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TASHQI KUCHLAR OSTIDA MAGNIT-ELASTIK PLASTINANING GEOMETRIK CHIZIQSIZ DEFORMATSIYASINI MATEMATIK MODELLASHTIRISH

Annotatsiya. Maqolada Gamilton–Ostrogradskiy variatsion tamoyili asosida elektromagnit maydon ta’siridagi magnitelastik plastinaning deformatsiyasi matematik model orqali tavsiflandi. Tizim energiyalari, elektromagnit kuchlar va mexanik bog‘lanishlar (Koshi, Guk qonunlari, Lorens kuchi, Maksvell tenzori) hisobga olindi. Model R-funksiya usuli va Bubnov–Galerkin, Gauss, Nyumark hamda iteratsion usullar yordamida yechiladi. Sonli tajribalar elektromagnit maydon ta’sirini ko‘rsatdi va yondashuv samaradorligini tasdiqladi..

Kalit so‘zlar: Gamilton-Ostrogradskiy tamoyili, Kirgof-Lyav gipotezasi, Bubnov Galerkin, Gauss, Nyumark, Koshi munosabatlari, Guk qonuni, Maksvell elektromagnit tenzori.

KIRISH

Murakkab konstruktiv shakldagi yupqa elektromagnitelastik plastinalardagi nochiziqli jarayonlarni matematik modellashtirish zamonaviy muhandislik tizimlarini, jumladan, aviatsiya konstruktsiyalari, piezoelektrik sensorlar va egiluvchan elektronika komponentlarini tahlil qilishda muhim ahamiyatga ega. Murakkab geometrik shakllarning mavjudligi kuchlanish va deformatsiya, chegaraviy effektlar hamda nochiziqli bog‘langan o‘zaro ta’sirlar kabi masalalarni yuzaga keltiradi, bu esa klassik chiziqli elastiklikdan tashqari modellashtirish yondashuvlarini qo‘llashni talab qiladi.

ADABIYOTLAR TAHLILI

Ushbu tadqiqotda variatsion tamoyillar, energiyaga asoslangan usullar va chegaraviy elementlar yondashuvlari yordamida nochiziqli bog‘langan qisman differensial tenglamalar shaklida tahlil olib borilgan. Olingan natijalar kompozit materiallar, adaptiv tuzilmalar va ko‘p fizikaviy simulyatsiya vositalari uchun nazariy asos yaratadi. Mazkur sohaning nazariy rivojiga S.A. Ambartsumyan, G.E. Bagdasaryan, M.V. Belubekyan, V.L. Rvachev, L.V. Kurpa, I.T. Selezov, M.R. Korotkina, S.A. Nazarov, V.A. Kozlov hamda akademik V.Q. Qobulov, X.A. Raxmatulin, Sh.A. Nazirov, T. Yuldashev, R. Indiaminov va F.M. Nuraliev kabi olimlar katta hissa qo‘shgan.

MATEMATIK MODEL ISHLAB CHIQISH

Magnetoelastik plastinaning nochiziqli deformatsiyasini tavsiflovchi matematik model Gamilton variatsion tamoyili asosida ishlab chiqilgan. Modelda Kirchhoff–Love plastina gipotezasi, Koshi munosabatlari, Lorens kuchi va Guk qonuni hisobga olinadi, shuningdek, elektromagnit maydon tenzori Maxvell tenglamalariga asoslanadi [1,2].

$$\int_t (\partial K - \partial P + \partial A)dt = 0 \qquad (1)$$

bu yerda: t - vaqt, $\partial -$ variasiya amali, $K -$ kinetik energiya, $П$ – potensial energiya, A – tashqi kuchlar bajargan ish.

Kirchhoff–Love gipotezasi bo‘yicha ingichka plastinaning qalinlik yo‘nalishidagi (Z-o‘qi) deformatsiyalari e’tiborga olinmaydi va o‘rta sirtning siljish komponentlari quyidagicha ifodalanadi:

$$u_1 = u(x,y,t) - z\frac{\partial w}{\partial x}, \quad u_2 = v(x,y,t) - z\frac{\partial w}{\partial y}, \quad u_3 = w(x,y,t) \qquad (2)$$

bu yerda: ingichka plastinaning o‘rta sirtining koordinata o‘qlari *(x,y,z)* bo‘yicha siljishlari;

Kinetik, potensial energiya va tashqi ish variatsiyalari Gamilton–Ostrogradskiy tamoyili orqali birlashtirilib, boshlang‘ich va chegaraviy shartlar bilan umumlashtirilgan muvozanat tenglamalari sistemasini hosil qiladi (3,4).

$$\begin{aligned}
&-\rho h\frac{\partial^2 u}{\partial t^2} + \frac{\partial N_{xx}}{\partial x} + \frac{\partial N_{xy}}{\partial y} + N_x + R_x + q_x + T_{zx} = 0,\\
&-\rho h\frac{\partial^2 v}{\partial t^2} + \frac{\partial N_{yy}}{\partial y} + \frac{\partial N_{xy}}{\partial x} + N_y + R_y + q_y + T_{zy} = 0,\\
&-\rho h\frac{\partial^2 w}{\partial t^2} + \frac{\partial^2 M_{xx}}{\partial x^2} + 2\frac{\partial^2 M_{xy}}{\partial x\partial y} + \frac{\partial^2 M_{yy}}{\partial y^2} + N_{xx}\frac{\partial^2 w}{\partial x^2} + N_{yy}\frac{\partial^2 w}{\partial y^2} + N_{xy}\frac{\partial^2 w}{\partial x\partial y} +\\
&+ \frac{\partial N_{xx}}{\partial x} + \frac{\partial N_{xy}}{\partial y}\frac{\partial w}{\partial x} + \frac{\partial N_{yy}}{\partial y} + \frac{\partial N_{xy}}{\partial x}\frac{\partial w}{\partial y} + N_z + R_z + q_z + T_{zz} = 0,
\end{aligned} \qquad (3)$$

Boshlag‘ich va chegaraviy shartlar:

$$\begin{aligned}
&\rho h\frac{\partial u}{\partial t}\delta u\Big|_t = 0,\ \rho h\frac{\partial v}{\partial t}\delta v\Big|_t = 0,\ \rho h\frac{\partial w}{\partial t}\delta w\Big|_t = 0,\ \left(N_{xx} + N_{Px} + N_{Tx}\right)\delta u\Big|_x = 0,\\
&\left(N_{xy} + N_{Py} + N_{Txy}\right)\delta v\Big|_x = 0,\ M_{xx}\delta\frac{\partial w}{\partial x}\Big|_x = 0,\ M_{xy}\delta\frac{\partial w}{\partial y}\Big|_x = 0,\\
&M_{yy}\delta\frac{\partial w}{\partial y}\Big|_y = 0,\ M_{xy}\delta\frac{\partial w}{\partial x}\Big|_y = 0, \left(N_{yy} + N_{Fy} + N_{Tyy}\right)\delta v\Big|_y = 0,\\
&\left(N_{xy} + N_{Fx} + N_{Tyx}\right)\delta u\Big|_y = 0,\quad N_{xx}\frac{\partial w}{\partial x} + N_{xy}\frac{\partial w}{\partial y} - \frac{\partial M_{xx}}{\partial x} - \frac{\partial M_{xy}}{\partial y} + N_{Pz} + N_{Txz}\quad \delta w\Big|_x = 0,
\end{aligned} \qquad (4)$$

bu yerda $N_{xx}, N_{yy}, N_{xy} -$ plastinaning qalinligi bo‘yicha normal va urunma kuchlar, $M_{xx}, M_{yy}, M_{xy} -$ plastinaning egilish va buralish momentlari, $\rho -$ jism zichligi, h- plastina

qalinligi, $R_x, R_y, R_z, N_x, N_y, N_z -$ hosil bo‘luvchi hajm kuchlari, $q_x, q_y, q_z, T_{zx}, T_{zy}, T_{zz} -$ sirt kuchlari, $T_{xx}, T_{xy}, T_{xz}, T_{yy}, T_{yz}, T_{zx}, -$ hosil bo‘luvchi kontur kuchlari.

MASALANING SONLI YECHIMI UCHUN HISOBLASH ALGORITMI

Elektromagnit maydon ta’siri ostidagi yupqa plastinalarning geometrik chiziqsiz deformatsion holatini baholash algoritmi quyidagi asosiy bosqichlardan iborat:



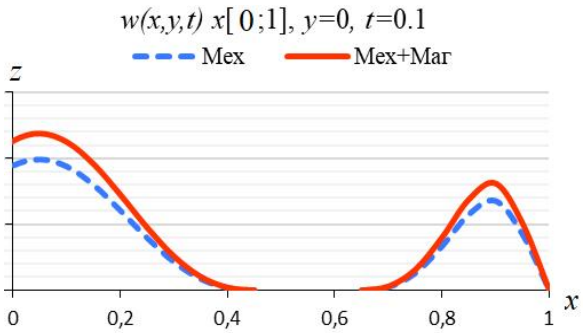
1-rasm. Masalani sonli yechish algoritmi

Harakat tenglamalaridagi noma’lum ko‘chish funksiyalari Bubnov–Galerkin, Gauss, Nyumark va iteratsion usullar yordamida hisoblanib, murakkab plastina uchun chegaraviy tenglamalar R-funksiya usuli orqali quriladi [4].

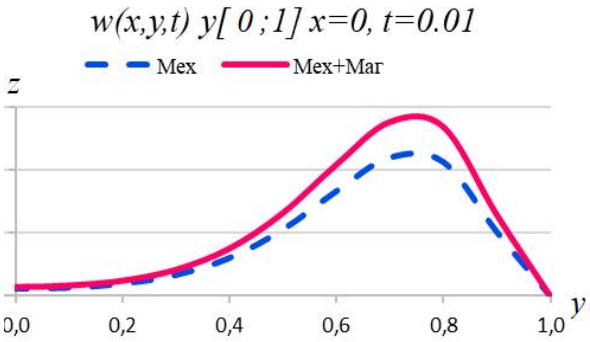
HISOBLASH NATIJALARI VA ULARNING TAHLILI

R-funksiya usuli yordamida aniqlangan nosimmetrik murakkab soha analitik ifodasi magnetoelastik plastinaning egilishini tahlil qilishda qo‘llanib, koordinata bo‘yicha taqsimot 3- va 4-rasmlarda maydon ostidagi deformatsiya xususiyatlarini aniq ko‘rsatadi [3–6].

Tadqiqotlar murakkab konfiguratsiyali magnitoelastik plastinaning sharnir mahkamlangan va markazi qattiq mahkamlangan chegaraviy shartlari ostida o‘tkazildi [7] . Olingan sonli natijalar asosida grafik tasvirlar keltirilgan.



3-rasm. Plastinaning (*Ox*) o‘qi bo‘ylab egilishi grafigi.



4-**rasm.** Plastinaning (*Oy)* o‘qi bo‘ylab egilish grafigi.

Elektro‘tkazuvchan yupqa magnitelastik plastinaning deformatsiyasi mexanik yuk, tashqi magnit maydon va harorat ta’siri ostida o‘rganildi. Natijalar ushbu uch omil plastinaning deformatsiyasiga sezilarli ta’sir ko‘rsatishini va ularning o‘zaro ta’siri deformatsiya qiymatlarida 14.8% farqni yuzaga keltirishini ko‘rsatdi. Shu sababli, ushbu materiallarni dizayn qilish va amaliy qurilmalarda qo‘llashda barcha asosiy ta’sirlarni birgalikda hisobga olish zarur. Tadqiqot natijalari magnitelastik plastinalarning samaradorligini oshirish va mexanik hamda magnit sensorlarni loyihalashda muhim ilmiy-amaliy ma’lumot beradi..

XULOSA

Ushbu tadqiqot elektromagnit maydon ta’siridagi murakkab konfiguratsiyaga ega yupqa plastinalarning geometrik chiziqsiz deformatsiyasini o‘rganishga bag‘ishlangan. Tadqiqotda elektromagnit maydonlarning nostandart shakllarga ega magnitelastik plastinalarning deformatsiya va kuchlanish holatlariga ta’siri aniqlangan. Murakkab konstruktiv shakllardagi plastinalarning tebranish xususiyatlarini tavsiflash uchun yangi matematik model ishlab chiqildi, shuningdek, boshqaruvchi tenglamalarni yechish uchun samarali hisoblash algoritmlari va dasturiy vosita taklif qilindi. Model ishonchliligi nosimmetrik plastina modellashtirilishi orqali tekshirildi, olingan natijalar grafik tasvirlar bilan ko‘rsatildi. Tadqiqot natijalari chiziqsiz bog‘langan masalalarni yechishda nazariy asos yaratadi va kompozit materiallar hamda ko‘p funksiyali konstruktiv tizimlarni loyihalashda amaliy ahamiyatga ega.

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