THE TASK OF FREE VIBRATIONS OF HIGH-RISE BUILDINGS WITH A CYLINDRICAL RESERVOIR WITH FLUID

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Annotation: At the article theoretical investigates the problem of the transverse vibration of a high-rise structure carrying two concentrated masses using an integral transformation. The solutions of the frequency equation are obtained.

Keywords: Structure, concentrated masses, ground, frequency, Laplace-Carson transform.

MUJASSAMLASHGAN MASSALI INSHOOTNING KO‘NDALANG TEBRANISHI MASALASI

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Annotatsiya: Maqolada mujassamlashgan ikki massali inshootning erkin ko‘ndalang tebranishi masalasi integral almashtirish usuli yordamida nazariy tadqiq etilib, chastota tenglamasi yechilgan.

Kalit so‘zlar: Inshoot, mujassamlashgan massa, grunt, chastota, Laplas-Karson almashtirishlari.

Tik inshootlarning tebranishini o‘rganish muhandislik-qurilish sohalarida muhim amaliy ahamiyatga ega dolzarb masalalardan hisoblanadi. Odatda inshootga o‘rnatilgan bitta mujassam massani inshoot bo‘ylab shu massaga ekvivalent ikki yoki undan ortiq massa bilan almashtirirsh maqsadga muvofiq bo‘ladi. Tashqi seysmik va garmonik kuchlar ta’sirida inshootning tebranma harakatini tahlil qilish, chastota va tebranish davrlarini aniqlash, inshootning turli qismlarida hosil bo‘ladigan zo‘riqishlar, kuchlanish va deformatsiyalarning tarqalishini, eguvchi moment, qirquvchi kuchlarni hisoblash yetarli qiyinchiliklarga ega bo‘lib, qilingan ilmiy-nazariy ishda shu hisoblashlarni yengillashtirish, inshoot uchun murakkab tajribalar o‘tkazilib olinadigan xarakterli kattaliklarni nazariy yo‘l bilan olish mumkinligini ko‘rsatish asosiy maqsad qilib olingan.

Ushbu maqolada o‘zgarmas ko‘ndalang kesimli tik inshootning egilishidagi erkin va majburiy tebranma harakati masalasi tadqiq etilgan. Inshootning egilishi tebranma harakati asosidan turli masofalarda o‘rnatilgan mujassamlashgan ikkita yuk bilan birgalikda tahlil etilgan. Mujassamlashgan yuklarni amalda mavjud, turli suyuqliklarga ega rezervuarlardan iborat jismlar deb ham qarash mumkin.

Tebranma harakat, garmonik tebranishlar va to‘lqinlar, turli jismlar va sistemalarning va ularning birgalikdagi tabranma harakati masalalari, to‘lqin harakati bilan bog‘liq turli masalalar [1-4] adabiyotlarda atroflicha ko‘rib chiqilgan.

Mujassamlashgan ikki massali yuk o‘rnatilgan, o‘zgarmas ko‘ndalang kesimli, tik inshootning erkin tebranma harakatini differensial tenglamasi

$$EJ\frac{\partial^4 u}{\partial x^4} = -m\frac{\partial^2 u}{\partial t^2} - M_1\frac{\partial^2 u}{\partial t^2}\delta(x-l_1) - M_2\frac{\partial^2 u}{\partial t^2}\delta(x-l_2) \tag{1}$$

ko‘rinishda bo‘ladi. Bu yerda M_1 hamda M_2 mos ravishda birinchi va ikkinchi yukning massasi [3].

(1) tenglama yechimini quyidagi

$$U(x,t)=\varphi(x)\cos\omega t \qquad (2)$$

ko‘rinishda izlaymiz.

Chegaraviy shartlar quyidagi ko‘rinishda bo‘lsin:

$$\begin{aligned} x=0: &\quad U\left(0,t\right)=U'(0,t)=0,\\ x=l: &\quad -M_2\frac{\partial^2 u}{\partial t^2}=EJ\frac{\partial^3 u}{\partial x^3},\ EJ\frac{\partial^2 u}{\partial x^2}=0. \end{aligned} \qquad (3)$$

(2) dan mos hosilalarni olib, (1) ga qo‘ysak:

$$\varphi^{IV}(x)-\frac{m\omega^2}{EJ}\varphi(x)=\frac{M_1}{EJ}\omega^2\varphi(l_1)\delta(x-l_1)+\frac{M_2}{EJ}\omega^2\varphi(l_2)\delta(x-l_2) \qquad (4)$$

kelib chiqadi.

Qulaylik uchun quyidagi belgilashlarni kiritamiz:

$$k^4=\frac{m\omega^2}{EJ};Q_1=\frac{M_1}{EJ}\omega^2;Q_2=\frac{M_2}{EJ}\omega^2;$$

Natijada (4) tenglama quyidagi ko‘rinishga keladi:

$$\varphi^{IV}(x)-k^4\varphi(x)=Q_1\varphi(l_1)\delta(x-l_1)+Q_2\varphi(l_2)\delta(x-l_2). \qquad (5)$$

$\varphi(x)$ ga mos chegaraviy shartlar esa quyidagicha bo‘ladi:

$$\begin{aligned} x=0: &\quad \varphi(0)=0,\\ &\quad \varphi'(0)=0,\\ x=l: &\quad M_2\omega^2\varphi(l)=EJ\varphi^{III}(l),\\ &\quad \varphi^{II}(l)=0. \end{aligned} \qquad (6)$$

Laplas-Karson integral almashtirishlari yordamida (5) ni integrallaymiz. Yechimni aniqlashda (5) tenglamani har bir hadini e^{-px} ga ko’paytirib, 0 dan ∞ gacha integrallaymiz:

$$\Phi(p)\xrightarrow{\cdot}\varphi(x) \qquad \Phi(p)=p\int_0^\infty \varphi(x)e^{-px}dx, \qquad (7)$$

$$F(p)\to f(x)=Q_1\varphi(l_1)\delta(x-l_1)+Q_2\varphi(l_2)\delta(x-l_2), \qquad (8)$$

$$p\int_0^\infty \varphi^{IV}(x)e^{-px}dx=-p\varphi^{III}(0)-p^2\varphi^{II}(0)-p^3\varphi^{I}(0)-p^4\varphi(0)+p^4\Phi(p), \qquad (9)$$

$$k^4 p\int_0^\infty \varphi(x)e^{-px}dx = k^4\Phi(p), \qquad (10)$$

$$p\int_0^\infty f(x)e^{-px}dx = p\int_0^\infty [Q_1\varphi(l_1)\delta(x-l_1)+Q_2\varphi(l_2)\delta(x-l_2)]e^{-px}dx =$$
$$= pQ_1\varphi(l_1)e^{-pl_1} + pQ_2\varphi(l_2)e^{-pl_2}. \qquad (11)$$

Chegaraviy shartlardan foydalanib, $\Phi(p)$ ni topamiz:

$$\Phi(p)\left[p^4-k^4\right]-p\varphi^{III}(0)-p^2\varphi^{II}(0)=p\left[Q_1\varphi(l_1)e^{-pl_1}+Q_2\varphi(l_2)e^{-pl_2}\right],$$

$$\Phi(p)-\frac{p}{p^4-k^4}\varphi^{III}(0)-\frac{p^2}{p^4-k^4}\varphi^{II}(0)=\frac{p}{p^4-k^4}\left[Q_1\varphi(l_1)e^{-pl_1}+Q_2\varphi(l_2)e^{-pl_2}\right].$$

Funksiyalardan “asli”ga qaytish uchun Laplas-Karson almashtirishlaridan foydalanamiz:

$$\frac{p}{p^4-k^4}\varphi^{III}(0)=\frac{1}{k^3}V(kx)\varphi^{III}(0), \quad \frac{p}{p^4-k^4}\varphi^{II}(0)=\frac{1}{k^2}U(kx)\varphi^{II}(0),$$
$$\frac{p}{p^4-k^4}Q_1\varphi(l_1)e^{-pl_1}=\frac{1}{k^3}V(k(x-l_1))Q_1\varphi(l_1), \quad \frac{p}{p^4-k^4}Q_2\varphi(l_2)e^{-pl_2}=\frac{1}{k^3}V(k(x-l_2))Q_2\varphi(l_2). \qquad (12)$$

Demak,

$$\Phi(p) \xrightarrow{\cdot} \varphi(x)=\frac{1}{k^3}V(kx)\varphi^{III}(0)+\frac{1}{k^2}U(kx)\varphi^{II}(0)+$$
$$+\frac{Q_1\varphi(l_1)}{k^3}V(k(x-l_1))\theta(x-l_1)+\frac{Q_2\varphi(l_2)}{k^3}V(k(x-l_2))\theta(x-l_2). \qquad (13)$$

Qulaylik uchun quyidagicha belgilashlar kiritamiz:

$$A=\frac{Q_1Q_2V(k(l_1-l_2))U(kl_2)+k^3Q_1U(kl_1)}{k^8+k^2Q_1Q_2V^2(k(l_2-l_1))}, \quad B=\frac{Q_2Q_1V(k(l_2-l_1))U(kl_1)+k^3Q_2U(kl_2)}{k^8+k^2Q_1Q_2V^2(k(l_2-l_1))},$$
$$C=\frac{Q_1Q_2V(k(l_1-l_2))V(kl_2)+k^3Q_1U(kl_1)}{k^9+k^3Q_1Q_2V^2(k(l_2-l_1))}, \quad D=\frac{Q_1Q_2V(k(l_2-l_1))V(kl_1)+k^3Q_2U(kl_2)}{k^9+k^3Q_1Q_2V^2(k(l_2-l_1))}, \qquad (14)$$

$$E=S(kl)+Ak^2T(k(l-l_1))+Bk^2T(k(l-l_2)), \quad F=\frac{1}{k}T(kl)+Ck^2T(k(l-l_1))+Dk^2T(k(l-l_2)), \qquad (15)$$
$$G=kV(kl)+Ak^3S(k(l-l_1))+Bk^3S(k(l-l_2)), \quad H=S(kl)+Ck^3S(k(l-l_1))+Dk^3S(k(l-l_2)),$$

bu yerda $S(x),T(x),U(x),V(x)$ funksiyalar Krilov funksiyalari.

Demak, biz izlayotgan yechim quyidagi koʻrinishda boʻlishi aniqlanadi:

$$\varphi(x)=(\frac{1}{k^2}U(kx)+AV(k(x-l_1))\theta(x-l_1)+BV(k(x-l_2)))\theta(x-l_2)\varphi^{II}(0)+$$
$$+(\frac{1}{k^3}V(kx)+CV(k(x-l_1))\theta(x-l_1)+DV(k(x-l_2)))\theta(x-l_2)\varphi^{III}(0). \quad (16)$$

Endi chegaraviy shartlardan foydalanib, umumiy yechimni aniqlaymiz. Ma'lumki, $\varphi^{II}(0)$, $\varphi^{III}(0)$ yagona yechimga ega bo'lishi uchun ular oldidagi koeffitsiyentlardan tuzilgan determinant 0 ga teng bo'lishi kerak:

$$\begin{cases} (S(kl)+Ak^2T(k(l-l_1))+Bk^2T(k(l-l_2)))\varphi^{II}(0)+ \\ +(\frac{1}{k}T(kl)+Ck^2T(k(l-l_1))+Dk^2T(k(l-l_2)))\varphi^{III}(0)=0 \\ (kV(kl)+Ak^2S(k(l-l_1))+Bk^3S(k(l-l_2)))\varphi^{II}(0)+ \\ +(S(kl)+Ck^3S(k(l-l_1))+Dk^3S(k(l-l_2)))\varphi^{III}(0)=0 \end{cases}. \quad (17)$$

(17) tenglamalardan $k_1, k_2, k_3, ...k_n$ lar aniqlanadi va mos $\omega_1, \omega_2, \omega_3, ...\omega_n$ chastotalar bir qiymatli aniqlanadi, so'ngra $T_i = \dfrac{2\pi}{\omega_i}$ ifodadan har bir chastotaga mos tebranish davrlari topiladi. Elektron hisoblash mashinasida *Maple 13* matematik dasturiy paketi yordamida aniqlangan k_i larning qiymatlari quyida jadvalda keltirilgan. Jadvalda keltirilgan chastota tenglamasining ildizlari inshoot va mujassamlashgan yuklarning o'rnatilish masofalari va massalarining turli qiymatlari uchun olingan.

Ushbu belgilashlarni kiritamiz:

$$Q_1=\frac{M_1\omega}{EJ}=\frac{M_1EJk^4}{mEJ}=\frac{M_1}{m}k^4,\ k^4=Q_1\frac{M_1}{m},\ k=\sqrt{\sqrt{Q_1\frac{M_1}{m}}},\ \omega=\sqrt{\frac{EJ}{m}k^4}. \quad (17)$$

Chastota tenglamalarining aniqlangan ildizlari jadvali

		k_i		k_i		k_i		k_i
l, m	40	0,0468	50	0,0374	100	0,0469	100	0,0469
l_1, m	30	0,1963	25	0,1570	20	0,1413	20	0,1413
l_2, m	20	0,2748	50	0,2826	70	0,2356	50	0,2357
M_1, kg	$2\cdot10^3$	0,3534	$4\cdot10^3$	0,3435	$1,1\cdot10^3$	0,3534	$1,1\cdot10^3$	0,3298
M_2, kg	10^3	0,4319	$2\cdot10^3$	0,4082	$3\cdot10^3$	0,4082	$3\cdot10^3$	0,4555
Q_1	$0,02k^4$	0,5104	$0,04k^4$	0,5340	$0,04k^4$	0,5340	$0,04k^4$	0,5774
Q_2	$0,01k^4$	0,6675	$0,02k^4$	0,6597	$0,02k^4$	0,6597	$0,02k^4$	0,6544

Shunday qilib, birinchi holda, ikki mujassamlangan massali yuk oʻrnatilgan tik gidroinshootning sof egilishidagi erkin tebranma harakati differensial tenglamasi, mos chegaraviy shartlarda olinib, shu inshootning xususiy tebranish chastota va davrlari topildi, umumiy yechim Laplas-Karson integral almashtirishlari yordamida aniqlandi. Har bir koʻndalang kesimlarda hosil boʻladigan eguvchi moment va qirquvchi kuch qiymatlarini aniqlovchi ifodalar aniqlandi. Ikkinchi holda aynan shu inshootning asosi tashqi qoʻzgʻatuvchi garmonik kuch ta’siri bilan harakatda boʻlgandagi majburiy tebranma harakati tahlil etildi. Gidroinshootning erkin va majburiy tebranma harakatini xarakterlaydigan asosiy kattaliklarning oʻzgarish qonunlari olinib, tahlil qilindi.

Bajarilgan ushbu ilmiy tadqiqot ishi natijalaridan uning mavzusiga yaqin ilmiy, ilmiy-amaliy, tajribaviy ishlarni bajarishda, xususan, mujassamlashgan massali tik gidroinshootlarning murakkab fazoviy tebranishlarini tadqiq etishda nazariy qoʻllanma sifatida foydalanish mumkin.

Adabiyotlar

1. Ахмедов А.Х. Суюқликка эга цилиндрик резервуар маҳкамланган тик иншоотнинг эркин тебранма ҳаракати частота тенгламаларининг таҳлили // “ЎзМУ хабарлари” журнали. – Тошкент, 2013. - №2. – Б. 39 – 41.
2. Ахмедов А.Х., Пардаев Р.К. Задача свободных колебаний высотных сооружений с цилиндрическим резервуаром с жидкостью. Polish Science Journal, Issue 3(36), Part 1., p.163-166, Warsaw 2021.
3. Каримов К.А., Ахмедов А.Х., Хабибуллаева Х.Н. Постановка и аналитическое решение задачи о свободных колебаниях сооружений несущих две сосредоточенные массы. Austrian Journal of Technical and Natural Sciences №3–4. Vienna, P. 35-37. 2016. ISSN 2310-5607.
4. Маматкулов Ш. Колебания и волны в гидроупругих и грунтовых средах.-Т.: Фан, 1987, 103 с.