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# DOIRAVIY SILINDRIK QOBIQNING XUSUSIY BURALMA TEBRANISHLARI

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**Annotatsiya**. Maqolada tashqi qatlamlari materiali qovushoq-elastik o‘rta qatlami materiali elastik bo‘lgan uch qatlamli doiraviy silindrik qobiqning erkin buralma tebranishlari chqastotaviy tahlili bayon etilgan. Bunda qobiqning o‘rta qatlami qalinligi va qalinliklari bir xil tashqi qatlamlarnikiga nisbatan hech bo‘lmaganda bir tartibga kichik deb hisoblanadi. Qobiqning nostatsionar buralma tebranishlari tenglamalari sifatida, avtorlar tomonidan, ularning bundan oldingi ishlarida keltirib chiqarilgan, tebranish tenglamalari qabul qilingan. Qobiqning erkin tebranishlarini tadqiq qilish uchun qabul qilingan tenglamalar tarkibidagi qobiq tashqi sirtlarida ta’sir etuvchi dinamik kuchlar nolga tenglashtirilgan holda chastota tenglamalari olingan, va ular amaliy matematik dasturlar paketi yordamida yechilgan. Turli holatlarda doiraviy tebranishlar chastotasi va to‘lqin soni orasidagi bog‘lanishlarning sonli natijalari olingan va grafiklari qurilgan. Grafiklar chetki va o‘rta qatlam materiallari va qalinliklari turlicha bo‘ lgan hollar uchun tahlil qilingan.

**Kalit so‘zlar:** Qobiq, chastota, qovushoq elastik,to‘lqin soni, kuchlanish, deformatsiya.

**Аннотация.** В статье изложен частотный анализ свободных крутильных колебаний трехслойной круговой цилиндрической оболочки, у которой наружные слои выполнены из вязко-упругого материала, а средний слой — из упругого материала. Предполагается, что толщина среднего слоя по сравнению с толщинами наружных слоев как минимум на порядок меньше. В качестве уравнений нестационарных крутильных колебаний оболочки приняты уравнения, полученные авторами в их предыдущих работах. Для исследования свободных колебаний оболочки из принятых уравнений, приравнивая к нулю динамические силы, действующие на внешних поверхностях оболочки, получены частотные уравнения, которые были решены с использованием пакета прикладных математических программ. Получены численные результаты зависимости частоты круговых колебаний от волнового числа в различных случаях и построены соответствующие



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графики. Графики проанализированы для случаев с различными материалами и толщинами наружных и среднего слоев.

**Ключевые слова**: оболочка, частота, вязко-упругость, волновое число, напряжение, деформация.

**Abstract.** The paper presents a frequency analysis of free torsional vibrations of a three-layer circular cylindrical shell, where the outer layers are made of viscoelastic material and the middle layer is elastic. It is assumed that the thickness of the middle layer is at least one order of magnitude smaller than the thicknesses of the outer layers. The equations of non-stationary torsional vibrations of the shell, previously derived by the authors in their earlier works, are used as the governing equations. To study free vibrations, the dynamic forces acting on the outer surfaces of the shell are set to zero, leading to the derivation of frequency equations. These equations are solved using applied mathematical software packages. Numerical results describing the relationship between the frequency of circular vibrations and the wave number are obtained for various cases, and corresponding graphs are constructed. The graphs are analyzed for different materials and thicknesses of the outer and middle layers.

**Keywords:** shell, frequency, viscoelasticity, wave number, stress, deformation.

## 1. KIRISH.

Elastik va qovushoq elastik muhitlarda to‘lqin tarqalish masalasini o‘rganish mexanikaning asosiy masalalardan biridir. Konstruktsiyalar tarkibidagi elastik va qovushoq elastiklik sutrukturalarda hosil bo‘ladigan kuchlanishlar va deformatsiyalarni ruxsat etilgan chegaragacha kamaytirishga xizmat qiladi. Shuning uchun konstruktsiyalarning turli xil elementlarining xususiyatlarini o‘rganish va yangi natijalar olish dolzarb muammo bo‘lib kelgan.Konstruksiyalarning qovushoq elastik xususiyatlarini hisobga olib dinamik masalalar yechishga ko‘proq e’tibor berilmoqda.

Qatlamli sutrukturalardan texnikaning turli sohalarida konstruktiv elementlar sifatida foydalanish ayniqsa sanoat, aviatsiya, kemasozlik va qurilishda keng rivojlangan. Jahonda muhandislik ob'yektlarining asosiy yuk ko‘taruvchi elementlari bo‘lgan qatlamli kompozit konstruksiyalarning materiallari sarfini kamaytirish masalalariga katta ahamiyat berilmoqda. Shu sababdan qovushoq elastik jismlar yangi materiallar sifatida keng qo‘llanilmoqda. Chiziqli nazariyaning uch o‘lchovli masalasini o‘rganishda aniq yechimlarga asoslangan doiraviy silindrik uch qatlamli qovushoq elastik jism uchun bo‘ylama -radial tebranishlarining matematik modeli [1] ishda taklif etilgan. Silindrik qobiqning ixtiyoriy kesimlarida kuchlanganlik-deformatsiyalanganlik holatini aniqlash imkonini beruvchi tenglamalar olingan. Silindrik qobiqlar bo‘ylama-radial tebranishlari chegaraviy masalalarining qat’iy formulirovkalari [2] ishda



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keltirilgan. Qovushoq suyuqlik bilan to‘ldirilgan doiraviy silindrik elastik qobiqning bo‘ylama tebranishlari [3] ishda o‘rganilgan. Bunda qobiq tashqi yuklardan xoli deb qaralgan. Bundan tashqari sof bo‘ylama tebranishlarni hisobga olgan holda qobiq nuqtalarning radial ko‘chishlari nolga teng deb qaralgan. Jismning buralma tebranishlari uchun fizik nochiziqli tenglamalari [4] ishda keltirib chiqarilgan. Bunda jismda ixtiyoriy kesimi nuqtalarining kuchlangan-deformatsiyalangan holatini aniqlash imkonini beradigan algoritm ishlab chiqilgan. Kesik konussumon sterjenning buralma tebranish tenglamalari va kuchlangan-deformatsiyalangan holati fizik nochiziqli munosabatni hisobga olgan holda, [5] ishda qaralgan. Uch qatlamli plastinkaning simmetrik va antisimmetrik tebranishlarini [6,7] maqolalarda o‘rganilgan. Bu ishda chiziqli elastiklik nazariyasi tenglamalarining aniq yechimlari asosida uch qatlamli plastinkaning ko‘ndalang tebranishlari nazariyasi ishlab chiqilgan. Uch qatlamli elastik plastinkaning garmonik antisimmetrik tebranishlari muammosi hal qilingan. Qovushoq suyuqlik bilan to‘ldirilgan elastik qobiqning bo‘ylama-radial tebranshlari [8] maqolada qaralgan.Qovushoq elastik materialdan yasalgan doiraviy silindrik uch qatlamli qobiq [9] ishda o‘rganilgan.Bu ishda qatlamlar o‘rtasidagi bikr kontakt shartlari mavjud bo‘lib, muommoning dinamik va kinematik kontakt shartlari shakllantirilgan. Doiraviy silindrik uch qatlamli qobiqning buralma tebranish tenglamalarini hisoblash algoritmi yaratilgan.

Qobiq nazariyasi asosida katta diametrli qovushoq elastik yupqa devorli quvurlarning chiziqli bo‘lmagan tebranishlari masalasini hal qilish uchun [10] ishda matematik model, raqamli algoritm va kompyuter dasturi yaratilgan. Uch qatlamli silindrik qobiqning kuchlanganlik-deformatsiyalanganlik holati, uning strukturaviy xususiyati, polimer to‘ldiruvchi moddasining fizik-mexanik xarakteristikalari bo‘yicha baholash natijalari [11-13] ishlarda keltirilgan. Uch qatlamli silindrik qobiqning tashqi qatlamlari yuqori mexanik xususiyatga ega bo‘lgan materiallar (po‘lat, yengil metal qotishmalari, yog‘och, plastmassa) dan yasalgan. Yuk ko‘taruvchi qatlamlar o‘rtasiga zichligi kichik materiallar, masalan kauchuk materiallar olingan. Qovushoq siqilgan suyuqlik gidrodinamikasining chiziqli tenglamalari modeli doirasida qovushoq suyuqlik bilan elastik qobiqning to‘lqin tarqalishi [14] ishda qaralgan. Ushbu maqola silindrik qobiq (elastik yoki qovushoq elastik) va suyuqlik (ideal yoki qovushoq) sistemalari o‘rtasidagi farqlar ko‘rib chiqilgan.

Qobiqlarning tebranishi mexanika va strukturaviy dinamikada keng o‘rganilgan sohalardan biridir. Silindrik qobiqlarning tebranishi ko‘plab tadqiqotchilar tomonidan keng o‘rganilgan. Shu jumladan ikkita funktsional gradiyentlangan qatlamlardan tashkil topgan. Ikki va uch qatlamli silindrik



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qobiqlarning tebranish chastotalari tahlili [15-17] ishlarda qaralgan. Adabiyotlarning tahlil qilishda Bir, ikki va uch qatlamli silindrik qobiq tenglamalari ko‘rilgan lekin qatlamning ixtiyoriy nuqtasi uchun chastota masalasi qaralmagan.

## 2. METOD.

Quyida silindrik qobiqning elastik va qovushoq elastik buralma tebranishlari tenglamalari, [18] ishda keltirib chiqarilgan uch qatlamli silindrik qobiq tenglamalarining xususiy holi sifatida qaralgan.

$$\begin{aligned}&\frac{r_1^2}{4}\lambda_0 v_0^{(0)}+\xi\left(\frac{1}{2}(\lambda_0-\frac{4}{r_1^2})+\frac{r_1^2}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\lambda_0^2\right)v_0^{(1)}=0\\&\frac{r_2^2}{4}\lambda_0 v_0^{(0)}+\xi\left(\frac{1}{2}(\lambda_0-\frac{4}{r_2^2})+\frac{r_2^2}{8}(\ln\frac{r_2}{\xi}-\frac{1}{4})\lambda_0^2\right)v_0^{(1)}=0\end{aligned}\qquad(1)$$

Agar qobiq materiali qovushoq -elastik bo‘lsa, $\lambda_n^m$ -operatorlari

$$\lambda^n=\left[\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right]^n,\ b^2=\frac{\mu}{\rho},\ (n=1,2).\qquad(2)$$

ko‘rinishni oladi, bu yerda

$$M(\varsigma)=\varsigma(t)-\int_0^t f(t-\tau)\varsigma(\tau)d\tau,\qquad(3)$$

$f(\tau)$- qovushoq-elastiklik operatori yadrosi. Qobiq materiali elastic bo‘lgan holda

$$M(\varsigma)=\varsigma(t)\qquad(4)$$

(2) ifodani (1) tenglamalar sistemasiga qo‘ysak

$$\begin{aligned}&\frac{r_1^2}{4}\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)v_0^{(0)}+\xi\left(\frac{1}{2}\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}-\frac{4}{r_1^2}\right)+\right.\\&\left.+\frac{r_1^2}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)^2\right)v_0^{(1)}=0\\&\frac{r_2^2}{4}\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)v_0^{(0)}+\xi\left(\frac{1}{2}\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}-\frac{4}{r_2^2}\right)+\right.\\&\left.+\frac{r_2^2}{8}\left(\ln\frac{r_2}{\xi}-\frac{1}{4}\right)\left(\frac{1}{b^2}M^{-1}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)^2\right)v_0^{(1)}=0\end{aligned}\qquad(5)$$

Xususiy holda, elastic qobiq uchun (4) munosabat o‘rinli bo‘ladi va (5) tenglamalar sistemasi quyidagi ko‘rinishga keladi



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$$\frac{r_1^2}{4}\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)v_0^{(0)}+\xi\left(\frac{1}{2}\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}-\frac{4}{r_1^2}\right)+\right.$$

$$\left.+\frac{r_1^2}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)^2\right)v_0^{(1)}=0$$

$$\frac{r_2^2}{4}\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)v_0^{(0)}+\xi\left(\frac{1}{2}\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}-\frac{4}{r_2^2}\right)+\right.$$

$$\left.+\frac{r_2^2}{8}\left(\ln\frac{r_2}{\xi}-\frac{1}{4}\right)\left(\frac{1}{b^2}\left(\frac{\partial^2}{\partial t^2}\right)-\frac{\partial^2}{\partial z^2}\right)^2\right)v_0^{(1)}=0$$

(6)

Olingan (5) tenglamalar sistemasini o‘lchamsiz kattaliklarga o‘tamiz. Buning uchun quyidagicha almashtirishlar kiritamiz [19].

$$r_1=\xi\cdot r_1^*, r_2=\xi\cdot r_2^*, t=\frac{\xi}{b}\cdot t^*, z=\xi\cdot z^*, v_0^{*(0)}=v_0^{(0)}, v_0^{(1)}=\xi\cdot v_0^{*(1)}.$$

Bu yerda b-ko‘ndalang to‘lqin tarqalish tezligi. (5) tenglamaning ikkala tomonini $M^2$ ga bo‘lamiz.

$$\frac{r_1^{*2}}{4}M\left(\left(\frac{\partial^2}{\partial t^{*2}}\right)-M\frac{\partial^2}{\partial z^{*2}}\right)v_0^{*(0)}+\left(\frac{1}{2}\left(M\left(\frac{\partial^2}{\partial t^{*2}}\right)-M^2\frac{\partial^2}{\partial z^{*2}}-M^2\frac{4}{r_1^{*2}}\right)+\right.$$

$$\left.+\frac{r_1^{*2}}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\left(\left(\frac{\partial^2}{\partial t^{*2}}\right)-M\frac{\partial^2}{\partial z^{*2}}\right)^2\right)v_0^{*(1)}=0$$

$$\frac{r_2^{*2}}{4}M\left(\left(\frac{\partial^2}{\partial t^{*2}}\right)-M\frac{\partial^2}{\partial z^{*2}}\right)v_0^{*(0)}+\left(\frac{1}{2}\left(\left(M\frac{\partial^2}{\partial t^{*2}}\right)-M^2\frac{\partial^2}{\partial z^{*2}}-M^2\frac{4}{r_2^{*2}}\right)+\right.$$

$$\left.+\frac{r_2^{*2}}{8}\left(\ln\frac{r_2}{\xi}-\frac{1}{4}\right)\left(\left(\frac{\partial^2}{\partial t^{*2}}\right)-M\frac{\partial^2}{\partial z^{*2}}\right)^2\right)v_0^{*(1)}=0$$

(7)

(7) tenglamalar sistemasi qulayroq bo‘lishi uchun (*) belgisini tashlab yuboramiz va hosil bo‘lgan tenglamalar sistemasining umumiy yechimini

$$v_0^{(0)}=C_1\exp(i(\omega t+kz)) \quad \text{va} \quad v_0^{(1)}=C_2\exp(i(\omega t+kz)). \qquad (9)$$

Ko‘rinishida izlaymiz. Bu yerda $k$ - to‘lqin soni, $\omega$ - tebranishlarning doiraviy chastotasi. (7) tenglamalar sistemasiga (9) ifodalarni qo‘ysak doiraviy silindrik qovushoq elastik silindrik qobiqning garmonik to‘lqin tarqalishida chastota tenglamasiga ega bo‘lamiz.



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$$\frac{r_1^2}{4}(1-N(\omega))\left(-\omega^2+(1-N(\omega))k^2\right)C_1+\left(\frac{1}{2}(1-N(\omega))\left(-\omega^2+\right.\right.$$
$$\left.\left.+(1-N(\omega))k^2-(1-N(\omega))\frac{4}{r_1^2}\right)+\frac{r_1^2}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\left(-\omega^2+(1-N(\omega))k^2\right)^2\right)C_2=0$$
$$\frac{r_1^2}{4}(1-N(\omega))\left(-\omega^2+(1-N(\omega))k^2\right)C_1+\left(\frac{1}{2}(1-N(\omega))\left(-\omega^2+\right.\right.$$
$$\left.\left.+(1-N(\omega))k^2-(1-N(\omega))\frac{4}{r_2^2}\right)+\frac{r_2^2}{8}(\ln\frac{r_2}{\xi}-\frac{1}{4})\left(-\omega^2+(1-N(\omega))k^2\right)^2\right)C_2=0 \quad (10)$$

bu yerda

$$N(\omega)=\int_0^\infty f(\varsigma)e^{-i\omega\varsigma}d\xi \quad (11)$$

Sonli hisoblashlar uchun qovushoq-elastiklik regular yadrosini qabul qilamiz

$$f(t)=\sum_{n=1}^{\infty}\frac{\alpha_n}{\tau_n}e^{-\frac{t}{\tau_n}},\sum_{n=1}^{\infty}\alpha_n=1,$$

Bunda $\alpha_n$–qatlamning qovushoq-elastik parametrlari;$\tau_n$ –relaksatsiya vaqtlari. U holda (11) formula quyidagi ko‘rinishni oladi

$$N(\omega)=\sum_{n=1}^{\infty}\frac{\alpha_n(1-i\omega\tau_n)}{1+\omega^2\tau_n^2},$$

(10) tenglamalardan $v_0^{(0)}$ *va* $v_0^{(1)}$ larga nisbatan ikkita algebraik bir jinsli tenglamalarga kelamiz. U holda (12) tenglamalar sistemasini hosil qilamiz.

$$\begin{cases}A_{11}C_1+A_{12}C_2=0\\A_{21}C_1+A_{22}C_2=0\end{cases} \quad (12)$$

Bu yerda

$$A_{11}=\frac{r_1^2}{4}\left(-(1-N(\omega))\omega^2+k^2\right),A_{21}=\frac{r_2^2}{4}\left(-(1-N(\omega))\omega^2+k^2\right),$$
$$A_{12}=\frac{1}{2}\left(-(1-N(\omega))\omega^2+k^2-\frac{4}{r_1^2}\right)+\frac{r_1^2}{8}(\ln\frac{r_1}{\xi}-\frac{1}{4})\left(-(1-N(\omega))\omega^2+k^2\right)^2$$
$$A_{22}=\frac{1}{2}\left(-(1-N(\omega))\omega^2+k^2-\frac{4}{r_2^2}\right)+\frac{r_2^2}{8}(\ln\frac{r_2}{\xi}-\frac{1}{4})\left(-(1-N(\omega))\omega^2+k^2\right)^2$$

Olingan (12) tenglamalar sistema noldan farqli yechimga ega bo‘lishi uchun bu sistemaning asosiy determinanti nolga teng bo‘lishi zarur va yetarli. Quyidagi chastota tenglamasiga ega bo‘lamiz.

$$A_{11}\cdot A_{22}-A_{12}\cdot A_{21}=0 \quad (13)$$

## 3. NATIJALAR.



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Ushbu (13) tenglamalar sistemasini «Maple 17» amaliy programmalar paketi yordamida sonli yechamiz va olingan natijalarni Exel programmasi yordamida grafiklarini olamiz.

Bir qatlamli doiraviy silindrik sutrukturaning giometrik harakteristikari quyidagicha

$$r_1 = 0.2\ ,\ r_2 = r_1 + h.\ h = r_2 - r_1.$$

Bu yerda $r_1, r_2$-qatlamning ichki va tashqi radiuslari, $h$-qatlam qalinligi. Bir qatlamli elastik jism materiali sifatida alyuminiy( $p_0 = 2700\ kg/m^3, E_0 = 7 \cdot 10^{10}\ kg/m^2, \nu_0 = 0.34$) olingan. Bir qatlamli qovushoq elastik jism materiali sifatida esa polipropilen( $E = 5{,}5 \cdot 10^{11}\ Pa; \rho = 920 kg/m^3; \nu = 0.35 - 0{,}38.$) olingan. Qovushoq-elastik parametrlari va relaksatsiya vaqtlarining quyidagi qiymatlari olingan.

$$\alpha_1 = 0{,}6; \alpha_2 = 0{,}3; \alpha_3 = 0{,}1; \tau_1 = 0{,}16 \cdot 10^5\ мкс; \tau_2 = 0{,}14 \cdot 10^7\ мкс; \tau_3 = 0{,}11 \cdot 10^8\ мкс.$$

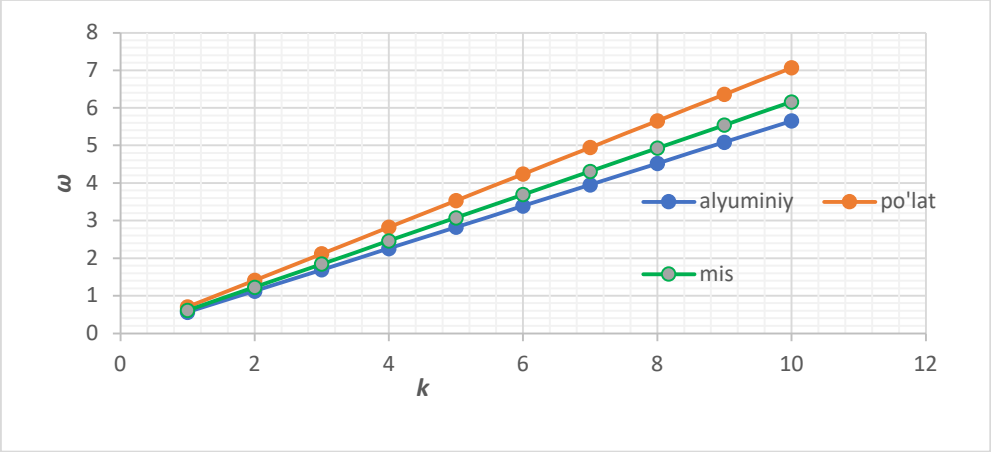
Doiraviy silindrik elastik va qovushoq elastik qobiq tebranishlarida chastotaning son qiymatlari quyidagi jadvallarda keltirilgan.

**1-jadval.**

| Doiraviy silindrik elastikk qobiq materiallari turlicha bo‘lganda chastota qiymatlari | | | | |
|---|---|---|---|---|
| k | | alyuminiy | po‘lat | mis |
| 1 | ReIM | 0.56568543020 | 0.64807407020 | 0.61644140010 |
| 2 | ReIM | 1.1313708470 | 1.2961481400 | 1.2328828000 |
| 3 | ReIM | 1.6970562870 | 1.944222210 | 1.8493242020 |
| 4 | ReIM | 2.2627417200 | 2.5922962780 | 2.4657655960 |
| 5 | ReIM | 2.8284268530 | 3.2403703550 | 3.0822069860 |
| 6 | ReIM | 3.3941118950 | 3.8884444640 | 3.6986484270 |
| 7 | ReIM | 3.9597993610 | 4.5365184500 | 4.3150900200 |
| 8 | ReIM | 4.5254781820 | 5.1845925660 | 4.9315337760 |
| 9 | ReIM | 5.0911765570 | 5.8326675990 | 5.5479636670 |
| 10 | ReIM | 5.6568586950 | 6.4807405560 | 6.1644191390 |



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**1-Rasm.Doiraviy silindrik elastik qobiqning materiali turlicha bo‘lganda chastota va to‘lqin soni orasidagi bog‘lanish**

**2-jadval**

| Qovushoq-elastik qobiq buralma tebranishlarida chastota qiymatlari (k-to‘lqin soni, $\omega$ -doiraviy chastota) | | | |
|---|---|---|---|
| k | | $\omega_1$ | $\omega_2$ |
| 1 | ReIM | 00.02464945949 | 06.221156716 |
| 2 | ReIM | 00.02453783074 | 06.134115576 |
| 3 | ReIM | 00.02451738717 | 05.987417861 |
| 4 | ReIM | 00.02451024858 | 05.778986461 |
| 5 | ReIM | 00.02450694734 | 05.507114125 |
| 6 | ReIM | 00.02450515485 | 05.173111365 |
| 7 | ReIM | 00.02450407431 | 04.787341952 |
| 8 | ReIM | 00.02450337309 | 04.378412610 |
| 9 | ReIM | 00.02450289238 | 03.993803081 |
| 10 | ReIM | 00.02450254857 | 03.675221172 |

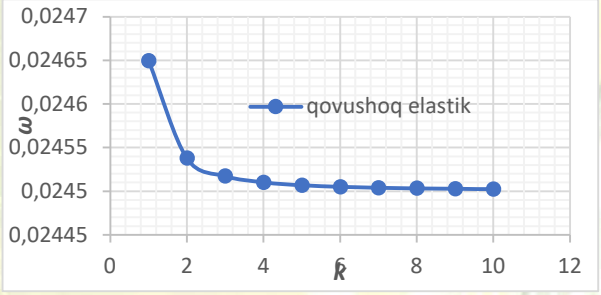
**3-jadval.**

| Doiraviy silindrik elastik va qovushoq-elastik qobiqning buralma tebranishlarida chastota qiymatlari | | | |
|---|---|---|---|
| k | | elastik | Qovushoq elastik |
| 1 | ReIM | 0.56568543020 | 06.221156716 |
| 2 | ReIM | 1.1313708470 | 06.134115576 |
| 3 | ReIM | 1.6970562870 | 05.987417861 |

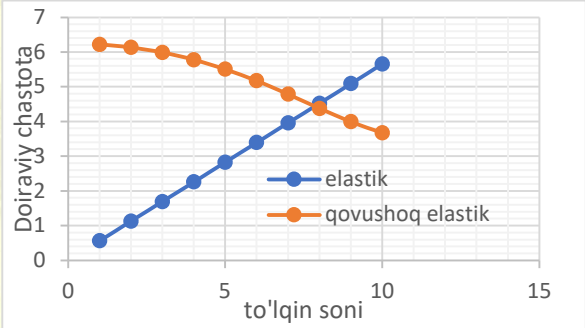


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| | | | |
|---|---|---|---|
| 4 | ReIM | 2.2627417200 | 05.778986461 |
| 5 | ReIM | 2.8284268530 | 05.507114125 |
| 6 | ReIM | 3.3941118950 | 05.173111365 |
| 7 | ReIM | 3.9597993610 | 04.787341952 |
| 8 | ReIM | 4.5254781820 | 04.378412610 |
| 9 | ReIM | 5.0911765570 | 03.993803081 |
| 10 | ReIM | 5.6568586950 | 03.675221172 |




**2-Rasm. Doiraviy silindrik qovushoq elastik qobiqda chastota va to‘lqin soni orasidagi bog‘lanish**




**3-Rasm.Doiraviy silindrik elastik va qovushoq elastik qobiqlarda chastota va to‘lqin soni orasidagi bog‘lanish**

## 4. NATIJALARNI TAHLIL QILISH.

Doiraviy silindrik elastik qobiqning buralma tebranishlarida elastik material turlicha bo‘lganda chastotaning qiymatlari to‘lqin sonining fiksirlangan qiymatlarida natijalar keltirilgan.1-jadvalda to‘lqin soni k=4 ga teng bo‘lganda qatlam materiali alyuminiyga qaraganda po‘lat va misda chastotaning oshishini ko‘rishimiz mumkin. Doiraviy silindrik qobiqning materiali qovushoq elastik jism bo‘lganda chastotaning qiymatlari 2-jadvalda keltirib o‘tilgan. 2-jadvaldan ko‘rinadiki to‘lqin soni oshib borishi bilan chastota kamayib boradi, elastik holatda 1-jadvalda esa to‘lqin soni ortib borgan sari chastota ortib borishini ko‘rishimiz mumkin. Doiraviy silindrik elastik va qovushoq elastik qobiqning (13) tenglamalar sistemasining yechimlari kompleks ildisdan iborat.3-jadvalda k=6 qiymatida doiraviy chastotaning qiymati elastik holatiga qaraganda chastotaning kamayishini ko‘rishimiz mumkin. 3-rasmga doiraviy silindrik qobiqning materiali qovushoq elastik va elastik bo‘lganda chastota va to‘lqin soni orasidagi bog‘lanish grafigi



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qurilgan va taqqoslangan. Qishloq xo‘jaligida quvur materiallarini ishlatishda elastik materiallar (po‘lat,mis,alyuminiy) ga qaraganda qovushoq elastik material polipropilen materiallaridan foydalanish qulayroq. Chunki quvurlarda tebranish kamroq bo‘ladi.

**5. XULOSA.**

Ushbu ishda doiraviy silindrik qobiqning chastota tenglamalari keltirib chiqarildi. Qatlam materiali elastik va qovushoq elastik bo‘lganda chastotaning sonli natijalar Maple 17 dasturi yordamida olindi va olingan natijalar asosida grafiklar qurildi. Natijalardan ko‘rinadiki qovushoq elastik jismda elastik jismga qaraganda chastota so‘nishini kuzatishimiz mumkin.

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