The General theory of degradation

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Abstract. For the first time proposed the General theory of the destruction of the object in time. The theory of degradation describes gradual the deterioration of the object in time. The article describes the main provisions of the theory of degradation. The theory is built on the energy approach. Shows the interaction of energy of the object and the energy of the external environment. Assumptions are made about the existence of every object to its form of energy. It considers different forms of distribution of energy of an object in time. Proposed and analyzed the most simple forms of the energy distribution. Different forms of energy lead to one the form of distribution energy potential in time. Using the law of conservation of energy, constructed the calculated dependence. The results of the calculations demonstrate that the potential time does not depend on energy. Was made analysis of the obtained model. Theory can be applied to the any object.

1. Introduction

Very often we see that charts the development different of the objects have the same form: diagram of materials and structures, charts the development of the organizations, societies [1-3]. Although the internal structure and energy, the driving forces of these objects are totally different. They have the moment of "birth" and "all" they have a life expectancy and "all" they die. The generalization "all" is certainly not have confirmed completely. Although supposition "death" of our universe is projected. Here is an attempt to explain why and how this happens. The question of the longevity or durability of the object has social, technical and economic aspects and must be discussed separately [4-8]. The General theory allows to model behavior of an object and also to use of hers in the analysis of their behavior in time [9-11]

2. The initial positions of the theory

In relativistic mechanics works the law of conservation (including rest energy) of energy. Energy is the General quantitative measure of different forms of matter in motion. To quantify the qualitatively different forms of movement to distinguish types of energy: mechanical, gravitational, electromagnetic, nuclear, thermal, etc. Energy is a definite function of the state of the material system, that is uniquely determined by the same parameters that define the state material system. in a circular process energy remains constant, that is, its change is zero. However, this does not mean that the individual components of the total energy for a circular process remain unchanged. The sum of all energies remains constant [12].

In order to assess degradation of the object is necessary to consider the process in time. The object itself is represented by a collection of particles, connected into a single system and the binding energy of this system equal to the difference between the total energy of the particles in a free state (i.e. when the particles do not interact) and the energy of the considered coupled system of the same particles [13].

3. General provisions of the theory

Consider the interaction of two systems: for example, the sample and press, what to be for transfer on the sample external destructive energy. The external energy $\boldsymbol{A}$ aimed at the destruction of the binding energy $\boldsymbol{U}$ of the particles in the sample.

Write the condition of destruction energy of the sample in time: $\mathbf{d}A/\mathbf{d}t \geq \mathbf{d}U/\mathbf{d}t$ - i.e. in each moment of time the external energy press (power) must exceed the internal binding energy (power) of the sample. Now suppose there is a graph of power distribution of the investigated object in time. Consider the graph in figure1 the axes of the "acceleration energy – time"- "$\boldsymbol{B}$–$\boldsymbol{t}$". On the considered graph, the vertical axis is the acceleration energy $\boldsymbol{B}$,J/s^2; the horizontal axis - time $\boldsymbol{t}$. Will take the acceleration energy $\boldsymbol{B}$ as some notional value then defines the change in power per unit of time. In the moment of time $\boldsymbol{t_o}$ (the beginning of the influence of the external energy that causes the destruction of the object) material system - sample is characterized by a set of macroparameters of $\boldsymbol{Q_1}$ and the binding energy of $\boldsymbol{U_1}$. At the moment of time $\boldsymbol{t_L}$ (the end of the interaction energies, is taken as the moment of destruction of the object). The difference $\boldsymbol{t_L - t_0 = L}$ describes the duration of the test. As each object begins to undergo external impact almost immediately after its identification, the time $\boldsymbol{t_0}$ can be called "birth", the point in time $\boldsymbol{t_L}$ - "death", and $\boldsymbol{L}$ – lifetime.

The point $\boldsymbol{0}$ is of the reference point time stamps and can be different from the starting point of interaction. Some of the possible distributions of energy $\boldsymbol{U}$ is marked in figure 1, the positions 1,2,3,4.

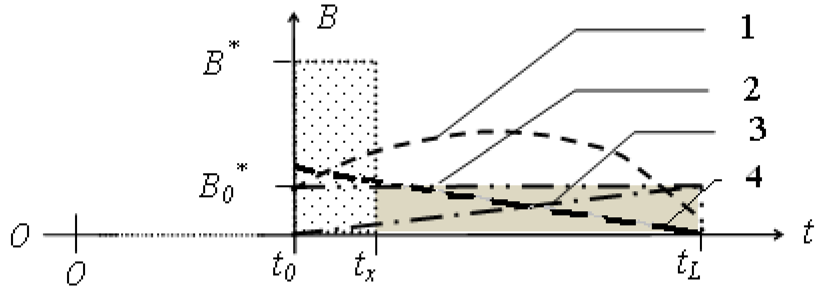

Figure 1. The possible cases of distribution power facilities in time.

The pattern of the distribution of power over time, can somehow different from the one pictured and, in General, change with time. However, if we assume that the external energetic influences, except controlled, is no, the shape of the distribution of power can be considered constant. The form of the power of external influence we can ask. If take the form of the power of external influence on the object of study in the form of a rectangle $\boldsymbol{B^* t_x}$, the condition of fracture energy of each sample in the current time $\boldsymbol{t_x}$ ($\boldsymbol{t_0}$=0) can be written:

$$\boldsymbol{B^* \cdot t_x > \int_{t_x}^{t_L} B(t)\mathrm{d}t}. \quad (1)$$

value
$$\boldsymbol{B^* = \frac{1}{t_x}\int_{t_x}^{t_L} B(t)\mathrm{d}t} \quad (2)$$

to will be the modified acceleration energy of the test object at the current point in time $\boldsymbol{t_x}$. Integral determines the power of the facility beyond the current time and into the future , so the value $\boldsymbol{B^*}$ predict the behavior of the energy of the sample in time. In the future, the value $\boldsymbol{B^*}$ will be called the "potential energy" to which it corresponds in nature and behavior. The value of $\boldsymbol{B^*dt}$ is an elementary power of resistance the energy of the sample. Then the distribution of its own power of the studied sample in time from the beginning of exposure t_0 to the current time t_x will look like:

$$P(t) = \int_{t_a}^{t_x} \left(\frac{1}{t_x} \int_{t_x}^{t_L} B(t)\mathrm{d}t \right). \tag{3}$$

According to (3) is considered the time interval from $t_0 = 0$ to t_L , provided $t_0 = 0 < t_a < t_x < t_L$. The value of the time t_a appears due to the inability t_x acceptance set to 0. In this case, the graph $P(t)$ is always positive, and t_x seeking t_a power seek to 0. However, this raises the question of what the value of t_a should be taken. The adoption of a certain constant value, t_a creates a lot of questions that have no logical explanation.

In this case, we propose to take the beginning of the impact of t_a as a value determined from the dependence $t_a = P_{el} / B_m$, where P_{el} is the current value of the elastic power, and the B_m module of elasticity of the object in the axes of "P - t". Then the line $P = B\ t$ in the plane «P - t» separates the working area of the object without ageing from the aging and destruction zone of the object (e.g. plastic deformation, pseudo-plastic deformation). A derivative of this line on the plane «B – t» is a horizontal line that shows that the movement along this line does not affect the "capacity" of an object in time, and it never gets old – not destroyed. If we assume the existence of the elastic region (zone without aging), her it may be possible to describe not only linear dependence.

4. Some models of the theory of degradation

Shows how, the potential of the object B^*, change from time for in depending on the initial power distribution of the sample in time for some examples. Figure 2 shows different variants of the ascending and descending graphs of the distribution of power conditional unit for 100 units of time.

Built in accordance with these graphs, the potential energy of the object shown in figure 3

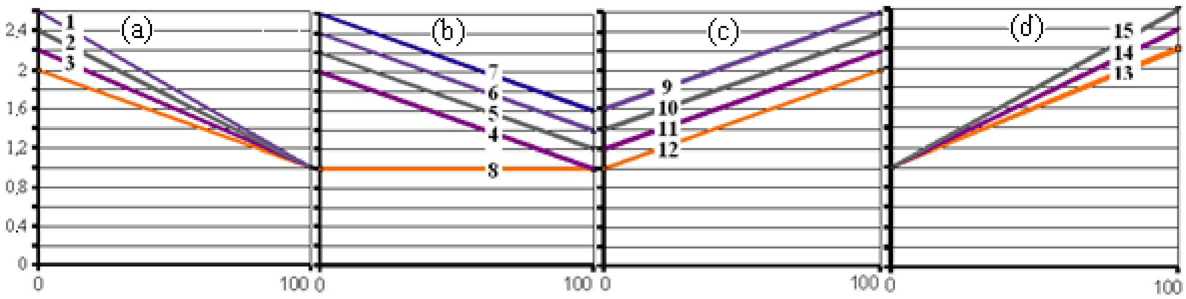

Figure 2. Options charts of power distribution of the object.

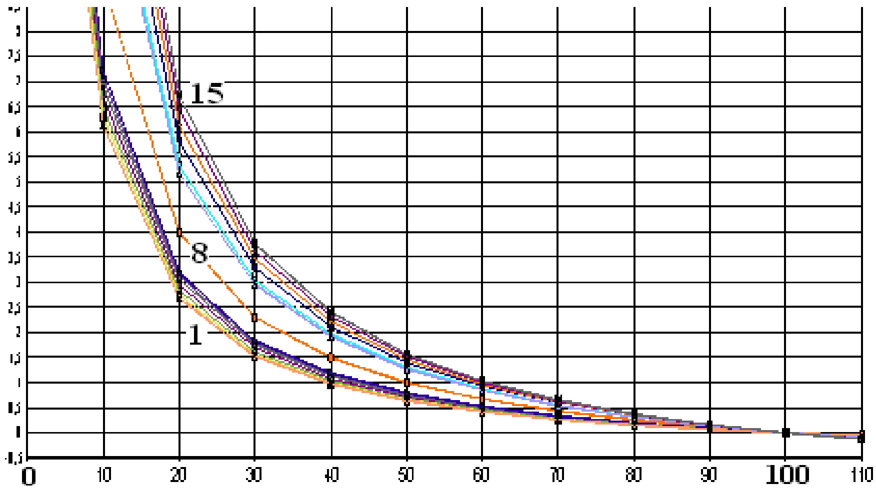

Figure 3. The graphs to change of potential of an object in time.

Numbers 1...15 in the figure 3 correspond to the numbers in figure 2.

The bottom line on the chart (figure 3) corresponds to a change in properties 1 in figure 2, the upper line corresponds to a change in properties 15. The middle line in figure 3 corresponds to line 8 (horizontal line) in figure 2.

Assume that the function describing the acceleration of energy over time, continuous over a selected period of time and can be approximately described by the Taylor formula. The Taylor formula will take the form of a polynomial:

$$B = b_0 + b_1 x + b_2 x^2 + b_3 x^3 + b_4 x^4 + b_5 x^5 + \dots \quad (4)$$

The coefficients bi in this formula depend on the value of the argument at the point in which we describe the function and depend on the value the derivative of this function at this point.

Write the value of the potential in arbitrary units and in accordance with the distribution of acceleration power of the object under the condition tL=1; 0 < tx = x ≤ 1:

$$B^* = \int_{t_x}^{t_L} B(t)dt/t_x = \frac{b_0}{1}\left(\frac{1}{x} - 1\right) + \frac{b_1}{2}\left(\frac{1}{x} - x\right) + \frac{b_2}{3}\left(\frac{1}{x} - x^2\right) + \frac{b_3}{4}\left(\frac{1}{x} - x^3\right) + \cdots . \quad (5)$$

Figure 4 shows graphs of a number: $y = -1; -x; -x^2; -x^3; \dots ; -x^{10}; -x^{20}$ for $0 < x \le L$. For the figure shows that to result increasing the exponent of the curves of the line graphs are highest to the degree coordinate axes, the influence of members of a number with higher degrees decreased. Consequently, the resulting series is convergent.

Next, figure 5 shows the graphs of the functions in the range: (**1/*x*-1**); 1/2 (**1/*x*-*x***); ... ;1/21 (**1/*x*-*x*^{20}**).

The row is obtained from (5) without taking into account the coefficients ***bi***. Potential, ***B**** obtained by summing the curves obtained from such the row with given coefficients ***bi***. Considering the curves what is demonstrate of figure 5 see that the row, describing power ***B**** converging. The obtained curves have similar shape. Fall schedule (1/***x***-1) gradually decreases In the subsequent diagrams result from is convex the lines with changing curvature. The greatest deviation of the curvature from smooth reduction (protuberance) on the plots along the vertically is 0.025 for the graph x^9. For clarity, in Figure 5 held straight line. The summation curves with the coefficients ***bi*** will produce curves similar to figure 3. With possibly wavy appearance. The tangent to the curve cannot have a negative slope, otherwise the possible intersection of the total curve with the axis absciss, that would mean move the point ***L***.

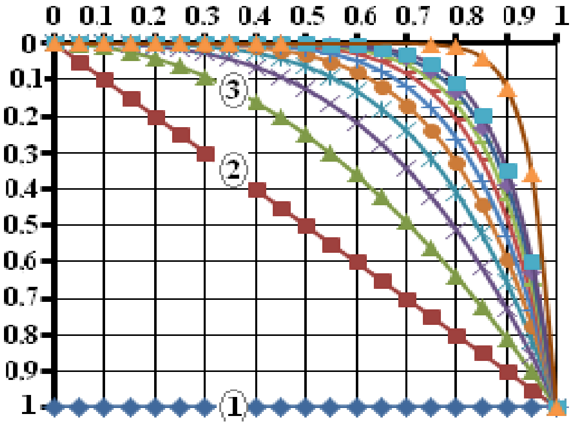

Figure 4. Graphs of functions for sequence.
$y = -1;\ -x;\ -x^2;\ -x^3\ \ .\ .\ .\ -x^{10};\ -x^{20}.$

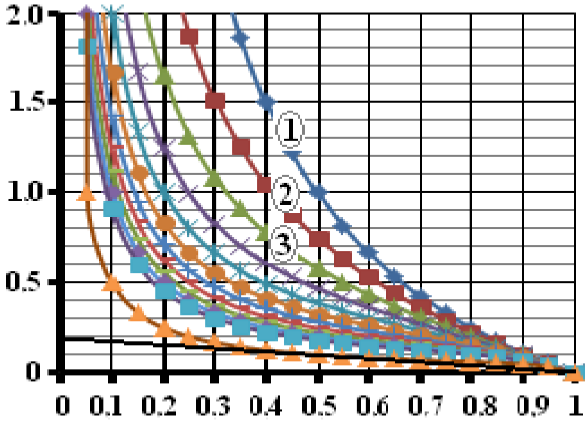

Figure 5. Graphs of functions for sequence.
$y = \left(\frac{1}{x} - 1\right); \frac{1}{2}\left(\frac{1}{x} - x\right); \dots ; \frac{1}{21}\left(\frac{1}{x} - x^{20}\right).$

The main conclusions from the analysis of the function:

1. The potentials of most of the functions have a similar shape, that is, the behavior of the potentials energy in time for most objects are alike

2. Can to be wave on the curve potentials energy of the object, i.e., the deceleration or acceleration of its reduction. The waves on the curve of potential energy can to be explained as a view of the function of the energy of acceleration or the method of approximation (polynomial).

IOP Conf. Series: Materials Science and Engineering 463 (2018) 022028 doi:10.1088/1757-899X/463/2/022028

3. The potential of the acceleration energy (without external influence) is constantly decreasing in time.

4. The increase potential of the acceleration energy in time is possible only due to the influence of external energy.

On the chart «***P-t***» the modulus of elasticity is determined by the ratio $P_{el}/t_{el} = E_{el}$, respectively, on the chart capacity – sloping line becomes horizontal with coordinate $B = E_{el}$, this means that the modulus of elasticity is the energy characteristic of on object.

In the case of rectangular plots of acceleration of energies for the having a permanent potential of the value on the chart to can write down the value of life expectancy as $L = \gamma x \geq x$ (γ – const, is greater than one), then the relationship of modulus of elasticity with acceleration energy is written as

$$B^* = B_1 \frac{L-x}{x} = B_1 \frac{\gamma x - x}{x} = B_1(\gamma - 1) = E_{el}.$$

In the case of a triangular plot $B^* = B_0 \frac{\gamma^2 x^2 - x^2}{2\gamma x x} = B_0 \frac{\gamma^2 - 1}{2\gamma} = E_{el}$

Consider the case: $\int_0^{t_L} B(t)dt = const = G = b_0 t_L + \frac{b_1 t_L^2}{2} + \frac{b_2 t_L^3}{3} + \frac{b_3 t_L^4}{4} + \cdots$

The current power of the object in this case is written as:

$$P(t) = G \ln\frac{x}{a} + \frac{b_0(a-x)}{1} + \frac{b_1}{4}(a^2 - x^2) + \frac{b_2}{9}(a^3 - x^3) + \frac{b_3}{16}(a^4 - x^4) + \cdots \quad (6)$$

5. Conclusion

To analyze the behavior of the object it is proposed to use the whole set of diagram of its behaviour in time. An example of the combined set of diagrams is shown in figure 6.

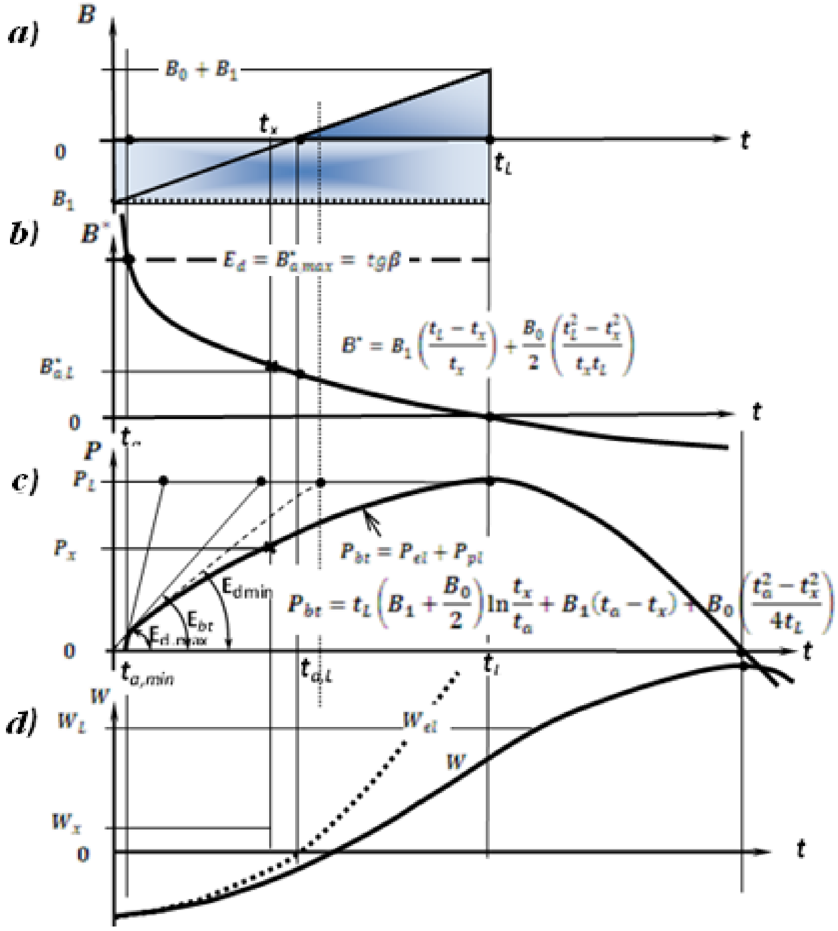

Figure 6 Combined behavior diagram object in time.

a) graph of acceleration energy;
b) graph of the potential;
c) graph of power change of the object during the interaction;
d) graph of energy change.

Each subsequent chart from top to bottom (except for charts of the acceleration energy and capacity) is the integral function from the previous chart.

The diagram ***a***) shows the estimated distribution's own "acceleration energy" of the object in time. This phenomenological assumption on the basis of which are derived all the subsequent builds.

The diagram ***b***) shows how the degree of increase of defects in the object, also and the degree of increase of information about the object.

The diagram ***c***) can be used to analyze stresses and deflections of a products, development or growth of cracks.

Diagrams ***c***) and ***d***) can be used to analyze the degradation of the object in time and valuations for the time and money on repairs (energy recovery) or the duration of economical operation

The whole set of diagrams is used to analyze the durability of the object and estimating its degradation with time.

References

[1] Alexandrovsky S V et al 2001 *Reinforced Concrete in the XXI century: The state and prospects of development of concrete and reinforced concrete in Russia* (Moscow: Gotika) p 684
[2] Kapitsa, S. P. 2008 *Essay on the theory of growth of mankind. The demographic revolution and information society* (Moscow:Institute of physical problems. P. L. Kapitza Institute for socio economic population problems of RAS)
[3] Karpenko N I and Mukhamediev T A 1988 *Efficient material-concrete construction* (Moscow: NIIZHB) pp 4–18
[4] Tamrazyan A G 2014 *Concrete and reinforced concrete — glance at future* (Vestnik MGSU) 4 pp 181–189
[5] Varlamov A A 2014 *Model the elastic behavior of the concrete* (Izvestiya KSASU) 3(29) pp 19-26
[6] Il'ichev V A 2003 *Russia and the world: economy of resources in building* (Architecture and construction of Moscow) 508-509 pp 72–80
[7] Rimshin V I 2005 *Durability problems Beton and reinforced concrete* 2 pp 27
[8] Erofeev V T, Al D S and Mishunyaeva O A 2016 *Ways to improve the durability and reliability of concrete structures* (Safety building Fund) 1 pp 13–19
[9] Bondarenko V M 2002 *Dialectics of mechanics of reinforced concrete* (Concrete and reinforced concrete) 1 pp 24–27
[10] Kolchunov V I, Yakovenko N A and Klyuev N V 2013 *Method physical models for resistance of concrete* (Industrial and civil construction) 12 pp 51–55
[11] Varlamov A A 2016 *On the design of the chart behavior of concrete* (Concrete and reinforced concrete) 1 pp 6–8
[12] Frish S E and Timoreva A V 1962 *The course of General physics* (Moscow) vol.1. p 523
[13] Paducov V A and Malarov I P 1985 *Fracture mechanics of rocks by explosion* (Irkutsk: Publishing house Irkut. University press) p 128