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

TOSHKENT KIMYO-TEXNOLOGIYA INSTITUTI

OZIQ-OVQAT SANOATI MASHINA VA JIHOZLARI-MEXANIKA ASOSLARI KAFEDRASI

“NAZARIY MEXANIKA” fanidan

Kurs ishi

Mavzu: MEXANIK SISTEMA KINETIK ENERGIYASI. ISH VA QUVVAT

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MEXANIK SISTEMA KINETIK ENERGIYASI. ISH VA QUVVAT

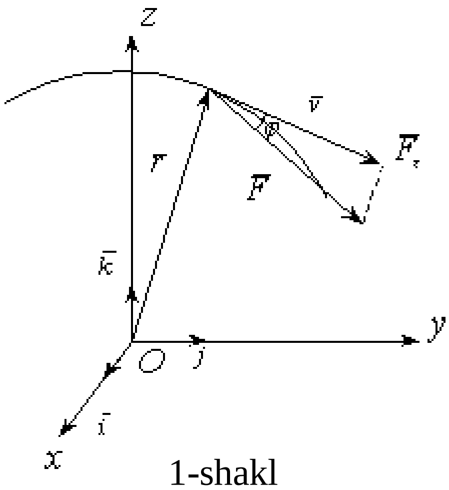
Кuchlarning ish.

Кuchlarning ishi – skalyar kattalik bo’lib kuchlar quyilgan nuqtalarning siljishiga bo’lgan ta’sirini ifoda etadi. Ishning o’lchov birligi jouldir.

Elementlar ishi

$\overline{F}$ kuchi ta’sirida harakt qilayotgan *M* nuqtani d$\bar{r}$ elementlar ko’chishdagi bajargan elementar ishi quyidagi *dA* kattalikka teng:

$$dA=F_{\tau}\cdot ds \quad (1)$$



1-shakl

F_{τ}, *F* kuchning tezlik yo’nalishi bo’yicha yotgan to’g’ri chiziqdagi proeksiyasi. Elementar ish *dA* skalyar kattalik. Uning ishorasi $\overline{F}_{\tau}$ni ishorasi bilan aniqlanadi. *dS* ni ishorasi xamisha musbat. $F_{\tau}>0$ bo’lsa $dA>0$, bo’lsa $F_{\tau}<0$ $dA<0$ bo’ladi.

$$F\tau=F\cos\alpha \quad (2)$$

Demak,

$$dA=F\cdot\cos\varphi ds \quad (3)$$

Agar $\varphi=0$ bo’lsa $dA=Fds$, *F* xarakatni tezlashtiradi, $\varphi=\frac{\pi}{2}$ bo’lsa $dA=0$, *F* kuchning ishi bajarilmaydi.

$\varphi=\pi$ bo’lsa $dA=-Fds$, *F* kuchi xarakatni sekinlashtiradi. Elementar ishni hisoblashni boshqacha formulalarini keltirib chiqaramiz.

Кinematikadan ma’lumki,

$$\bar{v}=\frac{d\bar{r}}{dt},\ |\bar{v}|=v=\frac{ds}{dt};\ \mathrm{ds}=|\,\mathrm{d}\bar{\mathrm{r}}\,|\,\mathrm{vdt} \quad (4)$$

(3) va (4) ga asosan, $dA=Fdr\cos\varphi$

Vektorlar qoidasiga asosan, *dA* ni quyidagicha yozamiz:

$$dA=\overline{F}\cdot d\bar{r} \quad (5)$$

Demak, kuchning elementar ishi kuch bilan kuch qo’yilgan nuqta radiusi vektorini differensialini skalyar ko’paytmasiga teng:

$$dA=\overline{F}\cdot d\bar{r}=\overline{F}\cdot\bar{v}\,dt=\overline{F}\cdot dt\cdot\bar{v} \quad (6)$$

Elementar ish kuchning elementar impulsi bilan tezlikning skalyar ko’paytmasiga teng. Ma’lumki,

$$\overline{F}=F_x\bar{i}+F_y\bar{j}+F_z\bar{k} \quad (7)$$

$$d\bar{r}=dx\bar{i}+dy\bar{j}+dz\bar{k} \quad (8)$$

Shuning uchun

$$dA=F_x dx+F_y dy+F_z dz \qquad (9)$$

formula elementar ishni analitik ifodasini belgilaydi.

Кuchning to'la ishi

$\overline{F}$ kuchning M_0 dan M nuqtaga ko'chgandagi to'la ishni topish uchun ko'chishdagi oraliqni n ta mayda kichik bo'lakchalarga bo'lamiz. U holda A ish quyidagicha topiladi.

$$A=lim\sum_{k=1}^{n} dA_k \qquad (10)$$

dA_k – kuchni elementar ko'chishdagi bajargan elementar ishi.

$$A=\int_{M_0}^{M} F_\tau dS \qquad (11)$$

Yoki

$$A=\int_{M_0}^{M} \overline{F}d\overline{r}=\int_{M}^{M}(F_x dx+F_y dy+F_z dz) \qquad (12)$$

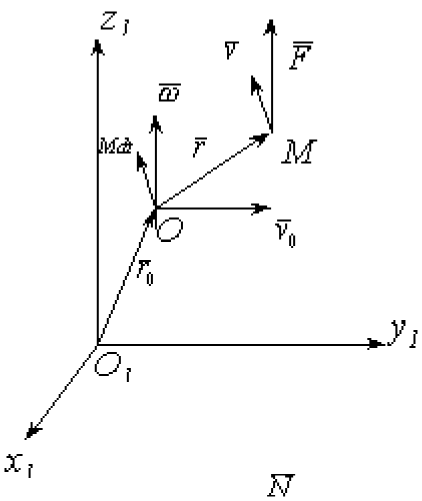
Shuning uchun
$$A=\int_{0}^{t} \overline{F}\overline{v}dt \qquad (13)$$

Umumiy xolda, harakatdagi jismni ixtiyoriy nuqtasining tezligini quyidagicha ifodalanadi:

$$\overline{v}=\overline{v}_0+\overline{\omega}_x\overline{r} \qquad (14)$$

lekin $\overline{V}_0 dt=d\overline{r}_0 \quad \overline{F}\cdot(\overline{\omega}\times\overline{r})=\overline{\omega}(\overline{r}\times\overline{F})=\overline{\omega}\cdot\overline{M}_0$

Yuqoridagilarni nazarda tutsak:



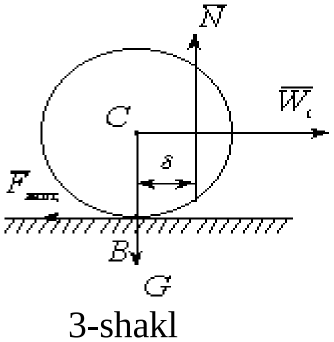
$$dA=\overline{F}\cdot\overline{V}dt=\overline{F}d\overline{r}\,0+\omega\cdot\overline{M}_0(\overline{F})dt=\overline{F}d\overline{r}_0+$$
$$+\omega dt\cdot M_0 cos\alpha,\ M_0 cos\alpha=M_0(\overline{F}),$$

$$dA=\overline{F}d\overline{r}_0+M_\omega(\overline{F})d\varphi \qquad (15)$$

Agar jism bir qancha $(\overline{F}_1\overline{F}_1,...\ \overline{F}_N)$ kuchlar ta'sirida bo'lsa:

$$dA=\sum_{k=1}^{n} dAk=(\sum_{k=1}^{n}\overline{F}_k)d\overline{r}_{ok}+\left[\sum_{k=1}^{N}M_0(F_k)\right]\overline{\omega}dt=\overline{R}d\overline{r}_0+\overline{L}_0\overline{\omega}dt=\overline{R}d\overline{r}_0 d\overline{\varphi}$$

$$dA=\overline{R}dr_0+\overline{L}_0 d\overline{\varphi}=\overline{R}d\overline{r}_0+\overline{L}_0\overline{\omega}dt,\quad dA=\overline{R}dr_0+\overline{L}_0\overline{\omega}dt$$
(16)



3-shakl

Jismni harakat qilgandagi dumalab ishqalanish kuchini ishi

Radiusi R o'lgan g'ildirak tekislik ustida sirg'anmasdan dumalaganida V nuqtasini tezligi nolga teng bo'ladi. $A=\int_{m_0}^{M}\overline{F}\overline{V}dt$ ga asosan, $\overline{V}_V=0$ demak $A=A(\overline{F})=0$. Ma'lumki sirtlar deformasiyalansa kuchlarni dumalashdagi momenti hosil bo'ladi. $M=\delta N$ – dumalashdagi ishqalanishni koefisenti, N normal reaksiya kuchi. $A=\delta N d\varphi$;

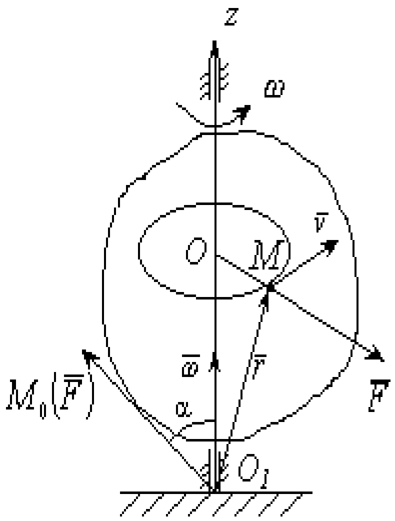
Agar $M=sonst$; $A=\delta N\varphi$ (17)

Aylanma harakatdagi jismga qo'yilgan kuchning ishi

OZ qo'zg'almas o'q atrofida aylanuvchi jismning *M* nuqtasiga $\overline{F}$ kuch ta'sir qilsin. Bu kuchning elementar ishini topamiz: $dA=\overline{F}\,\overline{V}dt$
lekin $\overline{V}=\overline{\omega}\times\overline{r}$ shuning uchun

$dA=\overline{F}\cdot(\overline{\omega}\times\overline{r})dt=\omega(\overline{r}\times\overline{F})dt$, bunda $\overline{r}\times\overline{F}=M_0(\overline{F})$

$\overline{F}$ kuchini *O* nuqtaga nisbatan momenti.



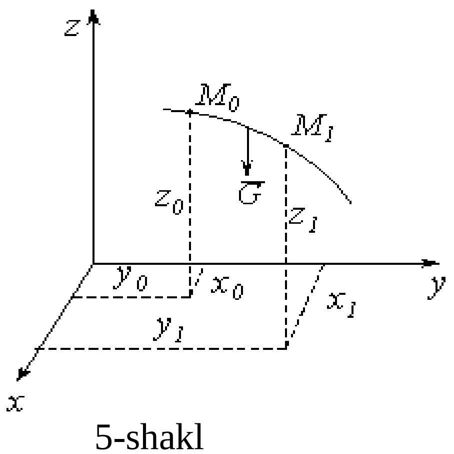
4-shakl

$dA=\overline{\omega}\cdot M_0(\overline{F})dt=\omega\cdot M_0(\overline{F})sos\alpha dt$ ammo, $M_0(\overline{F})sos\alpha=M_z(\overline{F})$, $\omega dt=\frac{d\varphi}{dt}\cdot dt=d\varphi$,

$dA=M_z(\overline{F})d\varphi$ $A=\int_{\varphi_0}^{\varphi}M_z(\overline{F})d\varphi$; $M_z(\overline{F})=sonst$

$A=M_z(\overline{F})(\varphi_1-\varphi_0)$ (18)

Quvvat



5-shakl

Kuchning vaqt birligidagi bajargan ishi *quvvat* deb ataladi.

$$N=\frac{dA}{dt};\quad N=\frac{F\tau ds}{dt}=F\tau\cdot V$$

(19)

Demak, quvvat kuchning nuqta traektoriyasiga o'tkazilgan urinmadagi proeksiyasi bilan nuqta tezligini ko'paytmasiga teng.

$A=\overline{F}\,d\overline{r}$ dan $N=\overline{F}\cdot\overline{V}=FVsos\varphi$ o'lchov birligi SI da vatt: (vt=1j/s). MKGSSda-1 kG·m/s. Texnikada quvvat birligi qilib 1 ot kuchini qabul qiladi.

1 ot kuchi 736 Vt (yoki 75 kG·m/s).

1kV t·s=3,6·10=367100 kg·m.

Mashina bajargan ishni uning quvvati va ishlagan soatini ko'paytmasidan iborat deb qarash mumkin.

Og'irlik kuchining ishi

G – og'irlik kuchi ta'siridagi nuqta M_0 dan M_1 holatga o'tgan bo'lsin. *G* ning koordinati o'qlaridagi proeksiyasi quyidagicha bo'ladi:

$$G_x=0;\ G_y=0;\ G_z=-G$$

$$dA = G_z dz = -Gdz$$

Nuqta M_0 dan M_1 holatga kelganida.

$$A=\int_{M_0}^{M_1}(-G)dz=G\int_{z_0}^{z_1}dz=G(z_0-z_1)$$

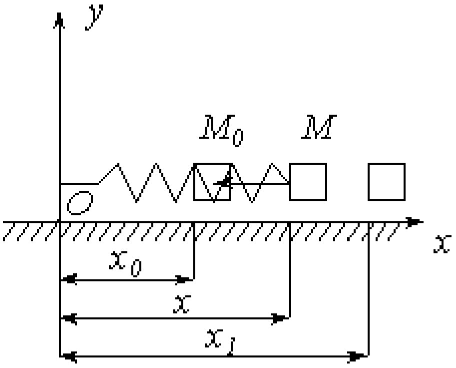
$$|z_0-z_1|=h,$$

$$A=G(z_0-z_1)=G(z_1-z_0)$$

$$A=G(z_1-z_0) \qquad (20)$$

Elastik kuchining ishi

Gorizontal tekislikda prujinaga maxkamlangan *M* yukni olaviz. Prujinani kuchlanmagan paytdagi xolati uchun koordinata boshini qabul qilamiz.



6-shakl

$$F_z=F_y=0;\ \ F_x=-cx.$$

$$dA=F_x dx+F_y dy+F_z dz$$

$$dA=-cxdx$$

$$A=\int_{M_0}^{M_1}dA=-\int_{x_0}^{x}cxdx=\frac{c}{2}(x_1^2-x_0^2)\ ;\ A=\frac{C}{2}(x_0^2-x_1^2)$$

(21)

Кinetik energiya

Moddiy nuqta va sistemaning kinetik energiyasi

Moddiy nuqtaning kinetik energiyasi deb nuqta massasi bilan uning tezligini kvadratini ko'paytmasini yarmiga teng bo'lgan skalyar kattalikka aytiladi:

$$T=\frac{mV^2}{2} \qquad (22)$$

Sistema kinetik energiyasi deb sistema nuqtalari kinetik energiyalarini yig'indisiga aytiladi.

$$T=\sum_{k=1}^{n}\frac{m_k V_k^2}{2} \qquad (23)$$

Uning o’lchov birligi - N·m

Agar sisitema nuqtalarining hammasi qo’zg’almas bo’lsa sistema kinetik energiyasi nolga teng bo’ladi.

Ilgarilama harakatdagi jismni kinematik energiyasi

Agar jism ilgarilama harakatda bo’lsa, jismning hamma nuqalarini tezligi teng, ya’ni $V_k = V$. Shuning uchun ilgarilama harakatdagi jismning kinetik energiyasi.

$$T=\sum_{k=1}^{n}\frac{m_k\cdot V_k^2}{2}=\frac{V^2}{2}\sum_{k=1}^{n}m_k=\frac{MV^2}{2} \qquad (24)$$

$M=\sum_{k=1}^{n}m_k$ -jismning massasi.

Aylanma harakatdagi jismni kinetik energiyasi

Agar jism aylanma harakatda bo’lsa, uning kinetik energiyasi quyidagiga teng bo’ladi:

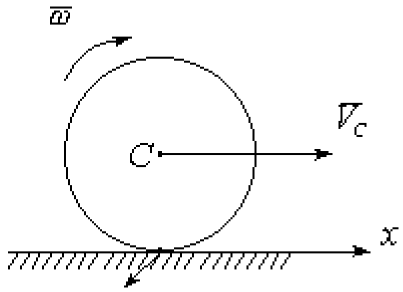
$$T=\sum_{k=1}^{n}\frac{m_k V_k^2}{2}=\sum_{k=1}^{n}\frac{m_k\omega^2 h^2}{2}=\frac{\omega^2}{2}\sum_{k=1}^{n}m_k\cdot h^2$$

Bundan $T=\dfrac{I_z\cdot\omega^2}{2}$ (25)

J_z jismni Z o’qiga nisbatan inersiya momenti.

b(tekis parallel harakatdagi jismni kinetik energiyasi.

Agar jism tekis-parallel harakatda bo’lsa, uning kinetik energiyasi quyidagicha bo’ladi.



7-shakl

$$\grave{O}=\frac{MV_c^2}{2}+\frac{J_z\cdot\omega^2}{2} \qquad (26)$$

J_z – jismni z-o’qiga nisbatan inersiya momenti.

Moddiy nuqta kinetik energiyasining o’zgarishi haqida teorema

$\overline{F}$ kuchi ta’siridagi m massaga ega bo’lgan moddiy nuqta uchun dinamikani qonunini quyidagicha yozamiz:

$$m\frac{dV}{dt}=F \qquad (27)$$

(27) ni ikki tomonini $d\bar{r}$ ga skalyar ravishda ko’paytiramiz.

$m\dfrac{d\overline{V}}{dt}\cdot d\bar{r}=\overline{F}d\bar{r}$, $m\overline{V}d\overline{V}=\overline{F}d\bar{r}$, $dA=m\overline{V}d\overline{V}$; $m\overline{V}d\overline{V}=d(\dfrac{m\overline{V}^2}{2})$ nihoyat

$$d\left(\frac{mV^2}{2}\right)=dA \qquad (28)$$

(28) dan nuqta kinetik energiyasining differensiali unga qo'yilgan kuchlarni elementar ishiga teng.

Agar (28) ni har ikkala tomonini *dt* ga bo'lsak,

$$\frac{d}{dt}\left(\frac{mV^2}{2}\right)=\frac{dA}{dt}, \quad \frac{d}{dt}\left(\frac{mV^2}{2}\right)=N \qquad (29)$$

Kinetik energiyadan vaqt bo'yicha olingan hosila, uning quvvatiga tengdir.

(17.28) ni M_0 dan M gacha integrallasak:

$\frac{mV^2}{2}=A+S$, $t=0$ da $A=0$, $V=V_0$, $C=\frac{mV_0^2}{2}$, $\frac{mV_0^2}{2}=A+\frac{mV_0^2}{2}$ bundan,

$$\frac{mV^2}{2}-\frac{mV_0^2}{2}=A \qquad (30)$$

Nuqta kinetik energiyasining biror ko'chishdagi o'zgarishi, unga qo'yilgan kuchlarni shu ko'chishdagi bajargan ishiga tengdir.

Sistema kinetik energiyasining o'zgarishi haqidagi teorema

Sistema *n*-ta moddiy nuqtalardan iborat bo'lsin. Bu nuqtalarni birini tanlab olamiz va unga ta'sir etuvchi kuchlarni tashqi va ichki kuchlarga ajratsak, nuqta uchun dinamikani qonuni quyidagicha bo'ladi.

$$m_k\frac{d\overline{V}_k}{dt}=\overline{F}_k^e+\overline{F}_k^i \qquad (31)$$

(31) ni har ikkala tomonini dr_k ga skalyar ravishda ko'paytirsak:

$$d\overline{r}_k\cdot m_k\frac{d\overline{V}_k}{dt}=\overline{F}_k^e d\overline{r}_k+\overline{F}_k^i d\overline{r}_k \text{ bo'ladi}$$

$$m_k\frac{d\overline{r}_k}{dt}\cdot d\overline{V}_k=\overline{F}_k^e d\overline{r}_k+\overline{F}_k^i d\overline{r}_k;\, m_k\overline{V}_k\cdot d\overline{V}_k=\overline{F}_k^e d\overline{r}_k+\overline{F}_k^i d\overline{r}_k \;\; d\left(\frac{m_k\overline{V}_k^2}{2}\right)=\overline{F}_k^e d\overline{r}_k+\overline{F}_k^i d\overline{r}_k \qquad (32)$$

(32) ni ikkala tomonini yig'indisini sistema uchun quyidagicha yozamiz:

$$d\sum_{k=1}^{n}\frac{m_k\overline{V}_k^2}{2}=\sum_{k=1}^{n}\overline{F}_k^e d\overline{r}+\sum_{k=1}^{n}\overline{F}_k^i d\overline{r}$$

yoki

$$dT=\sum_{k=1}^{n}dA_k^e+\sum_{k=1}^{n}dA_K^I \qquad (33)$$

Sistema kinetik energiyasining diferensiali sistemaga qo'yilgan tashqi va ichki kuchlarning elementar ishlarini yig'indisidan iboratdir.

Agar (33) ni integrallasak:

$$T_1-T_0=\int_0^1 d\sum_{k=1}^{n}\frac{m_kV_k^2}{2}=\sum_{k=1}^{n}\int_{M_0}^{M_1}dA_k^e+\sum_{k=1}^{n}\int_{M_0}^{M_1}dA_k^i$$

(17.34)

yoki $$T_1-T_0=\sum_{k=1}^{n}A_k^e+\sum_{k=1}^{n}A_k^i \qquad (35)$$

Sistemaning bir holatdan ikkinchi holatga ko’chishidagi kinetik energiyasining o’zgarishi unga qo’yilgan tashqi va ichki kuchlarning shu ko’chishidagi bajargan elementar ishlarning yig’indisiga teng.