MODELO MATEMÁTICO (MM) DE LÍQUIDOS À LUZ DA MANIFESTAÇÃO DO MECANISMO DE AQUECIMENTO DISSIPATIVO E OUTRAS PROPRIEDADES DA MATÉRIA

MATHEMATICAL MODEL (MM) OF A LIQUID IN THE LIGHT OF DISSIPATIVE HEATING MECHANISM MANIFESTATION AND OTHER PROPERTIES OF THE MATTER

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ (ММ) ЖИДКОСТЕЙ В СВЕТЕ ПРОЯВЛЕНИЯ МЕХАНИЗМА ДИССИПАТИВНОГО РАЗОГРЕВА И ДРУГИХ СВОЙСТВ МАТЕРИИ

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RESUMO

Este trabalho visa estudar a relação entre as manifestações dos modos de aquecimento dissipativo e deformação e estrutura do material. A relação entre o mecanismo de aquecimento dissipativo do material e tanto os modos de deformação quanto a estrutura do material, foi estabelecida apenas ao derivar equação de viscosidade teoricamente e ao criar um modelo matemático do material que estabeleceram o mecanismo de interação entre cargas externas e resistências internas consideradas neste trabalho. Os resultados do estudo permitiram criar um modelo matemático de líquidos descrevendo a manifestação das propriedades físico-mecânicas do material sob diferentes modos de deformação, incluindo o estabelecimento do mecanismo de aquecimento dissipativo e a eliminação de erros de cálculo. Com base nos dados obtidos, tem sido sugerido que a liberação de calor dissipativo é quase independente do período inicial de oscilação das unidades cinéticas no material. O uso desse modelo matemático no processamento de materiais otimizará os modos de tecnologias existentes e, ao desenvolver novos materiais, possibilitará planejar as propriedades dos materiais operando em determinadas temperaturas e cargas.

Palavras-chave: *modelo matemático, viscosidade, aquecimento dissipativo, modos de deformação*.

ABSTRACT

This work aims at studying the interrelation between the manifestations of dissipative warming up with modes of deformation and the structure of the material. The mechanism of dissipative warming up of the material, both with modes of deformation and the structure of the material, managed to connect only on the basis of the theoretical derivation of the viscosity equation and the creation of a mathematical model of the material that established the mechanism of interaction between external loads and internal resistance considered in this work. The results of the study allowed us to create a mathematical model of liquids, describing the manifestation of the physicomechanical properties of a material under different modes of its deformation, among them the establishment of a dissipative warming up mechanism and the elimination of calculation errors. On the basis of the data received, it was made an assumption that the dissipative heat release is almost independent of the initial period of oscillation of the kinetic units in the material. The use of this mathematical model on the practice of materials processing will optimize the modes of existing technologies, and when developing new materials, plan the properties of materials, operating at given temperatures and loads.

Keywords: *mathematical model, viscosity, dissipative warm-up, the modes of deformation*.

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АННОТАЦИЯ

Данная работа направлена на изучение взаимосвязи проявления диссипативного разогрева с режимами деформирования и структурой материала. Связать механизм диссипативного разогрева материала как с режимами деформирования, так и со строением материала удалось только на основе теоретического вывода уравнения вязкости и создания математической модели материала, установивших механизм взаимодействия внешних нагрузок и внутреннего сопротивления, рассмотренных в данной работе. Результаты исследования позволили создать математическую модель жидкостей, описывающую проявление физико-механических свойств материала при разных режимах его деформирования, в том числе установить механизм диссипативного разогрева и устранить погрешности расчетов. На основе полученных данных сделано предположение, что диссипативное тепловыделение практически не зависит от начального периода колебания кинетических единиц в материале. Применение данной математической модели в практике переработки материалов позволит оптимизировать режимы существующих технологий, а при разработке новых материалов, планировать свойства материалов, работающих при заданных температурах и нагрузках.

Ключевые слова: *математическая модель, вязкость, диссипативный разогрев, режимы деформирования.*

INTRODUCTION

The technology of dissipative heating of materials may have been familiar to ancient people. The processing technology of various materials, which belongs to Maya is quite interesting for our days. Until the end, it has not been unraveled, but there is a theory that in order to give different stones the same shape, the ancient people knew how to soften them. In the book The Unfinished Journey by Percy Fawcett, an interesting information is telling. In the forests on the slopes of the mountains of Bolivia and Peru dwells a small bird that looks like a kingfisher. It makes its nests above the river – in neat round holes on the surface of rocky slopes, which they also make. They fly to a cliff, holding in the beak the leaves of one particular plant, and then, clinging to the rock, like woodpeckers for a tree, begin to rub its surface in a circular motion until the leaf crumbles. Then they fly away again and return with the leaves, continuing the process of rubbing. After three or four times the bird no longer brings fresh leaves. It begins to peck the stone with a sharp beak and the rock begins to crumble like wet clay; a round hole is formed in it that is deep enough for the bird to make its nest (Fawcett, 2014; Sokolov, 2002).

This plant is called ek, which grows in all forests, Hun-Akhnu and Shbalank and it helps to soften hard stones. But it is unknown whether it is possible for them to soften granite, so this technology has not been completely unraveled. In Figure 1 it can be seen the result of stone softening technology of Mayan civilization.

The existing methods of calculations of the resistance to flow of fluids and polymer systems through channels of different lengths and sections, basing on the account of influence of the diagram of the speed regarding shear and dissipative heat generation on the change in the viscosity of the deformable material (Landau and Livshits, 1988; Vinogradov and Malkin, 1977; Blokhin and Semisalov, 2016; Kolodezhnov and Kapranchikov, 2010; Moskvitin and Sabirov, 1993) do not make it possible to eliminate the error of the calculations that increases with decreasing channel length and sometimes reaching up to 500%.

The reason for the manifestation of such anomalous behavior of liquids is associated with the input effect. Trying to explain the mechanism of its formation both on the basis of the above factors, undoubtedly having the place, and associating it with a structural change, flowing in the material in the pre-stationary stage of flow and affecting viscosity (Evdokimov and Eliseev, 2005; Yurchenko *et al.*, 1973). However, succeeded to relate the viscosity with the structure of liquids only after establishing the mechanism of interaction of external loads and the internal resistance of kinetic units (KU) of materials, having carried out the theoretical derivation of the Newtonian viscosity equation (Yurchenko and Yurchenko, 2017). In turn, this made it possible to carry out a number of refinements in the existing approach and create a mathematical Model (MM) of Newtonian and non-Newtonian fluids (Bernoulli, 1959), which eliminated the concept of anomalous effect.

The relevance of studying the mechanism of dissipative warming up in the processes of deformation of different materials is caused by the need to determine the value of this factor under certain deformation modes and its influence on the properties of materials to resist, including on the viscosity (Formalev and Kolesnik, 2017). In addition, further analysis of the process (carried out below) made it possible to uncover the mechanism of dissipative heat release, connecting it with both the structure and the modes of material deformation.

MATERIALS AND METHODS

Adopted at the theoretical derivation of the viscosity equation (Yurchenko and Yurchenko, 2017), the statement about the constancy of the interaction energy of kinetic units (KU) of a liquid allows us to show that by relating the value of this energy ($\xi = const$) or to the volume W, or to the mass m or to the force $F = m \cdot g$, can be consistently moved to different systems for evaluating the process in question, what and applied Bernoulli in his work (Bernoulli, 1959).

And since the dimension of these systems is determined as a result of reducing the energy of KU to permanent (m, W, m · g), the process of interaction of external and internal energies is considered at the level of the remaining variables ($\vartheta^2, P, Z = l$), through which are carried out differentiate and integrate of these variables in the received systems of their evaluation.

It goes without saying that an accepted research method based on the application of differentiation and integration of variables and neglecting permanent can lead to errors due to the distortion of the mechanics of the process itself. For example, how did this happen when Newton introduced a new characteristic of the process — the impulse of force J based on the representation of the process with the help of balancer weights when he neglected the oscillation amplitude.

RESULTS AND DISCUSSION:

We will simulate on the same weighers the process of interaction, only already at the level of balance of external and internal energy (E = n · ξ), written in the form of an expanded equation – Equation (1), where the action of potential energy is modeled as in the previous work (Mazo, 2007) by the force $F = M \cdot g = const$ on one of the equal arms of the balancing weights and the kinetic energy is applied to the second arm in the form of a certain number n of pulses I, acting during some period of time $T = {}^{t}/_{n}$ so that the amplitudes of oscillations of both arms will be the same $\lambda_1 = \lambda_2$, and the equilibrium is ensured by the balance of energies $E = n \cdot \xi$.

Given the discrete structure of the liquid, characterized by the limiting value of the amplitude of oscillation KU $\lambda = const$, the rate of the supplement of impulse was determined by offset rate KE $\vartheta = {}^{\lambda}/_{T}$. Therefore, writing down the balance of energies (1) at the level of impulse interaction (Equation 2), let's review the process of deformation taking into account the interaction of KU.

As a result, we obtain that when ${}^{l}/_{n} = \lambda$ the plastic deformation must occur at the level of the limiting amplitude $\lambda = const$. And given that $F = M \cdot g = const$ in Equation (2) characterizes the external influence, and the second term (${}^{I\lambda}/_{T}$) – internal resistance KU, we rewrite Equation (2) as Equation (3), where are the variables I and ϑ will be related by inverse proportional dependence for any amplitude value.

Reduction of which leads to the concept of a momentum of force (Equation 4), from where at $T = {}^{t}/_{n}$ get the definition of the pulse of force given by Newton (Equation 5), according to which some amount n of the pulse of force I, each of which consists of force F, acting during the time $t = T \cdot n$, produces the same effect as the force itself, acting continuously during all the entire interval t of the absolutely current time.

Thus, the process that is actually carried out in the energies balance system (3), transferred by Newton to the force balance system by banal reduction of equivalent amplitudes of oscillation ($F = M \cdot g = const$), that operating continuously in absolutely current time and space. In which the same value of speed (Equation 6) is determined by different values of l and t, thus introducing into the estimate of the process the uncertainty of these quantities, which transmits not only into Newton's Mechanics but also into the impulse interaction system.

Indeed, using the method of reducing both

sides of the equation by one and the same value, by attributing to the speed ϑ the left and right sides of Equation (3) – Equation (7), we will return again to the evaluation of the process in the system of a continuously acting force, when, to determine the value of the impulse of force, as part of $n = F \cdot {}^{T}/_{J}$ from this force, it becomes necessary to introduce the units of current time $[t] = 1c$, connected with the definition of the period T. What in the pulses balance system (4 ÷ 6) leads to the uncertainty of the meanings of amplitudes.

It remains only to show that the balance of energies can be achieved if strongly, but rarely or weakly, but often tapping on the unloaded arm. Passing, thus, to different amplitudes of oscillations, up to amplitudes of oscillations of KU. This allowed Newton to neglect the "imperceptible fluctuations" of the arms of the balance weights. As a result, the concept of the impulse of force was introduced into physics and the uncertainty of length into the Newton`s Mechanics.

The essence of uncertainty in both the first and second cases is associated with the uncertainty of the limiting value of the oscillation amplitude modeled with the help of balancer weights when the balance of energies can be performed at different amplitudes of the oscillations of their arms.

And because in real materials, due to their discrete structure, the amplitude of oscillation of KU has a limiting value $\lambda = const$, also just like the internal energy $\xi = const$, who provides a countering to the shift of the KU mass by $\lambda = const$ when an external force is applied (Equation 8), then the displacement rate of KU fluid is determined by the marginal amplitude $\lambda = const$ (Equation 9).

Whereas in a homogeneous continuous medium, displacement with the same speed is defined as a series of successive shifts in space and in time, similarly to Equation (6) – Equation (10).

Therefore, at the same speed value (9) and (10) the number of displaced KU fluids n, the determining value of the energy expended may be different. In (Blokhin and Semisalov, 2016), it was shown in the work, the value of the expended energy, at the same velocity, will depend on the number of displaced KU or on the frequency of their displacement per unit time.

Moreover, the introduction of the definition of the rate of relative shift of KU in a discrete medium ($\vartheta = {}^{\lambda}/_{T}$ at $\lambda = const$) into the energies balance equation (3) – Equation (11) allowed to explain the mechanics of the process under consideration in (Loitsyansky, 1987), and reduction of the amplitude λ which were carried out and the transformation led to the discovery of a potential barrier (Equation 12), in which the variables J and T is connected with the inversely-proportional dependence, when a change in one of them determines a change in the other due to the constancy of the product $m \cdot \lambda = const$ (Equation 13). Therefore, both the variables themselves and their increments connected by the same constant $m \cdot \lambda = const$ should not be divided.

Visually, such interrelation was showed earlier (Van-Dayk, 1986) for the case of KU shifting by a constant value $\lambda = const$, at $d\vartheta = {}^{\lambda}/_{dT}$, when $d\vartheta \cdot dT = \lambda = const$ turns, just like (12), into the inverse-proportional interrelation. Wherein, the nature of their relationship is explained by a nomogram, which is reflecting the resistance of KU the fluid to the action of external forces at a constant value of the potential barrier (12), shown in Figure 2 in the *II* quadrant from changes of speed of relative shift KU for the limiting displacement $\lambda = const$, which is presented in the *IV* quadrant.

Wherein, the constancy of the mass of KU m in the system of impulses of force (Figure 2, I), obtained by eliminating the speed of the relative shear, by reducing it from the definition from the energy of KU (Equation 14) shows that any change in the (14) of the pulse force value $J = F \cdot T$ leads to a directly proportional change in shear rate KE $\vartheta = {}^{\lambda}/_{T}$, the definition of which includes a constant $\lambda = const$.

Expressing in the Equation (14) the rate of the relative shift of KU, taking into account the discrete structure of the liquid (Equation 15) and have carried out the transformation of Equation (15) to the following form – Equation (16) we come again to the existence of the potential barrier (12) not only in the system of pulses but also in the transition to the current time t and the space in which the velocity is determined according to (10). Further, having conducted in Equation (11), written as Equation (17) the replacement in its right

part, according to (4), derivative $J \cdot n$ to $F \cdot t$ we will get Equation (18), which upon subsequent conversion to the form – Equation (19), where $l/t = \vartheta$ leads to the definition of the acceleration mechanism $a = \vartheta/T$ as speed changes ϑ at some period of time $T = t/n$.

It goes without saying that all the refinements made to the interaction of "external and internal forces" are aimed at clarifying the MM mechanism that evaluates the process at the level of the balance of impulse interaction. In this case, it is necessary to proceed from a consideration of the balance of external and internal energies (1) to consideration of the process at the level of the balance of impulses of force and to express the properties manifested by the liquid in the system of impulse interaction with the KU fluid.

For what, we will ascribe again the balance of KU (3) energies to the speed of their relative shift ϑ, writing down (Equation 20). Having transformed this Equation (20) in connection with the replacement of F to $m \cdot a$ and the abbreviations, we proceed to consider the process of interaction at the level of the impulse of force (Equation 21). Once again transforming Equation (21) as Equation (22), let's do its differentiation (Equation 23)

And since the shear rate of KU is determined taking into account the limiting value of the oscillation amplitude (9), and do not allowed to separate it, as in the case of the potential barrier (12), as the variables themselves ϑ and T, so and their increments ($d\vartheta \cdot dT = \lambda = const$) нельзя, we will express in Equation (23) the increment of the speed as Equation (24)

Then we carry out the transformation of Equation (23), contributing to the selection of a constant $\lambda = const$ (Equation 25), characterizing one plastic displacement of KU, included in the definition of external energy spent on reversible (elastic) and irreversible (plastic) deformations (Balashov, 2018), presenting them as a sum of displacements (Equation 26).

Consequently, to conduct further research, it is also necessary to express and the elastic displacement KU (λ_y) in the impulse interaction system. And as the interrelation of the internal energy of KU, which resists to their deformation, with the internal structure is currently only considered, so the definition of elastic displacement λ_y, as a function of the pulse of force, we will find from the experimentally established dependence (Equation 27).

Given that the force acts continuously in time, and the deformation of the sample is determined at standard speeds of movement of the clamps $\vartheta = l_y/t$, we specify the mechanics of the experiment by writing (27) as Equation (28).

As a result, the module G', *kg/s²* will receive the dimensionality G *kg/s*. Further, given, that $t = T \cdot n$, the action of a force can be transferred to the level of impulse interaction by writing – Equation (29). From where the amplitude of the elastic displacement of KU in the impulse system of the balance of forces, expressed as Equation (30).

In this case, the total external energy expended per one offset λ KU, determined according to (26), when replacing ϑ^2 to λ^2/T^2, will be written as Equation (31)

Further, taking into account the interrelation between kinetic and potential energies, presented in (Sadin, 2017), we consider the process at the level of transition from potential energy to kinetic at $\lambda = 0$, and due to the impossibility of separating variable ($dJ \cdot dT$), we will transform Equation (31) to the following type – Equation (32) and having spent the integrating (Equation 33) get an expression that determines the manifestation of the properties of liquids that depend on persistent (m, λ and G), as well as their loading in time, which are variables in the process under consideration (Equation 34).

Or after the conversions to the next form (Equation 35) and taking into account that the limiting amplitude of the oscillation of KU, as was shown earlier (Bazhenov and Kovalchuk, 2008), consists of 2 amplitudes, the deviation from the equilibrium state $\lambda_{ku} = 2\lambda$ the value of the pulse of force I, needed for that to achieve plastic displacement, is determined by the Equation (36), which actually represents the MM of the fluid at the level of the pulse interaction, the mechanism of which is shown in Figure 3.

As we can see, the resulting MM differs from the MM (Chizhiumov, 2007) only by the presence of the persistent C_1 and C_2 accurately reflects the mechanics of the deformation process itself, which shows that the change in amplitude is

determined according to the following Equation (37).

Figure 3 clearly shows the amplitude increase to the limiting value λ and its dependence on both the values $\bar{I}$ and T, which characterize the external influence, also and from m and G, which characterize the internal properties of the material. And since T according to (9) determines the duration of the shift of KU, then in channels of different length (Equation 38) even with the same meaning T (38) different forces $\vartheta_1 \neq \vartheta_2 \neq \ldots \neq \vartheta_n$, and, accordingly, and different expenses Q lead to a different number n of shifts KU per unit of time. Therefore, uncertainty is introduced into the strain estimate from the standpoint of a continuous medium due to the elimination of the potential barrier existing in nature (12), characterized by the derivative $m \cdot \lambda = const$.

In Figure 3, the overcoming of the potential barrier $m\lambda = JT$ presented as the achievement of the limiting value of the amplitude λ depending on the value of the pulse of force $I = m\vartheta$ and the duration of t of its application for certain values m and G.

All this led to different systems for evaluating the process in time. So, according to (36), in order to achieve the displacement of KU per unit time $t = 1$ sec, it is necessary to determine the value of the applied pulse of force, the corresponding period of oscillation $T = {}^{t}/_{n}$ KU. Then how from the position of the absolutely current time $[t]$ the increase in amplitude to the limiting value is determined by the number of beats $n = {}^{t}/_{T}$ and will depend on the process evaluation system in time. Accordingly, for a continuous medium and absolutely current time, the value of the impulse of force will be written as Equation (39).

In addition, the amplitude change for this case will be determined as Equation (40) and will depend on the impact force and the number of blows - the smaller the impact force, the greater the n, the smaller the increase in amplitude on time.

As can be seen from Figure 3, the resulting mathematical model of liquids (39) shows that derivative $I_1 \gg I_2$ leads to a reduction in numbers n_1 of the strikes at the arm of the balancer weights $([n]_1 \ll n_2)$, and, respectively, and duration $([t]_1 \ll t_2)$ of the achievement the limit value $\lambda = const$. What confirmed by the experimental fact, when the equilibrium of the arms of balancer weights can be achieved by tapping the unloaded arm with more force, but less often than with a smaller force applied much more often.

In the case when the process is evaluated relative to the unit of absolutely current time $[t = 1c]$, that is, with $t_1 = t_2 = [t = 1c]$, happens the transition to the definition of the concept of frequency γ, which estimates the number of oscillations n per unit time $[t = 1c]$ (Equation 41).

In order to visualize this process, it is necessary for Figure 3 to compress $\overline{I_2}t_2$ till the size $\overline{I_1}t_1$, by consolidating, thus the number of oscillations n_2 в $t = 1s$. In this case, the transition from different durations $t_1 \neq t_2 \neq \ldots \neq t_n$ to the standard $[t = 1s]$ leads to a change in the oscillation period T of kinetic units of the liquid (Equation 42).

And since in nature the period T of the KU fluctuation is determined by the property of the material, that the achievement of plastic shear depends on the values of m; G; λ; T_1; C_1 и C_2, which determine the behavior of the material under certain loads.

On the basis of the MM conclusion (Oleinik *et al.*, 2007), it was shown that in fluids, different from Newton fluids, in the process of deformation, the elastic deformations precede the plastic ones, and the energy expended on elastic deformation cannot be released immediately after plastic shear, as this would lead to a failure of harmonic oscillations of structure (Figure 3).

In the light of the mathematical model, this process reveals the constant C_2, which shows, that the release of elastic energy occurs during $C_2 = {}^{T}/_{4}$ and leads to an increase in the amplitude of the KU oscillation, as can be seen from Figure 3, and to the accumulation of internal energy due to the application of external energy. Surely, an increase in the amplitude of oscillation $\Delta\lambda$ will lead to a decrease in energy for subsequent deformation or to an increase in dissipative heat release.

Further, given that the flow of rubber mixtures through channels of different diameters ($\emptyset = 2r$) and lengths (L) can be considered at the

level of the balance of pressure P , acting on the surface of the section $S = \pi r^2$, and shear stress τ on the side surface of the channel $S_6 = 2\pi r \cdot L$ (Equation 43) express the shear stress τ as Equation (44). And taking into account Equation (4), we define the nature of its relationship with the impulse of force, written down – Equation (45).

Taking into account that in Equation (45) derivative $S \cdot T$ at $S = 1$ cm^2 and $T = const$ represents a constant $const$, then, according to (45), at $\tau \cdot const = \tau' = J$ the shear stress on the channel walls will fully obey the MM equation (36) and, taking into account the dissipative heat release determined by the constant $C_2 = T/4$, will be written as Equation (46).

For verification were conducted the experimental studies of three rubber compounds 7V-14, NO-68, and B-201 when pushed through a capillary viscometer through channels of different diameters ($\emptyset$) and lengths (L). Having accepted, that $(m \cdot G \cdot \lambda^2)$ in (46) determines the internal resistance, as a result of processing the experimental data, dependences $\tau(t)$ for rubber blend Б-201 at different temperatures (*60єС, 80єС, 100єС* и *120єС*), which very well obeyed MM (46), while the obtained knowledge C_1 and C_2 indeed remain constant even at different temperatures (Table 1), while the internal resistance depends on temperature.

Based on the data obtained, it can be assumed that the dissipative heat release is almost independent of the initial period of oscillations, since $T/4 = const$. And the change in shear stresses τ' with the increasing of temperature can be explained only by explaining the mechanics of the interrelation of the derivative $m \cdot G \cdot \lambda^2$. Which, as it turned out, in the study of pointed rubber mixtures, also affects on C_2 and C_1 (Table 2)

So, assuming that with an increase in the molecular weight of polyisobutylene rubber (Formalev *et al.*, 2018), the geometry of its molecules and electronic properties remain constant, only the molecular weight m will affect the property to resist the effects of external load (Golosnitskaya and Mordasov, 2011). Only in the case of testing rubbers with a molecular weight of 100 000 m.u. and 225 000 m.u. the difference in resistance to their external load according to (46) will differ by 1.5 times.

CONCLUSIONS:

After conducting the above research it can be said that the proposed MM allowed to associate the internal properties of liquids with the modes of their deformation, affecting on their resistance to external influence and uncovered their mechanism, which allows using MM both for practical and theoretical purposes. The advantage of the proposed MM is not only that it describes the behavior of a liquid (substance) under various conditions of deformation but also makes it possible to reveal the influence of each parameter of the structure of a substance on the properties manifested by it.

Experimental verification confirmed the calculation. The obtained curves of flow for these rubbers in the entire range of velocities in the channels of the same dimensions at the same temperature gave the ratio $\tau_{225}/\tau_{100} \cong 1.52$.

Since there is no possibility to study materials with the same molecular weight and different intramolecular properties (G and λ), about their influence on the character of the curves of flow $\tau(\vartheta)$ can be judged only formally, substituting different values of G and λ into Equation (46).

In addition, by revealed mechanism and features of dissipative heat release, this MM allows to choose the modes of application of external loads that contribute to the accumulation of dissipative energy in the material, leading to a change in its properties. This allows the development of new technologies for processing various materials, and also to show that those technologies for processing granite, which are attributed to the Mayan civilization, are a consequence of the manifestation of relaxation properties under the influence of long-term self-weight, which compelled the granite to flow along three vectors in accordance with the relief, on which the Mayan buildings are located.

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$$(E = M \cdot g \cdot l = F \cdot l) = n\left(m \cdot \vartheta^2 = J \cdot \vartheta = {}^{J\lambda}/_{T}\right) \quad (1)$$

$$F \cdot {}^{l}/_{n} = {}^{J\lambda}/_{T} \quad (2)$$

$$F \cdot \lambda = {}^{J\lambda}/_{T} = J \cdot \vartheta = const \quad (3)$$

$$F = {}^{J}/_{T} \text{ or } F \cdot T = J \ , \quad (4)$$

$$F \cdot t = J \cdot n \quad (5)$$

$$\vartheta = \frac{l_1}{t_1} = \frac{l_2}{t_2} = \cdots = \frac{l_n}{t_n} \quad (6)$$

$$\left(F \cdot \frac{\lambda}{\vartheta} = F \cdot T\right) = \left(J \cdot \frac{\vartheta}{\vartheta} = J\right) \quad (7)$$

$$F \cdot \lambda = J \cdot \vartheta = \xi = const \quad (8)$$

$$\vartheta = {}^{\lambda}/_{T} = {}^{const}/_{T} \quad (9)$$

$$\vartheta = \frac{l}{t} = \frac{n \cdot \lambda}{n \cdot T} = \frac{\lambda}{T} = \frac{l_n}{t_n} \quad (10)$$

$$F \cdot \lambda = m \cdot \vartheta^2 = m \cdot \frac{\lambda}{T} \cdot \frac{\lambda}{T} \quad (11)$$

$$J \cdot T = m \cdot \lambda = const \quad (12)$$

$$dJ = {}^{const}/_{dT} \text{ or } {}^{dT} = {}^{const}/_{dJ} \text{ from where } dJ \cdot dT = const \quad (13)$$

$$m = {}^{\xi}/_{\vartheta^2} = {}^{J \cdot \vartheta}/_{\vartheta^2} = {}^{J}/_{\vartheta} = const \quad (14)$$

$$m = {}^{J}/_{\vartheta} = J \cdot \frac{T}{\lambda} = const \quad (15)$$

$$m \cdot \lambda = J \cdot T = const \quad (16)$$

$$(m \cdot \lambda \cdot n = m \cdot l) = (J \cdot T \cdot n = Jt) = const \quad (17)$$

$$m \cdot l = F \cdot t \cdot T \quad (18)$$

$$F = \frac{m \cdot l}{T \cdot t} = {}^{m\vartheta}/_{T} = m \cdot a \tag{19}$$

$$\frac{J \cdot \vartheta}{\vartheta} = \frac{F \cdot \lambda}{\vartheta} \tag{20}$$

$$J = m \cdot \vartheta \tag{21}$$

$$\frac{1}{\vartheta} = \frac{m}{J}, \tag{22}$$

$$\frac{d\vartheta}{\vartheta^2} = m \cdot \frac{dJ}{J^2} \tag{23}$$

$$d\vartheta = {}^{\lambda}/_{dT} \tag{24}$$

$$\lambda_n = \frac{m \cdot \vartheta^2 \cdot dJ \cdot dT}{J^2} = const, \tag{25}$$

$$\lambda = \lambda_y + \lambda_n \tag{26}$$

$$F = G^{'} \cdot l_y \tag{27}$$

$$F = {}^{G \cdot l_y}/_{t} \tag{28}$$

$$F \cdot T = {}^{G \cdot l_y}/_{n} \text{ or } J = G \cdot \lambda_y \tag{29}$$

$$\lambda_y = {}^{J}/_{G} \tag{30}$$

$$\frac{\overline{J}}{G} + \frac{m\lambda^2 \cdot dJ \cdot dT}{T^2 \cdot J^2} = \lambda \tag{31}$$

$$\frac{1}{m \cdot \lambda^2 \cdot G} = \left(\frac{dJ}{J^3}\right) \cdot \left(\frac{dT}{T^2}\right) \tag{32}$$

$$\frac{1}{m \cdot \lambda^2 \cdot G} = (\int J^{-3} \cdot dJ) \cdot (\int T^{-2} \cdot dT), \tag{33}$$

$$\frac{1}{m \cdot \lambda^2 \cdot G} = \left(\frac{2}{J^2 + C_1}\right) \cdot \left(\frac{1}{T + C_2}\right) \tag{34}$$

$$\overline{J^2} = \frac{m \cdot 2\lambda^2 \cdot G}{T + C_2} - C_1 \tag{35}$$

$$\overline{J} = \sqrt{\frac{m \cdot \lambda_{ku}^2 \cdot G}{T + C_2} - C_1}, \tag{36}$$

$$\lambda = \sqrt{\frac{(J^2 + C_1) \cdot (T + C_2)}{m \cdot G}} \quad (37)$$

$$T = \frac{\lambda}{\vartheta} = \frac{n \cdot \lambda}{n \cdot \vartheta} = \frac{l_1}{\vartheta_1} = \frac{l_2}{\vartheta_2} = \cdots = \frac{l_n}{\vartheta_n} \quad (38)$$

$$J = \sqrt{\frac{(m \cdot \lambda^2 \cdot G) \cdot n}{t + C_2}} - C_1 \quad (39)$$

$$\lambda = \sqrt{\frac{(J + C_1) \cdot (t + C_2)}{(m \cdot G) \cdot n}} \quad (40)$$

$$\gamma_1 = \frac{J_1 \cdot 1}{J_1 \cdot n_1} \neq \frac{J_2 \cdot 1}{J_2 \cdot n_2} = \gamma_2 \quad (41)$$

$t_1 \ll t_2$ at $n_1 \ll n_2$ to $t_1 = t_2 = 1s$, the meaning $T_1 \gg T_2$ (42)

$$(P \cdot S = F) = \tau \cdot 2\pi r \cdot L \quad (43)$$

$$\tau = {}^{F}\!/_{2\pi r \cdot L} = {}^{F}\!/_{S} \quad (44)$$

$\tau = {}^{J}\!/_{T \cdot S}$ or $\tau \cdot S \cdot T = J$ (45)

$$\tau' = \sqrt{\frac{(m \cdot G \cdot \lambda^2)}{T + {}^{T}\!/_{4}}} - C_1 \quad (46)$$

Figure 1. *The result of stone softening technology of Mayan civilization*

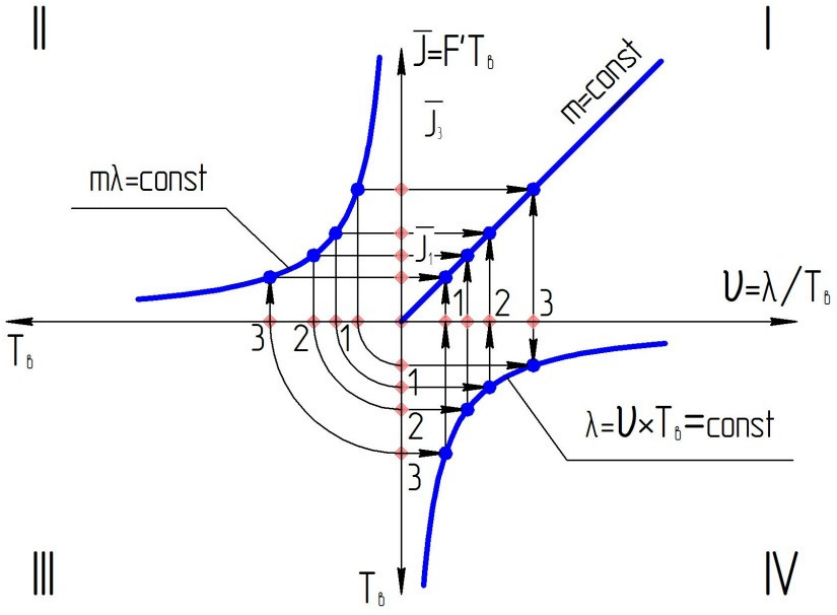

Figure 2. *Nomogram, reflecting the resistance of KU of Newton fluid to the action of external forces*

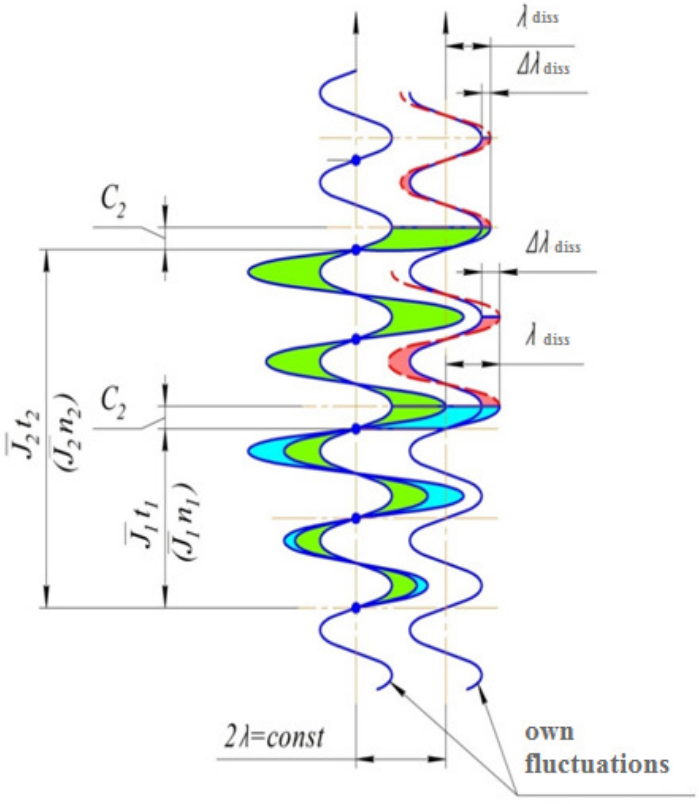

Figure 3. *Scheme of the increase in the amplitude of oscillations with a different nature of the external load, where the energy of dissipative heat release is associated with the nature of the increasing* $\Delta\lambda$

Table 1. *The value of the characteristics included in (46), determined on the basis of experimental data, obtained for the mixture B-201 in the temperature range 60 – 120єC.*

$t°C$	$m \cdot G \cdot \lambda^2$	$C_2 = {}^{T}/_{4}$	C_1
60	5.600	0.05	0.2
80	2.799	0.05	0.2
100	1.430	0.05	0.2
120	1.1865	0.05	0.2

Table 2. *The value of the characteristics that included in (46), determined on the basis of experimental data $\tau(t)$, obtained for different mixtures at a temperature of 60єC.*

Model of the rubber blend	$m \cdot G \cdot \lambda^2$	C_2	C_1
7V-14	89.50	0.6	10.0
NO-68	57.80	0.5	3.0
B-201	5.65	0.05	0.2