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RESEARCH, INNOVATION, RESULTS

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Optimization of the geometric parameters of the vibrating planetary mechanism

U.A. Ziyamukhamedova[1][a], **Sh.I. Mamaev**[1][b], **J.H. Nafasov**[1][c], **E.T. Turgunaliev**[1][d], **E.A. Rakhmatov**[2][e]

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Abstract: The subject of the research is optimizing the operation of the vibro-planetary mechanism. Based on the closure condition of contours, the article constructs projection equations of the links onto their corresponding coordinate axes. A functional relationship has been established between the kinematic parameters characterizing the movement of the mechanism's input and output links. The numerical calculations obtained are presented in the form of graphical relationships. The aim of the work is to optimize the geometric parameters of the vibro-planetary mechanism. The conclusions presented in the article can be applied in improving and designing modern technological equipment with mechanisms similar to the vibro-planetary mechanism.

Keywords: vibroplanetary mechanism, kinematic diagram, analytical study of the mechanism, mathematical model, condition of closed contours, metric synthesis of the mechanism, kinematic analysis of the mechanism, optimization, crank, slider, slider stone

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Vibroplanetar mexanizmning geometrik parametrlarini optimallashtirish

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Annotatsiya: Tadqiqot predmeti vibro-planetar mexanizmning ishlashini optimallashtirishdir. Maqolada konturlarning yopiqlik shartiga asoslanib, bo‘g‘inlarning tegishli koordinata o‘qlariga proyeksiya tenglamalari tuzilgan. Mexanizmning kirish va chiqish bo‘g‘inlari harakatini tavsiflovchi kinematik parametrlar o‘rtasidagi funksional bog‘liqlik aniqlangan. Olingan sonli hisob-kitoblar grafik bog‘lanishlar shaklida ifodalangan. Ishning maqsadi vibro-planetar mexanizmning geometrik parametrlarini optimallashtirishdan iborat. Maqolada keltirilgan xulosalardan vibro-planetar mexanizmga o‘xshash mexanizmli zamonaviy texnologik uskunalarni takomillashtirish va loyihalashda foydalanish mumkin.

Kalit so‘zlar: vibroplanetar mexanizm, kinematik sxema, mexanizmning analitik tadqiqi, matematik model, konturlarning yopiqlik sharti, mexanizmning metrik sintezi, mexanizmning kinematik tahlili, optimallashtirish, krivoship, kulisa, kulisa toshi

1. Kirish

Bugungi kunda mashmnasozlikda materialshunoslik sohasining rivojlanishida, zamonaviy materiallarni olishda qo‘llaniladigan mexanizmlarning o‘rni beqiyos. Materiilarlarni olish texnologiyalarini takomillashtirish bilan detallarning eksplutatsion ishonchliligini ta’minlash mumkin. Ayniqsa, polimer asosli kompozitsion materiallar to‘ldiruvchilarini kompozitsiya tarkibiga kiritishdan avval ularni faollashtirish, kompozitsiyaning strukturaviy tuzilishini yaxshilashligi ushbu sohada olib borilgan tadqiqodlardan ma’lum [1-4]. Ammo shuni ta’kidlash kerakki materiallar to‘ldiruvchilarini faollashtirishda mavjud usullarni [5-7] takomillashtirish bilan mavjud materiallardan mexanik jihatdan mustahkamroq materiallar olish imkoni mavjud. To‘ldiruvchilarni faollashtirishda taklif qilinayotgan vibro planetar faollashtirgich faollashtirish jarayonida bir vaqtning o‘zida ham aylanma, ham ilgarilanma qaytma harakatlanib faollashtirganligi hisobiga zarrachalarning sirt faolligini boshqa usullarga nisbatan yaxshiroq faollashtirishi aniqlangan [8].

To‘ldiruvchi zarrachalarni mexanik faollashtirish, kompozit materiallarda strukturalar shakllanishi va materialning fizik mexanik va ekspluatatsion xossalarining yaxshilanishi va strukturalar aro mustahkam bog‘lar hosil qilishda muhim rol o‘ynaydi. Tabiiy minerallar tarkibi

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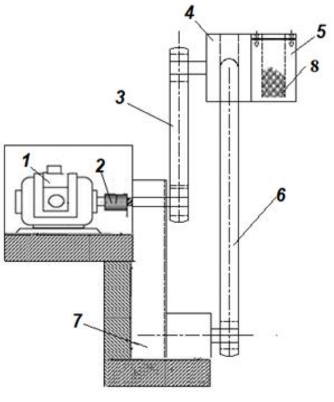
asosan ion bog‘li oksidlardan iborat bo‘lib, mexanik faollashtirish jarayonida musbat va manfiy zaryadlangan zarrachalar hosil bo‘lishida ta’sir etayotgan kuchlar va harakat traektoriyasi materialning xossalarini belgilab beruvchi asosiy omillardan hisoblanadi.

2. Tadqiqot metodologiyasi

Mexanokimyoviy hodisa ikkita asosiy komponentni o‘z ichiga oladi: mexanik energiyaning kimyoviy moddaga aylanishini belgilaydigan mexanokimyoviy va kimyoviy reaksiyalar jarayoni tufayli mexanik energiyani chiqaradigan mekanokimyoviy jarayon [9-10]. Bugungi kunda polimer kompozit materiallarning dispers to‘ldiruvchilarini mexanik faollashtirish jarayonida hosil bo‘ladigan manfiy va musbat zaryadlar strukturani shakillangishida qatlamlar orasida sodir bo‘layotgan fizik va kimyoviy jarayonlarda ishtirok etib materialning ekspluatatsion parametrlariga ta’sir ko‘rsatadi. Mexanik faollashtirilayotgan to‘ldiruvchi zarrachalarini bir vaqtning o‘zida ikki xil, turli yo‘nalishda ta’sir etuvchi kuchlar bilan faollashtirish, to‘ldiruvchi sifatining yaxshilanishiga sabab bo‘ladi.

Vibro-planetar mexanizmda(1-rasm) ilgarilanma qaytma harakatni, tayanchga mahkamlangan yo‘naltiruvchi richag(6) va tosh(4), aylanma harakatni esa elektrodvigvtel valiga mahkamlangan aylantiruvchi richag(3) ta’minlaydi. Mexanoaktivator(5) toshga ajraladigan birikma ko‘rinishida mahkamlangan. Mexanoaktivator ichiga solinngan maydalovchi sharlar(2), mexanoaktivator hajmining 0.8 qismini to‘ldirib turadi.

Stend ko‘rinishida yasalgan vibro planetar maydalanichimiz, aylanishlar chastotasini 750 ayl/minutdan 3000 ayl/minutgacha o‘zgartirish mumkin bo‘lgan elektrodvigatel(1) bilan jihozlangan. Bu esa aylanishlar chastotasining turli qiymatlarida natijalar olib, optimal chastotani tanlab olish imkonini beradi.



1- rasm. Vibro planetar faollashtirgichning umumiy ko‘rinishi:
1 - elektrodvigatel; 2 –mufta; 3- krivoship; 4- tosh;
5 - mexanoaktivator; 6 - yo‘naltiruvchi richag;
7 – maydalagich korpusi; 8 – maydalovchi sharlar

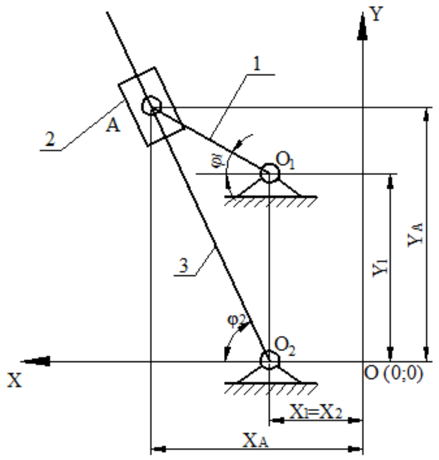
Vibro-planetar mexanizmning ishlash prinsipi kulisali mexanizm harakatiga asoslangan bo‘lib, mexanizdagi kulisa toshiga faollashtirish bunkeri - mexanoaktivator o‘rnatilagan. Mexanoaktivator ichidagi to‘ldiruvchilani faollashtiruvchi sharlarning to‘ldiruvchi zarrachalariga urilish kuchi natijasida zarrachalar faolligi ortib boradi. Demak mexanoaktivator ichidagi sharlarning zarrachalarga urilish kuchi qanchalik katta bo‘lsa faollashtirish vaqti kam, hamda zarrachalarning faollik darajasi shuncha yuqori bo‘ladi.

Mexanoaktivaor ichidagi sharlarning urilish kuchi, mexanizmning kulisa toshida hosil bo‘layotgan koriolis kuchiga bog‘liq bo‘lib, b kuch ortsa unga to‘g‘ri proporsional ravishda ortib boradi. Kulisa toshida hosil bo‘layotgan koriolis kuchining optimal qiymatini topish uchun vibro-planetar mexanizm krivoshipining uzunligini va burchak tezligini optimallashtirish talab etiladi..

3. Tahlil va natijalar

Vibroplanitar faollashtrgichning asosiy ish bajaruvchi mexanizmi sanalgan krivoship-kulisali mexanizmning zvenolar uzunligi tayanchlar orasidagi masofaning uzunligi o‘lchamlarini optimal qiymatinianiqlashda asosan mexanizm chiqish zvenosi burchak tezlanish qiymatlarining ratsional oralig‘i bo‘yicha aniqlash lozim bo‘ladi.

2-rasmda keltirilgan krivoship-kulisali mexanizmningkinimatik taxlil qilish uchun dekart kordinata tizimida joylashtiriladi. Kinimatik juftlarning obsissa va ordinata o‘qlari bo‘yicha kordinatalari o‘tkazilib, ularning proeksichlari bo‘yicha tosh va kulisa hosil qilgan kinimatik juft A nuqtasi uchun quyidagi tenglamalar tuzilishini hosil qilamiz.



2-rasm. Vibro planetar mexanizmning strukturaviy sxemasi

$$X_A = X_1 + O_1A\cos\varphi_1 = X_2 + O_2A\cos\varphi_2 \qquad (1)$$

$$Y_A = Y_1 + O_1A\sin\varphi_1 = Y_2 + O_2A\sin\varphi_2 \qquad (2)$$

Yuqorida keltirilgan 1 va 2 tenglamalar tizimida keltirilgan kattaliklarni quyidagicha belgilab olaylik:

$O_1A = l_1; X_1 = X_2 + O_1O_2; y_1 = a; y_2 = 0; O_2A = B.$

U xolda, 1 va 2 tenglamalar tizimi quyidagicha ko‘rinishni hosil qiladi:

$$X_A = X_1 + l_1\cos\varphi_1 = X_2 + B\cos\varphi_2 \qquad (3)$$

$$Y_A = a + l_1A\sin\varphi_1 = B\sin\varphi_2 \qquad (4)$$

Tenglamalar tizimidan foydalanib, kulisaning burilish burchagi φ_2 uchun quyidagi tenglamani hosil qilamiz:

$$\cos\varphi_2 = b_1\cos\varphi_1 \qquad (5)$$

$$\sin\varphi_2 = c_1 + b_1\sin\varphi_1 \qquad (6)$$

bu yerda, $b_1 = \frac{l_1}{B}; c_2 = \frac{a}{B}.$

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5 va 6 tenglamalar tizimlarini o‘ng va chap tomonlarini kvadratga oshirib qo‘shib chiqamish natijasida quyidagi tenglikni hosil qilamiz:

$$\sin\varphi_1 = \frac{1-c_2^2 b_1^2}{2c_2 b_1} \tag{7}$$

$$\varphi_1 = arcsin\varphi_1\left(\frac{1-c_2^2 b_1^2}{2c_2 b_1}\right) \tag{8}$$

φ_1 burilishida “B” qiymatni o‘zgarishini va tayanchlar orasidagi “a” masofa qiymatigacha bog‘liqligini ifodalaydi. Shuning uchun krivoshipning burchak tezligi ω_1 va burchak tezlanishlarini ε_1 larni aniqlashda quyidagi o‘zgarish funksiyalarini kirgizishimiz lozim:

$X_1 = X_1(t);\ X_2 = X_2(t);\ Y_1 = Y_1(t);\ Y_2 = Y_2(t);$ va $B = B(t)$.

Yuqoridagi funksiya qiymatlarini 8 tenglikka qo‘yib va ularni vaqt bo‘yicha differinsiallash orqali quyidagilarni qosil qilamiz:

$$\omega_1 = \frac{d\varphi_1}{dt} \quad \text{ва} \quad \varepsilon = \frac{d^2\varphi_1}{dt^2}$$

Bu tenglamalarni yechishni O₁ va O₂ kinimatik juftlar qo‘zg‘almas etib belgilab olish lozim, u holda ular orasidagi masofa:

$O_1O_2 = a = const$ ga teng bo‘ladi. U holda, 8 tenglamaga barcha o‘zgaruvchi funksiyalarni qiymatini qiymatini qo‘yib chiqamiz:

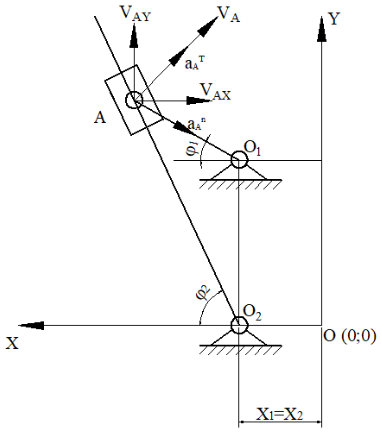
$$\varphi_1 = \arcsin\left[\frac{1-\frac{a^2}{B^2}-\frac{l_1^2}{B^2}}{\frac{2al_1}{B^2}}\right] = = \arcsin\left[\frac{B^2-(a^2+l_1^2)}{2al_1}\right] \tag{9}$$

Krivoshipning burchak tezligi ω_1 va burchak tezlanishi $\varepsilon_1$larni aniqlashda 9 tenglamani alohida holatda difrensiallash orqali aniqlaymiz:

$$\omega_1 = \frac{d\varphi_1}{dt} = \frac{2B}{\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}}\frac{dB}{dt} \tag{10}$$

$$\varepsilon_1 = \frac{d^2\varphi_1}{dt^2} = \frac{2\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}+\frac{4B\,(B^2-(a^2+l_1^2))^2}{\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}}}{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}\frac{d^2B}{dt^2} = \frac{2(4a^2l_1^2-(B^2-(a^2+l_1^2))^2+4B\,(B^2-(a^2+l_1^2))^2}{[4a^2l_1^2-(B^2-(a^2+l_1^2))^2]^{3/2}}\frac{d^2B}{dt^2} \tag{11}$$

Kulisali mexanizmning “A” nuqtasining tezlik va tezlanishlarini kordinata o‘qlariga proeksiyalash lozim bo‘ladi.



3-rasm. Kulisaga ta’sir etuvchi tezliklar

3-rasmda keltirilgan tezlik va tezlanishlarni kordinata o‘qi bo‘yicha proeksiyalarini quyidagicha aniqlaymiz:

$$V_A = \omega_1 l_1 = \frac{2Bl_1}{\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}}\frac{dB}{dt} \tag{12}$$

12 tenglamadagi funksiya qiymatini absissa va ordinata o‘qlari bilan proeksiyalash natijasida quyidagi tengliklarni hosil qilamiz:

$$V_{AX} = -V_A sin\varphi_1 = \frac{2Bl_1 sin\varphi_1}{\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}}\frac{dB}{dt} \tag{13}$$

$$V_{AY} = V_A cos\varphi_1 = \frac{2Bl_1 cos\varphi_1}{\sqrt{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}}\frac{dB}{dt} \tag{14}$$

Krivoship – pol’zunli mexanizmning “A” nuqtasining tezlanishini ham proeksiyalash orqali quyidagilarni aniqlaymiz:

$$\overrightarrow{a_A} = \overrightarrow{a_A^n} + a_A^\tau;$$
$$a_A = \sqrt{a_A^n + a_A^\tau} \tag{15}$$
$$\overrightarrow{a_X} = \overrightarrow{a_{AX}^n} + a_{AX}^\tau$$
$$\overrightarrow{a_Y} = \overrightarrow{a_{AY}^n} + a_{AY}^\tau \tag{16}$$

15 – formulada keltirib o‘tilgan a_A^n – normal tezlanishnigqiymatini quyidagi tenglama orqali aniqlaymiz:

$$a_A^n = \omega_1^2 l_1 = \frac{4B^2l_1}{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}\left(\frac{dB}{dt}\right)^2 \tag{17}$$

$$a_{AX}^n = -a_A^n\cos\varphi_1 = -\frac{4B^2l_1\cos\varphi_1}{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}\left(\frac{dB}{dt}\right)^2 \tag{18}$$

$$a_{AY}^n = a_A^n\sin\varphi_1 = -\frac{4B^2l_1\sin\varphi_1}{4a^2l_1^2-(B^2-(a^2+l_1^2))^2}\left(\frac{dB}{dt}\right)^2 \tag{19}$$

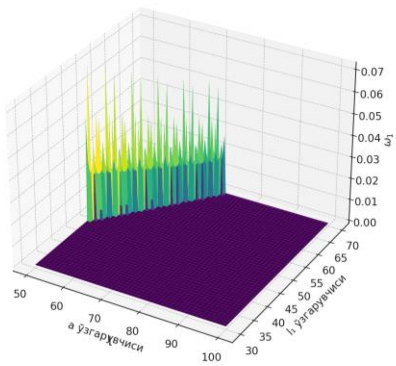
A nuqtaning tangensial tezlanishini esa quyidagicha aniqlaymiz:

$$a_A^\tau = \varepsilon_1 l_1 = \frac{2l_1(4a^2l_1^2-(B^2-(a^2+l_1^2))^2+4B\,(B^2-(a^2+l_1^2))^2}{[4a^2l_1^2-(B^2-(a^2+l_1^2))^2]^{3/2}}\frac{d^2B}{dt^2} \tag{20}$$

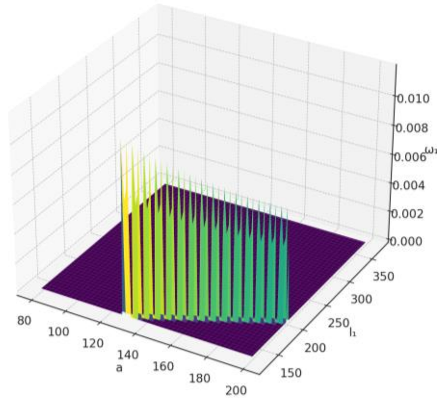
$$a_{AX}^\tau = -a_A^\tau\sin\varphi_1 = -\frac{2l_1(4a^2l_1^2-(B^2-(a^2+l_1^2))^2)+4B\,(B^2-(a^2+l_1^2))^2\sin\varphi_1}{[4a^2l_1^2-(B^2-(a^2+l_1^2))^2]^{3/2}}\frac{d^2B}{dt^2} \tag{21}$$

$$a_{AY}^\tau = a_A^\tau\cos\varphi_1 = -\frac{2l_1(4a^2l_1^2-(B^2-(a^2+l_1^2))^2)+4B\,(B^2-(a^2+l_1^2))^2\cos\varphi_1}{[4a^2l_1^2-(B^2-(a^2+l_1^2))^2]^{3/2}}\frac{d^2B}{dt^2} \tag{22}$$

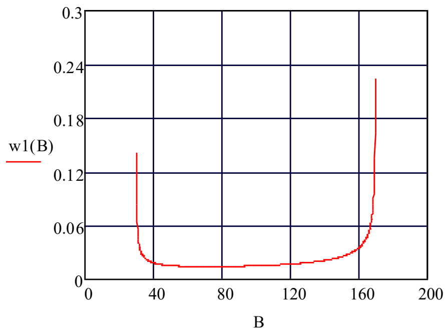
Hosil bo‘lgan (10), (11) tenglamalar tizimidan ω_1 va ε_1 larning vaqt birligi ichida o‘zgarish qiymatlari O₁ va O₂ tayanchlar orasidagi masofa “a” ning qiymati va krivoshipning uzunligi bo‘yicha MathCat-20 dasturi asosida tadqiqodlar o‘tkaziladi.



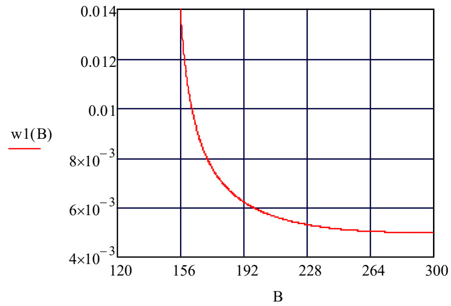
$y_1 = a$ ning qiymati 50 mm dan 100mm gacha, $O_1A = l_1$ ning qiymati 30 mm dan 70mm gacha oraliqdagi, xamda V o'zgarmas bo'lganda



$y_1 = a$ ning qiymati 80 mm dan 200mm gacha, $O_1A = l_1$ ning qiymati 150 mm dan 350mm gacha oraliqdagi, xamda V o'zgarmas bo'lganda

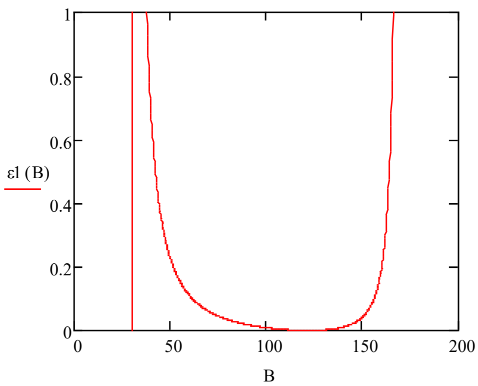


$y_1 = a = 100mm;\ O_1A = l_1 = 70mm$
va V ning o'zgarish qiymati 0 dan 200 oralig'ida bo'lganda

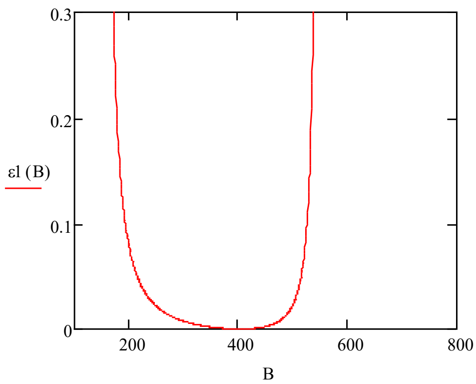


$y_1 = a = 200mm;\ O_1A = l_1 = 350mm$
va V ning o'zgarish qiymati 0 dan 200 oralig'ida bo'lganda

4-rasm. Mexanizm krovoship zvenosining burchak tezligini zvenolar va tayanchlar oralig'i orasidagi masofaga bog'likliuk grafigi



$y_1 = a = 100mm;\ O_1A = l_1 = 70mm$
va V ning o'zgarish qiymati 0 dan 200 oralig'ida bo'lganda



$y_1 = a = 200mm;\ O_1A = l_1 = 350mm$
va V ning o'zgarish qiymati 200 dan 800 oralig'ida bo'lganda

5-rasm. Mexanizm krovoship zvenosining burchak tezlanishi zvenolar va tayanchlar oralig'i orasidagi masofaga bog'likliuk grafigi

5 va 6 tenglamalar tizimidan foydalanib kulisaning burilish burchagi $\varphi_2$ning o'zgarishini ko'rib chiqaylik:

$$cos\varphi_1 = b_2 cos\varphi_2 \quad (23)$$

$$sin\varphi_1 = -c_3 + b_2 sin\varphi_2 \quad (24)$$

Bu yerda, $b_2 = \frac{B}{l_1}$; $c_3 = \frac{a}{l_1}$.

23 va 24 tenglamalarning o'ng va chap tomonlarini kvadratga oshirib, qo'shish orqali quyidagi tenglikni hosil qilamiz:

$$sin\varphi_2 = \frac{b_2^2 + c_3^2 - 1}{2c_3 b_2} \quad (25)$$

U holda φ_2 ning qiymati quyidagiga teng bo'ladi:

$$\varphi_2 = \arcsin\left[\frac{b_2^2 + c_3^2 - 1}{2c_3 b_2}\right] \quad (26)$$

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26 tenglamadagi b_2 va c_3 koefitsentlarning qiymatlarini qo‘yish orqali kulisaning umumiy burulish burchagi φ_2 ni hisoblash tenglamasini hosil qilamiz:

$$\varphi_2 = arcsin\left[\frac{B^2+a^2-l_1^2}{2Ba}\right] \quad (27)$$

Krivaship-kulisaning burchak tezligi ω_2 va burchak tezlanishi ε_2 larning qiymatlarini aniqlash uchun $X_1 = X_1(t)$; $X_2 = X_2(t)$; $Y_1 = Y_1(t)$; $Y_2 = Y_2(t)$; va $B = B(t)$ funksiyalarning o‘zgarish qonuniyatlaridan foydalanamiz.

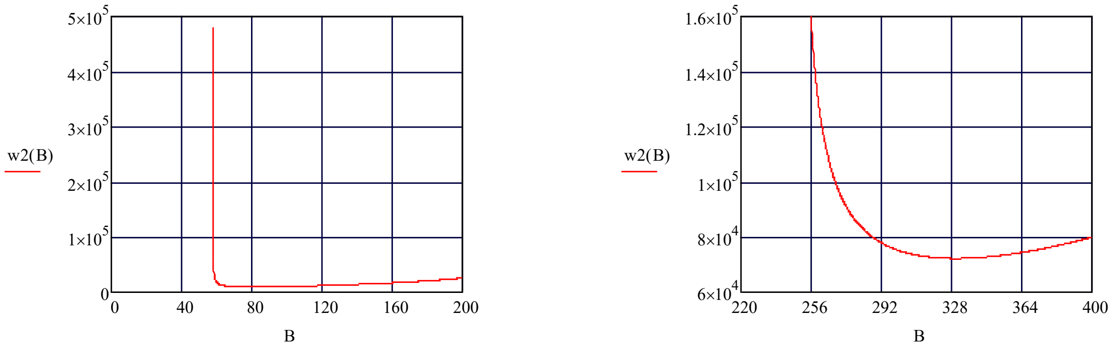
$$\left.\begin{aligned}\omega_2 &= \frac{d\varphi_2}{dt}\\ \varepsilon_2 &= \frac{d^2\varphi_2}{dt^2}\end{aligned}\right\} \quad (28)$$

27 tenglamani birinchi va ikkinchi tartibli difrensiallash orqali quyidagi tenglamalarni hosil qilamiz:

$$\omega_2 = \frac{d\varphi_2}{dt} = \frac{\frac{B}{a}}{\sqrt{\frac{4B^2a^2-(B^2+a^2-l_1^2)^2}{4B^2a^2}}}\frac{dB}{dt} = \frac{2B^2a^2}{\sqrt{4B^2a^2-(B^2+a^2-l_1^2)^2}}\frac{dB}{dt} \quad (29)$$

$$\varepsilon_2 = \frac{d^2\varphi_2}{dt^2} = \frac{4Ba\sqrt{4B^2a^2-(B^2+a^2-l_1^2)^2}-\frac{8Ba^2-2(B^2+a^2-l_1^2)\cdot 2B}{\sqrt{4B^2a^2-(B^2+a^2-l_1^2)^2}}}{4B^2a^2-(B^2+a^2-l_1^2)^2}\frac{d^2B}{dt^2} = \frac{4Ba(4B^2a^2-(B^2+a^2-l_1^2)^2)-2a^2-(B^2+a^2-l_1^2)}{4B^2a^2-(B^2+a^2-l_1^2)^{3/2}}\frac{d^2B}{dt^2} \quad (30)$$

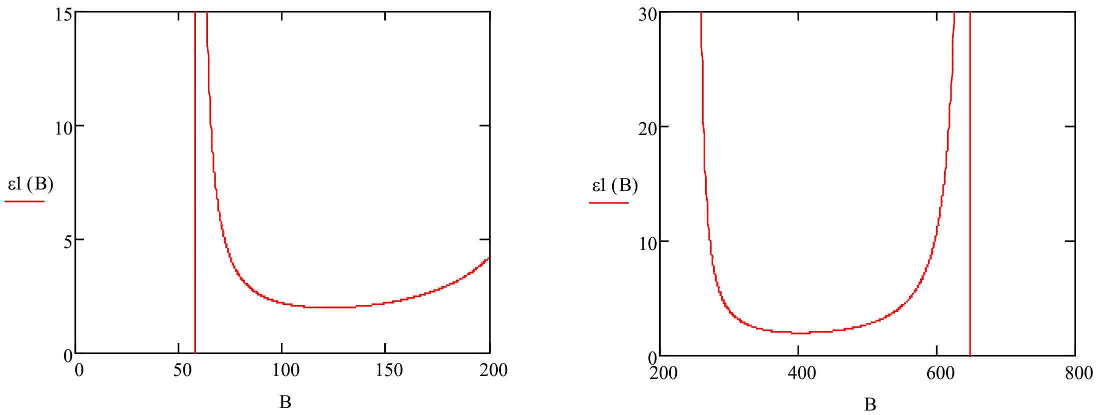
Yuquridagi 29 va 30 tenglamalar tizimini MathCad-20 dasturida hisoblash orqali quyidagilarni aniqlaymiz:



$y_1 = a = 100mm; O_1A = l_1 = 70mm$
va V ning o‘zgarish qiymati 0 dan 200 oralig‘ida bo‘lganda

$y_1 = a = 200mm; O_1A = l_1 = 350mm$
va V ning o‘zgarish qiymati 220 dan 400 oralig‘ida bo‘lganda

6-rasm. Mexanizm kulisa zvenosining burchak tezligini zvenolar va tayanchlar oralig‘i orasidagi masofaga bog‘liklilik grafigi



$y_1 = a = 100mm; O_1A = l_1 = 70mm$
va V ning o‘zgarish qiymati 0 dan 200 oralig‘ida bo‘lganda

$y_1 = a = 200mm; O_1A = l_1 = 350mm$
va V ning o‘zgarish qiymati 200 dan 800 oralig‘ida bo‘lganda

7-rasm. Mexanizm kulisa zvenosining burchak tezlanishi zvenolar va tayanchlar oralig‘i orasidagi masofaga bog‘likliuk grafigi

4. Xulosa

Polimer kompozit materiallarning dispers to‘ldiruvchilarini mexanik faollashtirish jarayonida qo‘llash mumkin bo‘lgan mexanik aktivatorni loyihalashda geometrik paramterlarini optimallashtirish lozim. Shuning uchun xam yuqorida keltirib o‘tilgan birinchi va ikkinchi tartibli differensial tenglamalar ustida olib borilgan tadqiqotlar shuni ko‘rsatadiki, mexanik aktivator tayanchlari orasidagi, krivoship va kulisa uzunliklarini optimal ko‘rsatgichlarini aniqlash imkoniin beradi. Bu bora, asosan mexanik aktivatorga qo‘yilgan talablar asosida, ularning geometrik parametrlarini optimal ko‘rsatgichlarini aniqlash imkoni mavjud. Bunda, asosan kelgusi tadqiqot ishlarida polimer kompozit materiallarning dispers to‘ldiruvchilarini mexanik faollashtirishda qanday tezlik, tezlanish va qanday markazdan qochma kuch ta’siri faollashtirish lozimligini aniqlash lozim bo‘ladi.

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