TOSHKENT IRRIGATSIYA VA QISHLOQ XO'JALIGINI MEXANIZATSIYALASH MUHANDISLARI INSTITUTI

Fan: Materiallar qarshiligi

Mavzu 07

Nuqtaning kuchlanganlik holati to'g'risida tushuncha

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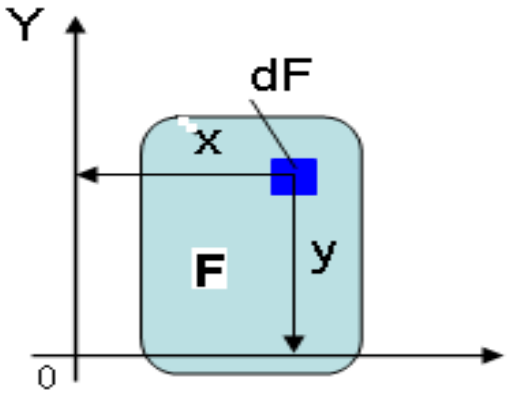
Reja:

1. Nuqtadagi kuchlanish xolati to'g'risida tushuncha va uning turlari.
2. Urinma kuchlanishning juftlik konuni.
3. Chiziqli kuchlanish xolatida qiya yuzachadagi kuchlanishlar.
4. Tekis kuchlanish xolatida qiya kesimlardagi kuchlanishlar.
5. Bosh kuchlanishlar.
6. Ekstremal urinma kuchlanishlar.

Tekis shakllarning statik va inertsiya momentlari



1-rasm

$$S_x = \int_F y dF \qquad S_y = \int_F x dF \tag{1}$$

$$S_x = F \cdot Y_c, \quad S_y = F \cdot X_c \tag{2}$$

$I_x = \int_F y^2 dF$ - tekis shaklning x o'qiga nisbatan inertsiya momenti; (3)

$I_y = \int_F x^2 dF$ - tekis shaklning u o'qiga nisbatan inertsiya momenti; (4)

$I_{xy} = \int_F xy dF$ - tekis shaklnig markazdan kochirma inertsiya momenti; (5)

$I_\rho = \int_F \rho^2 dF$ - tekis shaklning qutb inertsiya momenti. (6)

Oddiy shakllarning inersiya va qarshilik momentlari (markazdan o'tgan o‘qlarga nisbatan)

a) *To'gri to'rtburchak:*

$$I_X = \int_{-h/2}^{h/2} bY^2 dY = b\int_{-h/2}^{h/2} Y^2 dY = \frac{bh^3}{12}$$

$$I_Y = \int_{-b/2}^{b/2} hX^2 dX = h\int_{-b/2}^{b/2} X^2 dX = \frac{hb^3}{12}$$

b)*Kvadrat:*

$$I_x = I_y = \frac{a^4}{12}$$

v) *Uchburchak:*

$$I_x = \frac{b\,h^3}{36}$$

$$I_y = \frac{b\,h^3}{48}$$

g) *Doira:*

$$I_P = \int_F \rho^2 dF = 2\pi \int_0^{d/2} \rho^3 d\rho = \frac{2\pi d^4}{64} = \frac{\pi d^4}{32}$$

$$I_X = I_Y = \frac{I_P}{2} = \frac{\pi d^4}{64}$$

d) *Xalqa:*

$$I_P = \int_A \rho^2 dF = 2\pi \int_{d_1/2}^{d/2} \rho^3 d\rho = \frac{2\pi d^4}{64} - \frac{2\pi d_1^4}{64} = \frac{\pi d^4}{32}\left(1 - \frac{d_1^4}{d^4}\right) = \frac{\pi d^4}{32}\left(1 - \alpha^4\right)$$

$$I_X = I_Y = \frac{I_P}{2} = \frac{\pi d^4}{64}\left(1 - \alpha^4\right)$$

a) To'gri to'rtburchak:

$$W_x = \frac{I_x}{Y_{max}} = \frac{\frac{bh^3}{12}}{\frac{h}{2}} = \frac{bh^2}{6}; \quad W_x = \frac{bh^2}{6}(sm^3)$$

$$W_y = \frac{hb^2}{6}(sm^3)$$

b) Kvadratda:

$$W_x = W_y = \frac{a^3}{6}\left(sm^3\right)$$

v) Doira:

$$W_x = W_y = \frac{\pi d^3}{32}\left(sm^3\right) \qquad W_p = \frac{\pi d^3}{16}\left(sm^3\right)$$

g) Xalqa:

$$W_x = W_y = \frac{\pi D^3}{32}(1-\alpha)\left(sm^3\right) \qquad W_p = \frac{\pi D^3}{16}\left(1-\alpha^4\right)\left(sm^3\right)$$

Parallel o‘qlarga nisbatan inersiya momentlari o’rtasidagi bog’lanish

$$x_1 = x + b, y_1 = y + a \qquad I_X = \int_F Y^2 dF; \quad S_X = \int_F Y dF = 0; \quad F = \int_F dF$$

$$I_{x_1} = \int_F y_1^2 \cdot dF, \quad I_{y_1} = \int_F x_1^2 \cdot dF, \quad I_{x_1 y_1} = \int_F x_1 \cdot y_1 \cdot dF$$

$$I_{x_1} = \int_F Y_1 dF = \int_F (y + a)^2 dF = \int_F y^2 dF + 2a \int_F y dF + a^2 \int_F dF = I_x + 2aS_x + a^2 \cdot F$$

$$\int_F y dF = S_x, \int_F x dF = S_y, \int_F dF = F \quad \text{bulganligi uchun}$$

$$I_{x_1} = I_x + a^2 \cdot F, \quad I_{y_1} = I_y + b^2 \cdot F,$$

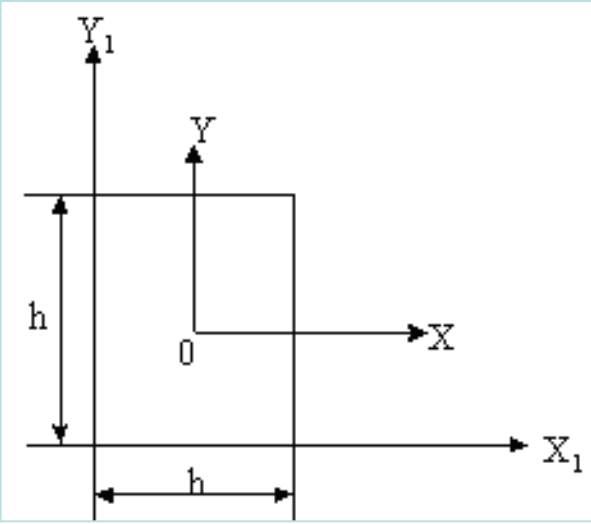
$$I_{x_1 y_1} = I_{xy} + a \cdot b \cdot F, \quad I_{\rho_1} = I_\rho + \left(a^2 + b^2\right) \cdot F$$

Misol:

Berilgan: h=4 sm

b=2 sm, F=bh=8 sm^2

$$I_x = \frac{bh^3}{12} = \frac{2 \cdot 4^3}{12} = \frac{96}{12} = 8\ (sm^4)$$



$$I_y = \frac{b^3 h}{12} = \frac{2^3 \cdot 4}{12} = \frac{32}{12} = 2{,}667\ (sm^4)$$

$$I_{x_1} = I_x + \left(\frac{h}{2}\right)^2 \cdot F = \frac{bh^3}{12} + \left(\frac{h}{2}\right)^2 \cdot b \cdot h = \frac{2 \cdot 4^3}{12} + \left(\frac{4}{2}\right)^2 \cdot 2 \cdot 4 =$$

$$= 8 + 32 = 40\ (sm^4)$$

$$I_{y_1} = I_y + \left(\frac{b}{2}\right)^2 \cdot F = \frac{hb^3}{12} + \left(\frac{b}{2}\right)^2 b \cdot h = \frac{4 \cdot 2^3}{12} + \left(\frac{2}{2}\right)^2 \cdot 2 \cdot 4 = 2{,}667 + 8 = 10{,}667\ (sm^4)$$

Bosh inersiya o‘qlari va bosh inersiya momentlari

Bosh inersiya momentlari o’qlardan biriga nisbatan *max* bo’lsa, ikkinchisiga nisbatan *min* bo’ladi va qo’yidagicha topiladi:

$$I_{\substack{\max\\ \min}} = \frac{I_x + I_y}{2} \pm \frac{1}{2}\sqrt{\left(I_x - I_y\right)^2 + 4I_{xy}^2}$$

Bosh o’qlarning vaziyati quyidagi formula orqali topiladi:

$$tg2\alpha = \frac{2I_{xy}}{I_y - I_x}$$

Quyidagi kattaliklar tekis shaklning o‘qlarga nisbatan inersiya radiuslari deyiladi.

$$i_x = \sqrt{\frac{I_x}{F}}, \quad i_y = \sqrt{\frac{I_y}{F}}, \quad (sm)$$

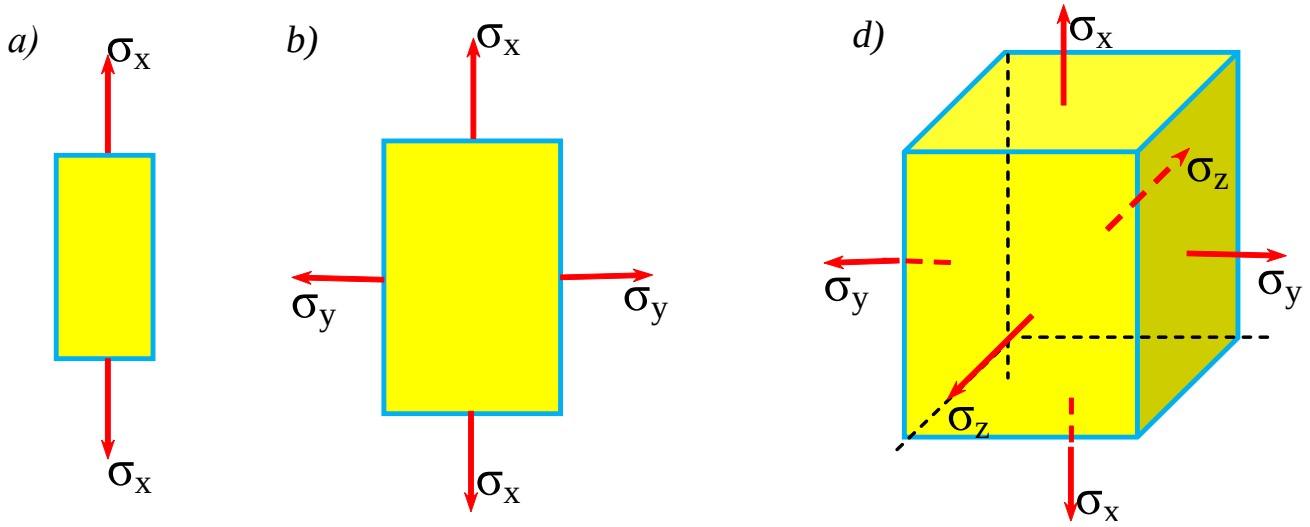
Nuqtadagi kuchlanish xolati to'g'risida tushuncha va uning turlari.

Nuqtaning kuchlanish xolati deb, shu nuqta orkali o'tkaziladigan barcha yuzalarda paydo bo'ladigan kuchlanishlar to'plamiga aytiladi. nuqtaning kuchlanish xolati uch turga bo'linadi, ya'ni:

a). Agar $\sigma_x \neq 0$; $\sigma_y = \sigma_z = 0$; bo'lsa bunday kuchlanganlik xolati ***chiziqli yoki bir o'qli*** kuchlanganlik xolati deyiladi

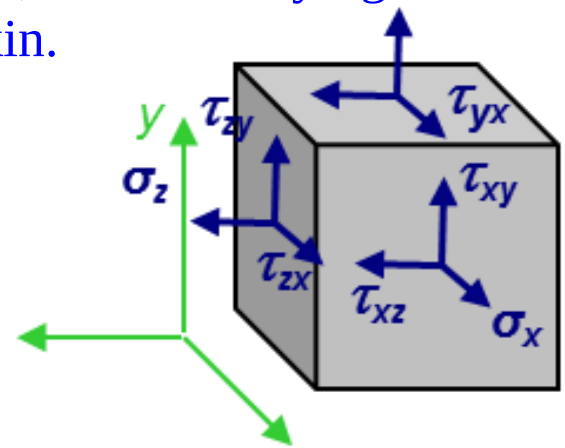
b). $\sigma_x \neq 0$; $\sigma_y \neq 0$; $\sigma_z = 0$; bo'lsa ***tekis yoki ikki o'qli*** kuchlanganlik xolati deb yuritiladi

d). Agar $\sigma_x \neq 0$; $\sigma_y \neq 0$; $\sigma_z \neq 0$. bo'lsa ***xajmiy yoki uch o'qli*** kuchlanganlik xolati deb yuritiladi



1 rasm

Sterjen kesimlarida hosil bo'ladigan kuchlanishlarning miqdori va turi kesimning tashqi yuklamaga nisbatan joylashishiga bog'liq bo'lib, nuqtadan o'tuvchi kesimlardagi barcha normal va urinma kuchlanishlar birgalikda nuqtaning kuchlanish holatini ifodalaydi. Kuchlanish holatini tekshirish uchun ko'rilayotgan nuqta atrofidan 6 ta kesim o'tkazib to'g'ri burchakli elementar parallelepiped ajratamiz (2 rasm). Parallelepipedning barcha qirralari *a* nuqtadan o'tgani uchun, uning o'lchamlari kichraytirilsa u shu nuqtaga intiladi. Bu holda kesishuvchi tekisliklardagi kuchlanishlarni, tekshirilayotgan nuqtaga ta'sir qilayotgan kuchlanishlar deb qarash mumkin.



2 rasm

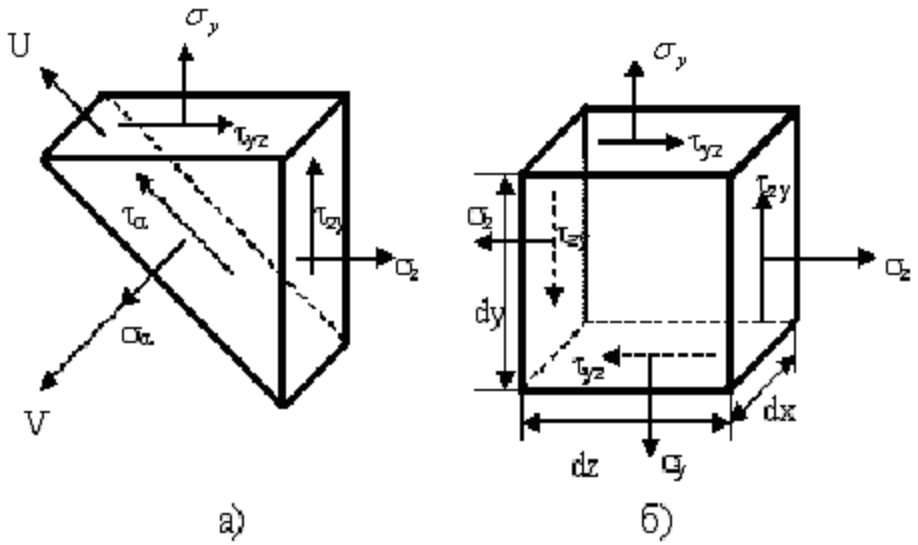
Kesishuvchi yuzachalarda hosil bo'layotgan to'la kuchlanishni 3 ta tashkil etuvchilarga ya'ni – bittasi yuzachaga normal **bo'lgan-normal kuchlanishga**, ikkitasini esa kesim tekisligida yotuvchi **urinma kuchlanishlarga** ajratish mumkin.

Normal kuchlanishlarni mos x, y, z o'qlari bo'yicha σ_x, σ_u, σ_z *h*arflari bilan belgilaymiz (2 rasm). Urinma kuchlanishlarni ikkita indeksli (τ) harfi bilan belgilaymiz.

Birinchi indeks yuzachaning qaysi o'qqa perpendikulyarligini ko'rsatsa, ikkinchisi τ vektor yo'nalishini ko'rsatadi. O'qlarning musbat yo'nalishini an'anaviy ravishda olamiz (2 rasm).

Cho'zuvchi σ kuchlanishlarni musbat, siquvchi σ kuchlanishlarni manfiy deb olamiz. Urinma τ kuchlanishlarning ishorasi biz ko'rayotgan masalalarda uncha ahamiyatga ega emas.

Cheksiz kichik elementning qirralarida (nuqtadan o'tuvchi o'zaro tik 3 ta tekisliklarda) hosil bo'ladigan kuchlanishlar 3a rasmda ko'rsatilgan. elementning ko'rinmayotgan qirralarida ham huddi shunday qarama-qarshi yo'nalgan kuchlanishlar hosil bo'ladi.



3 rasm

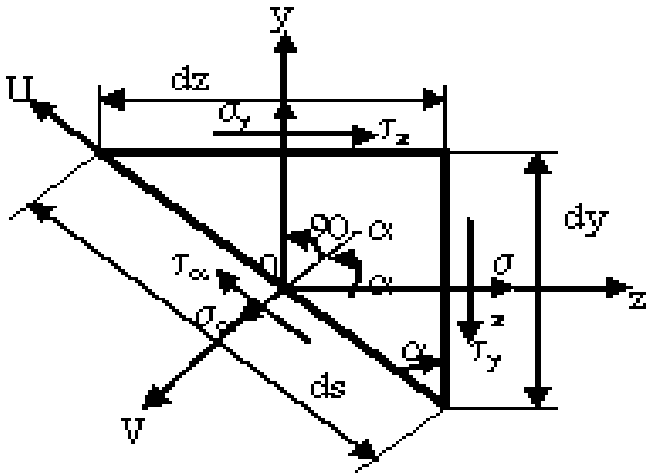
Agar ko'rilayotgan nuqta atrofidan shunday parallelepiped ajratish mumkin bo'lsaki, uning barcha qirralarida kuchlanishlar mavjud bo'lsa, bunday kuchlanish holati hajmiy yoki **fazoviy kuchlanish holati** deyiladi (3 rasm).

Agar ajratilgan parallelepipedning ikkita qarama-qarshi qirralari kuchlanishdan holi bo'lsa, bunday kuchlanish holati tekis (3 b rasm), to'rtta qarama-qarshi qirralari kuchlanishdan holi bo'lsa **chiziqli kuchlanish holati** deb ataladi.

Masalan: suvning gidrostatik bosimi ostidagi jismda fazoviy kuchlanish **holati** hosil bo'ladi. Materiallar qarshiligida hajmiy yoki fazoviy kuchlanish holati deyarli amalda ko'rilmaganligi uchun, tekis kuchlanish holatini tekshiramiz.

Chiziqli kuchlanish holat esa tekis kuchlanish holatining xususiy holidan kelib chiqadi. Tekis kuchlanish holatida kuchlanishlarni quyidagicha, faqat bitta indeks orqali ham belgilash mumkin, ya'ni deb.

Tekis kuchlanish holatida bo'lgan elementar prizmaning (3a, 4 rasmlar) muvozanatini ko'ramiz.



4 rasm

4 rasmda barcha kuchlanishlarning musbat yo'nalishlari ko'rsatilgan. prizmaning o'lchamlari kichik bo'lganligi uchun kuchlanishlar uning qirralari bo'ylab tekis taqsimlangan deb qaraymiz, ya'ni qirraga ta'sir etuvchi kuch kuchlanishning qirra yuzachasiga ko'paytmasiga teng.

Statikaning muvozanat tenglamalariga asosan prizmaga (4 rasm) ta'sir qilayotgan barcha kuchlardan *U* va *V* o'qlariga proektsiyalar olib, ularning yig'indisini nolga tenglaymiz:

$$\sum U = \tau_\alpha ds \cdot dx - \left(\sigma_z \cdot dy \cdot dx + \tau_z \cdot dz \cdot dx\right)\cos\alpha + \left(\sigma_y \cdot dz \cdot dx - \tau_y dy \cdot dx\right)\cos\left(90-\alpha\right) = 0$$

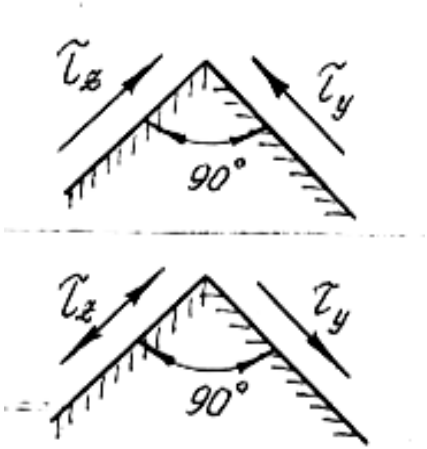
$$\sum V = \sigma_\alpha ds \cdot dx - \left(\sigma_z \cdot dy dx + \tau_z \cdot dz dx\right)\sin\alpha + \left(\sigma_y \cdot dz \cdot dx - \tau_y dy \cdot dx\right)\sin\left(90-\alpha\right) = 0$$

o nuqtaga nisbatan momentlar yig'indisini olib uni ham nolga tenglaymiz:

$$\sum M_0 = \tau_y dy \cdot dx \cdot \frac{dz}{2} + \tau_z \cdot dz \cdot dx \cdot \frac{dy}{2} = 0$$

bundan $\tau_y = -\tau_z$ kelib chiqib, bu tenglik urinma kuchlanishlarning juftlik qonuniyati deyiladi.

(4) tenglik o'zaro tik yuzachalarda hosil bo'luvchi urinma kuchlanishlar miqdor jihatidan teng, yo'nalish jihatidan qarama-qarshi ekanligini isbotlaydi (4 rasm).



(1) va (2) tengliklarni ixchamlasak quyidagi munosabatlar hosil bo'ladi:

$$\sigma_\alpha = \sigma_z \cos^2 \alpha + \sigma_y \sin^2 \alpha + \tau_z \sin 2\alpha$$

$$\tau_\alpha = \frac{\sigma_z - \sigma_y}{2} \sin 2\alpha - \tau_z \cos 2\alpha$$

Hosil bo'lgan (5) va (6) ifodalar, agar o'zaro tik ikkita yuzachada σ_x, σ_y, τ_z, qiymatlari ma'lum bo'lsa berilgan nuqtadan o'tuvchi ixtiyoriy yuzachada hosil bo'ladigan σ_α *va* τ_α kuchlanishlarni topish imkoniyatini beradi. Bu erdagi z, u o'qlarining yo'nalishlari ixtiyoriy bo'lishi mumkin.

Qiya yuzachaga tik bo'lgan, ya'ni $\alpha+90^0$ burchakka burilgan yuzachadagi normal kuchlanishni (5) formulaga asosan *topsak*

$$\sigma_\alpha+90=\sigma_z\cos^2(\alpha+90^0)+\sigma_y\sin^2(\alpha+900)+\tau_z\sin^2(\alpha+90^0)$$ bo'ladi.

yuqoridagi (2) bilan (7)ni qo'shib quyidagini hosil qilamiz:

ya'ni $$\sigma_\alpha+\sigma_{\alpha+90}=(\sigma_x+\sigma_y)\ (sin^2\alpha+cos^2\alpha)$$

$$\sigma_\alpha+\sigma$$

$$_{\alpha+90}=\sigma_x+\sigma_y=cont.$$

natijada tekshirilayotgan nuqtadan o'tuvchi tik yuzachalardagi normal kuchlanishlarning yig'indisi o'zgarmas miqdor ekanligi isbotlandi. Berilgan α *burchakning o'zgarishi bilan har bir qiya yuzachadagi normal kuchlanishning qiymati ham o'zgaradi. Demak, shunday o'zaro tik yuzachalar mavjud bo'lishi kerakki, ularning birida normal kuchlanish eng katta, ikkinchisida esa eng kichik qiymatga ega bo'ladi.*

Bu yuzachalar bosh yuzachalar deyilib, unda hosil bo'lgan kuchlanishlar esa **bosh kuchlanishlar** deb ataladi (shunday natija tekis kesimlarning inertsiya momentlarida ham olingan edi).

Bosh yuzalar va bosh kuchlanishlar. muhandislik konstruktsiyalarini hisoblaganda nuqta orqali o'tgan barcha yuzalarda hosil bo'ladigan kuchlanishlarni bilish shart emas, faqat kuchlanishlarning eng katta va kichik qiymatlarini aniqlash etarli. Shuning uchun bosh kuchlanishlarni va bu kuchlanishlar hosil bo'layotgan bosh yuzalarni aniqlash asosiy masalalardan biri bo'ladi. Tekshirilayotgan nuqtadan o'tuvchi bosh yuzachalar σ_z, σ_y kuchlanishga ega bo'lgan yuzachalarga nisbatan α burchakka burilgan bo'lsin. Ixtiyoriy qiya yuzada hosil bo'ladigan kuchlanish σ_α ni α burchak funktsiyasi ((5.5)ga asosan) deb qarab, α bo'yicha birinchi tartibli hosila

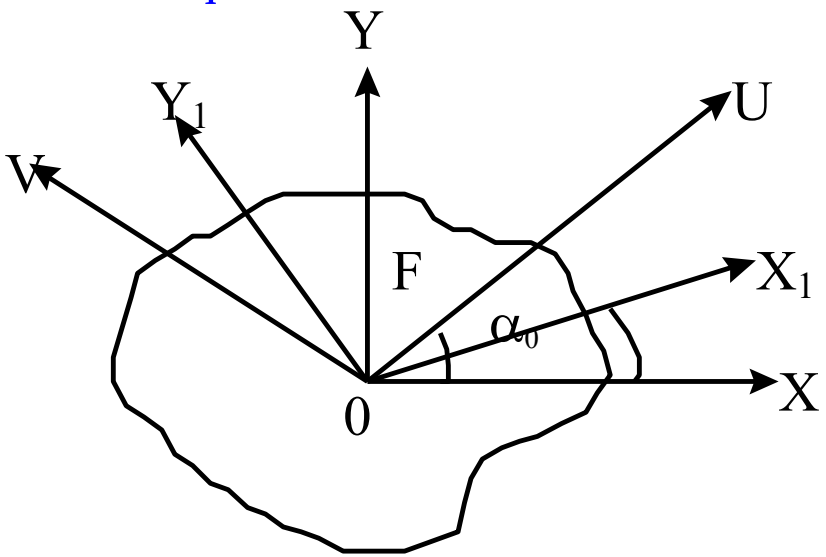
$\frac{d\sigma_\alpha}{d\alpha}$ olamiz va uni nolga tenglaymiz:

$$\frac{d\sigma_\alpha}{d\alpha} = -\sigma_z 2\sin\alpha\cos + \sigma_y 2\sin\alpha\cos\alpha + \tau_z 2\cos 2\alpha = -(\sigma_z - \sigma_y)\sin 2\alpha + 2\tau_z \cos 2\alpha = 0$$

$$\mathrm{tg}2\alpha_0 = \frac{2\tau_z}{\sigma_z - \sigma_y}$$

Bosh inersiya o‘qlari va bosh inersiya momentlari

Bosh inersiya o’qlari va bosh inersiya momentlar formulalardan kurinib turibdiki tekis shaklning I_{X1}, I_{Y1}, I_{X1Y1} inersiya momentlarining qiymatlari α burchakka bog’lik bulib, uning o’qlarga nisbatan olingan inersiya momentlarning yigindisi har doim o’zgarmas miqdor bo’lar ekan.



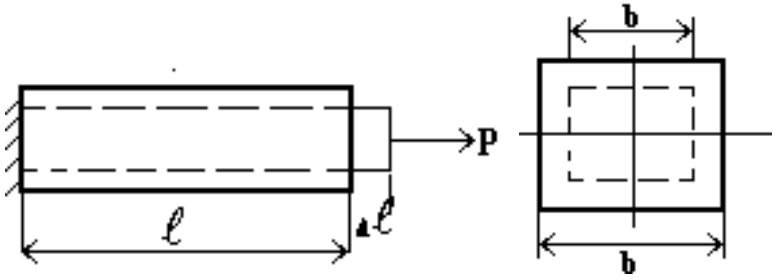
$$I_{x_1} = I_x \cdot \cos^2\alpha + I_y \cdot \sin^2\alpha - I_{xy}\sin 2\alpha$$

$$I_{y_1} = I_y \cdot \cos^2\alpha + I_x \cdot \sin^2\alpha + I_{xy}\sin 2\alpha$$

$$I_{x_1y_1} = \frac{I_x - I_y}{2}\sin 2\alpha + I_{xy} \cdot \cos 2\alpha$$

Umumlashtirilgan GUK qonuni.

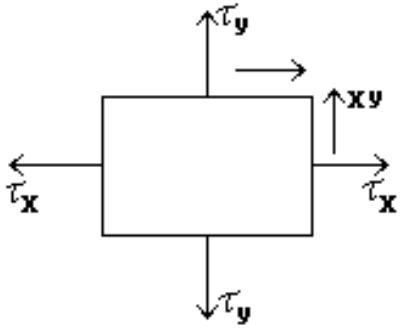
*Chiziqli kuchlanish holatida Guk qonuni:



$$\varepsilon = \frac{\Delta \ell}{\ell} \qquad \varepsilon' = -\frac{\Delta b}{b}, \qquad \Delta b = b - b_1$$

$$\varepsilon = \frac{\sigma}{E}, \qquad \varepsilon'' = -\mu \frac{\sigma}{E} \qquad \left|\frac{\varepsilon'}{\varepsilon}\right| = \mu$$

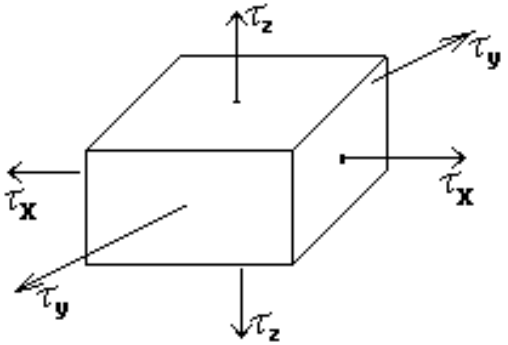
*Tekis kuchlanish holatida Guk qonuni:



$$\varepsilon_X = \frac{1}{E}\left(\sigma_X - \partial \sigma_y\right) \qquad \gamma_{Xy} = \frac{1}{G}\tau_{Xy} \qquad G = \frac{E}{\eta(1+\partial)}$$

$$\varepsilon_y = \frac{1}{E}\left(\sigma_y - \partial \sigma_X\right)$$

*Hajmiy kuchlanish holati:



$$\varepsilon_X = \frac{1}{E}\left[\sigma_X - \partial\left(\sigma_y + \sigma_Z\right)\right]$$

$$\varepsilon_y = \frac{1}{E}\left[\sigma_y - \partial\left(\sigma_X + \sigma_Z\right)\right] \qquad \gamma_{Xy} = \frac{1}{G}\tau_{Xy}$$

$$\varepsilon_Z = \frac{1}{E}\left[\sigma_Z - \partial\left(\sigma_X + \sigma_y\right)\right]$$

Bizdan inersiya moment I_{X1}, I_{Y1} larni ekstremal kiymatlariga keladigan α burchakni kiymatini topish talab kilinsin.

Bu masalani xal kilish uchun *a* ni funksiyasi deb I_{Y1} dan α buyicha xosil olib uni nolga tenglaymiz.

$$\frac{dI_{y_1}}{d\alpha} = -I_y 2\cos\alpha\sin\alpha + 2I_x \sin\alpha\cos\alpha + 2I_{xy}\cos\alpha = 0$$

$$\left(I_x - I_y\right)\sin 2\alpha = -2I_{xy}\cos 2\alpha \cdot x \quad \frac{-2I_{xy}}{I_x - I_y} = \frac{\sin 2\alpha}{\cos 2\alpha} = tg2\alpha$$

Bu formuladan kurinib turibdiki $\alpha = \alpha_0$ burchakka burilgan koordinata uklariga nisbatan olingan tekis shaklning bitta inersiya momenti max va ikkinchisi esa min kiymatga ega bular ekan. Bunday uklar bosh uklar deb, bu uklarga nisbatan olingan inersiya momentlar bosh inersiya momentlar deb ataladi.

Bundan ko‘rinadiki, bosh o‘qlarga nisbatan markazdan qochma inersiya moment nolga teng bo‘lib, aksincha markazdan qochirma inersiya moment nolga teng bo‘lgan o‘qlar bosh inersiya o‘qlari bo‘lar ekan.

Demak, ixtiyoriy ikkita o‘zaro tik o‘qlardan biri kesimning simmetriya o‘qi bo‘lsa, u o‘q bosh o‘qlardan biri bo‘lib, kesimning og‘irlik markazi orqali o‘tuvchi simmetriya o‘qi esa bosh markaziy o‘q bo‘ladi.

Bosh o‘qlar kupincha u va v deb belgilanadi. Shunday qilib bosh o‘qlarni yunalishi quyidagi formula yordamida aniqlanar ekan.

$$\operatorname{tg}2\alpha_0 = \frac{2I_{xy}}{I_y - I_x}$$

Bosh o‘qlarni qiymati esa quyida formula orqali topiladi:

$$I_{\substack{\max\\ \min}} = I_{\substack{u\\ v}} = \frac{I_x + I_y}{2} \pm \frac{1}{2}\sqrt{\left(I_x - I_y\right)^2 + 4I_{xy}^2}$$

Olingan natijalardan kurinadiki:

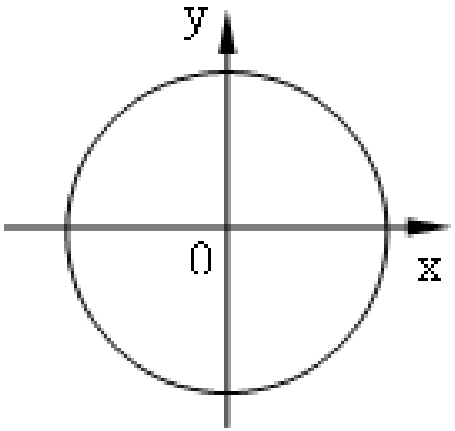
1. Bosh o‘qlarga nisbatan markazdan qochirma inersiya moment har doim nolga teng buladi *(Iuv=0)*

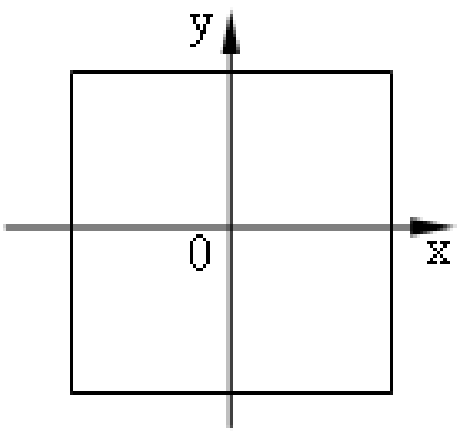
2.Bosh o‘qlarga nisbatan o‘qlarga nisbatan olingan inersiya momentlar ekstremalkiymatga ega, ya’ni $I_{\substack{\max\\ \min}}$ ga teng.

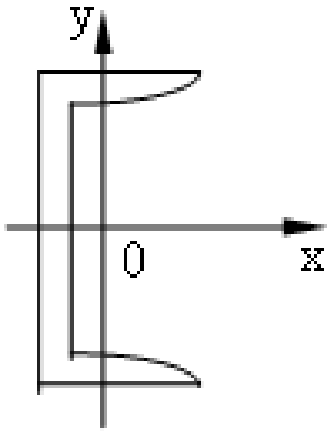
3. Bosh o‘qlar tekis shaklning ogirlik markazidan utsa bunday o‘qlar markaziy bosh o‘qlar deyiladi.

4. Shakl biror simmetriya o‘qiga ega bulsa u holda bu simmetriya o‘qi markaziy bosh o‘qlardan biri buladi.

Tekis shaklning har qanday simmetrik o‘qi uning bosh o‘qlaridan biri bo‘ladi.







Agarda simmetrik o‘q bitta bo‘lsa, unga perpendkulyar turgan ikkinchi o‘q ham bosh o‘q hisoblanadi.

Nazorat savollari va topshiriqlar:

1. Jismning biror nuqtasining kuchlanganlik holati deb nimaga aytiladi?
2. Murakkab kuchlanishning qanday turlarini bilasiz?
3. Normal va urinma kuchlanishlar ishoralari qanday qabul qilinadi?
4. Chiziqli cho‘zilishda qiya yuzalardagi kuchlanishlarning turli burchak ostidagi yuzalarda kuchlanishlar qanday miqdorlarni qabul qilishini ko‘rsatib bering?
5. O‘zaro perpendikulyar bo‘lgan yuzalarda normal kuchlanishlar yig‘indisi nimaga teng ekanligini ko‘rsating?
6. Urinma kuchlanishlarning juftlik qonunini izohlab bering?
7. Mustahkamlikning birinchi va ikkinchi nazariyalarini izohlab buring?
8. Mustahkamlikning uchinchi va energetik nazariyalarini izohlab buring?

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