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YOYSIMON TO‘RLI YUZA SIRTI BO‘YLAB PAXTA BO‘LAKCHASINI TAQSIMLANISH QONUNIYATINI ANIQLASH.

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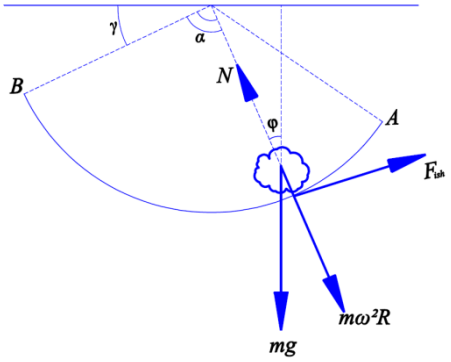
Tavsiya etilayotgan yoysimon to‘rli yuza sirti bo‘ylab dastlaki $\overset{\smile}{AB} = L_1$ yoy bo‘ylab paxta oqimining harakatini tashqi kuchlar ta’sirida ko‘rib chiqamiz.



1- rasm. $\overset{\smile}{AB}$ yoy bo‘ylab paxta oqimining harakat sxemasi.

$\overset{\smile}{AB} = S_1$ bo‘yicha deferensial tenglamasini ifodalaymiz.

$$\begin{cases} m\ddot{L}_1 = mg\sin\varphi - F_{тр} \\ m\omega^2 R = N - mg\cos\varphi \end{cases} \qquad (1)$$

$$-\begin{cases} \varphi + 90^0 + x = 180^0 \\ x + \alpha + \gamma = 180^0 \end{cases} \Rightarrow \begin{cases} \varphi + 90^0 = \alpha + \gamma \\ \varphi = -90^0 + \alpha + \gamma \end{cases}$$

$$\begin{cases} m\ddot{L}_1 = mg\sin(-(90^0 - (\alpha+\gamma))) - f - N \\ m\omega^2 R = N - mg\cos(-(90^0 - (\alpha+\gamma))) \end{cases} \Rightarrow \begin{cases} m\ddot{L}_1 = -mgs\cos(\alpha+\gamma) - f - N \\ m\omega^2 R = N - mg\sin(\alpha+\gamma) \end{cases} \qquad (2)$$

(2) tenglamadan siklon sirtiga ta’sir qiluvchi normal bosim kuchini aniqlaymiz

$$N = m\omega^2 R + mg\sin(\alpha+\gamma) \qquad (3)$$

(3) tenglamani (2) tenglamadagi N normal bosim kuchiga qo‘yamiz

$$m\ddot{L}_1 = -mg\cos(\alpha+\gamma) - f(m\omega^2 R + mg\sin(\alpha+\gamma)) \qquad (4)$$

(4) tenglamani sodda ko‘rinishga keltiramiz

$$m\cdot\ddot{L}_1 + \frac{f\cdot m}{R}\dot{L}_1^2 = -m\cdot g\cdot\cos(\alpha+\gamma) - f\cdot m\cdot g\cdot\sin(\alpha+\gamma) \qquad (5)$$

(5) tenglama ikkinchi tartibli bir jinsli bo‘lmagan deferensial tenglamani bir jinsli va hususiy ko‘rinishda aniqlaymiz

$\ddot{L}_1 = \frac{dL_1}{dt} \cdot \frac{2dL_1}{2dL_1} = \frac{d(\dot{L}_1)^2}{2dL_1}$ ko‘rinishida ifodalaymiz.

$$\frac{d(\dot{L}_1)^2}{2dL_1} + \frac{f}{R} \cdot \dot{L}_1^2 = -f \cdot g \cdot \sin(\alpha+\gamma) - g \cdot \cos(\alpha+\gamma) \qquad (6)$$

(6) differensial tenglamasi umumiy yechimini aniqlash uchun dastlab bir jinsli qismini hisoblaymiz.

α + γ = β belgilash kiritamiz. $Z = Z_1 + Z_2$

bu yerda Z_1 – bir jinsli qismi; Z_2 – hususiy ishi hisoblanadi.

$\frac{d(\dot{L}_1)^2}{2dL_1} + \frac{f}{R}\dot{L}_1^2 = 0$ $\dot{L}_1^2 = Z_1$ belgilash kiritamiz

$$\frac{dz_1}{2dL_1} + \frac{f}{R} z_1 = 0 \Rightarrow \frac{dz_1}{z_1} = -\frac{2f}{R} dL_1 \Rightarrow \ln z_1 = -\frac{2 \cdot f}{R} \cdot L_1 \Rightarrow z_1 = e^{-\frac{2f}{R}L_1} \cdot c_1 \qquad (7)$$

$z_1 = \dot{L}_1^2$ ni (30) tenglikga qo‘yamiz

$\dot{L}_1^2 = e^{-\frac{2f}{R}S_1} \cdot c_1 \Rightarrow \dot{L}_1 = e^{-\frac{f \cdot L_1}{R}} \cdot c_1$

boshlang‘ich sharoitdan foydalanib changli maxsulotni dastlabki harakatini t=0 $\dot{L}_1 = v_0$ $L_1 = 0 \Rightarrow c_1 = v_0$ taxlil qilamiz.

$\dot{L}_1 = e^{-\frac{f \cdot S_1}{R}} \cdot v_0$

bu ifodani integrallab quyidagi ko‘rinishga keltiramiz.

$$\frac{dL_1}{dt} = e^{-\frac{f \cdot L_1}{R}} \cdot v_0 \Rightarrow e^{-\frac{f \cdot L_1}{R}} \cdot dL_1 = v_0 dt \qquad \frac{R}{f} e^{-\frac{fL_1}{R}} = v_0 \cdot t + c_2 \qquad (8)$$

boshlang‘ich shartdan foydalanib s_2 o‘zgarmasni aniqlaymiz t=0 $\dot{S}_1 = 0 \Rightarrow c_2 = \frac{R}{f}$.

aniqlangan s_2 o‘zgarmasni qiymatini (8) tenglikka qo‘yamiz

$$\frac{R}{f} e^{-\frac{f}{R} \cdot L_1} = v_0 \cdot t + \frac{R}{f}; \quad e^{-\frac{f}{R} \cdot L_1} = \frac{R}{f} v_0 \cdot t + 1;$$

$$\frac{f}{R} L_1 = \ln\left(\frac{f}{R} v_0 \cdot t + 1\right) \Rightarrow L_1 = \frac{R}{f} \ln\left(\frac{f}{R} v_0 \cdot t + 1\right) \; L_1 = \frac{R}{f} \ln\left(\frac{f}{R} v_0 \cdot t + 1\right)$$

(9)

(6) differensial tenglamani umumiy yechimini aniqlash uchun bir jinsli bo‘lmagan qismini hisoblaymiz.

$z_2 = A\sin\beta + B\cos\beta$ (10)

ko‘rinishida ifodalaymiz

$\dot{z}_2 = A\cos\beta - B\sin\beta$

$\ddot{z}_2 = -A\sin\beta - B\cos\beta$

bu ifodani (6) tenglamaga qo‘yamiz

$$-\frac{A}{2}\sin\beta - \frac{B}{2}\cos\beta + \frac{f}{R}\cdot A\cos\beta - \frac{f}{R}\cdot B\sin\beta = -fg\sin\beta - g\cos\beta$$

$$\begin{cases} -\frac{A}{2} - \frac{f}{R}B = fg \\ \frac{f}{R}A - \frac{B}{2} = -g \end{cases}$$

bu ifodadan A va V o‘zgarmas qiymatlarini aniqlaymiz.

$$\Delta = \begin{vmatrix} -\frac{1}{2} & -\frac{f}{R} \\ \frac{f}{R} & -\frac{1}{2} \end{vmatrix} = \frac{1}{4} + \frac{f}{R^2} = \frac{R^2 + 4f^2}{4R^2};\quad \Delta = \begin{vmatrix} -fg & -\frac{f}{R} \\ -g & -\frac{1}{2} \end{vmatrix} = \frac{f\cdot g}{2} - \frac{f\cdot g}{R} = \frac{f\cdot g\cdot(R-2)}{2R};$$

$$\Delta = \begin{vmatrix} -\frac{1}{2} & -fg \\ \frac{f}{R} & -g \end{vmatrix} = -\frac{f^2 g}{R} - \frac{g}{2} = \frac{-g(2f^2+R)}{2R}.$$

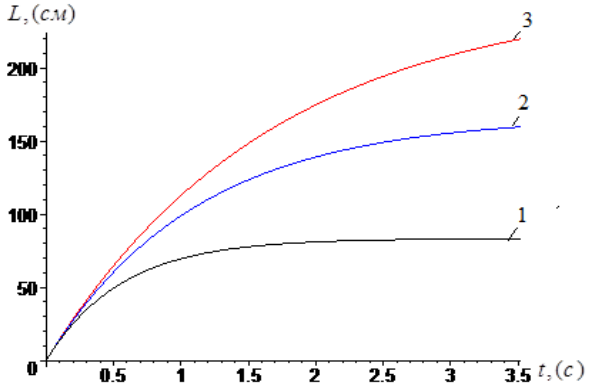
$$A = \frac{\Delta_A}{\Delta} = \frac{2Rfg(R-2)}{R^2+4f^2},\ B = \frac{\Delta_B}{\Delta} = \frac{2Rg(2f^2+R)}{R^2+4f^2}$$

$$z_2 = \frac{2\cdot R\cdot f\cdot g\cdot(R-2)}{R^2+4\cdot f^2}\sin\beta - \frac{2\cdot R\cdot g\cdot(2\cdot f^2+R)}{R^2+4\cdot f^2}\cos\beta \qquad (11)$$

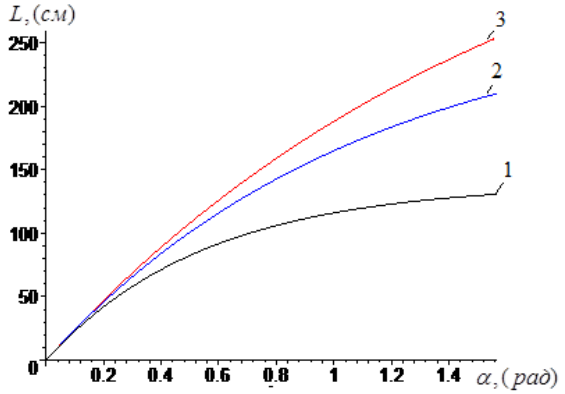
AV sirtidagi paxta oqimining harakatini ifodalovchi tenglamani umumiy ko‘rinishini xosil qilamiz.

$$L = \frac{R}{f}\ln\left(\frac{f}{R}\cdot v_0\cdot t + 1\right) + \frac{2\cdot R\cdot f\cdot g\cdot(R-2)}{R^2+4\cdot f^2}\sin(\alpha+\gamma) - \frac{2\cdot R\cdot g\cdot(2\cdot f^2+R)}{R^2+4\cdot f^2}\cos(\alpha+\gamma) \qquad (12)$$

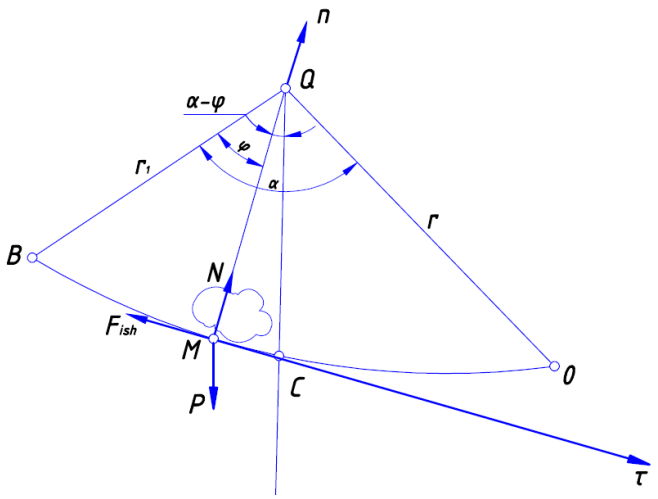
(12) tenglama paxta oqimining iflosliklarni ajratishda markazdan qochma kuchiga, qamrash burchagiga ishqalanish koeffitsiyentiga va oraliq masofalariga bog‘liqlik tenglamasi keltirib chiqarildi. Bu tenglamani harakat trayektoriyasini aniqlashda Maple-6 dasturidan foydalanib grafiklarda taxlil qilingan va ratsional qiymatlari aniqlangan.



2-rasm. Paxta oqimining harakatini turli xil m_1=2 gr, m_2=10 gr, m_3=50 gr massadagi iflosliklardan ajratishda yoy uzunliklariga bog‘liqlik grafiklari



3-rasm. Paxta oqimi harakatini turli xil m_1=2 gr, m_2=10 gr, m_3=50 gr massadagi iflosliklardan ajratishda uzatishda markaziy burchakga bog‘liqlik grafiklari.



8-rasm. Paxta bo‘lakchasini to‘rli yuza bo‘ylab harakat sxemasi

Paxta oqimining to‘rli setka sirtidagi harakati differensial tenglamasining VO uchastkada ifodalaymiz. Paxta bulakchalariga ta’sir kiluvchi tashki kuchlar

$$\gamma = \frac{\pi}{2} - (\alpha - \varphi); v_\tau = R \cdot \dot{\varphi}; \overline{F}_{ишк} = f \cdot N$$

$$m\ddot{L} = k\dot{L}^2 + d \sin pt \qquad (13)$$

$$\dot{L}dL = \frac{d\dot{L}}{dt} \cdot dL = \dot{L}d\dot{L}$$

(13) differensial tenglamani integrallaymiz

$$\frac{\dot{L}d\dot{L}}{\frac{k}{m}\dot{L}^2+\frac{d}{m}\sin pt}=dL \qquad \frac{m}{2k}\ln\left(\frac{k}{m}\dot{L}^2+\frac{d}{m}\sin pt\right)=L+C_1 \tag{14}$$

(14) tenglikdan S_1o‘zgarmas qiymatni aniqlashda boshlang‘ich shartdan foydalanamiz.

t = 0 L=0 $\dot{L}=0 \quad \Rightarrow C_1=\frac{m}{2k}\ln\left(\frac{d}{m}\sin pt\right)$

aniqlangan o‘zgarmas qiymatni (14) tenglamaga qo‘yamiz.

$$\frac{m}{2k}\ln\left(\frac{k}{m}\dot{L}^2+\frac{d}{m}\sin pt\right)-L+\frac{m}{2k}\ln\left(\frac{d}{m}\sin pt\right) \qquad \dot{L}^2=\frac{d}{k}\sin pt\left(e^{\frac{2k}{m}L}-1\right)$$

chegaraviy shartdan foydalanib L=L_1 $\dot{L}=v_B$

$$v_B=\sqrt{\frac{d}{k}\sin pt\left(e^{\frac{2k}{m}L_1}-1\right)} \tag{15}$$

BO yoy bo‘ylab oqimining xarakat differensial tenglamasini ifodalaymiz

$$\begin{cases} m\frac{dv_\tau}{dt}=mg\cos\left(\frac{\pi}{2}-\gamma\right)-F_{ишк} \\ m\frac{v^2}{R}=N+F_{эл}+mg\cos\gamma \end{cases} \tag{16}$$

(16) tenglamaladan paxta bo‘lakchalarini normal bosim kuchini aniqlaymiz.

$$\begin{cases} mR\ddot{\varphi}=mg\sin\gamma-f\cdot N \\ m\frac{v^2}{R}=N+k\cdot\Delta l+mg\cos\gamma \end{cases} \tag{17}$$

(17) tenglamadan urinma bo‘ylab harakatlanayotgan paxta oqimining foydalanib urinma tezligini yechimini aniqlaymiz.

$R\ddot{\varphi}=g\cos(\alpha-\varphi)-\frac{fN}{m}\Big/\cdot d\varphi$ bundan $\ddot{\varphi}d\varphi=\frac{d\dot{\varphi}}{dt}\cdot d\varphi=\dot{\varphi}d\dot{\varphi}$

$$\dot{\varphi}d\dot{\varphi}=\left(\frac{g}{R}\cos(\alpha-\varphi)-\frac{fN}{m}\right)\cdot d\varphi \qquad \frac{\dot{\varphi}^2}{2}=\frac{g}{R}\sin(\alpha-\varphi)-\frac{fN}{m}\cdot\varphi+C_1 \tag{18}$$

boshlang‘ich shartdan foydalanib S_1 o‘zgarmas qiymatini aniqlaymiz

$$\varphi=0 \quad \dot{\varphi}=\frac{v_B}{R}=\frac{1}{R}\sqrt{\frac{d}{k}\sin pt\cdot\left(e^{\frac{2kL_1}{m}}-1\right)}$$

(18) tenglikka qo‘yamiz

$$\frac{d}{2R^2k}\sin pt\left(e^{\frac{2kL_1}{m}}-1\right)=\frac{g}{R}+L_1$$

$$C_1=\frac{d}{2R^2k}\sin pt\left(e^{\frac{2kL_1}{m}}-1\right)-\frac{g}{R}$$

$$\frac{\dot{\varphi}^2}{2}=\frac{g}{R}\sin(\alpha-\varphi)-\frac{tN}{m}\cdot\varphi+\frac{d}{2R^2k}\sin pt\left(e^{\frac{2kL_1}{m}}-1\right)-\frac{g}{R}$$

$$v_\tau=R\cdot\dot{\varphi}=\sqrt{2gR\sin(\alpha-\varphi)-2\cdot\frac{fN}{m}\cdot R^2\varphi+\frac{d}{k}\sin pt\left(e^{\frac{2kL_1}{m}}-1\right)-2gR} \qquad (19)$$

(19) tenglama paxta oqimining VO yoy bo‘ylab urinma tezlikni ifodalaydi.

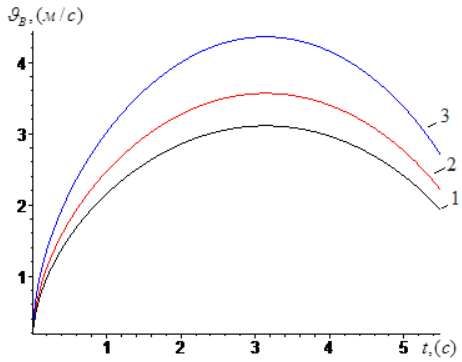
(14) tenglamadan VO yoy bo‘ylab normal bosim kuchini aniqlaymiz

$$N_1=\frac{m}{R}v^2-k\Delta l-mg\sin(\alpha-\varphi) \qquad (20)$$

(20) tenglamadagi v^2 tezligi o‘rniga paxta oqimiga V nuqtadagi tezligini qo‘yib normal bosim kuchini aniqlaymiz

$$v_B=\sqrt{\frac{d}{k}\sin pt\left(e^{\frac{2kL_1}{m}}-1\right)}$$

B nuqtasidagi tezligini paxta bo‘lakchasining massasiga bog‘liqlik tenglamasini Maple dasturidan foydalanib grafiklarda tahlil qilingan.



9-rasm. VO yoy bo‘ylab paxta bo‘lakchasining harakatini uning turli xil massadagi $m_1=0,03\ gr$; $m_2=0,05\ gr$; $m_3=0,07\ gr$ qiymatlarini vaqt bo‘yicha o‘zgarish grafigi

Xulosa.

Yuqoridagi 2.9-2.10-rasmlarda takomillashgan qoziqchali barabanning paxta bo‘lakchalariga ta’siri natijasida to‘rli sirt bo‘ylab harakati asosan xar bir qoziqchali barabanga uzatish va shu orqali paxta bo‘lakchalaridagi mayda iflosliklarni tozalash samaradorligini oshirishga erishilgan. Parametrlar: k=0,50÷0,65; V=3,5÷8,5 m/s; f=0,25÷0,30; m=0,20÷0,30 gr; φ=10÷20; R=0,16÷0,20 m; g=9,81m/s^2 qiymatlarda paxta bo‘lakchasining harakati tahlil qilingan.

Grafiklar taxlilidan parametr μ (1/nm) asosan paxta oqimidagi ifloslik miqdorining nisbiy ajralish koeffitsiyenti $\varepsilon=\frac{m_0-m}{m_0}$ ga ko‘proq ta’sir etishini ko‘rsatib turibdi.

Parametr μ oshishi bilan bog‘lanish va qiya joylashgan qoziqcha sirtida paxta bo‘lakchalariga ta’sir etuvchi normal kuchlarning qiymatlarining kamayishi ε

koeffitsiyentning esa oshishi kuzatilayapti. Masalan, μ=0,02, h=0,3 bo‘lganda bog‘lanish va normal kuchlar mos ravishda R = 7 m, R=10 m ga teng bo‘lsa, μ=0,3 bo‘lsa, R = 5 m, R= 6 m ga teng bo‘ladi.
Koeffitsiyent ε esa mrs ravishda 15% va 22% ga teng bo‘ladi. Qoziqchaning qiyalik burchagi $\varphi=5\text{-}7^0$ ga teng bo‘lganda to‘rli yuzaning kamaygan sari bog‘lanish kuchlar R, N xamda koeffitsiyent ε qiymatlari kamayishi kuzatilayapti.

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