$\nabla^2\Phi = \frac{\rho}{\left(\lambda + 2\mu + \mu_e H^2\right)}\left[\frac{\partial^2\Phi}{\partial t^2}\right] + \frac{\gamma}{\left(\lambda + 2\mu + \mu_e H^2\right)}\left(T + \tau_1\frac{\partial T}{\partial t}\right) \tag{25}$$

$$\nabla^2\Psi = \frac{\rho}{\left(\mu - \frac{P}{2}\right)}\left[\frac{\partial^2\Psi}{\partial t^2}\right] \tag{26}$$

and Eq. (16) reduces to

$$K\nabla^2 T = \rho C_e\left(\frac{\partial T}{\partial t} + \tau_0\frac{\partial^2 T}{\partial t^2}\right) + T_0\gamma\frac{\partial}{\partial t}\left(1 + t_0\delta\frac{\partial}{\partial t}\right)\nabla^2\Phi \tag{27}$$

where $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$.

Solution using the **GL model**

In the Green–Lindsay theory: $\tau_1 \geq \tau_0 > 0$, and $\delta = 0$,

Solution using the CT theory

In the CT theory: $\tau_1 = \tau_0 = 0$ and $\delta = 0$.

We model the effect of initial stress and magnetized on reflection and refraction of plane waves at a solid–liquid interface under the perfect boundary conditions in the context of the GL and CT theories. The wave amplitudes' ratios with initial stress and magnetic field with the angle of incidence are obtained in the framework of the GL and CT models investigated numerically and presented graphically. The reflected and refracted amplitudes depend on the angle of incidence, initial stress, and magnetic field. The nature of this dependence is different for diverse reflected waves. The initial stress and magnetized media play a significant role and have the inverse trend for the reflected and transmitted waves. The heat sources affect strongly the amplitudes of the refracted p- and T-waves, but there is a slight change in the amplitudes of other waves.

Finally, it appears that the reflection and refraction coefficients strongly appear in the phenomena with many applications, especially in seismic waves, earthquakes, volcanoes, and acoustics.

In chapter (Five), shear waves' propagation in a non-homogeneous anisotropic incompressible medium under the influence of the electromagnetic field, gravity field, rotation, and initially stressed medium are studied. Analytical analysis reveal that the velocity of the propagation of the shear waves depends upon the direction of propagation, anisotropy, magnetic field, rotation, gravity field, non-homogeneity of the medium, and initial stress. The frequency equation that determines the velocity of the shear waves is obtained. The dispersion equations is obtained and investigated for different cases. In fact, these equations are in agreement with the corresponding classical results when the medium is isotropic.

The results obtained are discussed and presented graphically. The results indicate that the effects of the gravity field, initial stress, magnetic field, electric field anisotropy, and rotation are very pronounced.

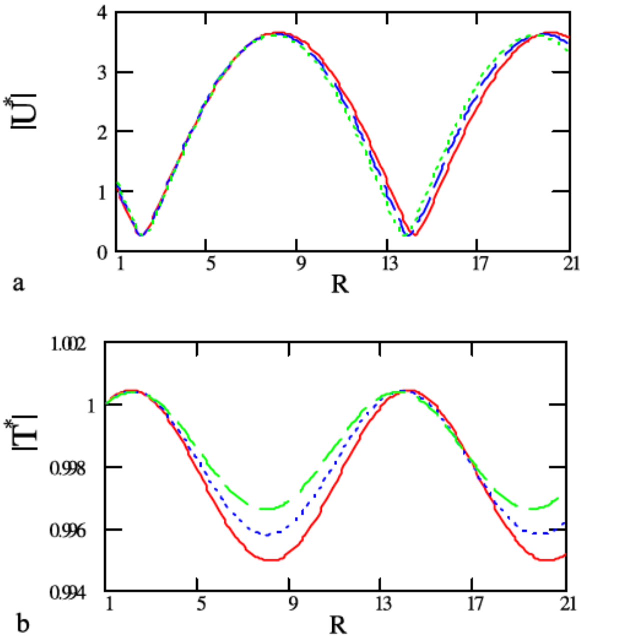


Fig. 4: Variations of the absolute values of the displacement and temperature respect to radius with the influences of magnetic field: Ho = 10^5 (solid line), Ho = 2×10^5 (dashed line), Ho = 3×10^5 (dotted line).

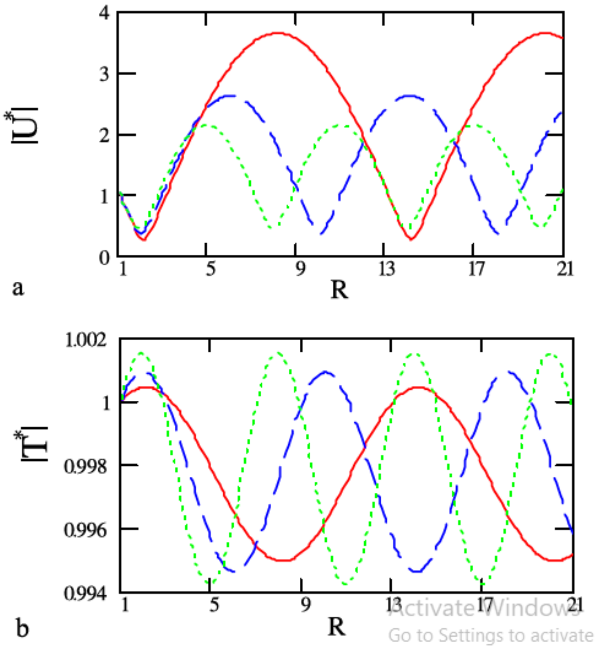


Fig. 5: Variations of the absolute values of the displacement and temperature respect to radius with the influences of frequency: ω = 0.2 (solid line), ω = 0.3 (dashed line), ω = 0.4 (dotted line).

We consider an unbounded incompressible anisotropic medium under initial stresses s_{11} and s_{22} along the $x-, y-$directions, respectively. When the medium is slightly disturbuted (u,v), the incremental stresses $s_{11},\ s_{12}$ and s_{22} are developed, and the equations of motion in incremental state become

$$\frac{\partial s_{11}}{\partial x}+\frac{\partial s_{12}}{\partial y}-P\frac{\partial w_3}{\partial y}-\rho g\frac{\partial v}{\partial x}+F_x=\rho\left[\ddot{u}+\left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_x+\left(2\vec{\Omega}\times\dot{\vec{u}}\right)_x\right], \qquad (28)$$

$$\frac{\partial s_{12}}{\partial x}+\frac{\partial s_{22}}{\partial y}-P\frac{\partial w_3}{\partial x}+\rho g\frac{\partial u}{\partial x}+F_y=\rho\left[\ddot{v}+\left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_y+\left(2\vec{\Omega}\times\dot{\vec{u}}\right)_y\right] \qquad (29)$$

where

$$F_i=\left(\vec{J}\times\vec{B}\right)_i .$$

- where F_x and F_y are the components of the magnetic field in x and y directions, respectively. The initial stress $P=s_{22}-s_{11}$, the rotational components about $z-$ axis, $w_3=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$, ρ represent the density of the medium. g is the acceleration due to gravity, (u,v) are incremental deformation, and $\vec{\Omega}$ is the angular rotation.
- For a slowly moving medium, the variations of the magnetic field and electric field are given by the Maxwell's equation in the following form:

$$curl\ \vec{h} = \vec{J} + \varepsilon_0 \dot{\vec{E}}, \quad curl\ \vec{E} = -\mu_e \dot{\vec{h}}, \quad div\ \vec{h} = 0, \quad div\ \vec{E} = 0,$$

$$\vec{E} = -\mu_e \left(\dot{\vec{u}} \times \vec{H} \right), \qquad \vec{h} = curl(\vec{u} \times \vec{H}_0) \tag{30}$$

where

$$\vec{H} = \vec{H}_0 + \vec{h}(x, y, t), \qquad \vec{H}_0 = (H_0, 0, 0)$$

where $\vec{B}$ is a magnetic induction vector, $\vec{E}$ is an electric intensity vector, $\vec{F}$ is the Lorentz's body forces vector, $\dot{\vec{u}}$ is the velocity vector $\vec{h}$ is perturbed magnetic field vector, $\vec{H}$ is magnetic field vector, $\vec{H}_0$ is a pri**mary constant magnetic field vector,** H_0 **is the absolute magnetic field,** $\vec{J}$ **is an electric current density vector, and** μ_e **is** the **magnetic permeability,** ε_0 **is the electric permeability.**

The incremental stress-strain relations for an incompressible medium may be taken as

$$s_{11} = 2Ne_{xx} + s, \quad s_{22} = 2Ne_{yy} + s \ \text{ and } \ s_{12} = 2Qe_{xy} \tag{31}$$

where $s = \frac{s_{11+} s_{22}}{2}$, e_{ij} are incremental strain components, and N and Q are the rigidities of the medium.

The Maxwell's stress equation

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - H_k h_k \delta_{ij} \right]. \tag{32}$$

The incompressibility condition $e_{xx} + e_{yy} = 0$ is satisfied by

$$u = -\frac{\partial \phi}{\partial y}, \quad v = \frac{\partial \phi}{\partial x}. \tag{33}$$

Substituting from Eqs. (30) and (31) into Eqs. (28) and (29), we get

$$\frac{\partial s}{\partial x} - 2N\frac{\partial^3 \phi}{\partial x^2 \partial y} + \frac{\partial}{\partial y}\left[Q\left(\frac{\partial^2 \phi}{\partial x^2} - \frac{\partial^2 \phi}{\partial y^2} \right) \right] - \frac{P}{2}\frac{\partial}{\partial y}\left(\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} \right)$$
$$= \rho\left[g\frac{\partial^2 \phi}{\partial x^2} - \frac{\partial^3 \phi}{\partial y \partial t^2} + \Omega^2 \frac{\partial \varphi}{\partial y} - 2\Omega \frac{\partial^2 \phi}{\partial x \partial t} \right], \tag{34}$$

$$\frac{\partial s}{\partial y} + \frac{\partial}{\partial y}\left(2N\frac{\partial^2 \phi}{\partial x \partial y} \right) + Q\left(\frac{\partial^3 \phi}{\partial x^3} - \frac{\partial^3 \phi}{\partial x \partial y^2} \right) - \frac{P}{2}\left(\frac{\partial^3 \phi}{\partial x^3} + \frac{\partial^3 \phi}{\partial x \partial y^2} \right)$$
$$+ \mu_e H_0^2 \left(\frac{\partial^3 \phi}{\partial x^3} + \frac{\partial^2 \phi}{\partial x \partial y^2} - \varepsilon_0 \mu_e \frac{\partial^3 \phi}{\partial x \partial t^2} \right) = \rho\left[g\frac{\partial^2 \phi}{\partial x \partial y} + \frac{\partial^3 \phi}{\partial x \partial t^2} - \Omega^2 \frac{\partial \varphi}{\partial x} - 2\Omega \frac{\partial^2 \phi}{\partial y \partial t} \right]. \tag{35}$$

Assuming non- homogeneities as

$$\left.\begin{aligned} Q &= Q_0(1+ay), \\ N &= N_0(1+by), \\ \rho &= \rho_0(1+cy) \end{aligned}\right\} \tag{36}$$

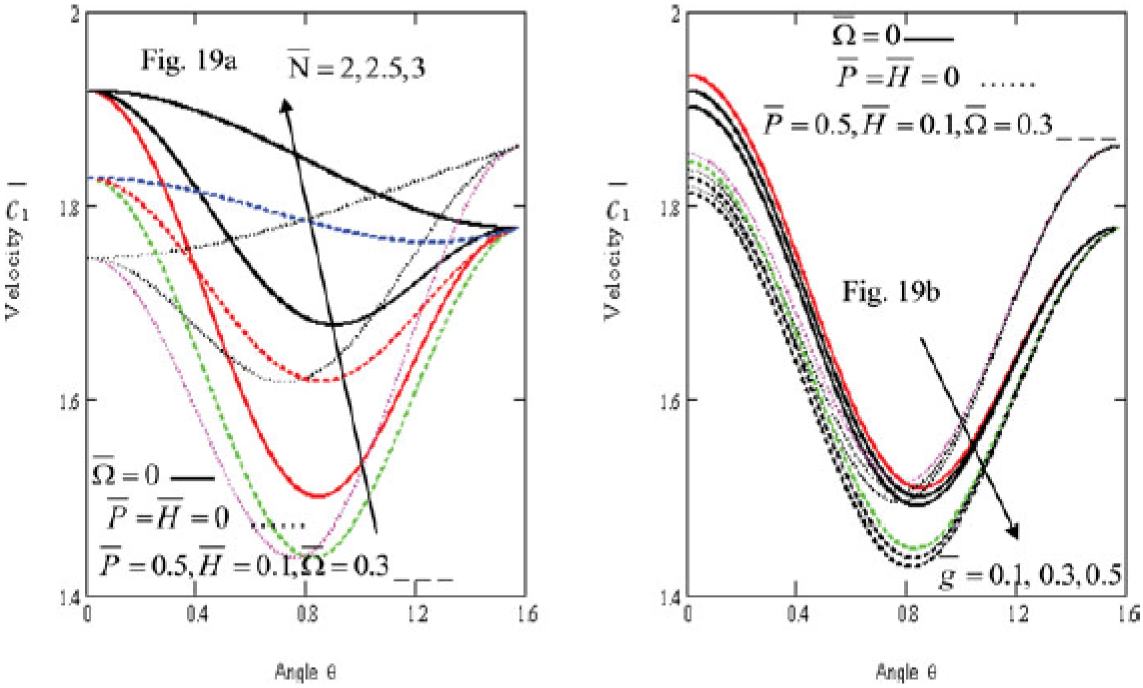


Figure 6: Variation of velocity $\overline{C_1}$ with respect to the angle θ: without rotation, without initial stress and magnetic field, and in the presence of all parameters: (a) $\overline{N}$ and (b) $\overline{g}$.

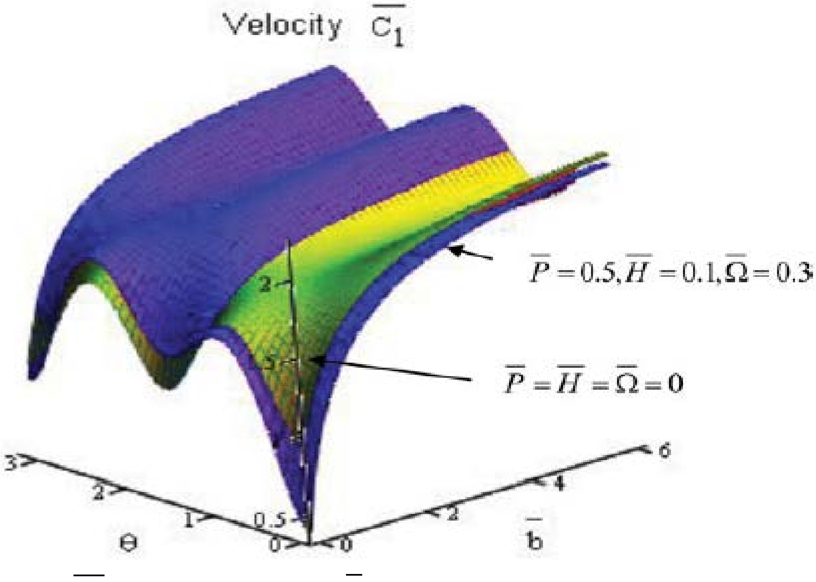


Figure 7. Variation of velocity $\overline{C_1}$ with respect to $(\theta, \overline{b})$ with and without magnetic, rotation, and initial stress.

We concluded from the results obtained analytically and displaying the numerical results graphically, we conclude the following remarks:

- The depth $\overline{b}$ affects positively the waves' velocity $\overline{C_1}$.
- The angle of incidence θ affects periodically as increasing and decreasing on the velocity.
- The magnetic field $\overline{H}$ and gravity $\overline{g}$ cause interruption on the waves'

velocity.

- The waves' velocity $\overline{C_1}$ is affected strongly by the angular velocity (rotation) when compared with the results obtained in the absence of the rotation that indicate that the influence of rotation in aircrafts and planes has utilitarian aspects in geophysics, eeology, biology, acoustics,…, and plasma.

- All parameters affect strongly on the waves' velocity, expect for $\overline{\zeta}$ that decreases slightly on $\overline{C_1}$.

•**In chapter (Six)**, an estimation is made to study the propagation of the Stoneley waves in magneto-thermoelastic materials with voids and two thermal relaxation times in the context of the Green Lindsay (GL) model. The basic governing equations are formulated in the xz-plane and the magnetic field are considered in y-axis that acts perpendicular to the wave propagation. We applied the Lame's potential method to solve the problem. The boundary conditions that the continuity of the forces stresses and Maxwell's stresses components, displacement components, heat flux, temperature, and volume fraction field are illustrated at the interfaces between two dissimilar half-spaces to obtain the frequency equation of the Stoneley waves in the media. Some special cases with neglecting: (i) the magnetic field and (ii) the thermal relaxation times parameters are deduced as special cases from this study. Moreover, the numerical results are displayed graphically.

The governing equations for an isotropic, homogeneous elastic solid with generalized thermoelasticity with voids and incremental heat flux at the reference temperature T_0 taking into our account the GL theory and the fields (thermal, magnetic, voids, and elastic) are given, as follows:

$$\sigma_{ij} = \left(\lambda e_{kk} - \beta\left(1+\tau_1\frac{\partial}{\partial t}\right)\Theta + b\Phi\right)\delta_{ij} + 2\mu e_{ij}, \quad (37)$$

$$q_i + \tau_0 \ddot{q}_i = K\Theta_{,i}, \quad (38)$$

$$S_i = \alpha\Phi_{,i}, \quad (39)$$

$$\rho\eta = \beta e_{kk} + \alpha\Theta + m\Phi, \quad (40)$$

$$g = -be_{kk} - \xi\Phi + m\Theta, \quad (41)$$

$$\rho T_0 \dot{\eta} = q_{i,i}, \quad (42)$$

$$e_{ij} = \frac{1}{2}\left(u_{i.j} + u_{j,i}\right), \quad w_{ij} = \frac{1}{2}\left(u_{j.i} - u_{i,j}\right). \quad (43)$$

The Maxwell's electromagnetic stress tensor τ_{ij} is given by

$$\tau_{ij} = \mu_e\left(H_i h_j + H_j h_i - \left(H_k.h_k\right)\delta_{ij}\right). \quad (44)$$

The equation of motion

$$\sigma_{ji,j} + F_i = \rho\ddot{u}_i \quad (45)$$

which tends to

$$\mu u_{i.jj} + (\lambda+\mu)u_{j,ij} - \beta\left(1+\tau_1\frac{\partial}{\partial t}\right)\Theta_{,i} + b\Phi_{,i} + F_i = \rho\ddot{u}_i. \quad (46)$$

The equation of heat conduction under the GL model

$$\rho C_e(\dot{\Theta}+\tau_0\ddot{\Theta})+\beta T_0\dot{u}_{k,k}+mT_0(\dot{\Phi}+\tau_0\ddot{\Phi})=K\Theta_{,ii}, \qquad (47)$$

$$\alpha\Phi_{,ii}-bu_{k,k}-\xi\Phi+m\Theta=\rho\chi\ddot{\Phi} \qquad (48)$$

where

$$F_i=\left(\vec{J}\times\vec{B}\right)_i. \qquad (49)$$

Consider that the medium is a perfect electric conductor, we take the linearized Maxwell's equations governing the electromagnetic field, taking into account the absence of the displacement current (SI), as shown in the following form

$$\left.\begin{array}{ll} curl\,\vec{h}=\vec{J}, & curl\,\vec{E}=-\mu_e\dfrac{\partial\vec{h}}{\partial t}, \\ div\,\vec{h}=0, & div\,\vec{E}=0 \end{array}\right\} \qquad (50)$$

where

$$\vec{h}=curl\left(\vec{u}\times\vec{H}_0\right) \qquad (51)$$

where we used

$$\vec{H}=\vec{H}_0+\vec{h}(x,z,t), \qquad \vec{H}_0=(0,H,0). \qquad (52)$$

For two-dimensional motion in the xz-plane, Eqs. (46)-(48) are written as

$$\left(\lambda+2\mu+\mu_eH^2\right)\frac{\partial^2u_1}{\partial x^2}+\left(\lambda+\mu+\mu_eH^2\right)\frac{\partial^2u_3}{\partial x\partial z} + \mu\frac{\partial^2u_1}{\partial z^2}-\beta\,\tau^1\frac{\partial\Theta}{\partial x}+b\frac{\partial\Phi}{\partial x}=\rho\frac{\partial^2u_1}{\partial t^2}, \qquad (53)$$

$$\left(\lambda+2\mu+\mu_eH^2\right)\frac{\partial^2u_3}{\partial z^2}+\left(\lambda+\mu+\mu_eH^2\right)\frac{\partial^2u_1}{\partial x\partial z} + \mu\frac{\partial^2u_3}{\partial x^2}-\beta\,\tau^1\frac{\partial\Theta}{\partial z}+b\frac{\partial\Phi}{\partial z}=\rho\frac{\partial^2u_3}{\partial t^2}, \qquad (54)$$

$$\rho C_e\,\tau^0\frac{\partial\Theta}{\partial t}+\beta\,T_0\left(\frac{\partial^2u_1}{\partial x\partial t}+\frac{\partial^2u_3}{\partial z\partial t}\right) + m\,\tau^0T_0\frac{\partial\Phi}{\partial t}=K\left(\frac{\partial^2\Theta}{\partial x^2}+\frac{\partial^2\Theta}{\partial z^2}\right), \qquad (55)$$

$$\alpha\left(\frac{\partial^2\Phi}{\partial x^2}+\frac{\partial^2\Phi}{\partial z^2}\right)-b\left(\frac{\partial u_1}{\partial x}+\frac{\partial u_3}{\partial z}\right)-\xi\Phi+m\Theta=\rho\chi\frac{\partial\Phi}{\partial t} \qquad (56)$$

where

$$\tau^0=1+\tau_0\frac{\partial}{\partial t}, \quad \tau^1=1+\tau_1\frac{\partial}{\partial t}.$$

The displacement components u_1 and u_3 may be written in terms of the scalar and the vector potential functions, φ and ψ, respectively, as shown in the following form:

$$u_1 = \frac{\partial \varphi}{\partial x} - \frac{\partial \psi}{\partial z}, \qquad u_3 = \frac{\partial \varphi}{\partial z} + \frac{\partial \psi}{\partial x}. \tag{57}$$

The previous results show that the effect of the magnetic field and thermal relaxation time on the velocity of the Stoneley waves and attenuation coefficient in magneto-thermoplastic materials with voids. We have the values of these waves increased or decreased with the increasing of the values of the magnetic field and thermal relaxation time.

Due to the complicated nature of the governing equations for the generalized magneto-thermoelasticity theory, the work done in this field is unfortunately limited in number. The method used in this study is quite successful in dealing with such problems. This method gives exact solutions in the elastic medium without any assumed restrictions on the actual physical quantities that appear in the governing equations of the problem considered.

The importance of the phenomena is observed from the following conclusions:

-The Stoneley waves' velocity and attenuation coefficients take small values with the presence of the magnetic field compared with the corresponding values in the absence of H.

-The Stoneley waves' velocity increases with the increase of the relaxation times in the presence and absence of H and vice versa for the attenuation coefficients.

- The Stoneley waves' velocity decreases with the increase of the magnetic field H with and without thermal relaxation times and vice versa for the attenuation coefficient.

The results presented in this chapter should prove useful for researchers in material science, designers of new materials, low-temperature physicists, and those working on the development of the theory of hyperbolic propagation of hyperbolic thermoelastic. Relaxation time and voids exchange with the environment arising from and inside nuclear reactors influence their and operations. The study of the phenomenon of the relaxation time and the magnetic field is also used to improve the conditions of oil extractions. It is concluded that the influence of the magnetic field, voids parameters, and thermal relaxation times are very pronounced in the surface waves' propagation phenomena.

•**In chapter (Seven)**, we investigated the propagation of surface waves in a nonhomogeneous rotating fibre-reinforced viscoelastic anisotropic media of higher order of n-th order including the time rate of strain. The general surface wave speed is derived to study the effect of rotation on surface waves. Particular cases for the Stoneley, Love, and Rayleigh waves are discussed. The results obtained in this investigation are more general in the sense that some earlier published results are obtained from our result as special cases. Also, the results of the homogeneous media can be deduced from this investigation. For order zero, our results agreed with fibre-reinforced materials. By neglecting the reinforced elastic parameters, the results reduce to well-known isotropic medium. It is also observed that surface waves cannot propagate in a fast rotating medium. A comparison is made with the results obtained in the presence and absence of rotation and parameters for fibre-reinforced of the material medium. Numerical results were given and illustrated graphically. The results indicate that the effect of rotation and parameters for fibre-reinforced of the material are very pronounced.

A medium consists of two non-homogeneous anisotropic fibre-reinforced semi-infinite elastic solid media M1 and M2 with different elastic and reinforcement parameters. The non-homogeneity of the material depends on the space variable. It is assumed that non-homogeneity grows or decays slowly. Its rate of growth or decay is proportional to its value at that point, i.e.,

$\frac{d\lambda}{dx_2} = \alpha\lambda;$ where λ is an elastic parameter.

This implies

$$\frac{d\lambda}{dx_2} = m\lambda,$$

where m is a constant, which is positive for the inhomogeneity growth and negative for decay.

The above equation implies

$$\lambda = \lambda_o e^{mx_2}$$

For m=0, $\lambda = \lambda_o$, Thus for $m = 0$, the medium is homogeneous.

The two media are perfectly welded in contact at a plane interface. Let us take orthogonal Cartesian axes $Ox_1x_2x_3$ with the origin at O. Ox_2 points vertically upwards to the medium M(x_2> 0). The media M1 (x_2> 0) and M2 (x_2< 0) are separated at x_2= 0. Both media rotate about an axis.

It is assumed that the waves travel in the positive direction of the x1-axis and at any instant, all particles have equal displacements in any direction parallel to Ox3. Given those assumptions, the propagation of waves is independent of x3.

The propagation equations of the small elastic disturbances are, as follows:

$\tau_{ij,j} = \rho\{\ddot{u}_i + \Omega_j u_j \Omega_i - \Omega^2 u_i - 2\varepsilon_{ijk}\Omega_j \dot{u}_k\}$, where ε_{ijk} is the Levi-Civita tensor, τ_{ij} are components of stress, ρ is the mass density, and u_i is the displacement vector. The upper suffix dot shows the time derivative with respect to time and comma followed by an index that shows the partial derivative with respect to a coordinate. It is assumed that the body rotates about z-axis with an angular frequency Ω, i.e., $\mathbf{\Omega} = \Omega(0,0,1)$

In the component form, the equation of motion becomes

$$\left.\begin{aligned} \tau_{11,1} + \tau_{12,2} + \tau_{13,3} &= \rho\{\ddot{u}_1 - \Omega^2 u_1 - 2\Omega\dot{u}_2\}, \\ \tau_{21,1} + \tau_{22,2} + \tau_{23,3} &= \rho\{\ddot{u}_2 - \Omega^2 u_2 + 2\Omega\dot{u}_1\}, \\ \tau_{31,1} + \tau_{32,2} + \tau_{33,3} &= \rho\ddot{u}_3. \end{aligned}\right\} \qquad (58)$$

The general equation for a fibre-reinforced linearly elastic anisotropic media w.r.t. a direction $\overline{a} = (a_1, a_2, a_3)$ is as

$$\tau_{ij}=D_\lambda\varepsilon_{kk}\delta_{ij}+2D_{\mu_T}\varepsilon_{ij}+D_\alpha(a_ka_m\varepsilon_{km}\delta_{ij}+\varepsilon_{kk}a_ia_{j)+}2(D_{\mu_L}-D_{\mu_T})(a_ia_k\varepsilon_{kj}+a_ja_k\varepsilon_{ki})+D_\beta(a_ka_m\varepsilon_{km}a_ia_j$$

Strain tensor is $\varepsilon_{ij}=\frac{1}{2}(u_{i,j}+u_{j,i})$ and D_λ, D_{μ_T} are elastic parameters. D_α, D_β and $(D_{\mu_L}-D_{\mu_T})$ are reinforced anisotropic viscoelastic parameters of higher order , s .

In the present problem, we consider exponentially decaying non-homogeneous material. Hence, the density, elastic module, and elastic parameters may be taken in the following form

$$\rho=\rho_o e^{-mx_2}$$

$$D_\lambda=\lambda_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_\mu=\mu_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}$$

$$D_\alpha=\alpha_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_{\mu_L}=\mu_{L_k}\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}$$

$$D_\beta=\beta_k\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2} \qquad D_{\mu_T}=\mu_{T_k}\left(\frac{\partial}{\partial t}\right)^k e^{-mx_2}$$

$$k=0,1,2...s.$$

An Einstein summation convention for repeated indices is used.

By choosing the fibre direction as $\bar{a}=(1,0,0)$, the components of stress becomes

$$\tau_{11}=(D_\lambda+2D_\alpha+4D_{\mu_L}-2D_{\mu_T}+D_\beta)\varepsilon_{11}+(D_\lambda+D_\alpha)\varepsilon_{22}+(D_\lambda+D_\alpha)\varepsilon_{33},$$

$$\tau_{22}=(D_\lambda+D_\alpha)\varepsilon_{11}+(D_\lambda+2D_{\mu_T})\varepsilon_{22}+D_\lambda\varepsilon_{33},$$

$$\tau_{33}=(D_\lambda+D_\alpha)\varepsilon_{11}+D_\lambda\varepsilon_{22}+(D_\lambda+2D_{\mu_T})\varepsilon_{33},$$

$$\tau_{13}=2D_{\mu_L}\varepsilon_{13},$$

$$\tau_{12}=2D_{\mu_L}\varepsilon_{12},$$

$$\tau_{23}=2D_{\mu_T}\varepsilon_{23}.$$

Using the strain tensor, the above equations and taking all derivatives w.r.t. x_3 become zero.

The equations (58) of motion take the following form

$$(D_\lambda+2D_\alpha+4D_{\mu_L}-2D_{\mu_T}+D_\beta)u_{1,11}+(D_\alpha+D_\lambda+D_{\mu_L})u_{2,21}+D_{\mu_L}u_{1,22} -mD_{\mu_T}\left(u_{1,2}+u_{2,1}\right)=\rho\{\ddot{u}_1-\Omega^2u_1-2\Omega\dot{u}_2\}, \tag{59a}$$

$$(D_\alpha+D_\lambda+D_\mu)u_{1,12}+D_\mu u_{2,11}+(D_\lambda+2D_{\mu_T})u_{2,22}-m\left(D_\lambda+D_\alpha\right)u_{1,1} -m\left(D_\lambda+2D_{\mu_T}\right)u_{2,2}=\rho\{\ddot{u}_2-\Omega^2u_2+2\Omega\dot{u}_1\}, \tag{59b}$$

$$D_{\mu_L}u_{3,11}+D_{\mu_T}u_{3,22}-mD_{\mu_T}u_{3,2}=\rho\ddot{u}_3, \tag{59c}$$

Similarly, we can get similar relations in medium M_2 with ρ, D_α, D_λ, D_{μ_L}, D_{μ_T} and D_β are replaced by ρ', $D_{\alpha'}$, $D_{\lambda'}$, $D_{\mu'_L}$, $D_{\mu'_T}$ and $D_{\beta'}$.

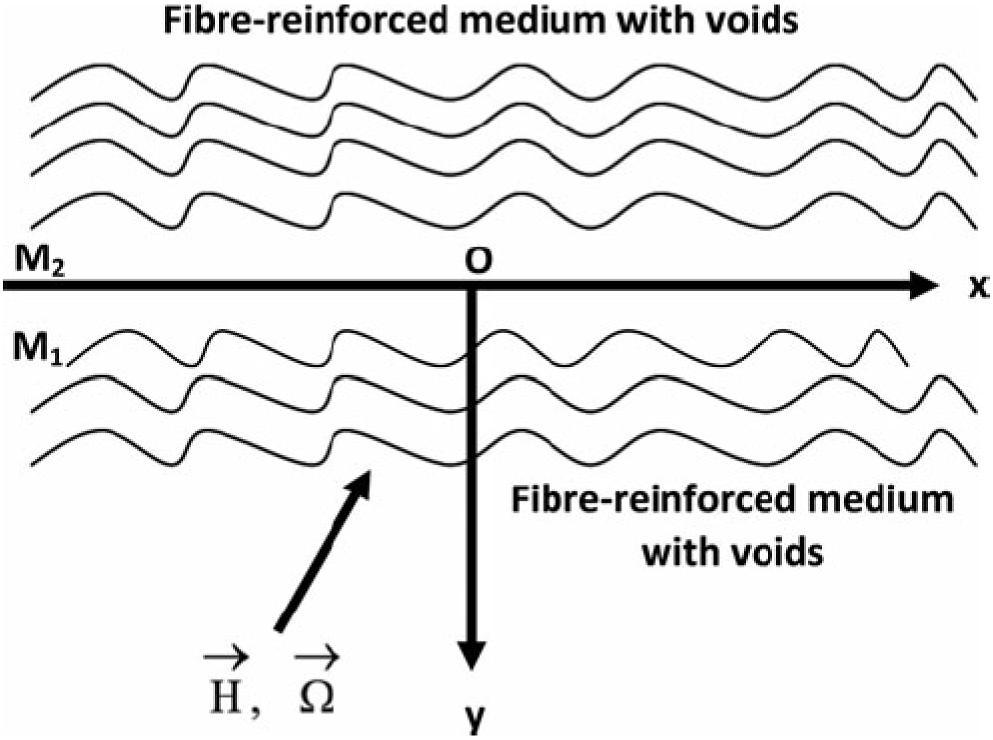


Figure 7: Diagrammatic representation of the problem.

We conclude that

- The surface waves in non-homogeneous, anisotropic, fibre-reinforced viscoelastic solid media under the rotation and higher order k of nth order including the time rate of strain are investigated. It is observed that viscoelastic surface waves are affected by the rotation, inhomogeneity, frequency, and time rate of strain parameters. These parameters influence the wave velocity to an extent depending on the corresponding constants characterizing and viscoelasticity of the material. So, the results of this analysis become useful in circumstances where these effects cannot be neglected. These velocities depend upon the fibre-reinforced parameters ‘a’ confirming that these waves are affected by the rotation of the media.
- The Love waves in non-homogeneous media are only affected by viscosity, rotation, frequency, higher order k of net order, including time rate of strain, frequency, and thickness of the medium. In the absence of all fields, the dispersion equation is in complete agreement with the corresponding classical result.
- Based on the Rayleigh waves in a non-homogeneous, general viscoelastic solid medium of higher order, including the time rate of change of strain, we find that the wave velocity equation proves that there is a dispersion of waves due to the presence of rotation, frequency, inhomogeneity, and viscosity. The results are in complete agreement with the corresponding classical results in the absence of all fields.
- The wave velocity equation of the Stoneley waves is very similar to the corresponding problem in the classical theory of elasticity. The dispersion of waves is due to the presence of rotation, phase velocity, frequency, and viscosity

of the solid. Furthermore, the wave velocity equation of this generalized type of surface waves is in complete agreement with the corresponding classical result in the absence of all fields.

•**In chapter (Eight)**, we study the propagation of the SV-waves under the effect of the electromagnetic field and initial stress for three models in thermoelasticity; The couple (CD), and Green-Lindsay (G-L) theories, as well as the dual-phase-lag theory (DPL). The problem of the reflection and transmission of thermoelastic waves at a solid-liquid interface in the presence of electromagnetic fields and initial stress is investigated subjected to certain boundary conditions. The appropriate expressions to find the amplitude ratios of the incident waves (SV-waves) is obtained. The reflection and transmission coefficients for the incident SV-waves are computed numerically. The effect of electric field, magnetic field, and initial stress are illustrated graphically. Comparisons are made with the obtained results in the presence and absence of the considered variables and displayed graphically. The results indicate that the effect of the electric field, magnetic field, and initial stress on the SV-waves incidence at the interface between solid-liquid media are very pronounced.

1) The dynamical equations of motion and the rotating frame of reference for a plane strain under initial stress in the absence of a heat source, taking into account the presence of Lorentz's force, are

$$\begin{aligned}\frac{\partial S_{11}}{\partial x}+\frac{\partial S_{21}}{\partial y}-P\frac{\partial \bar{\varpi}}{\partial x}+F_x=\rho\frac{\partial^2 u}{\partial t^2}\\ \frac{\partial S_{21}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \bar{\varpi}}{\partial x}+F_y=\rho\frac{\partial^2 v}{\partial t^2}\end{aligned}\qquad(60)$$

where $\bar{\varpi}=\frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)$, F_x and F_y are components of the electromagnetic field in x and y directions, respectively.

2) The stress-strain relations with incremental isotropy are given as

$$\begin{aligned}S_{11}&=(\lambda+2\mu+P)e_{xx}+(\lambda+P)e_{yy}-\gamma\left(T+\tau_1\frac{\partial}{\partial t}T\right)\\ S_{22}&=\lambda e_{xx}+(\lambda+2\mu)e_{yy}-\gamma\left(T+\tau_1\frac{\partial}{\partial t}T\right)\\ S_{12}&=2\mu e_{xy}\end{aligned}\qquad(61)$$

3) The incremental strain-components are given by

$$e_{xx}=\frac{\partial u}{\partial x},\qquad e_{yy}=\frac{\partial v}{\partial y},\qquad e_{xy}=\frac{1}{2}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\qquad(62)$$

4) The modified heat conduction equation is

$$K\left(1+\tau_\Theta\frac{\partial}{\partial t}\right)\nabla^2 T=\rho C_e\left(\frac{\partial T}{\partial t}+\tau_0\frac{\partial^2 T}{\partial t^2}\right)+T_0\gamma\left[\frac{\partial}{\partial t}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+\tau_0\delta_{ij}\frac{\partial^2}{\partial t^2}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\right]\qquad(63)$$

where C_e is specific heat per unit mass, e_{ij} is strain components, K is thermal conductivity, P is initial stress, S_{11}, S_{22}, S_{12} are incremental stress components, λ and

μ are Lame's constants, T_0 is natural temperature of the medium, δ_{ij} is Kronecker delta, T is the absolute temperature of the medium, τ_0 and τ_1 are thermal relaxation times, α_t is the coefficient of linear thermalexpansion, u_i is the components of the displacement vector, ϖ is magnitude of local rotation, and τ_Θ is the phase-lag of the gradient of temperature.

5) Taking into account the absence of the displacement current, the linearized Maxwell's equations governing the electromagnetic fields for a slowly moving solid medium having a perfect electrical conductivity are

$$curl\vec{h} = \vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t}, \quad -\mu_e \frac{\partial \vec{h}}{\partial t} = curl\vec{E}, \quad div\vec{h} = 0, \quad div\vec{E} = 0,$$
$$\vec{E} = -\mu_e \left(\frac{\partial \vec{u}}{\partial t} \times \vec{H}_0 \right), \quad \vec{h} = curl(\vec{u} \times \vec{H}_0), \quad \vec{F}_i = \mu_e (\vec{J} \times \vec{H}_0)_i \qquad (64)$$

where

$$\vec{H} = \vec{H}_0 + \vec{h}(x, y, t), \ \vec{H}_0 = (0, 0, H).$$

Using Eq. (64), we obtain

$$F_x = \mu_e H^2 \left[\frac{\partial e}{\partial x} - \varepsilon_0 \mu_e \frac{\partial^2 u}{\partial t^2} \right]$$
$$F_y = \mu_e H^2 \left[\frac{\partial e}{\partial y} - \varepsilon_0 \mu_e \frac{\partial^2 v}{\partial t^2} \right] \qquad (65)$$
$$F_z = 0$$

- Where $\vec{E}$ is an electric intensity vector, $\vec{F_i}$ is the Lorentz's body force vector, $\vec{h}$ is the perturbed magnetic field vector, $\vec{H}$ is the magnetic field vector, $\vec{H}_0$ is the primary constant magnetic field vector, $\vec{J}$ is the electric current density vector, μ_e is the magnetic permeability, and ε_0 is the electric permeability.

6) The Maxwell's stress equation can be given in the following form

$$\tau_{ij} = \mu_e \left[H_i h_j + H_j h_i - (\overrightarrow{H_k}.\overrightarrow{h_k})\delta_{ij} \right], \ i, j = 1, 2, 3 \qquad (66a)$$

where τ_{ij} is the Maxwell's stress tensor, which reduces to

$$\tau_{11} = \tau_{22} = \mu_e H^2 \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right), \ \tau_{12} = 0. \qquad (67b)$$

We study the above basic equations for the following three different theories:

(iv) Classical and Dynamical coupled theory (1956) (CD)

$$\delta_{ij} = 0, \ \tau_0 = 0, \ \tau_\Theta = 0, \ \tau_1 = 0$$

(v) Green and Lindsay's theory (1972) (GL)

$$\delta_{ij} = 0, \ \tau_1 \geq \tau_0 > 0, \ \tau_\Theta = 0$$

(vi) Dual phase-Lag theory (DPL)

$$\delta_{ij} = 1, \ \tau_0 > 0, \ \tau_1 = 0, \ 0 \leq \tau_\Theta < \tau_0.$$

- In the context of the (CD), (G-L) and (DPL) models, the effect of the initial stress and electromagnetic field on the reflection and refraction at the interface between solid-liquid media under perfect boundary conditions are discussed.

We conclude the following remarks:

- The reflected amplitudes depend on the angle of incidence, initial stress, electromagnetic field, and thermal relaxation times.
- The initial stress and the electromagnetic field play a significant role that has the inverse trend for the reflected and transmitted waves.
- The three thermoelastic theories have effects on the reflection and refraction phenomena.
- In the DPL model, it appears that $|Z_1| < |Z_4| < |Z_5| < |Z_2| < |Z_3|$ the smallest affects $|Z_1|$, but the largest affects $|Z_3|$.
- It is observed that the reflection coefficient strongly appears in the phenomena that have several applications, especially in seismic waves, earthquakes, volcanoes, and acoustics.
- The results presented in this chapter are very helpful for researchers concerned with material science, designers of new materials, low-temperature physicists, and those working on the development of a theory of hyperbolic propagation. Studying the phenomenon of rotation, the magnetic field and diffusion are also used to improve the conditions of oil extractions.

•**In chapter (Nine)**, the problem of the reflection and refraction of the thermoelastic wave at a solid-liquid interface in the presence of the magnetic field and initial stress is investigated. The problem is solved in the context of the three-phase-lag model of thermoelasticity. The appropriate expressions to find the amplitude ratios for all the three cases of p-wave incidence, SV-wave incidence, and thermal wave incidence are developed. However, the ratios of the amplitudes of the reflected and refracted waves to that of the incident waves are computed numerically for earth's crust-water interface, for incident p-wave only, considering the initial stress to be tensile as well as compressional both. The obtained results are presented graphically to show the effect of phase lags, magnetic field, and initial stress.

Let us consider a plane interface between solid half-space, homogeneous, isotropic, elastic material, and liquid medium with a primary temperature T_0 and magnetic field acting in the $z-$direction. The magnetic field effect $\vec{H}$ in both media acts in the $z-$direction, but the solid medium M is only under initial stress P. The plane p-, T-, or SV- wave is incident in the medium M on the interface plane, which reflects the p-wave (dilatational wave), SV-wave(rotational wave), and thermal wave (dilatational wave). The rest of the waves continues to travel in the other medium M' after refraction, as p-wave and thermal wave.

We assume a Cartesian coordinate system $oxyz$ with the origin 'o' on the plane $y=0$. Because we consider a two-dimensional problem, we restrict our analysis to the plane strain problem parallel to the oxy-plane. Hence, all field variables depend only on x, y and time t.

For easy reference, we follow a convention: All quantities in the medium M

are presented unprimed, whereas the corresponding quantities (except for initial stress) in the medium M' are represented as primed.

The initial stress components affect the medium M, where θ is the angle of incidence for plane wave; θ_1 and θ_2 are the angles of the reflected waves; θ_1' and θ_2' are the angles of the transmitted waves; $\vec{H}$ is the magnetic field vector acting in the $z-$direction; A_1, A_3 and A_5 are the amplitudes of the incident waves; A_2, A_4 and A_6 are the amplitudes of the reflected waves; A_2' and A_4' are the amplitudes of the transmitted T-and SV-waves, respectively (there are two transmitted waves only in the medium M').

Let us consider a plane interface between solid half-space, homogeneous, isotropic, elastic material, and liquid medium with a primary temperature T_0 and magnetic field acting in the $z-$direction. The magnetic field effect $\vec{H}$ in both media acts in the $z-$direction, but the solid medium M is only under initial stress P. The plane p-, T-, or SV- wave is incident in the medium M on the interface plane, which reflects the p-wave (dilatational wave), SV-wave (rotational wave), and thermal wave (dilatational wave). The rest of the waves continues to travel in the other medium M' after refraction, as p-wave and thermal wave.

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3. Basic equations:

Dynamical equations of motion:

Dynamical equations of motion for plane under initial stress in the absence of a heat source, taking into account the presence of Lorentz force, are

$$\frac{\partial S_{11}}{\partial x}+\frac{\partial S_{12}}{\partial y}-P\frac{\partial \varpi}{\partial y}+F_x=\rho\frac{\partial^2 u}{\partial t^2}$$

$$\frac{\partial S_{12}}{\partial x}+\frac{\partial S_{22}}{\partial y}-P\frac{\partial \varpi}{\partial x}+F_y=\rho\frac{\partial^2 v}{\partial t^2} \tag{68}$$

where $\varpi=\frac{1}{2}\left[\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right]$, F_x and F_y are the components of the magnetic field in the x and y directions, respectively.

Stress-strain relations:

The stress-strain relations with incremental isotropy are given as

$$S_{11} = (\lambda + 2\mu + P)e_{xx} + (\lambda + P)e_{yy} - \gamma T$$
$$S_{22} = \lambda e_{xx} + (\lambda + 2\mu)e_{yy} - \gamma T \tag{69}$$
$$S_{12} = 2\mu e_{xy}$$

Incremental stress components:

The incremental stress components are given as

$$e_{xx} = \frac{\partial u}{\partial x},\ e_{yy} = \frac{\partial v}{\partial y},\ e_{xy} = \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) \tag{70}$$

Three-phase-lag heat conduction equation:

$$K\left(1+\tau_t \frac{\partial}{\partial t}\right)\nabla^2 \dot{T} + K^*\left(1+\tau_v \frac{\partial}{\partial t}\right)\nabla^2 T = \left(1+\tau_q \frac{\partial}{\partial t} + \frac{\tau_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left[\rho C_e \ddot{T} + \gamma T_0\left(\frac{\partial \ddot{u}}{\partial x} + \frac{\partial \ddot{v}}{\partial y}\right)\right] \tag{71}$$

where K is the thermal conductivity, K^* is the material constant characteristic of the theory, ρ is the mass density, C_e is the specific heat at constant strain. τ_q, τ_t, τ_v are the phase lags of heat flux, temperature gradient, and thermal displacement gradient, respectively.

Linearized Maxwell equations:

Taking into account the absence of the displacement component, the linearized Maxwell equations governing the electromagnetic fields for a slowly moving medium having perfect electrical conductivity are

$$curl\,\vec{h} = \vec{J}, \qquad curl\,\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t}, \qquad div\,\vec{h} = 0, \qquad div\,\vec{E} = 0 \tag{72}$$

We use $\vec{H} = \vec{H}_0 + \vec{h}, \quad \vec{H}_0 = (0,0,H), \quad \vec{h} = (0,0,h)$

Then, the components of the Lorentz's body forces are obtained as

$$F_x = \mu_e H^2\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 v}{\partial x \partial y}\right),\ F_y = \mu_e H^2\left(\frac{\partial^2 u}{\partial x \partial y} + \frac{\partial^2 v}{\partial y^2}\right) \tag{73}$$

The Maxwell's stress equation can be obtained as

$$\tau_{ij} = \mu_e\left(H_i h_j + H_j h_i - H_k . h_k \delta_{ij}\right) \tag{74}$$

which reduces to

$$\tau_{11} = \tau_{22} = \mu_e H^2\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \tau_{12} = 0$$

We present the effect of initial stress and magnetization of reflection and refraction of plane waves at a solid-liquid interface under perfect boundary conditions in the context of the three-phase-lag model.

From the theoretical and numerical discussion, the followings concluding remarks can be drawn:

$|Z_1|, |Z_2|, |Z_4|$ and $|Z_5|$ start from their maximum values arriving at zero at $\theta = 90^0$ but $|Z_3|$ arrive at unity at $\theta = 90^0$. There is a slight change in the variation of the magnetic field and initial stress. $|Z_1|, |Z_2|, |Z_4|$ and $|Z_5|$ start from their maximum values arriving at zero at $\theta = 90^0$ but $|Z_3|$ arrives at unity at $\theta = 90^0$. Moreover, there is a slight change in the variation of the phase-lags.

In chapter (Ten), the interaction between the magnetic field and the thermal field in an elastic half-space, homogeneous, and isotropic under two temperature and initial stress are investigated using a normal mode method in the framework of the Lord–S¸hulman theory, with thermal shock and rotation. The medium rotates with a uniform angular velocity. It is considered to be permeated by a uniform magnetic field and hydrostatic initial stress. The general solution we obtain is finally applied to a specific problem. The variations in temperature, the dynamical temperature, the stress, and the strain distributions through the horizontal distance are calculated by an appropriate numerical example. They are also graphically illustrated.

In the following section, we consider that the medium is a perfect electric conductor. We also consider that the Maxwell equations, taking into account the absence of the displacement current (SI), take the form:

$$curl\,\vec{h} = \vec{J}$$

$$curl\,\vec{E} = -\mu_e \frac{\partial \vec{h}}{\partial t} \tag{75}$$

$$div\,\vec{h} = 0\ ,\ div\,\vec{E} = 0$$

$$where\ \ \vec{h} = curl(\vec{u}\times\vec{H}_0)\ \ ,\ \vec{H} = \vec{H}_0 + \vec{h}(x,y,t)$$

The heat conduction equation takes the form

$$K\phi_{,ii} = (\frac{\partial}{\partial t} + \tau_0 \frac{\partial^2}{\partial t^2})(\rho C_E T + \gamma T_0 u_{i,j}) \tag{76}$$

The stress strain relation are as follows:

$$\sigma_{ij} = \lambda e\delta_{ij} + 2\mu\, e_{ij} - \gamma T\delta_{ij} - P(\delta_{ij} + \omega_{ij}) \tag{77}$$

where $e_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i})$, $\omega_{ij} = \frac{1}{2}(u_{j,i} - u_{i,j})$

The medium rotates uniformly with an angular velocity $\underline{\Omega} = \Omega \underline{n}$, where $\underline{n}$ is a unit vector representing the direction of the axis of rotation. The displacement equation of motion in the rotating frame of reference has two additional terms: The centripetal acceleration $\underline{\Omega}\times(\underline{\Omega}\times\underline{u})$ due to time-varying motion only and the Coriolis acceleration $2\underline{\Omega}\times\underline{\dot{u}}$, where $\underline{u}$ is the dynamic displacement vector.

The equation of motion takes the form

$$\rho[\ddot{u}_i + \{\underline{\Omega}\times(\underline{\Omega}\times\underline{u})\}_i + (2\underline{\Omega}\times\underline{\dot{u}})_i] = \sigma_{ij,j} + F_i \tag{78}$$

where $\vec{F} = \vec{J}\times\vec{B}$, $\vec{B} = \mu_e \vec{H}_0$

The equation relates between the dynamical heat and heat conduction written as:

$$\phi - T = a\phi_{,ii}\,, \tag{79}$$

where $a > 0$ indicates the two-temperature parameter.

Assume that an elastic homogenous half-space $x \geq 0$ rotates uniformly with angular velocity Ω, in the presence of the constant magnetic field $\vec{H}_0$ directed along the x-axis and of an initial compression P obeying to Eqs. (75)-(77). The displacement components for the 2D medium have the form

$$u_x = u(x,y,t)\,, \qquad u_y = \mathrm{v}(x,y,t)\,, \qquad u_z = 0\,. \tag{80}$$

The heat conduction equation takes the form

$$K\left(\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}\right)=\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\rho C_E T+\gamma T_0\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right). \tag{81}$$

In chapter (Eleven), we study two-temperature thermoelasticity in a generalization form to solve the half-space problem of two dimensions under gravity, initial stress, and perturbed magnetic field. The fundamental equations are solved considering a new mathematical technique under the Lord-Şhulman (LS), Green-Naghdi (GN type III), and three-phase-lag (3PHL) theories to investigate displacement, stress components, and temperature distribution. The results obtained by the three theories, i.e. (LS), (GN type III), and (3PHL) considering the absence and the presence of gravity, magnetic field, and initial stress are compared. The results are numerically calculated and graphically displayed to exhibit the physical meaning of the phenomenon and the external parameters' effect. A comparison is made between the results obtained in the absence and the presence of the external considered parameters and with the previous results obtained by other researchers.

Considering an isotropic semi-infinite elastic solid, Oxyz is a Cartesian orthogonal coordinate system. Any point O of the boundary of the plane and Oy are downward to the medium vertically, as displayed in Figure 1.

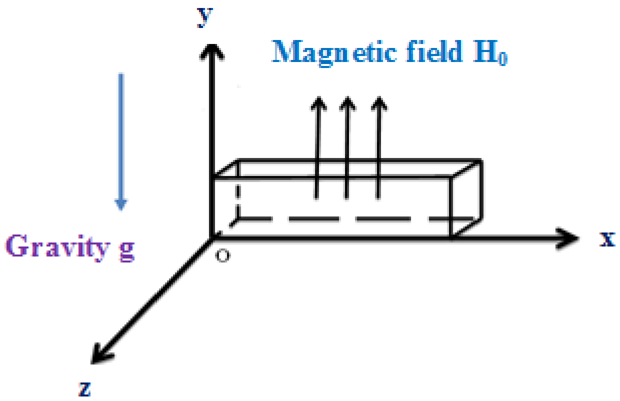

Figure 8: Shows the problem formulation

We formulate the fundamental equation of the problem, as follows:

(i)The constitutive equation (stress-strain relation) considering initial stress takes the following form:

$$\sigma_{ij}=(\lambda\theta-\gamma TP)\delta_{ij}+2\mu e_{ij}-P\,w_{ij},\quad w_{ij}=\frac{1}{2}(u_{j,i}-u_{i,j}) \tag{82}$$

(ii)The equation of heat conduction assuming three thermoelastic theories forms is as follows

$$\left(K^*+\tau_v^*\frac{\partial}{\partial t}+K\tau_T\frac{\partial^2}{\partial t^2}\right)\nabla^2\varphi=\left(1+\tau_q\frac{\partial}{\partial t}+\frac{\tau_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left[\rho C_e\ddot{T}+\gamma T_0\ddot{e}\right],\ \tau_v^*=K+K^*\tau_\upsilon \tag{83}$$

(iii)The motion equation with body force and heat source absent takes the following form

$$\sigma_{ji,j}+F_i=\rho\ddot{u}_i,\quad (i,j=1,2,3) \tag{84}$$

(iv)The relation of the conductive and the thermodynamic temperatures takes the form

$$\varphi-T=a\nabla^2\varphi \tag{85}$$

Consider that the displacement current is absent, the equations of linearized Maxwell's that govern the magnetic field for a solid slowly moving and having a perfect electrical conductivity can be written as:

$$\text{curl}\,\mathbf{h}=\mathbf{J}-\varepsilon_{\mathbf{0}}\dot{\mathbf{E}}, \tag{86a}$$

$$\text{curl}\,\mathbf{E}=-\mu_e\frac{\partial\mathbf{h}}{\partial t}, \tag{86b}$$

$$\text{div}\,\mathbf{h}=0, \tag{86c}$$

$$\text{div}\,\mathbf{E}=0, \tag{86d}$$

$$\mathbf{E}=-\mu_e\left(\frac{\partial\mathbf{u}}{\partial t}\times\mathbf{H_0}\right), \tag{86}$$

$$\mathbf{E}=\text{curl}(\mathbf{u}\times\mathbf{H_0}), \tag{86f}$$

$$\mathbf{F_i}=\mu_e(\mathbf{J}\times\mathbf{H_0})_i \tag{86g}$$

Where we use

$$\mathbf{H}=\mathbf{H_0}+\mathbf{h}(x,y,t),\quad \mathbf{H_0}=(0,0,\mathbf{H}).$$

Using Eq. (86), we obtain

$$F_x=\mu_eH_0^2\frac{\partial e}{\partial x}$$
$$F_z=\mu_eH_0^2\frac{\partial e}{\partial z} \tag{87}$$
$$F_y=0$$

The stress of the Maxwell produced from the magnetic field can be formed as

$$\tau_{ij}=\mu_e\left[H_ih_j+H_jh_i-(\overrightarrow{H_k}.\overrightarrow{h_k})\delta_{ij}\right],\ i,j=1,2,3 \tag{88a}$$

which is reduced to

$$\tau_{xx}=\tau_{zz}=\mu_eH_0^2\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial z}\right),\quad \tau_{xz}=0. \tag{88b}$$

Equation (83) is the generalized thermoelastic solid equation field applicable to the following:

i. (LS) theory: $K^*=\tau_v=\tau_T=\tau_q^2=0,\tau_q>0$

ii. (GN type II) theory: $\tau_v=\tau_T=\tau_q=0$

ii. (3PHL) theory: $\tau_v<\tau_T<\tau_q>0$

The dimensionless variables take the form:

$$(x',z',u',v')=C_0\eta(x,z,u,v),\qquad (t',\tau_T',\tau_\upsilon',\tau_q')=C_0^2\eta(t,\tau_T,\tau_\upsilon,\tau_q),\quad h'=\frac{h}{H_0}$$
$$(\theta',\varphi')=\frac{(T,\varphi)-T_0}{T_0},\left(\sigma_{ij}',\tau_{ij}'\right)=\frac{\left(\sigma_{ij},\tau_{ij}\right)}{\rho C_0{}^2},\qquad g'=\frac{g}{C_0^3\eta} \tag{89}$$

where $\eta=\frac{\rho C_e}{K}$, $C_2^2=\frac{\mu}{\rho}$ and $C_0^2=\frac{\lambda+2\mu}{\rho}$.

When we substitute from equation (89) into Eqs. (83)-(85), we get:

$$\left(C_k+C_\upsilon\frac{\partial}{\partial t}+C_T\frac{\partial^2}{\partial t^2}\right)\nabla^2\varphi-\left(1+T_q\frac{\partial}{\partial t}+\frac{T_q^2}{2}\frac{\partial^2}{\partial t^2}\right)(\ddot{\theta}+\frac{\gamma}{\rho C_e}\ddot{e}) \tag{80}$$

$$\varphi-\theta=\beta\ \nabla^2\varphi \tag{91}$$

where $C_k=\frac{K^*}{\rho C_e C_0^2}$, $C_v=\frac{\tau_v^*}{\rho C_e C_0^2}$, $C_T=\frac{K\tau_T\eta}{\rho C_e}$

The equations of the motion approach

$$a_1^*\nabla^2 u+a_2\frac{\partial e}{\partial x}-a_0\frac{\partial\theta}{\partial x}+g\frac{\partial w}{\partial x}=\beta\,\ddot{u} \tag{92}$$

Assuming the scalar potential and the vector potential functionsand

$$a_1^*\nabla^2 w+a_2\frac{\partial e}{\partial z}-a_0\frac{\partial\theta}{\partial z}-g\frac{\partial u}{\partial x}=\beta\,\ddot{w} \tag{93}$$

where

$$\varepsilon=\frac{\gamma}{\rho C_e},\ \ a_1^*=\frac{2\mu-P}{2\rho C_0^2},\ a_2=\frac{2\lambda+2\mu+P+2\mu_e H_0^2}{2\rho C_0^2},\ \ a_0=\frac{\gamma T_0}{\rho C_0^2},\ \beta=1+\frac{\varepsilon_0\mu_e H_0^2}{\rho}.$$

$$u=\frac{\partial\Pi}{\partial x}-\frac{\partial\psi}{\partial z},\qquad w=\frac{\partial\Pi}{\partial z}+\frac{\partial\psi}{\partial x}. \tag{94}$$

Substituting Eq. (94) into Eqs. (92) and (93), we obtain

$$\left(\nabla^2-\beta*\frac{\partial^2}{\partial t^2}\right)\Pi-a_3^*\frac{\partial\psi}{\partial x}-a_0^*\theta=0 \tag{95}$$

$$\left(\nabla^2-\beta**\frac{\partial^2}{\partial t^2}\right)\psi+a_4\frac{\partial\Pi}{\partial x}=0 \tag{96}$$

where

$$R_H^2=\frac{\mu_e H_0^2}{\rho C_0^2},\ \ \beta^*=\frac{\beta}{1+R_H^2},\ \ a_0^*=\frac{a_0}{1+R_H^2},\ \ a_3^*=\frac{g}{1+R_H^2},\ \ a_4=\frac{g}{a_1^*},\ \ \beta^{**}=\frac{\beta^*}{a_1^*}$$

In this work, we provide an analytical solution based upon the Lame potentials and the normal mode technique for the problem of thermoelastic in a solid medium that is developed, utilized, and compared graphically. The strong effect of the Green-Naghdi theory (GN) is compared with the slight effect between the Lord–Shulman (LS) and the three-phase-lag model (3PHL). The physical quantities converge to zero with an increasing of the distance z and continuously satisfying the considered boundary conditions. The deformation of the body depends on the nature of the external forces applied (the electromagnetic field, two-temperature, initial stress, and gravity), as well as the type of the thermoelastic theories and boundary conditions. The time parameter, as well as relaxation time, gravity, and electromagnetic field have a strong effect and play a strong significant role in all the obtained physical quantities for the components of stresses, displacement, and temperature decreasingly or increasingly. Therefore, the presence of the field of electro-magnetic, gravity, two-temperature, initial stress, and relaxation times in the present model is of significance. The considered method is interesting and applicable to a wide range of phenomena in thermodynamics, thermoelasticity, and magneto-thermoelasticity. The transient behaviors of field variables are studied in detail, and the influences of variations in field variables on each other are discussed. Thus, they provide useful information for practical scientists/ technologists/ researchers/ seismologists/ engineers working in this experimental field on wave propagation. The present chapter introduces the effect of gravity, initial stress, electromagnetic field, and two temperatures dependence on the displacement components, temperature, and components of stress that indicate the significant effect on them. Finally, the results provide significant motivation to study the magneto-thermoelectric conducting materials as a new applicable class of electro-magneto-thermoelectric solids. The results prove useful for researchers in material science, designers of new materials, physicists, engineers, and those working on the electro-magneto-thermoelasticity development of and in practical situations, especially in geomagnetic, geophysics, acoustics, optics, and oil prospecting.

In chapter (Twelve), we discuss the longitudinal harmonic waves' reflection from a solid elastic half-space with electromagnetic and gravity fields influence considering a fractional order via fractional exponential function method. The clarifications are required for the reflection amplitudes ratios (i.e., the ratios between the reflected waves amplitude to the incident wave amplitude). The results obtained are calculated analytically and displayed graphically to show the physical meaning of the phenomenon. A comparison is made between the fractional and integer derivatives. The results of this chapter demonstrate the rigor and effectiveness of the considered fractional technique.

2. Mathematical preliminaries

We mention some concepts and properties of the calculus of fractional differential equations, as follows:

2.1 Definition: The fractional integral operator of the Riemann–Liouville of order $\alpha \geq 0$, of a function $f \in C\mu, \mu \leq -1$ is:

$$J^{\alpha} f(x) = \frac{1}{\Gamma(\alpha)} \int_0^x (x-t)^{\alpha-1} f(t)dt, \quad x > 0, \quad \alpha > 0$$
$$J^0 f(x) = f(t) \tag{97}$$

2.2 The properties of the operator J^{α} for $f \in C\mu, \mu \leq -1$, $\alpha, \beta > 0, and \ \gamma \leq -1$ are

1. $J^{\alpha} J^{\beta} f(x) = J^{\alpha+\beta} f(x)$

2. $J^{\alpha} J^{\beta} f(x) = J^{\beta} J^{\alpha} f(x)$

3. $J^{\alpha} x^{\gamma} = \dfrac{\Gamma(\gamma+1)}{\Gamma(\gamma+\alpha+1)} x^{\alpha+\gamma}$

(98)

2.3 Definition: The fractional derivative of $f(x)$ for the Caputo sense is defined as:

$$D^{\alpha} f(x) = J^{m-\alpha} D^{m} f(x) = \frac{1}{\Gamma(m-\alpha)} \int_0^x (x-t)^{m-\alpha-1} f^{(m)}(t) dt, \tag{99}$$

$m-1 < \alpha < m, m \in N, x > 0$

2.4 Definition: It is the smallest integer that exceeds α, the Caputo fractional derivatives of the order $\alpha > 0$ is defined as:

$$D^{\alpha} f(x,t) = \frac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}} = \begin{Bmatrix} \dfrac{1}{\Gamma(m-\alpha)} \displaystyle\int_0^t (t-\tau)^{\varepsilon-1} \frac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}} d\tau, & m-1 < \alpha \le m \\ \dfrac{\partial^{\alpha} f(x,t)}{\partial t^{\alpha}}, & \alpha = m \in N \end{Bmatrix} \tag{100}$$

2.5 The properties of the operator D^{α} of the Caputo fractional derivatives of order $\alpha > 0$ are

$$D^{\alpha} x^{\gamma} = \frac{\Gamma(\gamma+1)}{\Gamma(\gamma-\alpha+1)} x^{\gamma-\alpha},$$

$$.D^{\alpha} e^{t} = t^{-\alpha} \sum_{n=0}^{\infty} \frac{t^{n}}{\Gamma(n-\alpha+1)} \tag{101}$$

The fundamental equations of thermo-microstretch in the Cartesian coordinate system (x, y, z) with z - axis pointed into the media are considered. The primary magnetic field intensity acts y-axis (i.e., $\boldsymbol{H} = (0, H_0, 0)$). We take into account the linearized equations of the electro-dynamics of the moving media slowly:

$$\boldsymbol{J} = curl\ \boldsymbol{h} - \varepsilon_0 \frac{\partial^{\beta}}{\partial t^{\beta}} E, \tag{102}$$

$$curl\ \boldsymbol{E} = -\mu_o \frac{\partial^{\beta}}{\partial t^{\beta}} \boldsymbol{h}, \tag{103}$$

$$\boldsymbol{E} = -\mu_0 \left(\frac{\partial^{\beta}}{\partial t^{\beta}} \boldsymbol{u} \times H\right), \tag{104}$$

$$\nabla . \boldsymbol{h} = 0 . \tag{105}$$

The motion equation in the presence of the magnetic field and gravitational is:

$$\sigma_{\ell i,\ell} + F_i + G_i = \rho \frac{\partial^{\alpha}}{\partial t^{\alpha}} u_i, \tag{106}$$

$$F_i = \mu_0 (J \times H)_i,\ G_i = \rho g \left(\frac{\partial w}{\partial x}, 0, -\frac{\partial u}{\partial x}\right). \tag{107}$$

From the results obtained analytically and graphically, we conclude that

- The amplitude ratio $|z_1| = 1$ at $\theta = 90^{o}$ indicates the SV wave, but $|z_2| - |z_5|$ equal zero.

- The gravity field makes a strong influence on the reflection coefficients $|z_1|-|z_3|$ but slight change in small values of gravity on $|z_4|$ and $|z_5|$.
- The effect of the electric and magnetic fields nearly has the same behavior on the reflection coefficients that have a strong effect on the phenomena.
- The existence of the magnetic field affects strongly by comparing with the correspondence if the magnetic field is absent.

In chapter (Twelve), we estimate the action of rotation on the generalized thermoelasticity model containing one thermal relaxation time for an annular isotropic cylinder and an infinitely long of temperature-dependent on physical properties. This phenomenon is numerically solved considering the finite difference technique under the effectiveness of the rotation and the decayed heat flux on the obtained components that is graphically drawn. The numerical results are portrayed to unravel the influence of various parameters. A comparison is discussed with the previous results obtained by others if the new parameters are neglected.

Formulation of the problem

We consider an annular cylinder with an infinitely long consisting of an isotropic elastic material with a dependence on temperature material properties. We show the cylindrical coordinates (r, φ, z), and the center is the origin of the cylindrical polar coordinate system. All the physical variables, which depend on material properties used in this phenomenon are functions of radial coordinate r and time t.

The relation between the stress and strain takes the following form:

$$\sigma_{ij} = 2\mu e_{ij} + \left(\lambda\Delta - \gamma\overline{\mathrm{T}}\right)\delta_{ij} \tag{108}$$

where $\overline{\mathrm{T}} = \mathrm{T} - \mathrm{T}_0$

The stress-displacement relation for the isotropic medium is defined by

$$e_{ij} = \frac{1}{2}\left(u_{i,j} + u_{j,i}\right). \tag{109}$$

The governing equations of motion may be established as

$$\sigma_{ij,j} = \rho\left[\ddot{\vec{u}}_i + \left(\vec{\Omega}\times\vec{\Omega}\times\vec{u}\right)_i + \left(2\vec{\Omega}\times\dot{\vec{u}}\right)_i\right] \tag{110}$$

When the heat sources are absent, the equation of heat conduction is established as

$$\left(K\overline{\mathrm{T}}_{,i}\right)_{,i} = \frac{K}{\kappa}\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}} + T_0\gamma\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\Delta \tag{111}$$

In this study, we assume that the property of the material is characterized by

$$\lambda = \lambda_0 f\,(\mathrm{T}), \quad \mu = \mu_0 f\,(\mathrm{T}), \quad K = K_0 f\,(\mathrm{T}), \quad \gamma = \gamma_0 f\,(\mathrm{T}),$$

where λ_0, μ_0, K_0 and γ_0 are constants, and $f\,(\mathrm{T})$ is a non-dimensional function of temperature.

In another case of an independent on temperature material properties

f (T), and $\lambda=\lambda_0,\ \mu=\mu_0,\ K=K_0,\ \gamma=\gamma_0$.

From equations (108)-(111), we get

$$\sigma_{ij}=\left[2\mu e_{ij}+\left(\lambda_0\Delta-\gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right]f\ (\mathrm{T}) \tag{112}$$

$$\rho\left(\ddot{u}_i-\Omega^2u-2\Omega\dot{u}\right)=\left[2\mu e_{ij}+\left(\lambda_0\Delta-\gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right]_{,j}f\ (\mathrm{T})+\left[2\mu e_{ij}+\left(\lambda_0\Delta-\gamma_0\overline{\mathrm{T}}\right)\delta_{ij}\right]\left(f\ (\mathrm{T})\right)_{,j} \tag{113}$$

$$\left(K_0 f\ (\mathrm{T})\overline{\mathrm{T}}_{,i}\right)_{,i}=\frac{K_0 f\ (\mathrm{T})}{\kappa}\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}}+\gamma_0 f\ (\mathrm{T})T\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\Delta \tag{114}$$

For the simplicity, we approximate the function $f\ (\mathrm{T})$ as $f\ (\mathrm{T})=1-\alpha\mathrm{T}$, where α is a material parameter. From Eq. (112), we get the stress components as

$$\sigma_{rr}=\left[\left(\lambda_0+2\mu_0\right)\frac{\partial u}{\partial r}+\lambda_0\frac{u}{r}-\gamma_0\overline{\mathrm{T}}\right]\left(1-\alpha\mathrm{T}\right) \tag{115}$$

$$\sigma_{\varphi\varphi}=\left[\left(\lambda_0+2\mu_0\right)\frac{u}{r}+\lambda_0\frac{\partial u}{\partial r}-\gamma_0\overline{\mathrm{T}}\right]\left(1-\alpha\mathrm{T}\right) \tag{116}$$

In the cylindrical form, we put the equation of motion as

$$\frac{\partial\sigma_{rr}}{\partial r}+\frac{1}{r}\left(\sigma_{rr}-\sigma_{\varphi\varphi}\right)=\rho\left[\frac{\partial^2u}{\partial t^2}-\Omega^2u-2\Omega\frac{\partial u}{\partial t}\right] \tag{117}$$

From (115)-(117), we obtain:

$$\begin{aligned}&(\lambda_0+2\mu_0)\left[\frac{\partial^2u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}-\frac{u}{r^2}\right](1-\alpha\mathrm{T})-\left[\alpha\left\{(\lambda_0+2\mu_0)\frac{\partial u}{\partial r}+\lambda_0\frac{u}{r}-\gamma_0\overline{\mathrm{T}}\right\}+\gamma_0(1-\alpha\mathrm{T})\right]\frac{\partial\overline{\mathrm{T}}}{\partial r}\\&=\rho\left[\frac{\partial^2u}{\partial t^2}-\Omega^2u-2\Omega\frac{\partial u}{\partial t}\right]\end{aligned} \tag{118}$$

Equation (114) is

$$\left(\frac{\partial^2\overline{\mathrm{T}}}{\partial r^2}+\frac{1}{r}\frac{\partial\overline{\mathrm{T}}}{\partial r}\right)-\frac{\alpha}{1-\alpha\mathrm{T}}\left(\frac{\partial\overline{\mathrm{T}}}{\partial r}\right)^2=\frac{1}{\kappa}\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\overline{\mathrm{T}}+\frac{T_0\gamma}{K_0}\left(\frac{\partial}{\partial t}+\tau_0\frac{\partial^2}{\partial t^2}\right)\left(\frac{\partial u}{\partial r}+\frac{u}{r}\right) \tag{119}$$

For simplicity, we introduce the non-dimensional quantities:
where ϖ is the exponent of decaying.

Solution of the problem

To find the numerical solutions of the temperature displacement, and stress components, we use the finite difference technique. The domain of the solution $\{(r,t):R\in[A,B],t\in[0,\tau]\}$ is changed by a grid described by the node points set (r_m,t_n). The uniform mesh defined by $r_m=A+mh;m=0,1,\ldots,N$ and $t_n=nk;n=0,1,\ldots,P$, where $h=(B-A)/N$ is taken as mess width, and $k=\tau/P$ is considered to be the time step. Furthermore, we suppose that τ is the final value of time. The explicit finite difference scheme for the partial differential coefficients concerning the independent variables r and t are presented, as follows:

$$\begin{aligned}&\frac{\partial u}{\partial r}=\frac{u_{m+1}^n-u_{m-1}^n}{2h}+o\left(h^2\right),\qquad \frac{\partial^2u}{\partial r^2}=\frac{u_{m+1}^n-2u_m^n+u_{m-1}^n}{h^2}+o\left(h^2\right),\\&\frac{\partial u}{\partial t}=\frac{u_m^{n+1}-u_m^{n-1}}{2k}+o\left(k^2\right)\end{aligned} \tag{120}$$

Using the equations of the explicit finite difference, we obtain:

$$u_m^{n+1}=\Gamma_1 u_m^n-u_m^{n-1}+\nu_1\left[\begin{array}{l}\left[1-\beta\left(\theta_m^n+1\right)\right]\left\{\left(u_{m+1}^n-2u_m^n+u_{m-1}^n\right)+\frac{h}{2r_m}\left(u_{m+1}^n-u_{m-1}^n\right)-\frac{h^2}{r_m^2}u_m^n\right\}\\-\frac{h}{2}\left\{a_1\left[1-\beta\left(2\theta_m^n+1\right)\right]+\beta\left(\frac{u_{m+1}^n-u_{m-1}^n}{2h}+\lambda_1\frac{u_m^n}{r_m}\right)\right\}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)\end{array}\right] \tag{121}$$

$$\theta_m^{n+1}=\frac{1}{\left(k+2\tau_0\right)}\left[\begin{array}{l}4\tau_0\theta_m^n+\left(k-2\tau_0\right)\theta_m^{n-1}+2\nu\left\{\left(\theta_{m+1}^n-2\theta_m^n+\theta_{m-1}^n\right)+\frac{h}{2r_m}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)\right\}\\-\frac{a_2k}{2h}\left\{\left(u_{m+1}^{n+1}-u_{m+1}^{n-1}-u_{m-1}^{n+1}+u_{m-1}^{n-1}\right)+\frac{2h}{r_m}\left(u_m^{n+1}-u_m^{n-1}\right)\right\}\\-\frac{a_2\tau_0}{h}\left\{\begin{array}{l}\left(u_{m+1}^{n+1}-2u_{m+1}^n+u_{m+1}^{n-1}-u_{m-1}^{n+1}+2u_{m-1}^n-u_{m-1}^{n-1}\right)\\+\frac{2h}{r_m}\left(u_m^{n+1}-2u_m^n+u_m^{n-1}\right)\end{array}\right\}\\-\frac{\beta\nu}{2\left[1-\beta\left(\theta_m^n+1\right)\right]}\left(\theta_{m+1}^n-\theta_{m-1}^n\right)^2\end{array}\right] \tag{122}$$

The stresses become

$$\left[\sigma_{rr}\right]_m^n=\left[1-\beta\left(\theta_m^n+1\right)\right]\left[\frac{u_{m+1}^n-u_{m-1}^n}{2h}+\lambda_1\frac{u_m^n}{r_m}-a_1\theta_m^n\right] \tag{123}$$

$$\left[\sigma_{\varphi\varphi}\right]_m^n=\left[1-\beta\left(\theta_m^n+1\right)\right]\left[\frac{u_m^n}{r_m}+\lambda_1\frac{u_{m+1}^n-u_{m-1}^n}{2h}-a_1\theta_m^n\right] \tag{124}$$

From the explicit finite difference scheme and the initial condition, we get

$$\frac{\partial u_m^0}{\partial t}=\frac{u_m^1-u_m^{-1}}{2k}=0,\qquad \frac{\partial\theta_m^0}{\partial t}=\frac{\theta_m^1-\theta_m^{-1}}{2k}=0 \tag{125}$$

From equation (125), u_m^{-1} and θ_m^{-1} can be eliminated from equations (121) and (122) and we get the equations satisfied by u_m^n and θ_m^n for $t\left(n=0\right)$, which is the first level as the following form

$$u_m^1=u_m^0+\frac{\nu_1}{2}\left[\begin{array}{l}\left[1-\beta\left(\theta_m^0+1\right)\right]\left\{\left(u_{m+1}^0-2u_m^0+u_{m-1}^0\right)+\frac{h}{2r_0}\left(u_{m+1}^0-u_{m-1}^0\right)-\frac{h^2}{r_0^2}u_m^0\right\}\\-\frac{h}{2}\left\{a_1\left[1-\beta\left(2\theta_m^0+1\right)\right]+\beta\left(\frac{u_{m+1}^0-u_{m-1}^0}{2h}+\lambda_1\frac{u_m^0}{r_m^0}\right)\right\}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)\end{array}\right] \tag{126}$$

$$\theta_m^1=\theta_m^0+\left[\begin{array}{l}\frac{\nu}{2\tau_0}\left\{\left(\theta_{m+1}^0-2\theta_m^0+\theta_{m-1}^0\right)+\frac{h}{2r_0}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)\right\}\\-\frac{a_2}{4h}\left\{\left(2u_{m+1}^1-2u_{m+1}^0-2u_{m-1}^1+2u_{m-1}^0\right)+\frac{4h}{r_0}\left(u_m^1-u_m^0\right)\right\}\\-\frac{\beta\nu}{8\tau_0\left[1-\beta\left(\theta_m^0+1\right)\right]}\left(\theta_{m+1}^0-\theta_{m-1}^0\right)^2\end{array}\right] \tag{127}$$

Using the boundary condition at $r=A$, we get

$$\frac{u_1^n-u_{-1}^n}{2h}+\lambda_1\frac{u_0^n}{r_0}-\theta_0^n=0\quad\text{and}\quad\theta_0^n=e^{-\varpi t_n} \tag{128}$$

Substituting the expression for u_{-1}^n from equation (128) into equation (121), we get the equation satisfied by u_m^n for $r=A$ (the level $m=0$), as follows

$$u_0^{n+1} = \Gamma_1 u_0^n - u_0^{n-1} + \nu_1 \left[\begin{array}{l} \left[1-\beta\left(\theta_0^n+1\right)\right] \left\{ \begin{array}{l} 2\left(u_1^n - u_0^n + h\lambda_1 \dfrac{u_0^n}{r_0} - a_1 h \theta_0^n\right) \\ + \dfrac{h^2}{r_0}\left(a_1\theta_0^n - \lambda_1 \dfrac{u_0^n}{r_0}\right) - \dfrac{h^2}{r_0^2} u_0^n \end{array} \right\} \\ -\dfrac{h}{2}\left\{a_1\left[1-\beta\left(\theta_0^n+1\right)\right]\right\}\left(-3\theta_0^n + 4\theta_1^n - \theta_2^n\right) \end{array} \right] \tag{129}$$

where $\Gamma_1 = \dfrac{-\left(2k+\Omega^2 k^2\right)}{1+\Omega k}$, $\quad \nu_1 = \dfrac{k^2}{h^2\left(1+\Omega k\right)}$

Using the boundary condition in equation (119) and equation (123) at $r = B$

$$\frac{u_{N+1}^n - u_{N-1}^n}{2h} + \lambda_1 \frac{u_N^n}{r_N} - \theta_N^n = 0 \quad \text{and} \quad \theta_N^n = 0 \tag{130}$$

Substituting u_N^{n+1} from equation (130) into equation (121), we get the equation of the level $m = N$ as

$$u_N^{n+1} = \Gamma_1 u_N^n - u_N^{n-1} + \nu_1 \left[\begin{array}{l} \left[1-\beta\left(\theta_N^n+1\right)\right] \left\{ \begin{array}{l} 2\left(u_{N-1}^n - u_N^n + h\lambda_1 \dfrac{u_N^n}{r_N} + a_1 h \theta_N^n\right) \\ + \dfrac{h^2}{r_N}\left(a_1\theta_N^n - \lambda_1 \dfrac{u_N^n}{r_N}\right) - \dfrac{h^2}{r_N^2} u_N^n \end{array} \right\} \\ -\dfrac{h}{2}\left\{a_1\left[1-\beta\left(\theta_N^n+1\right)\right]\right\}\left(3\theta_N^n - 4\theta_{N-1}^n - \theta_{N-2}^n\right) \end{array} \right] \tag{131}$$

The above equations (121)-(131) depict the model of finite difference scheme for the present problem to set the values of displacement, temperature, and stresses at different points of the solution domain $A \le r \le B$, $0 \le t \le \tau$. The local truncation error is an accurate second-order in time and space $O\left(k^2+h^2\right)$. It approaches zero as $k \to 0$ and $h \to 0$.

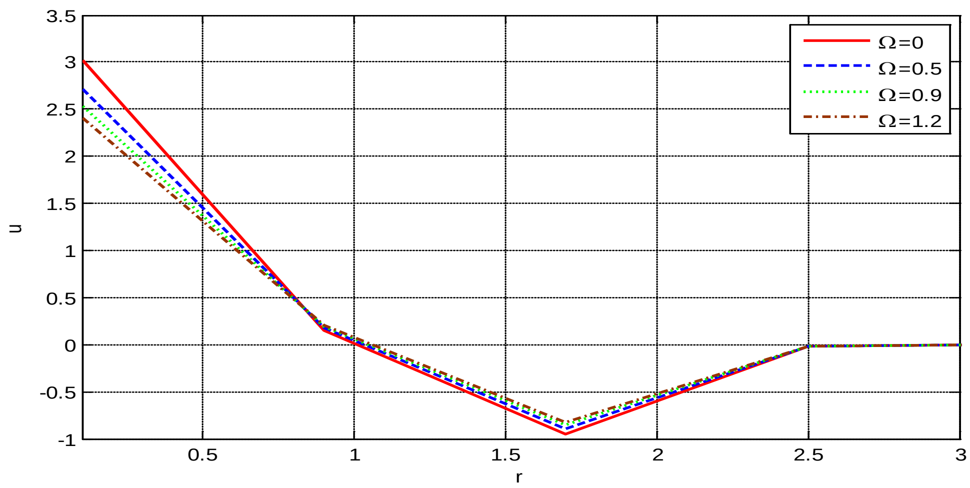

Figure 8: The displacement u variation with and without rotation

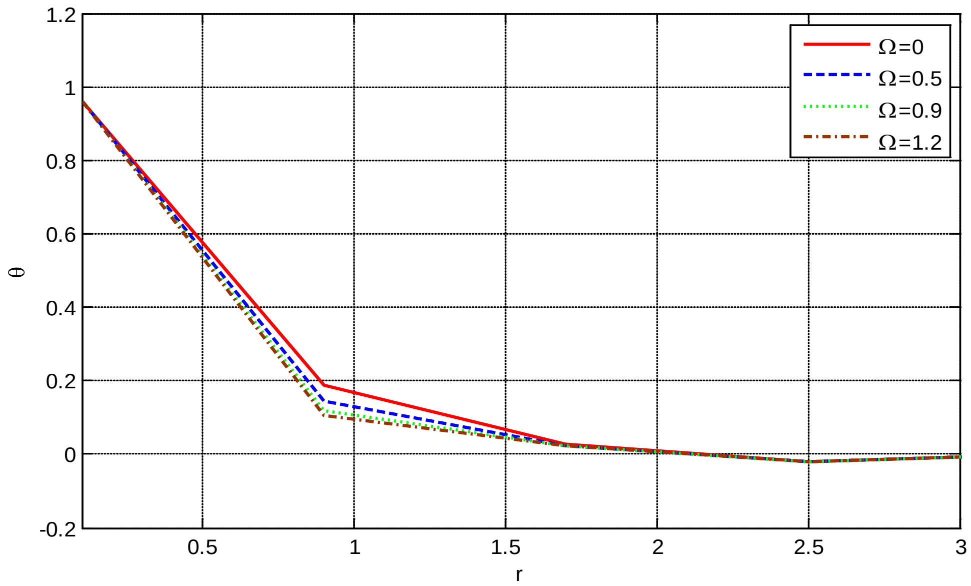

Figure 9: The temperature variation with and without rotation

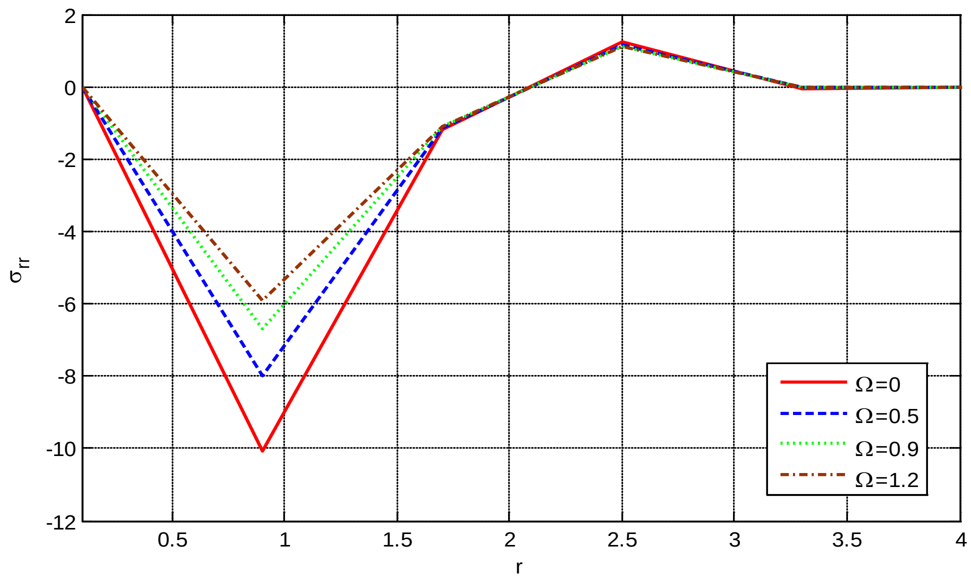

Figure 10: The radial stress variation with and without rotation

Conclusion

The technique considered in the current paper provides tremendous success in dealing with these types of problems. The considered technique gives numerical solutions in the thermoelastic medium in the absence of any supposed restriction on the physical quantities assumed that appear in the considered governing equations of the problem. The survey of the exponent phenomenon of the heat flux decayed and rotation is also useful for improving the oil extra conditions.

GENERAL CONCLUSION

Generally, from the results obtained in the thesis, it is concluded that in the context of the (CD) Classical Dynamical, the (LS) Lord-Şhulman, the (GL) Green-Lindsay, the Dual-Phase-Lag (DPL), the Green-Naghdi (GN type III), and the Three-Phase-Lag (TPL) theories of thermoelasticity (Sentence is interrupted should be continued).

We investigate the problem of reflection and refraction of thermoelastic waves at a magnetized solid–liquid interface in the presence of initial stress. In the context of the GL and CT theories of thermoelasticity, the problem was solved, and the effect of magnetic field, external heat sources, and initial stress on p-, T-, and SV-waves propagation were discussed.

Shear waves propagation in a non-homogeneous anisotropic incompressible medium under the influence of the electromagnetic field, plotothermal, semiconducting, gravity field, rotation, and initially stressed medium was studied.

Analytical analysis reveals that the velocity of the propagation of the shear waves depends upon the direction of propagation, the anisotropy, magnetic field, rotation, gravity field, non-homogeneity of the medium, and the initial stress.

The frequency equation that determines the velocity of the shear waves was obtained.

The dispersion equations obtained and investigated for different cases angle of incidence, electro-magnetic field, and gravity have a significant effect on the amplitudes of reflection coefficients. This finding indicates their valuable effect on the phenomena and have many experimental applications in engineering, geophysics, aircrafts, astronomy, petroleum extracting, etc.

The finite difference technique considered provides tremendous success in dealing with these types of problems and gives numerical solutions in the thermoelastic medium in the absence of any supposed restrictions on the physical quantities assumed that appear in the considered governing equations of the problem.

НАУЧНЫЙ СОВЕТ DSC.03/30.12.2019.FM.01.02 ПО ПРИСУЖДЕНИЮ УЧЕНЫХ СТЕПЕНЕЙ ПРИ НАЦИОНАЛЬНОМ УНИВЕРСИТЕТЕ УЗБЕКИСТАНА

УНИВЕРСИТЕТ ЮЖНАЯ ДОЛИНА ЕГИПТА

ЭЛЬСАИД МУХАМЕД АБО-ДАХАБ ХЕДАРИ

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ОТРАЖЕНИЯ И ПРОПУСКАНИЯ МАГНИТО-ТЕРМОУПРУГИХ ВОЛН И РАСПРОСТРАНЕНИЯ ПОВЕРХНОСТНЫХ ВОЛН

05.01.07 – Математическое моделирование. Численные методы и программные комплексы

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ВВЕДЕНИЕ (аннотация докторской диссертации (DSc))

Актуальность и востребованность темы диссертации. По мере все большего внедрения современных компьютерных технологий, в технике и естествознании особую актуальность начало приобретать методы математического моделирования, который является универсальным для исследования сложных задач. В последние десятилетия все больше внимания уделяется проблемам магнито-термоупругости, принимая во внимание влияние различных факторов, таких как электромагнитное поле, вращение, тепловое поле, фототермический, полупроводниковый, пустоты и т. д., на распространение волн, особенно отражение, преломление (пропускание). или поверхностные волны как: волны Рэлея, Стоунли и Любви. Вышеупомянутые проблемы важны для технических приложений, связанных с явлением распространения волн, особенно в машиностроении, геофизике, материаловедении и геологии. Настоящая работа посвящена математическому моделированию для современных и важных инженерных задач и состоит из следующих пунктов: (i) Распространение волн (отражение или отражение и передача), связанных со многими научными и инженерными областями из-за определение амплитуд волн для коэффициентов отражения или преломления (пропускания), которые играют важную роль в определении опасности волн; (ii) влияние внешних параметров, таких как вращение, электромагнитное поле, пустоты, начальное напряжение и диффузия, на распространение волн для определения того, что эти параметры оказывают положительное или отрицательное влияние на коэффициенты отражения или преломления; (iii) Рассмотренные здесь времена релаксации и теории термоупругости позволяют устранить парадокс бесконечной скорости из-за теплового поля, чтобы соответствовать практическим результатам; (iv) взаимодействие между смещением и температурой с внешними полями, такими как гравитация, электромагнитное поле, вращение, диффузия и пустоты; (v) Поверхностные волны, которые имеют множество применений, особенно при землетрясениях и вулканах, и многослойные свойства влияют на распространение поверхностных волн.

Данное диссертационное исследование в определенной степени служит выполнению задач, предусмотренных Указами Президента Республики Узбекистан от 7 февраля 2017 года «О стратегии действий по дальнейшему развитию Республики Узбекистан», Постановлениями Президента Республики Узбекистан №ПП-1730 от 21 марта 2012 года «О мерах по дальнейшему внедрению и развитию современных информационно-коммуникационных технологий», №ПП–1442 от 15 декабря 2010 года «О приоритетах развития промышленности Республики Узбекистан в 2011-2015 годах», № ПП-2789 от 17 февраля 2017 года «О мерах по дальнейшему совершенствованию деятельности академии наук, организации, управления и финансирования научно-исследовательской деятельности» и Постановлением Кабинета Министров Республики Узбекистан №24 от 1 февраля 2012 года «О мерах по созданию условий для дальнейшего развития компьютеризации и информационно коммуникационных технологий на местах», а также в других нормативно-правовых документах, принятых в данной сфере.

Это диссертационное исследование в определенной степени послужит выполнению поставленных задач.

Целью исследования Основная цель данной работы - смоделировать математические методы и провести численное моделирование по отражению и передаче и распространению волн, а также распространению поверхностных волн, которые имеют широкий диапазон применение, что связано с некоторыми явлениями, связанными с инженерной деятельностью, геофизикой, биологией, материаловедением и добычей нефти для определения его амплитуд, скоростей и коэффициентов затухания за счет внешних параметров. Все задачи рассматриваются в рамках термоупругих теорий (CT), (LS), (GL), (GN типов I, II, III), (DPL) и (TPHL).

Задачи исследования

Разработать некоторую новую теорию термоупругости с учетом новых параметров, таких как вращение, электромагнит, пустоты, диффузия и так далее.

Создание математических моделей для уравнений движения, уравнения температуры, уравнения диффузии и уравнения пустот. Чтобы получить амплитуды распространения волн (отражение или отражение и пропускание), исследованы (i) отношения амплитуд (коэффициенты отражения или отражения и преломления) (ii) касается распространения поверхностных волн, уравнения частоты, скорости поверхностных волн и коэффициентов затухания (iii) Относительно зависимых от времени проблем теплового шока, учитывая метод нормальной моды, будут указаны компоненты смещения, распределение температуры, компоненты напряжений, трение из-за пустот и диффузия из-за массообмена.

Научная новизна исследования состоит в: охвате оба аспекта теории обобщенной магнито-термоупругости для решения задач в двумерном полупространстве при тепловом ударе, начальном напряжении и двух температурах.

Качественном исследование свойств математической модели реализованной с использованием метода потенциалов Ламе в контексте (CD)- Классическая динамическая, (LS)- Лорд-Şhulman, (GL) -Грин-Линдсей, (GN) Грин-Нагди (I, II и III типов), Dual-фазно-лаговые (DPL) и трехфазно-лаговые (TPL) термоэластики.

Изучение проблемы отражения и преломления термоупругих волн на намагниченной границе раздела твердое тело-жидкость при наличии начального напряжения.

В контексте теорий термоупругости ГЛ и КТ решение проблемы влияния магнитного поля, внешних источников тепла и начальных напряжений на распространение P-, T- и SV-волн.

Исследование распространение поперечных волн в неоднородной анизотропной несжимаемой среде под воздействием электромагнитного поля, гравитационного поля, вращения и изначально напряженной среды.

На основе аналитического анализа установление зависимости скорости распространения поперечных волн от направления распространения, анизотропии, магнитного поля, вращения, гравитационного поля, неоднородности среды и начального напряжения.

Разработка математической модели, дающая возможность определение скорость поперечных волн для частотного уравнения.

Предложенное дисперсионное уравнение для разных случаев, когда граничные условия:

(i) Полные, нормальные напряжения на границе эквивалентны начальному напряжению;

(ii) касательные напряжения исчезают на границе;

(iii) граница падения теплоизолирована.

Выводы.

Из результатов, полученных в диссертации, сделан вывод, что в контексте (CD) Классическая динамическая, (LS) Лорд-ulhulman, (GL) Грин-Линдсей, Dual-Phase-Lag (DPL), Грин- Теории термоупругости Нагди (GN type III) и трехфазного запаздывания (TPL) исследованы поверхностные волны в неоднородных, анизотропных, армированных волокнами вязкоупругих твердых средах при вращении и более высокого n-го порядка, включая временную скорость деформации.

Исследование влияния на вязкоупругие поверхностные волны вращения, неоднородности, частоты и скорость изменения параметров деформации. Эти параметры влияют на скорость волны в той или иной степени в зависимости от соответствующих констант, характеризующих и вязкоупругости материала.

Показаны, что отраженные амплитуды зависят от угла падения, начального напряжения, электромагнитного поля и времени тепловой релаксации.

- Установлено, что в начальном напряжении электромагнитное поле играет значительную роль, которая имеет обратную тенденцию для отраженных и прошедших волн.

Исследованы поверхностные волны в неоднородных, анизотропных, армированных волокнами вязкоупругих твердых средах при вращении и более высоком порядке n-го порядка, включая временную скорость деформации.

Установлено, что на вязкоупругие поверхностные волны влияют вращение, неоднородность, частота и скорость изменения параметров деформации. Эти параметры влияют на скорость волны в той или иной степени в зависимости от соответствующих констант, характеризующих и вязкоупругости материала. Таким образом, результаты этого анализа становятся полезными в обстоятельствах, когда этими эффектами нельзя пренебрегать. Эти скорости зависят от армированных волокном параметров «a», подтверждающих, что на эти волны влияет вращение среды.

Получена и проанализирована оценка решения для изучения распространения волн Стоунли в магнито-термоупругих материалах с пустотами и двумя временами тепловой релаксации в контексте модели Грина Линдсея (GL) на основе потенциального метода Ламе для решения проблемы.

Заключение

Основное внимание в этой работе было уделено математическому моделированию процессы термоупругости: распространение поперечных волн в неоднородной анизотропной несжимаемой среде под воздействием электромагнитного поля, фототермического, полупроводникового, гравитационного поля, вращения и изначально напряженной среды на основе изучению качественных и количественных характеристик дифференциальных уравнений, описывающие эти процессы.

Исследована проблема отражения и преломления термоупругих волн на намагниченной границе раздела твердое тело-жидкость при наличии начального напряжения.

В контексте теорий термоупругости была решена ГЛ и КТ проблема, и установлено влияние магнитного поля, внешних источников тепла и начальных напряжений на распространение p-, T- и SV-волн.

Аналитический и численный анализ скорости распространения поперечных волн в зависимости от направления распространения, анизотропии, магнитного поля, вращения, гравитационного поля, неоднородности среды и начального напряжения.

Получено частотное уравнение, определяющее скорость поперечных волн.

Были получены дисперсионные уравнения и они исследованы для различных случаев в зависимости от угля падения, электромагнитного поля и сила тяжести оказывают существенное влияние на амплитуды коэффициентов отражения, что указывает на его ценное влияние на явления, и имеют множество экспериментальных применений в технике, геофизике, самолетостроение астрономии, нефтедобычи и др.

Изучено распространение поперечных волн в неоднородной анизотропной несжимаемой среде под воздействием электромагнитного поля, гравитационного поля, вращения и изначально напряженной среды. Аналитический анализ показывает, что скорость распространения поперечных волн зависит от направления распространения, анизотропии, магнитного поля, вращения, гравитационного поля, неоднородности среды и начального напряжения.

Получено частотное уравнение, определяющее скорость поперечных волн. Дисперсионные уравнения получены и исследованы для разных случаев. Показано, что фактически эти уравнения согласуются с соответствующими классическими результатами, когда среда изотропна.

Полученные результаты представляются в визуализированное форме. Результаты исследований показали, что эффекты гравитационного поля, начального напряжения, магнитного поля, анизотропии электрического поля и вращения существенно влияние на распрстранени волнн в различных средах

Эълон қилинган ишлар рўйхати
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