Application of the Umov-Poynting Vector for Solving Heat Transfer Problems in Technology

Kuts N.G.[1)]

Propagation of heat fluxes has been examined taking into account atomic-molecular and cluster structures of different aggregate states. Heat propagation was examined not from the position of temperature conductivity but from the position of heat energy propagation using the Umov-Poynting vector. Heat capacity was defined making allowance for degrees of freedom excitation probability for each particle forming the medium. Changes in the aggregate state, the medium structure and its heat capacity caused by temperature change were taken into consideration in heat propagation. It was clarified what kinds of heat exchange processes appear at the interface of different aggregate states. The failure of the heat transfer equation – to describe heat propagation in different media – has been shown. The application of the Umov vector allows solving problems of thermal conductivity in any media specifying the medium and values of heat fluxes at the interface.

Key words: thermal conductivity, heat transfer, heat flux, heat capacity, heat-transfer equation, Umov-Poynting vector, aggregate states.

Introduction

THE classical theory of heat transfer was developed by Fourier, who showed that such a phenomenon can be described by the equation as follows [1]:

$$\frac{\partial T}{\partial t} = \chi \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right), \tag{1}$$

where $\chi \cong \overline{l} / c_V \rho$ is a temperature conductivity coefficient proportional to the free-path length $\overline{l}$ and inversely proportional to the specific heat capacity c_V and to the density of the medium ρ; i.e., the coefficient depends on the material and on its physical state. It can be purely empirically found in each particular case; therefore, it is not a universal constant. Besides, a solution of the differential equation of form (1) is only possible where there are boundary and initial conditions. While for homogeneous and isotropic materials these conditions can be specified and then somehow checked, for non-homogeneous, anisotropic and particularly for multilayered media of different structures and aggregate states, it is practically not possible. Hence, there occurs *an objective*: developing a more general model of heat propagation in different media taking into cosideration all physical and chemical properties inherent to this medium. The objective can be reached by solving the problems as follows:
- at heat propagation, one should not only take into account the atomic-molecular structure of the particular medium being considered, but also its cluster structure;
- heat propagation should be considered not from the viewpoint of temperature conductivity, but from the viewpoint of heat energy propagation through a given medium;
- heat capacity should be considered with account of the probability of exciting the degrees of freedom for all particles forming the medium;
- heat propagation should be considered with regard to changes – with temperature - in the medium aggregate state, in its structure, and in heat capacity;
- one should find out which processes of heat exchange take place at the interfaces of different aggregate states.

The purpose in hand and heat propagation problems to be solved– in all the aggregate states – present a challenge. It is obvious that for each aggregate state, one should consider their own specificity of the interaction of atom, molecular and cluster particles. Below, we will consider how one reaches the purpose in hand and solves the problems for each aggregate state.

Gaseous medium

When applied to gases, the heat transfer equation (1) is solved taking into account an empirical formula offered by Eken [1]:

$$\overline{l} = 10^2 \frac{\eta C_V}{M} \left(1 + \frac{9R}{4C_V} \right), \tag{2}$$

where η is a dynamic viscosity, M is a molar mass, R is a universal gas constant and C_V – is molar heat capacities under a constant volume. We leave out of consideration the question of how the dynamic viscosity of gas medium and specific heat capacity vary with temperature. On detailed consideration of the heat transfer process, one should be careful with empirical formulas.

The general problem of heat propagation in gases – with the application of the molecular-kinetic theory – is solved rather convincingly. As a result, the heat propagation law is

---

[1)] Lutsk National Technical University, Department of motor vehioles end vehicles technolgies, Lvivska 75, 43-018 Lutsk, UKRAINE

obtained in the form:

$$Q = K \frac{dT}{dl} St .$$ (3)

Here: $K = \frac{1}{3} \rho c_V \bar{c} \bar{l}$ - isthe thermal conductivity coefficient depending on *the* gas density ρ and the specific heat capacity c_V; $\bar{c} = \sqrt{\frac{\gamma k_B T}{m_a}}$ - is the velocity of sound propagation in the gas; $\bar{l} \approx \frac{1}{\sqrt{2}\pi D^2 n}$ is the free-path length which is inversely proportional to the gas particles concentration n and to the square of the mean diameter of gas particles D^2; $\frac{dT}{dl}$ is the temperature gradient; S is the area through which heat is transferred, and t is the heat transfer time.

The thermal conductivity coefficient in the heat transfer equation depends on the basic parameters which characterize a gas state. At a given temperature gradient, all these parameters depend on the temperature value which varies as heat propagates along a selected direction. At a given temperature gradient, the heat transfer equation (3) enables the evaluation ofthe heat amount only in the initial area and at the initial instant of time. Therefore, the situation inside the gas medium is rather ambiguous. For this reason, we will use a more general approach offered by Umov [2]. The Umov-Poynting vector permits obtaining the value of the energy flux along a selected direction, which is defined by the formula as follows:

$$\vec{P}_e = [\vec{w}\vec{v}], \quad [\text{Wt/m}^2].$$ (4)

For the gas medium, the energy density is defined by its internal heat energy. Then, neglecting the radiant energy, we have:

$$w = \frac{i}{2} k_B T \cdot n$$ (5)

and the velocity of propagation:

$$v = \sqrt{\frac{\gamma k_B T}{m_a}} .$$ (6)

For the majority of practical problems, the pressure is assumed to be constant ($P = const$) and the Umov-Poynting vector takes a form (in the absolute value):

$$P_e = \frac{i}{2} P \sqrt{\frac{\gamma k_B T}{m_a}} .$$ (7)

Here, P is the pressure in the gas, i is the number of degrees of freedom, k_B - the constant of Boltzmann and $\gamma = C_P / C_v$ is the ratio of heat capacity under constant pressure and constant volume. The change of the heat capacity ratio with temperature can be neglected, and the change in the number of degrees of freedom, involved in the gas at a given temperature, will be considerable, since:

$$i = \sum_k i_k W_k .$$ (8)

where i_k is the quantity *of the k-th* degree of freedom,

$W_k = \int\limits_{E_{coup.,k}}^{\infty} f(E,T)dE$ is the probability of the excitation *of the k- th* degree of freedom, and $f(E,T)$ is the function of the Maxwell-Boltzmann distribution over energies.

All gases – and even the He gas – are composed of molecules. The internal heat energy is contained in translational, rotational and vibrational degrees of freedom. The probability of excitation of translational degrees of freedom in gases is equal to the unit, since the particle coupling energy of gases is – by the definition of the gas state – equal to zero. The probability of excitation of rotational degrees of freedom in gases is also equal to zero owing to the absence of friction between gas particles. Only for vibrational degrees of freedom, the probability of their excitation is different from zero and is defined by the energy of atoms coupling in gas molecules. Therefore, for two-atom gases – in the neglect of excitation of vibrational degrees of freedom – $i = 5$, and $i = 6$ for multinuclear molecules.

At low temperatures, clusters are formed and then the quantity of degrees of freedom being excited is obtained as:

$$i = \frac{1}{\sum\limits_j n_j} \sum_j \sum_k n_j i_k W_k ,$$ (9)

and by the definition of the density of energy by Eq. (5), one should account for the reduction of general concentration of particles at the cluster formation. In this case:

$$n = n_0 (1 + \sum_\zeta N_\zeta - \sum_\zeta N_\zeta W_\zeta) .$$ (10)

Here, $n_0 = 1/r_{cl.}^3$; N_ζ is the number of particles in the ζ-th coordination layer and $W_\zeta = \int\limits_0^{E_{coupl.,\zeta}} f(E,T)dE$ is the probability that a particle of the ζ-th coordination layer stays in the cluster.
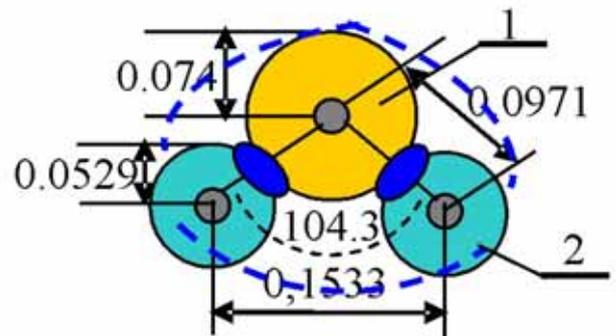

Figure 1. A water molecule and the size (in nm) of: 1 - atom of oxygen; 2 - atom of hydrogen

According to Eqs. (9) and (10), one obtains the number of degrees of freedom and the concentration of particles in the intermediate zone when the gas state gradually changes into the liquid state in a certain temperature interval. In the liquid state, the situation becomes more complicated.

Medium in the liquid state

In the liquid state, heat transfer is also described by solving the equation of heat transfer (1) with the use of empirical formulas to define the free-path length at different temperatures. Such a method of analyzing heat transfer in liquid media is approximate and does not reflect the real processes taking place in liquids at heat propagation. The application of the Umov-Poynting vector to describe heat propagation in a liquid medium is thus more fruitful. The heat energy density is also defined by Eq. (5), and the number of degrees of freedom excited in liquids by Eq. (9). However, in Eq. (5), one should consider that the particle concentration in inter-cluster volumes sharply decreases owing to the essential growth of the particle number in cluster formations. Hence, in liquids there are two grades of particles: 1 - molecules, interacting among themselves by covalent and ionic coupling energy with due account for electron-dipole and dipole-dipole interactions, and 2 - cluster formations, mainly with the first coordination layer. [*]

In heat engineering, water is for the most part used as heat carrier, because it has the maximum heat capacity. For this reason, all necessary heat engineering calculations will be executed for water in the liquid state. The water molecule is shown in Fig. 1. The effective radius of a water molecule is – from the data specified in Fig. 1 – 0.0926 nm. The oval selects a region of increased electronic density between atoms of oxygen and hydrogen. In the closely-packed state occurring in clusters, the distance between water molecules is 0.0185 nm. The distance between water clusters in the liquid state is obtained in terms of the density value. For water molecules, $r_0 = \sqrt[3]{\dfrac{m_{H2O}}{8\rho}}$. In normal conditions, $r_0 = 0.155$ nm, and the effective radius of the water basic cluster is $r_{cl.} = 0.297$ nm. According to the data from the reference guide [4], the ionization energy of the water molecule is 12.614 eV. Under the value of the effective radius and of the ionization energy of the first multiplicity, the energies of ionization of the second and third multiplicity are obtained as well as the effective radiuses and effective charges of the water molecule of the second and third multiplicity of ionization.

Using these data and the technique described in [5], one computed the coupling energies of the water molecule inside the cluster and the inter-cluster binary interaction. These values were found to be : $E_{\text{couple},1} = 0{,}178$ eV and $E_{\text{couple, 2}} = 0{,}086$ eV, respectively. Free molecules of water in the liquid state are connected between themselves by the energy of 0.0647 eV. On the liquid surface, molecules are surrounded by six molecules in the horizontal plane and by one molecule in the vertical plane. Then, the resultant coupling energy of individual molecules on the water surface will be 0.45 eV which coincides with the value obtained from the data on saturated vapors (0.46 eV), and from the value of the surface tension force.

The liquid state occurs when $E_{couple,1} \geq 3k_BT_L$.(T_L - temperature of the liquid). At the boiling temperature, the energy of binary coupling is decreased by a quantity of:

$$E_{boil} \cong 3k_BT_{boil} = 0.0964 \text{ eV} \qquad (11)$$

and at the melting temperature by a quantity of:

$$E_{melt}\, 3k_BT_{melt} = 0.0706 \text{ eV.} \qquad (12)$$

In the interval between the boiling temperature of 373 K and the ice melting temperature of 273 K, water stays in the liquid state. It turns out that the binary coupling between clusters in the liquid state is so weak that clusters practically do not interact among themselves and are free. In the temperature range where the liquid state is implemented, the heat energy density is defined also according to Eq.(5), but taking into account Eqs.(9) and (10). Then:

$$w_L = \frac{i}{2} k_B T_{eff}.n\,, \qquad (13)$$

where n is the total particle concentration.

Free water molecules do translational movements; and, colliding with clusters, they implement the exchange coupling between clusters which has a spherical symmetry. The arising spherically symmetric forces of interaction at the equilibrium distance prevent volumetric compression and simultaneously promote free spreading out of the liquid. Free two-atom molecules in the liquid state have three translational and two rotational degrees of freedom, and three-atom molecules have three translational and three rotational degrees of freedom. Clusters in the liquid state have three vibrational and three torsion-and-vibrational degrees of freedom.

Heat propagation in liquids (in the absence of radiant heat exchange) is defined by the velocity of sound propagation. Normally, the velocity of sound in water is obtained from the empirical formula $v = \sqrt{\rho k_S}$, where k_S is the adiabatic coefficient of compression. For every particular liquid, the adiabatic coefficient of compression is defined empirically. Therefore, the liquid state is not sufficiently investigated with regard to the formation of cluster structures.

In liquids, only longitudinal sound waves propagate along a normally applied force. Under the action of such a momentum, some mass of liquid dm will start traveling at a velocity of v. Then:

$$\vec{F}dt = dm\vec{v} \qquad (14)$$

If equality (14) is divided by the area of force action S, then we obtain the pressure pulse:

$$Pdt = \frac{dmv}{S}\,. \qquad (15)$$

Expressing the mass dm in terms of density, and pressure in terms of the Young's modulus, we obtain, with consideration of Eq. (13):

$$E = \rho v^2. \qquad (16)$$

From here, we obtain the velocity of propagation of longitudinal waves of compression in liquids $v = (E/\rho)^{1/2}$.

The module of volumetric compression for a flat wave of compression is defined :

$$E = \frac{[E_{coupl.,1}(r) - E_{coupl.,1}(r_0)]}{2\pi e^2 r_0^3} \frac{3k_BT}{E_{coupl.,1}(r_0)} \frac{1}{N_{cl.}}$$

where $N_{cl.}$ is the number of particles in the cluster at a temperature of T.

---

[*] Previously, as applied to water, oit was believed [3] that these are splinters of not thawed ice, formed by hydrogen coupling. In fact, these are clusters and the coupling between them is defined by dipole-dipole coupling.

The mean effective radius of the water molecule is ~ 0.926 Å, and the mean effective distance between molecules, obtained from the value of water density, is 1.552 Å. From here, the fraction of free volume in water is ~ 0.79, and, if accounting for the formation of clusters, then this fraction of free volume in water increases. One should consider that only free volume lends itself to compression. For this reason, at sound propagation in liquids, the maximum compression coefficient is:

$$\chi = 1 - \frac{4r_0^3}{r_1^3} = 1 - \frac{4 \cdot 0,926^3}{1,552^3} = 15\% \ .$$

In gases, the compression of free volume of molecules can reach 100 %, and in liquids it is 7 times less (for water 15 %). With respect to this parameter, the liquid corresponds to the gas. For water, such compression is generally not reachable. In reality, at sound propagation in water, pulse compression occurs, which depends on the amplitude of a sound wave. To obtain the dependence of sound velocity on temperature, one should regard the compression coefficient as a variational parameter.

Table 1 shows the pulse compression values at which the velocities of sound wave propagation correspond to experimental data. With respect to the compression module, water approaches the solid.

Table 1. The magnitude of the volumetric module of compression, the velocity of propagation of sound, and the coefficient of volumetric compression of water versus temperature

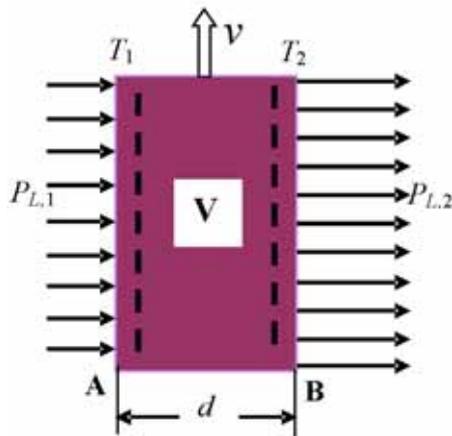| Parameters	Temperature, K					
	273	283	293	303	350	373
$E \cdot 10^{-9}$, Pa	1.96	2.09	2.20	2.26	2.64	2.86
v, m/s	1401	1446	1482	1503	1625	1692
χ , %	9.80	9.60	9.50	9.55	9.60	9.60

Figure 2. A diagram of heat propagation in a medium in a one-dimensional approximation

The liquid state is a complicated system of interacting particles which – under the influence of an external disturbance – can come nearer and diverge to sufficiently large distances. For this reason, the molecules in the liquid state execute random translational movements inside the liquid.

On the basis of Eqs. (5) and (16), the heat transfer in liquids is defined by the value of the Umov-Poynting vector.

$$P_L \approx \frac{1}{2} k_B T n \left(6W_2 + 3W_1 \right) \sqrt{\frac{E}{\rho}} \ . \tag{17}$$

Here

$$W_2 = \int_{E_{coupl.} - 3k_B T}^{\infty} f(E,T) dE$$

and

$$W_1 = \int_0^{E_{coupl.} - 3k_B T} f(E,T) dE$$

A general diagram of heat propagation in a one-dimensional case is given in Fig. 2. Under the action of the heat flux $P_{L,1}$, the surface A of the considered flat layer of the liquid medium is heated up to the temperature T_1. The heat flux $P_{L,2}$ from the surface B affords the temperature T_2. When not taking into account the processes of heating up and cooling of bonding surfaces, then one can apply the heat transfer equation (1). But such a case is not really implemented in Nature. Besides, when solving an equation of the second order, it is necessary to establish boundary and initial conditions which one cannot formulate without the reasons of their occurrence in each particular case. We will consider some different cases.

At $P_{L,1} > P_{L,2}$, the medium will heat up. In a time of t, the medium will heat up to a temperature of:

$$T = T_0 + \frac{P_{L,1} - P_{L,2}}{\rho d \bar{c}_V} t \ . \tag{18}$$

The process of heating up works continuously.

At $P_{L,1} < P_{L,2}$, the medium being considered should be cooled continuously under the law (18).

Solids

The solid is a crystal. In the solid crystal lattice, the internal heat energy is formed by longitudinal and transverse vibrations of clusters. Besides, one should account for the energy of random translational moving of particles in inter-cluster free volumes, and for the energy of torsion vibrations of clusters with respect to their own centre of gravity. The resultant internal heat energy is represented as:

$$Q = \sum_j \frac{3}{2} W_j E_j = \frac{3}{2} k_B T_{eff.} \ , \tag{19}$$

where $j = 1$ corresponds to the energy of translational degrees of freedom E_1 with the probability of their excitation W_1; $j = 2$, 3, and 4 correspond to the energy and probability of their excitation for torsional, longitudinal and transverse vibrations of clusters inside the crystal lattice. If in the medium being considered, a temperature difference is created in some direction, then energy transfer occurs. In the most general case, energy transfer is defined – according to Eq. (4) – by the Umov-Poynting vector.

The heat energy density should be found as:

$$w = \frac{3}{4\pi r_{cl.}^3} \frac{3}{2} k_B T_{eff.} \ . \tag{20}$$

Earlier, while considering the classical theory of heat capacity, one assumed that the internal energy in solids was only defined by harmonic oscillations of individual atoms or molecules with respect to their equilibrium. As a result, the internal energy of solids was only presented – according

to the law of uniform distribution of heat energy over degrees of freedom – through the vibrational degrees of freedom as $3 \cdot k_B T/2$ [6]. To agree with the Dulong and Petit law, such oscillations were attributed two more degrees of freedom, conditioned by the fact that the oscillative mode of motion contains two kinds of energy – kinetic and potential – which continuously convert to one another in equal quantities.

Such an approach contradicts the law of uniform distribution over degrees of freedom, as the temperature is defined by the maximum energy contained in one degree of freedom rather than by the energy contained in its fraction. One should consider that any absorption of energy is conditioned by the excitation of a definite degree of freedom with respect to its energy of coupling. At considerable energy of coupling between particles inside solids, their excitation is practically excluded.

The contradictions between the classical theory of heat capacity at low temperatures, near the absolute zero, and the experimental data were removed by the quantum theory which assumed that the crystal as a unit executed oscillations. Then the crystal at low temperatures was to have executed elastic vibrations, and the sound was to have propagated in the environment. However, such a phenomenon is not observed.

Therefore, the internal energy of solids is not defined by the oscillations of the individual particles composing it or of the whole crystal relative to equilibrium, but by the behavior of individual clusters and by their interaction with different particles in the solid. At low temperatures, the internal energy is conditioned by the value of coupling energy of the particles – of the third coordination sphere – with the basic cluster. In this case, all contradictions are removed, as it has been shown in [7].

In solids, the individual free atoms, molecules or clusters are in the inter-cluster volume. The total number of particles in each free inter-cluster volume is:

$$N_{coupl.} = \sum_i N_i \int_{E_i}^{\infty} f(E, T_{eff.}) dE . \qquad (21)$$

If only translational degrees of freedom are excited, then one particle is fallen at the internal energy $3k_B T_{eff}/2N_{coupl.}$. Similarly, one defines the energy – fallen at one particle – for rotational and vibrational degrees of freedom.

The heat propagation process in solids should be considered as successive excitation – from a cluster to a cluster – of all degrees of freedom defining the internal heat energy according to Eq. (20). At that, one should consider that the heat flux action is not carried out on the pure material directly, but through an intermediate layer of oxides of the given material and through a layer of adsorbed atoms, molecules of the environment, and, in each case, with its own velocity of heat flux propagation.

In solids, in the process of temperature decrease and owing to atoms interaction with each other, stable two-atom molecules are created, and then the interaction of atoms with two-atom molecules creates three-atom molecules. The resulting molecules interact among themselves, with each other and with individual atoms. At that, the creation of three-atom molecules cannot occur owing to triple collisions of atoms with each other, but such molecules are created at binary interaction of atoms with two-atom molecules.
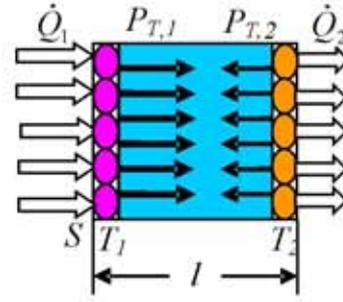

Figure 3. A general diagram of heat propagation in solids

The obtained coupling energies of the binary interaction of particles in molecular structures and of their relative disposition in the process of cluster structure creation testify that cluster structures are only created owing to the binary interaction of individual atoms with each other, and such a cluster structure is considered in [6]. At temperatures near the absolute zero, in the third coordination layer, complicated structural formations can occur, leading to the increase in energy of coupling between crystal particles which should inevitably change the physical and mechanical properties of the solid at low temperatures.

Clusters are not only formed by the binary interaction between individual atoms, but also through the creation of structures around three-atom molecules. As a result, there are implemented complex allotropic changes in the solid, according to the growth or reduction of the crystal temperature [3]. All this should be considered when defining the volumetric density of heat energy in the solid.

Let us consider heat propagation in the solid. A general diagram of heat supply and suction applied to the solid is given in Fig. 3. On the solid surface, there are oxide layers or adsorbed atoms/molecules. These surface layers define the interaction with the heat flux falling on the solid $\dot{Q}_1$ and with that, going out $\dot{Q}_2$. The falling heat flux heats up the surface layer to the temperature T_1, and the outgoing heat flux maintains the temperature T_2. In these circumstances, $T_1 > T_2$. Inside the solid, the heat flux $P_{T,1}$ occurs, and the flux $P_{T,2}$ moves in the opposite direction. Both fluxes are defined by the Umov-Poynting vector:

$$P_{T,1} = 3k_B T_1 n \sqrt{\frac{E_1}{\rho}}; \ P_{T,2} = 3k_B T_2 n \sqrt{\frac{E_2}{\rho}} .$$

In a time of dt, the solid will heat up and its temperature will increase by a quantity dT. On the basis of the heat-balance equation, we obtain:

$$(P_{T,1} - P_{T,2})Sdt = c_V Sl\rho dT .$$

Hence it follows that the solid will be heated up from T_2 to T_1. The time, during which the process continues, is:

$$t = \int_{T_2}^{T_1} \frac{c_V l \rho^{3/2} dT}{3k_B T_1 \sqrt{E_1} \left(1 - T\sqrt{E} / T_1 \sqrt{E_1}\right)} . \qquad (22)$$

If we account for the arising heat fluxes, absorbed by solid, and the value of heat rejection, then integral (22) becomes more complicated, as the temperature on the borders varies, and we have a non-stationary heat transfer problem. In each particular case, it is quite a solvable problem. Specifically, such a problem has been solved in [5].

Conclusion

The heat transfer problem has not been considered from the viewpoint of solving the differential equation of the second order offered by Fourier, but from a more general viewpoint to apply the Umov-Poynting vector. In this approach, heat propagation in different media is considered from a unified position. Boundary conditions follow from the statement of the problem itself, and they should not be prescribed. In order to obtain the heat propagation flux, one should establish the medium and the heat flux values on the borders.

References

[1] Physical quantities. Handbook / A.P.BABICHEV, N.A.BABUSHKINA, A.M.BRATKOVSKY, et al..; Editors I.S.GRIGORIEV, E.Z.MEILIHOVA. – M.; Energoizdat, 1991, - 1232 pages.

[2] SIVUKHIN,D.V.: *Course of general physics. Electricity.* – M: Science. 1996. P. 2. – 320 pages.

[3] RADTSIG,A.A., SMIRNOV,V.M.: *Handbook on nuclear and molecular physics.* – M: Atomizdat. 1980 - 240 pages.

[4] GLINKA,N.L.: *General chemistry: Educational aid for higher education institutions.* 23rd ed., corrected/ editor V.A.Rabinovich. - L: Chemistry, 1983. - 704 pages.

[5] KUTS,N.G., GRECHIHIN,L.I.: *Influence of stationary and non-stationary heat transfer on operational efficiency of diesel engine.*, Advance technologies and systems of machine-building. International collection of proceedings. - Donetsk. DonNTU. 2011. Issue No. 42. pp. 137–148.

[6] SIVUKHIN,D.V.: *Course of general physics.* Thermodynamics and molecular physics. – M: Science. 1972. – 551 pages.

[7] GRECHIKHIN,L.I.: *Nanoparticles and nanotechnologies.* - Minsk.: «Right and economy», LLC, 2008. - 406 pages.

Primena Umov-pointnog vektora pri rešavanju problema prenosa toplote u tehnici

Razmatra se problematika prostiranja toplotnog fluksa uzimajući u obzir atomsko-molekularnu i klaster (oblik čestica) strukturu različitih agregatnih stanja materije. Prostiranje toplote se ne razmatra sa aspekta termičke provodljivosti, već u kontekstu toplotnog prostiranja koristeći pri tome Umov-Pointni vektor. Toplotni kapacitet je definisan na osnovu verovatnoće ekscitacije (pobuđivanja) različitih stepena slobode za svaku od čestica formirane sredine. Pri prostiranju toplote uzima se uobzir promena agregatnog stanja, struktura sredine i toplotni kapacitet u funkciji od temperature. Objašnjen je proces razmene toplote u graničnom podruju različitih agregatnih stanja. Pokazana je nemogućnost primene jednačine toplotne provodljivosti pri prostiranju toplote kroz različita agregatna stanja. Primenom Umov-Pointnog vektora rešava se problem prenosa toplote i toplotnog fluksa u graničnom području bilo koje sredine.

Ključne reči: **toplotna provodnost, prenos toplote, toplotni fluks, toplotni kapacitet, jednačina prenosa toplote, Umov-Pointni vektor, agregatno stanje.**

Применение вектора Умова для решения теплопроводных задач в технике

Рассмотрено распространение тепловых потоков с учетом атомно-молекулярной и кластерной структуры разных агрегатных состояний. Распространение тепла рассмотрено не с позиций температуропроводности, а с позиций распространения тепловой энергии, используя вектор Умова-Пойнтинга. Теплоемкость определена с учетом вероятности возбуждения разных степеней свободы для каждых частиц, формирующих среду. При распространении тепла учитывалось изменение агрегатного состояния, структуры среды и ее теплоемкости от температуры. Выяснены, какие процессы теплообмена возникают на границе раздела разных агрегатных состояний. Показана несостоятельность применения уравнения теплопроводности для получения распространения тепла в разных средах. Применение вектора Умова позволяет решать теплопроводные задачи в любых средах, задавая среду и величины потоков тепла на границах раздела.

Ключевые слова: **теплопроводность, теплопередача, тепловой поток, теплоемкость, уравнение теплопроводности, вектор Умова-Пойнтинга , агрегатные состояния.**

Application du vecteur Um Point pour la résolution du problème de transfert thermique dans la technique

Dans ce papier on étudie le problème de la diffusion de flux thermique en considérant la structure atomique moléculaire et le cluster (formes des particules) de différents états de matière. La diffusion de la chaleur n'est pas examinée du point de vue la conductance thermique mais dans le contexte de la diffusion en utilisant le vecteur Um Point. La capacité thermique se définit en partant de la probabilité d'excitation de divers degrés de liberté pour chaque particule du milieu formé. Pendant la diffusion de la chaleur on tient compte du changement de l'état,de la structure du milieu et de la capacité thermique en fonction de la température . On a expliqué le processus de l'échange de chaleur dans la région limite de différents états de matière. On a démontré aussi l'impossibilité d'emploi de l'équation de la conductance thermique au cours de la diffusion de la chaleur à travers les divers états de matière. A l'aide du vecteur Um Point on résout le problème du transfert de la chaleur et du flux thermique dans la région limite de chaque milieu.

Mots clés: **conductance thermique, transfert de chaleur, flux thermique, capacité thermique, équation du transfert de chaleur, vecteur Um Point, état de matière.**