



## HALQALI IP YIGIRISH MASHINASI YUK VALIGINING CHIZIQSIZ QAYISHQOQ YUZADAGI TEBRANISHI MASALASI

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**Annotatsiya:** *Qo'yilgan masala yechish va bunda xususiy tebranishlari haqida masalaning yechimi Mathcad dasturi yordamida amalga oshirildi. Aniq yechim qabul qiluvchi mukammal ip tebranishlari masalada tekshirilgan va o'tkazilgan hisoblar qiymatlari aniq natijalarga mos kelganligi aniqlangan.*

**Kalit so'zlar:** *tebranish jarayoni, integro-differensial tenglamalar, Bubnov-Galerkin usuli, Mathcad dasturi, mexanik tebranishlar, yigiruv mashinasi dinamikasi, elastik asos, sonli yechim.*

Misol tariqasida yigiruv jarayonida yugurdak harakati keltiramiz. Yugurdak ballon hosil bo'lish, mashina harakati bilan bog'liq bo'lgan turli dinamik kuchlar ta'sirida bo'ladi. Bu kuchlar markazga intilma va Koriolis tezlanishlariga bog'liq bo'lib, nafaqat xususiy chastota va tebranish formasiga ta'sir etadi, balki aylanayotgan valning ustuvorligiga ham o'z ta'sirini ko'rsatadi. Aylanayotgan valning dinamik holatini o'rganishda klassik usullardan foydalanamiz. Masalan [1] ga asoslanib, Eyler-Bernullining harakat differensial tenglamasidan foydalanamiz. Bu holda ipning qovushqoq-elastiklik xususiyatini hisobga olib, mexanikaviy parametrlarni integral operatorlar orqali ifodalanadi. Bundan tashqari elastik asosni ham ta'sirini hisobga olamiz. Yugurdakga qo'yilgan kuchga qarab, vaqtning har bir intervali uchun o'zining integro-differensial tenglamalarini yozamiz:

birinchi intervalda tashqi kuch ta'sir etmaydi

$$a^2 \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} + a^2 \int_0^t G_1(t - \tau) \frac{\partial^2 u}{\partial x^2} d\tau + e \int_0^t G_3(t - \tau) \left(\frac{\partial^2 u}{\partial x^2}\right)^3 d\tau g'; \quad (0 < t < t_1) \quad (1)$$

ikkinchi intervalda kuch ta'sir etadi

$$a^2 \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} + a^2 \int_0^t G_1(t - \tau) \frac{\partial^2 u}{\partial x^2} d\tau + e \int_0^t G_3(t - \tau) \left(\frac{\partial^2 u}{\partial x^2}\right)^3 d\tau g' + f(t); \quad (t_1 < t < t_2) \quad (2)$$

uchinchi intervalda yana kuch ta'sir etmaydi

$$a^2 \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} + a^2 \int_0^t G_1(t - \tau) \frac{\partial^2 u}{\partial x^2} d\tau + e \int_0^t G_3(t - \tau) \left(\frac{\partial^2 u}{\partial x^2}\right)^3 d\tau g'; \quad (t_2 < t < t_b) \quad (3)$$



bu yerda  $t_1$  - kuch ta'sir etish vaqti;  $t_2$ - kuch ta'siri to'xtagan vaqt;  $t_b$ - valning to'liq harakat vaqti. (1; 2; 3) integro-differensial tenglamalar quyidagi chegaraviy va boshlang'ich shartlarni qanoatlantirishi kerak:

$$u_i/x=0 = q_1(t); u_i/x=L = q_2(t); i = 1,2,3 \quad (4)$$

$$u_1/t=0 = 0; \frac{\partial u_1}{\partial t}/t=0 = 0; u_2/t=t_1 = u_1/t=t_1; \frac{\partial u_2}{\partial t}/t=t_1 = \frac{\partial u_1}{\partial t}/t=t_1;$$

$$u_3/t=t_2 = u_2/t=t_2; \frac{\partial u_3}{\partial t}/t=t_2 = \frac{\partial u_2}{\partial t}/t=t_2 \quad (5)$$

(1; 2; 3; 4; 5) tenglamalarga Bubnov-Galerkin metodini qo'llab qo'yilgan masala bo'lib,

$$\begin{aligned} \ddot{T}(t) + 2b\dot{T}(t) + \lambda^2 T(t) + \gamma T^3(t) = \\ = \lambda^2 \int_0^t G(t-s)T(s)ds + \gamma \int_0^t G_1(t-s)T^3(s)ds + f(t); \\ T(t=0) = T_0; \dot{T}(t=0) = \dot{T}_0 \end{aligned} \quad (6)$$

ko'rinishdagi integro-differensial tenglamalar sistemasiga keltiriladi.

Shuni ta'kidlab o'tish joizki, iplarning bo'ylama, ko'ndalang va buralma tebranma harakatlari ham integro-differensial tenglamalar sistemasiga keltiriladi. (4) ko'rinishdagi integro-differensial tenglamalar o'rtalashtirish [2, 3], Laplasning integral o'zgartirishlar, L.YE.Malsev darajali qator usullari bilan yechiladi. Bu ishda L.YE. Malsev usuli chiziqsiz tenglamalar uchun umumlashtirilgan. Buning uchun [4, 8] ga asosan (4) integro-differensial tenglamalarni o'ziga yaqin bo'lgan differensial tenglamalar bilan almashtiramiz. Bunda elastik asosning ta'siri quyida keltirilgan  $a_2$  koeffitsiyentga kiradi.

$$\begin{aligned} \ddot{\bar{T}}(t) + a_1\dot{\bar{T}}(t) + a_2\bar{T}(t) + a_3\bar{T}^3(t) = \bar{f}(t) \\ \bar{T}(t=0) = \bar{T}_0; \dot{\bar{T}}(t=0) = \dot{\bar{T}}_0 \end{aligned} \quad (7)$$

bu yerda

$$a_1 = 2b + \lambda\omega_s + \gamma\omega_{s1}, a_2 = \lambda^2(1 - \omega_c), a_3 = \gamma(1 - \omega_{c1}) \quad (8)$$

$$\omega_s = \int_0^t G(s) \cos(\lambda s) ds; \omega_{s1} = \int_0^t G_1(s) \cos(\lambda s) ds;$$

$$\omega_s = \int_0^t G(s) \sin(\lambda s) ds; \omega_{s1} = \int_0^t G_1(s) \sin(\lambda s) ds \quad (9)$$

(7) tenglamani yechimini sonli usul bilan aniqlaymiz. Umumiy holda (1; 2 ;3) tenglamaning koeffitsiyentlari o'zgaruvchan va vaqtni funksiyasidan iborat bo'ladi.

Bu yerda tashqi kuchni uchta ko'rinishiga asosan tenglamani yechamiz:

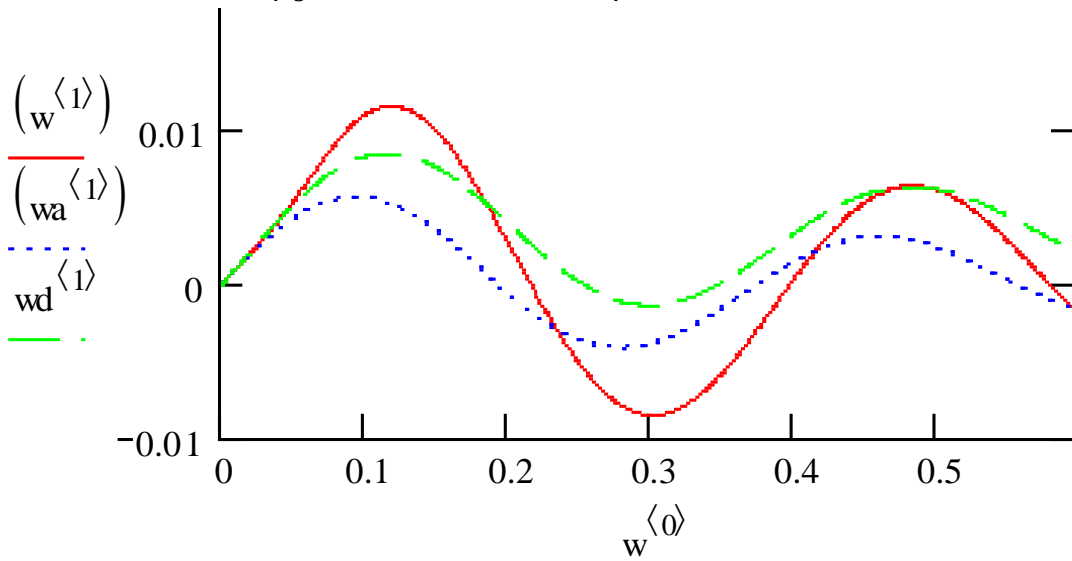
1.  $f(t) = f_0 \sin \omega t$  - kuch funksiyasi garmonik ko'rinishda.
2.  $f(t)$  – kuch uchburchakli impuls ko'rinishida.
3.  $f(t)$  – kuch to'rtburchakli impuls ko'rinishida.

Bu uchala hol uchun sonli natijalar olingan va ular grafiklar ko'rinishida 1-, 2-rasmlarda keltirilgan. Bunda tenglamaga kiruvchi, tajribalar natijasida olinib, mavjud usul orqali olingan parametrlarning quyidagi qiymatlari qabul qilingan:

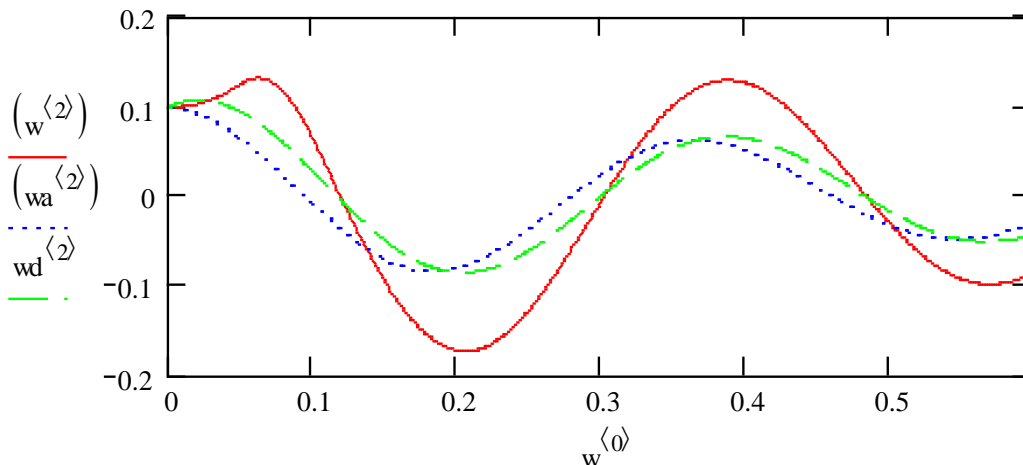


$$A_1 = 0.12; \alpha_1 = 0.15; \beta_1 = 0.005; A_3 = 0.2; \alpha_3 = 0.2; e = 0.76;$$

$$\beta_3 = 0.005; b = 0.65; \gamma = 1.25.$$



**1-rasm. Ko'chishlarni ( $w^{(1)}=u_1, w^{(2)}=u_2, w^{(3)}=u_3$ ) vaqt  $t$  ( $t = w^{(0)}$ ) birligi ichida o'zgarish grafiklari**



**2-rasm. Ko'chish tezligini ( $w^{(2)}, wa^{(2)}, wd^{(2)}$ ) vaqtga  $t$  ( $t = w^{(0)}$ ) bog'liqligini ifodalovchi egri chiziqlar**

Grafikda  $w^{(1)}$  - uchburchakli impuls ta'siridagi ko'chish;  $wa^{(1)}$  - to'rtburchakli impuls ostidagi ko'chish;  $wd^{(1)}$  - garmonik kuch ta'siridagi ko'chish;  $w^{(2)}, wa^{(2)}, wd^{(2)}$  - yuqoridagilarga mos keluvchi ko'chish tezliklari.  $w$  ma'lum bo'lgandan keyin  $u$ , ni aniqlaymiz va undan keyin deformatsiya  $\varepsilon = \frac{\partial u}{\partial x}$  formuladan topiladi. Ishda taklif etilgan usul ixtiyoriy vaqt  $t$  va koordinata  $x$  larning qiymatlari uchun qaralayotgan mexanik sistemani kuchlanish-deformatsiya holatini to'liq aniqlaydi.

Ma'lumki halqali yigiruv mashinasi dinamika nuqtai nazaridan yuklangan mashina hisoblanadi. Ayniqsa ularning tezliklarini keskin oshirilishi mashina elementlarining dinamikasini, ya'ni undagi tebranishlarni yanada mukammalroq



o'rganishni talab etadi. Olib borilgan tajribalar yigiruv mashinasi zvenolaridagi tebranishlarni muhimligini va uni hisobga olish zarurligini ko'rsatdi. Bunda to'qima hosil qiluvchi mexanizm asosiy harakatidan tashqari qo'shimcha tebranma harakatda bo'ladi.

**Xulosa:** *Tadqiqotda qo'yilgan masala yechimi algoritmi Mathcad dasturi yordamida amalga oshirildi. Algoritmning samaradorligi aniq yechim qabul qiluvchi mukammal ip tebranishlari haqidagi masalada tekshirilgan va o'tkazilgan hisoblar qiymatlari aniq natijalarga mos kelganini ko'rsatadi.*

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