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Issiqlik o’tkazuvchanligi anizatrop bo’lgan jism materialda issiqlik tarqalishini madellashtirish.

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Annotatsiya. Ushbu ishda issiqlik o’tkazuvchanligi fazoda yo’nalishga bog‘liq bo‘lgan anizotrop materiallarda issiqlik tarqalish jarayonining matematik modellashtirilishi ko’rib chiqilgan. Tadqiqotda issiqlik o‘tkazuvchanlik tenzori yordamida uch o‘lchovli issiqlik o‘tkazish tenglamasi tuzildi. Anizotrop issiqlik o’tkazuvchanlikning real materiallarda (kompozitlar, kristallar, qatlamli strukturalar) namoyon bo’lishi va bunday tizimlarda issiqlik tarqalishini sonli usullar (masalan, sonli differensial usullar yoki sonli elementlar usuli) yordamida modellashtirish imkoniyatlari tahlil qilindi. Natijalar anizotrop tuzilmali jismlarda issiqlik tarqalishini aniqlik bilan oldindan baholash uchun foydali hisoblanadi.

Kalit so‘zlar: anizotropiya, issiqlik o’tkazuvchanlik tenzori, issiqlik o’tkazish tenglamasi, sonli modellashtirish, kompozit materiallar.

Аннотация

В данной работе рассмотрено математическое моделирование процесса теплопередачи в анизотропных материалах, где теплопроводность зависит от направления в пространстве. С использованием тензора теплопроводности сформулировано трёхмерное уравнение теплопереноса. Рассмотрены реальные примеры анизотропных материалов — композиты, кристаллы, слоистые структуры, а также возможности численного моделирования процесса теплопередачи в таких системах (метод конечных разностей, метод конечных элементов). Полученные результаты полезны для точного прогнозирования распределения температуры в анизотропных телах.

Ключевые слова: анизотропия, тензор теплопроводности, уравнение теплопереноса, численное моделирование, композитные материалы.

Abstract

This study presents the mathematical modeling of heat transfer in anisotropic materials, where thermal conductivity depends on spatial direction. Using the thermal conductivity tensor, a three-dimensional heat conduction equation is formulated. Real cases of anisotropic materials such as composites, crystals, and layered structures are analyzed, along with numerical approaches (finite difference and finite element methods) for simulating heat propagation. The results are valuable for accurately predicting temperature distribution in anisotropic solids.

Keywords: anisotropy, thermal conductivity tensor, heat conduction equation, numerical modeling, composite materials.

Kirish. Hozirgi zamon ilm-fanida issiqlik jarayonlarini o‘rganish nafaqat fundamental fizika, balki muhandislik, energetika, kimyo, materialshunoslik, elektronika va kosmik texnologiyalar kabi ko‘plab sohalar uchun ham juda katta ahamiyat kasb etadi. Issiqlik o‘tkazuvchanlik hodisasi har qanday jismda energiyaning harorat gradiyenti bo‘yicha harakatini tavsiflaydi va ko‘plab tabiiy hamda texnologik jarayonlarning asosida yotadi.Texnika va sanoatning turli sohalarida issiqlik jarayonlarini chuqur o’rganish muhim ahamiyat kasb etadi. Ko‘plab zamonaviy materiallar — ayniqsa, kompozitlar, kristallar, o’tkazuvchanligi yo‘nalish bo‘yicha farq qiladi. Shu sababli, bunday materiallarda issiqlik tarqalishini modellashtirish uchun klassik izotrop model yetarli emas, balki anizotrop issiqlik o’tkazuvchanlik tenzori asosidagi yondashuv zarur bo’ladi.

Ushbu ishda anizotrop jismda issiqlik tarqalishining matematik modelini tuzish, uni tahlil qilish hamda sonli usulda yechish tamoyillari bayon etiladi.Quyidagi formula orqali issiqlik tarqalish masalasini ko’rib chiqsek.

Haroratga bog’liq kimyoviy reaksiyaga ega materialdagi issiqlik o’tkazuvchan jismlarda issiqlik tarqalish masalasi.

Berilgan:

Tc= 423 K
T0= 383 K
p= 10950 kg/m^3
Cp= 236 $m^2 \cdot K/s^2$
L= 0.5 m

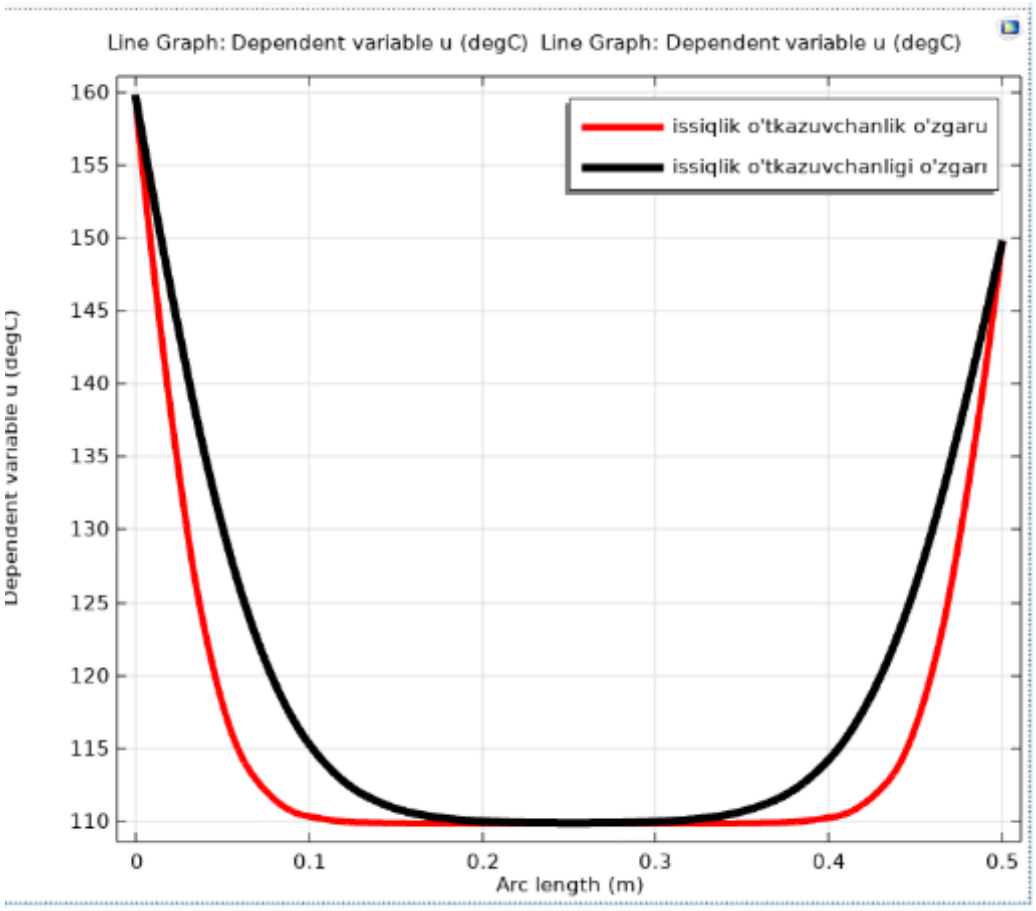
$$e_a\frac{\partial^2 u}{\partial t^2}+d_a\frac{\partial u}{\partial t}+\nabla\cdot(-c\nabla u-\alpha u+\gamma)+\beta\cdot\nabla u+au=f$$

$$\nabla=\frac{\partial}{\partial x}$$

1)

Plastinka UO_2 dan tayyorlagan bo’lsa: T_h=383K , T_c=433K, T_0=423K.

Comsol dasturi orqali ushu jarayonni modellashtirganda quyidagi grafikka ega bo’linadi.Bu grafikda issiqlik o’tkazuvchanlik o’zgaruvchan va o’zgarmas qiymatlari solishtirib natijaga ega bo’linadi.



Xullosa: Anizotrop jismlarda issiqlik o‘tkazuvchanlikni modellashtirish oddiy izotrop modelga nisbatan murakkabroq bo‘lsa-da, u real materiallarning issiqlik xatti-harakatini aniqroq tavsiflaydi. Issiqlik o‘tkazuvchanlik tenzori yordamida tuzilgan model har xil yo‘nalishlardagi issiqlik oqimini hisobga oladi.
Sonli modellashtirish (FDM yoki FEM) issiqlik tarqalishini tahlil qilish, material tanlash va issiqlik boshqaruv tizimlarini optimallashtirishda samarali vosita hisoblanadi.

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