O’ZBEKISTON RESPUBLIKASI OLIY VA O’RTA MAXSUS TA’LIM VAZIRLIGI

Andijon Mashinasozlik instituti
„Umumtexnika fanlari” ***kafedrasi***

„MATERIALLAR QARSHILIGI”*fanidan*

Mustaqil ish

Bajardi*:„AT “** ***yo’nalishi **II** ***kurs*** **I** ***guruh talabasi***

Mutalipov M

Tekshirdi*:*Xadjiyeva S.

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MAVZU: STATIK NOANIQ MASALALAR.
REJA:

Cho’zilish va siqilishga ishlaydigan konstruksiyalar 2 sistemaga bo’linadi.

1.Statik noaniq masalalar

2.Statik aniq masalalar.

Biz ko’rib cho’qadigan bu ikki masaladan birinchisini ko’rib chiqamiz. Noma'lumlarini statikaning muvozanatlik tenglamalari yordamida aniqlab bo’lmaydigan masalalar statik noaniq masalalar deyiladi. Bu masalalar quyidagi tartibda yechiladi.

a) masalaning statik noaniqlik darajasi aniqlanadi ya'ni statikaning masala uchun mumkin bo’lgan tenglamalari to’zi ladi. Bu tenglamalarni sonidan nechtaga orto’q bo’lsa, masala shuncha marta statik noaniq deyiladi.

b) masalaning deformasiyalanish Har tidan foydalanib qo’shimcha, Ortiqcha noma'lumlar soniga teng bo’lgan, tenglamalar to’zi ladi.

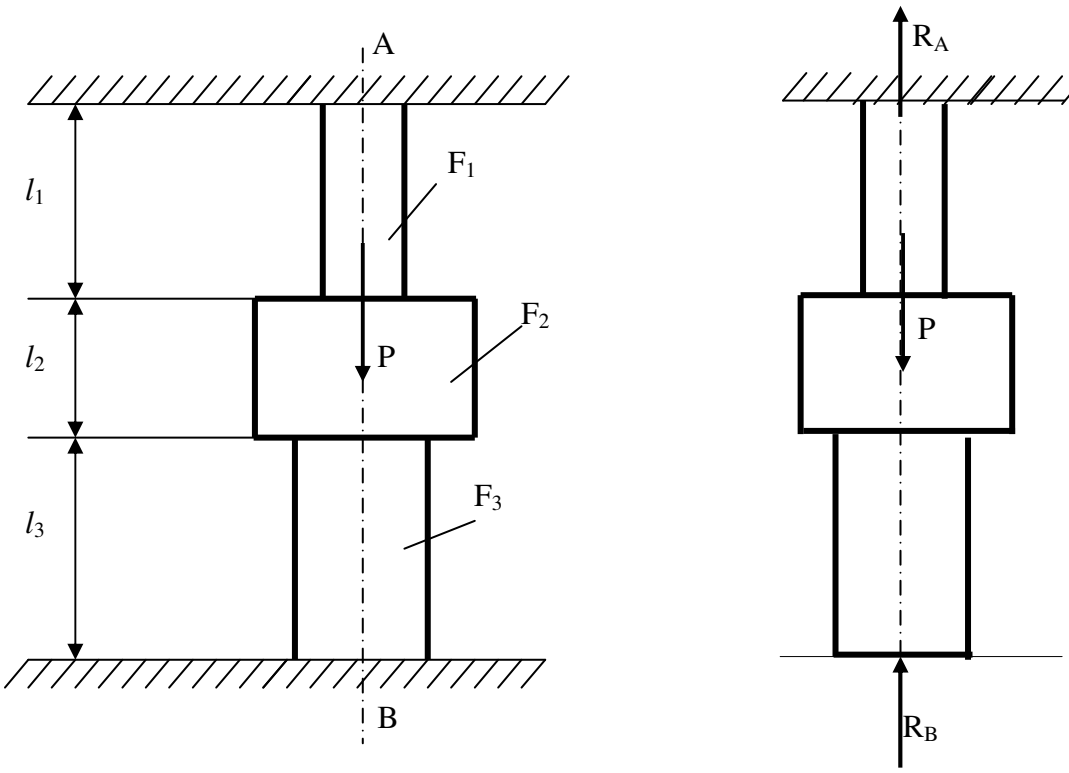
v) deformasiya tenglamalar birgalikda yechilib, zarur ma'lumotlar topiladi.

d) masalaning qolgan Har tlari statik aniq masalalaridek bajariladi.

Materiallar qarshiligining ko’pchilik masalalarida bruslarga ta'sir qiluvchi ichki kuchlarni faqat absolyut qattiq jismning muvozanat tenglamalari yordamidagina aniqlab bo’lmaydi. Statik noaniq masala mashina yoki konstruksiya qismlarida qo’shimcha zo’riqishning kelib cho’qishi natija6sida paydo bo’ladi.

Masalan: Temir yo’l relslari qishda torayadi, yozda kengayadi. Statik noaniq masalalarni yechishda asosiy masala qo’shimcha zo’riqishdan kelib cho’qargan deformasiyani yoki ko’chishni hisobga olib qo’shimcha tenglama to’zi sh. Bu masalalarni yechishda sterjenlarning deformasiyalarini hisobga olish kerak bo’ladi. Shuning uchun ham aniqlangan zo’riqishlarning qiymati, sterjenlarning o’lchamlariga, elastiklik hossalariga bog’lo’qdir.

Ikki tomon bilan qistirib mahkamlangan ustunda tayanch reaksiya kuchlarini aniqlaymiz. Shakl-1 mumkin bo’lgan statika tenglamalarini tuzamiz. Bunday masalalarni yechishda asosiy sistema tanlash usulidan foydalaniladi, ya'ni tayanchlardan birining usto’nga ta'siri noma'lum reaksiya kuchi bilan almashtiriladi. Shu usulda hosil qilingan sistema asosiy sistema deyiladi.



$$\Sigma У=0 \qquad R_1-F+R_2=0 \qquad \Sigma x=0 \quad (1)$$

Statika tenglamalari bitta undagi noma'lum ikkita, demak masala bir marta statik noaniq. Qo'shimcha tenglamani berilgan va asosiy sistemalardan foydalanib to'zi ladi. Berilagan sistemada umumiy mutlok deformasiya nolga teng

$$\Delta l=0 \qquad (2)$$

Bu Har t asosiy sistemada ham bajarishi zarur.

$$\Delta= \Delta l_F + \Delta l_{R1} =0 \qquad (3)$$

Ohirgi ifodani Guk qonuni yordamida ma'lum va no'malum kuchlar bilan almashtiramiz.

Asosiy sistemaning B nuqtadagi ko'chishini topib, uni nolga tenglashtiramiz, chunki statik aniqmas sistemaning bu nuqtasi mahkamlanganligi uchun u ko'cha- olmaydi.

B nuqtaning ko'chishini topish uchun Guk qonunidan foydalanamiz:

$$-\frac{R_B l_3}{EF}-\frac{R_B l_2}{EF_2}-\frac{R_B l_1}{EF_1}+\frac{Pl_1}{EF_1}=0; \qquad (4.)$$

hosil bo'lgan (1) ва (4) tenglamalarni birgalikda echib, noma'lum R_a va R_B reaktsiyalarni aniqlaymiz:

$$R_A = \frac{P\left(\frac{l_2}{F_2}+\frac{l_3}{F_3}\right)}{\frac{l_1}{F_1}+\frac{l_2}{F_2}+\frac{l_3}{F_3}}; \quad R_B = \frac{Pl_1}{F_1\left(\frac{l_1}{F_1}+\frac{l_2}{F_2}+\frac{l_3}{F_3}\right)}.$$

Yuqorida keltirilgan ikki misol asosida, statik aniqmas masalalarni echish uchun quyidagi rejadan foydalaniladi:

1)Berilgan masalada barcha reaktsiya kuchlarining yoki noma'lum zo'riqish kuchlarining yo'nalishi ko'rsatiladi;

2)Shu masala uchun lozim bo'lgan hamma muvozanat tenglamalari yozilib, uning aniqmaslik darajasi belgilanadi;

3)Sistemaning ayrim qismlarining deformatsiyalari orasidagi bog'lanishlardan foydalanib barcha qo'shimcha tenglamalar to'zi ladi;

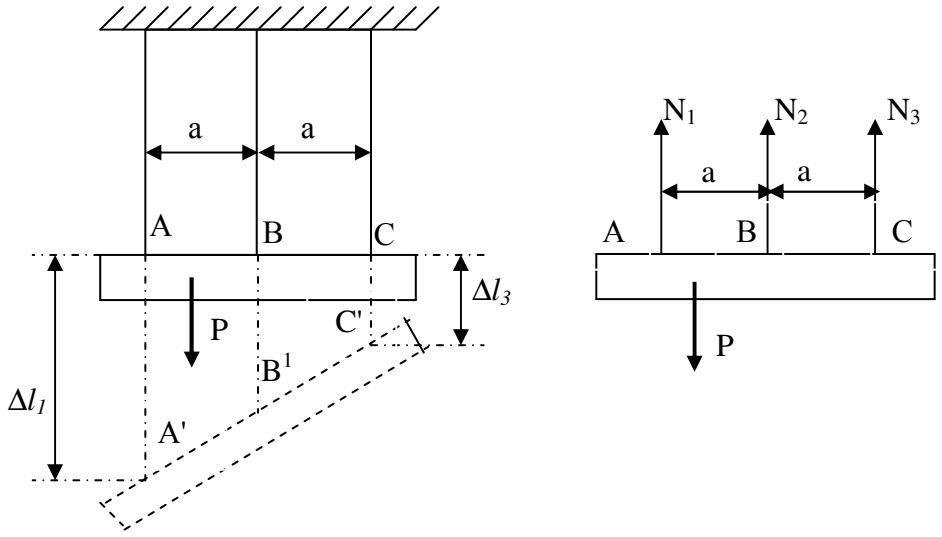
4)Qo'shimcha tenglamalardagi deformatsiyalar, Guk qonunidan foydalanib, tegishli zo'riqish kuchlari bilan almashtiriladi;

5) Hosil bo'lgan tenglamalar birgalikda echilib, barcha noma'lum kuchlari topiladi.Agar statik aniqmas masala asosiy sistema tanlash usuli bilan echiladigan bo'lsa, yuqoridagi planning 3 va 4– punktlari quyidagicha o'zgartiriladi:

6) Sterjen Ortiqcha botlanishlardan ozod qilinib asosiy sistema tanlanadi va bu asosiy sistemaga berilgan va Ortiqcha noma'lum kuchlar ta'sir ettiriladi;

7)Asosiy sistemaning Ortiqcha noma'lum kuch qo'yilgan nuqtasining ko'chishi topilib, nolga tenglashtiriladi.

4 Sterjenlar sistemasini tekshiramiz ***Мисол тариқасида*** қуйида кўрсатилган системани текширамиз. Материаллар қаршилигининг кесиш усулидан фойдаланиб, унинг учта стерженида N_1,N_2,N_3 эластик кучлар номаълум эканлигини аниқлаб оламиз. Бу кучлар параллел кучлар системасини ташкил этади, шунинг учун фақат иккита мувозанат тенгламасини тузиш мумкин



$$\sum Y_K = 0; \qquad N_1 + N_2 + N_3 - P = 0; \quad (4.1)$$

$$\sum M_A = 0; -N_2 \cdot a - N_3 \cdot 2a + P \cdot \frac{a}{2} = 0. \quad (4.2)$$

Bu ikki tenglamada 3-ta noma'lum, demak yana bitta munozabat to'zi sh zarur. Bu qo'shimcha munosabatni sistemaning elementlarida hosil bo'ladigan deformatsiya-larning munosabatidan foydalanib to'zi ladi. Binobarin, sistemaning deformatsiyadan keyingi vaziyatini shaklda ko'rsatilgan. Biz ko'rayotgan hol uchun sistemaga qo'yilgan kuch ta'siridan, AS brus absolyut bikr bo'lgani uchun, A_1S_1 vaziyatini oladi, bu vaziyat shtrix bilan chizilgan. Shakldan ko'rinib turibdiki, brusning deformatsiyadan keyingi va avvalgi vaziyatlari ASS_1A_1 trapetsiyani hosil qiladi; trapetsiyaning asoslari ikki chetki sterjenlarning absolyut cho'zilishidan iborat bo'lib, o'rtadagi sterjenning absolyut cho'zilishi trapetsiyaning o'rta chizitidir, binobarin;

$$BB' = \Delta l_2 = \frac{\Delta l_1 + \Delta l_3}{2}. \qquad (A)$$

Bu absolyut cho'zilishlarni Guk qonuni yordamida tegishli noma'lum zo'riqish kuchlari orqali ifodalaymiz:

$$\Delta l_1 = \frac{N_1 l}{EF}, \quad \Delta l_2 = \frac{N_2 l}{EF} \quad \text{ва} \quad \Delta l_3 = \frac{N_3 l}{EF}.$$

Bu formulalarni yozishda uchala sterjenning materialini, ko'ndalang kesimining yuzalari va uzunliklari bir hil deb qabul qildik. Bularni (A) tenglamaga qo'yib, quyidagi qo'shimcha tenglamani hosil qilamiz:

$$N_2 = \frac{1}{2}(N_1 + N_3). \qquad (4.3)$$

Ana endi uchala tenglamani birgalikda echib,

$N_1 = \frac{7}{12}P, \quad N_2 = \frac{4}{12}P, \quad N_3 = \frac{1}{12}P.$ larni hosil qilamiz.

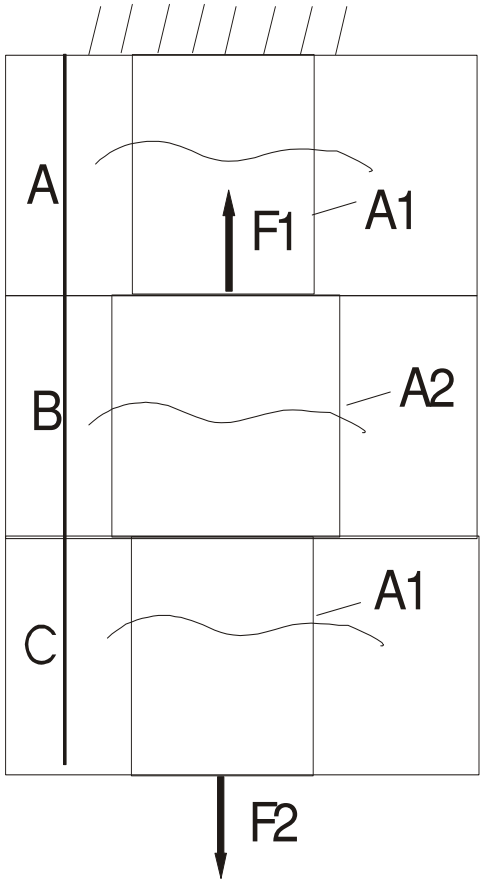
1-Masala

Chozilish va siqilishda statik aniq masala

Reja

1. Bir uchi bilan maxkamlangan sterjin uchaska kesimlari aloxida aloxida qirqilib muvozanat tenglamasi topilsin.
2. Kesim uchun boylama kuch N aniqlansin.
3. Kesimlar uchun kuchlanish G mutloq defarmasiya Δl bilan (belgilansin) topilsin.
4. Topilgan qiymatlar asosida boylama kuch, kuchlanish mutloq defarmasiya epyuralari qurilsin.

Berilgan



$F=1.4t=14k$
$A_1=1.2sm^2=12\ 10^{-4}$
$A_2=1.1sm^2=11\ 10^{-4}$

$a=1.3m$
$b=1.1m$
$c=1.7m$
$E=2\ 10^8$ мп

Topish kerak:
N-?
G-?
Δl -?

Yechish:

1. N bo'ylama kuchni aniqlaymiz:

I.I $N_1-F_2=0$

$N= F_2=28kn$

II.II $N_2-F_2=0$

$N_2=28kn$

III.III $N_3+F_1- F_2=0$

$N_3=-F_1+F_2=14kn$

2. σ kuchlanishni aniqlaymiz:

$$G=\frac{N}{A}$$

$$G_1=\frac{N_1}{A_1}=\frac{28kn}{1.2\cdot10^{-4}}=233\cdot10^{-4}\,kn/m^2$$

$$G_2=\frac{N_2}{A_2}=\frac{28kn}{1.1\cdot10^{-4}}=2545\cdot10^{-4}\,kn/m^2$$

$$G_3=\frac{N_3}{A_1}=\frac{14kn}{1.2\cdot10^{-4}}=11.6\cdot10^{-4}\,kn/m^2$$

3. Δl mutlaq deformatsiyani aniqlaymiz:

$$\Delta l=\frac{N\cdot l}{E\cdot A}$$

$$\Delta l=\frac{N_1\cdot C}{E\cdot A_1}=\frac{28\cdot1.7}{2\cdot10^8\cdot1.2\cdot10^{-4}}=19.8\cdot10^{-4}$$

$$\Delta l=\frac{N_2\cdot B}{E\cdot A_2}=\frac{28\cdot1.1}{2\cdot10^8\cdot1.1\cdot10^{-4}}=14.\cdot10^{-4}$$

$$\Delta l=\frac{N_3\cdot C}{E\cdot A_1}=\frac{14\cdot1.3}{2\cdot10^8\cdot1.2\cdot10^{-4}}=7.58\cdot10^{-4}$$

2-masala

Chozilish va siqilishda statik noaniq masala

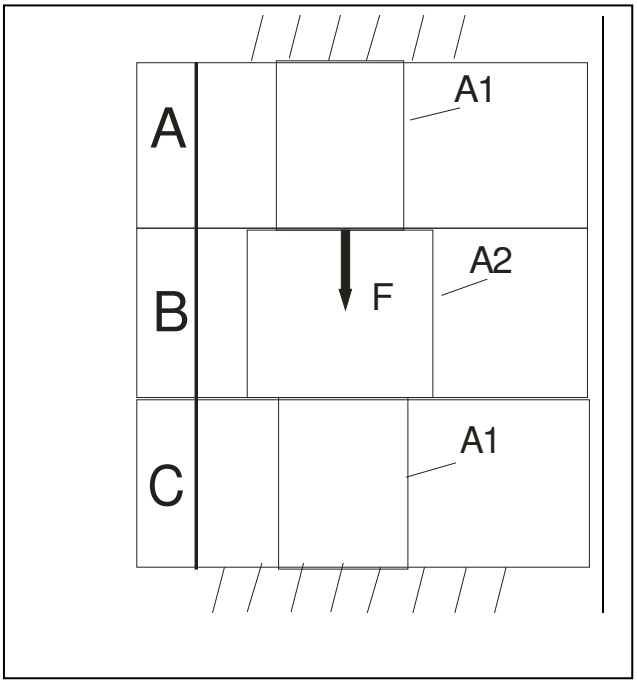
Reja

1. Ikki tomondan qistirilib maxkamlangan polat sterjin uchun berilgan sistema asosiy sistemaga aylantirilsin hamda muozanat tenglamasi tuzilsin.
2. Statik noaniq masala static aniq masalaga aylantirilsin.
3. Berilgan polat sterjin uchun N,G, Δl aniqlansin.
4. Topilgan qiymatlar asosida N,G, Δl epyuryasi topilsin.
5. Mutloq defarmasiya 0ga tengligi aniqlansin $\Delta l = 0$

Berilgan

F=450
$A_1=11*10^{-4}$
$A_2= 22*10^{-4}$

a=2.2 m
b=2.4 m
c=1.8m
E=2 10^8мп



Topish kerak:

R_A -? R_B -?
N-? G-?
Δl -?

Yechish:

Muvozanat tenglamasini tuzamiz:

R_A-F+R_B=0

$$\Delta l = \frac{N \cdot l}{E \cdot A} \quad \Delta l = 0$$

$$\Delta l = \Delta l_F + \Delta l_{RB} = 0$$

$$\Delta l_F = \frac{F \cdot C}{E \cdot A}$$

$$\Delta l_{R_B} = \frac{R_B \cdot a}{E \cdot A_1} \cdot \frac{R_B \cdot b}{E \cdot A_2} \cdot \frac{R_B \cdot c}{E \cdot A_1} = 0$$

$$\Delta l = \frac{R_B \cdot a}{E \cdot A_1} \cdot \frac{R_B \cdot b}{E \cdot A_2} \cdot \frac{R_B \cdot c}{E \cdot A_1} + \frac{Fl}{E \cdot A_1} = 0$$

$$R_B = \frac{F \cdot \left(\frac{c}{A_1}\right)}{\frac{a}{A_1} + \frac{b}{A_2} + \frac{c}{A_1}} = \frac{450 \cdot \left(\frac{1.8}{11 \cdot 10^{-4}}\right)}{\left(\frac{2.2}{11 \cdot 10^{-4}} + \frac{2.4}{22 \cdot 10^{-4}} + \frac{1.8}{11 \cdot 10^{-4}}\right)} = 156$$

R_A=F-R_B=450-156=294

1) N bo'lama kuchni aniqlaymiz:

I.I N_1+ R_B =0

N= - R_B =-156кн

II.II N_2- R_B =0

N_2=-156кн

III.III N_3-F_1+ R_B =0

N_3=F_1-R_B =294кн

2) σ kuchlanishni aniqlaymiz:

$$G = \frac{N}{A}$$

$$G_1 = \frac{N_1}{A_1} = \frac{-156}{11 \cdot 10^{-4}} = -14.19 \cdot 10^{-4} \, kí \, / m^2$$

$$G_2 = \frac{N_2}{A_2} = \frac{-156}{22 \cdot 10^{-4}} = -7.1 \cdot 10^{-4} \, kí \, / m^2$$

$$G_3 = \frac{N_3}{A_1} = \frac{294}{11 \cdot 10^{-4}} = 26.73 \cdot 10^{-4}\ kn/m^2$$

3) Δl mutlaq deformatsiyani aniqlaymiz:

$$\Delta l = \frac{N \cdot l}{E \cdot A}$$

$$\Delta l = \frac{N_1 \cdot a}{E \cdot A_1} = \frac{-156 \cdot 2.2}{2 \cdot 10^8 \cdot 11 \cdot 10^{-4}} = -15.6 \cdot 10^{-4}$$

$$\Delta l = \frac{N_2 \cdot b}{E \cdot A_2} = \frac{-156 \cdot 2.4}{2 \cdot 10^8 \cdot 22 \cdot 10^{-4}} = -8.51 \cdot 10^{-4}$$

$$\Delta l = \frac{N_3 \cdot c}{E \cdot A_1} = \frac{294 \cdot 1.8}{2 \cdot 10^8 \cdot 11 \cdot 10^{-4}} = 24.05 \cdot 10^{-4}$$

$$\Delta l = \Delta l_1 + \Delta l_2 + \Delta l_3$$

$$\Delta l = \left(-15.6 \cdot 10^{-4}\right) + \left(-8.51 \cdot 10^{-4}\right) + \left(24.05 \cdot 10^{-4}\right) = 0$$

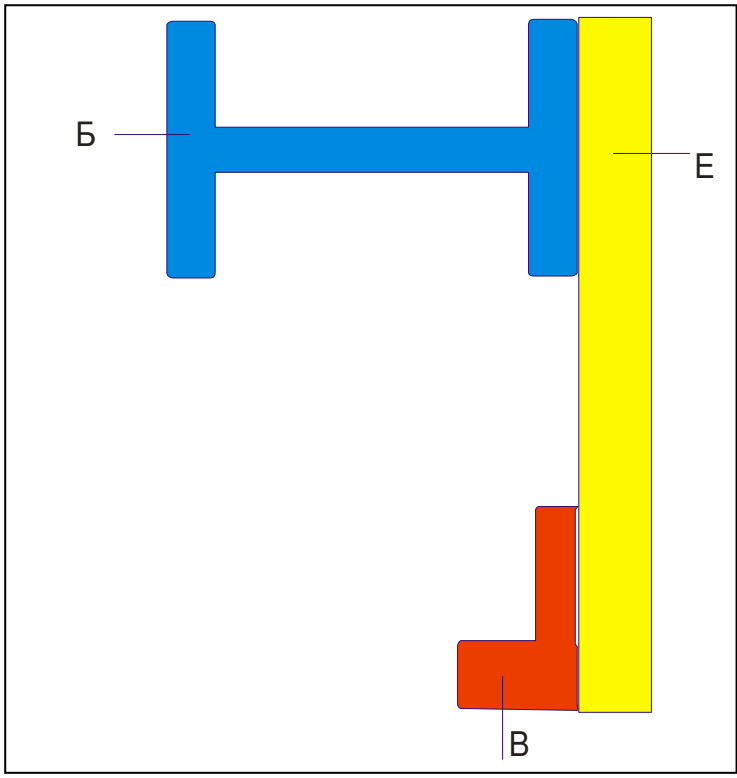
3-masala

Yassi kesimlarning geometrik harakteristikalari

Berilgan nosimmetrik kesim uchun bosh inersiya momentlari aniqlansin va inersiya o'qlari o'tkazilsin, buning uchun:

1. Og'irlik markazining koordinatalari aniqlansin
2. Og'irlik markazi orqali o'tadigan x_c , y_c o'qlarga nisbatan markazdan qochirma inersiya momentlari topilsin
3. Bosh markaziy o'qlarning yo'nalishlari aniqlansin
4. Bosh markaziy o'qlarga nisbatan inersiya momentlarining qiymatlari topilsin
5. Inersiya radiuslari topilsin
6. Tekshirish bajarilsin

Berilgan:



1. B teng yonli burchak
   100*100*10

$h_1 = 10sm$ $b_1 = 10sm$

$I_{x_{0_1}} = 284sm^4$ $A_1 = 19.2sm^2$

$I_{x_1} = I_{y_1} = 179sm^4$

$I_{y_{0_1}} = 74.1sm^4$ $Z_{0_1} = 2.83sm$

d_1=1.sm

2. E vertical to'g'ri tortburchak

$b_2 = 1sm$ $h_2 = 20sm$

$A_2 = 1.0 \cdot 20 = 20sm^2$

$$I_{x_2} = \frac{b_2 h_2^3}{12} = \frac{10 \cdot 20^3}{12} = 666.67sm^4$$

$$I_{y_2} = \frac{b_2^3 h_2}{12} = \frac{1.0^3 \cdot 20}{12} = 1.67sm^4$$

3-shakl

3. Б koshtavir

$h_3 = 9sm$ $b_3 = 18sm$ $d_3 = 5.1sm$

$A_3 = 23.4sm^2$ $I_{x_3} = 1290sm^4$

$I_{y_3} = 82.6sm^4$

Yechish:

1) Og'irlik markazi orqali o'tadigan x_c , y_c o'qlarga nisbatan markazdan qochirma inersiya momentlarini aniqlaymiz:

$c_1 = b_3 - z_{0_1} = 9 - 2.83 = 6.17sm$

$c_2 = b_3 + \frac{b_2}{2} = 9 + \frac{1.0}{2} = 9.5sm$

$c_3 = \frac{b_3}{2} = 4.5sm$

$k_1 = z_0 = 2.83sm$

$k_2 = \frac{h_2}{2_3} = \frac{20}{2} = 10sm$

$k_3 = h_2 - \frac{b_3}{2} = 20 - \frac{9}{2} = 15.5sm$

$$x_c = \frac{c_1A_1 + c_2A_2 + c_3A_3}{A_1 + A_2 + A_3} = \frac{6.17 \cdot 19.2 + 9.5 \cdot 20 + 4.5 \cdot 23.4}{19.2 + 20 + 23.4} = \frac{118.5 + 190 + 105.3}{62.6} = 6.61sm$$

$$y_c = \frac{k_1A_1 + k_2A_2 + k_3A_3}{A_1 + A_2 + A_3} = \frac{2.83 \cdot 19.2 + 10 \cdot 20 + 15.5 \cdot 23.4}{19.2 + 20 + 23.4} = \frac{54.3 + 200 + 362.7}{62.6} = 9.86sm$$

2) Bosh markaziy o'qlarga nisbatan inersiya momentlarining qiymatlarini aniqlaymiz:

$a_1 = c_1 - x_c = 6.17 - 6.61 = -0.44sm$

$a_2 = c_2 - x_c = 9.5 - 6.61 = 2.89sm$

$a_3 = c_3 - x_c = 4.5 - 6.61 = -2.11sm$

$m_1 = k_1 - y_c = 2.83 - 9.86 = -7.03sm$

$m_2 = k_2 - y_c = 10 - 9.86 = 0.14sm$

$m_3 = k_3 - y_c = 15.5 - 9.86 = 5.64sm$

$$I_{x_c} = I_{x_1} + a_1^2A_1 + I_{x_2} + a_2^2A_2 + I_{x_3} + a_3^2A_3 =$$

$$= 179 + (-0.44)^2 \cdot 19.2 + 666.67 + (-2.89)^2 \cdot 20 + 0{,}288 + 1290 + (-2.11)^2 \cdot 23.4 = 2410.6sm^4$$

$$I_{y_c} = I_{y_1} + m_1^2A_1 + J_{y_2} + m_2^2A_2 + I_{y_3} + m_3^2A_3 =$$

$$= 179 + (-7.03)^2 \cdot 19.2 + 1.67 + 0.14^2 \cdot 20 + 82.6 + 5.64^2 \cdot 23.4 = 1956.9sm^4$$

$$I_{x_1 y_1} = \frac{I_{x_0} - I_{y_0}}{2} = \frac{284 - 74.1}{2} = 105 sm^4$$

$$I_{x_c y_c} = I_{x_1 y_1} + a_1 m_1 A_1 + I_{x_2 y_2} + a_2 m_2 A_2 + I_{x_3 y_3} + a_3 m_3 A_3 =$$
$$= 105 + 0.44 \cdot (-7.03) \cdot 19.2 + 2.89 \cdot 0.14 \cdot 20 - 2.11 \cdot 5.64 \cdot 23.4 = -106$$

4) Markaziy bosh inersiya o'qlari vaziyatini aniqlaymiz:

$$tg 2\alpha = \frac{2 \cdot I_{x_c y_c}}{I_{y_c} - I_{x_c}} = \frac{2 \cdot (-106)}{1956.9 - 2410.6} = -\frac{212}{453.7} = -0.48$$

5) Markaziy bosh inersiya momentlari qiymatlarini aniqlaymiz:

$$I_{u,v} = \frac{I_{y_c} + I_{x_c}}{2} \pm \sqrt{\left(\frac{I_{y_c} - I_{x_c}}{2}\right)^2 + I_{x_c y_c}{}^2}$$

$$I_{u\max} = \frac{I_{y_c} + I_{x_c}}{2} + \sqrt{\left(\frac{I_{y_c} - I_{x_c}}{2}\right)^2 + I_{x_c y_c}{}^2} = \frac{1956.9 + 2410.6}{2} + \sqrt{\left(\frac{7956.9 - 2410.6}{2}\right)^2 + (-106)^2} = 2434.2 sm$$

$$J_{v\min} = \frac{J_{y_c} + J_{x_c}}{2} - \sqrt{\left(\frac{J_{y_c} - J_{x_c}}{2}\right)^2 + J_{x_c y_c}{}^2} = 2183.8 - 250.4 = 1933.4 sm^4$$

6) Tekshirish:

$$J_{y_c} + J_{x_c} = J_{\max} + J_{\min}$$
$$2410.6 + 1956.9 = 2434.2 + 1933.4$$
$$4367.5 = 4367.6$$