The Result of Loads Superposition Upon the Matter and Particularly Upon the Environment

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It is analyzed: – the actions whose effects are different stresses that can load a body or the environment; – the superposition problem of two or several loads. On the basis of critical energy principle, a relationship is established, consisting of dimensionless values, for the evaluation the stress state with respect to a value defined as admissible state. The result can be applied to loads superposition in some cases, such as: – solid bodies; – environmental pollution with a single sort of pollutant; – environmental multiple pollution: chemical, radiations and magnetic.

Keywords: superposition of loads, nonlinear behaviour, chemical pollution, radiation pollution, magnetic pollutions, synergy

Any kind of external actions upon the matter produces effects which are cumulate in time and can produce changes in matter state, expressed by the value of specific properties such as physical, chemical, biological etc.

The external actions may be *loads* of a certain nature (mechanical, thermal, electrical, nuclear, magnetic, etc) or *loads* of same nature, but different types. For example, a mechanical action can be represented by: force, pressure, bending stress, torsion stress etc.

But external actions may be represented by substances, radiation, chemicals etc. For example, some of substances may have as effect corrosion and / or erosion of solid bodies. Some of chemicals may have as effect the cumulation of a particular component in a material body (solid, liquid or gaseous), or cumulation of radiation etc.

Therefore are distinguishable:

-effects of external actions on a specific physical properties of a material (breaking strength, yield strength, electrical resistance, thermal or electrical conductivity, magnetic permeability etc...)

-effects of external actions on environmental pollution;

-effects of external actions upon living organisms.

The external actions can be simultaneous, successive or some of them are simultaneous and others are successive.

In summary, a body defined geometrically, or a part bounded from the environment (located inside of a so called *control volume*) may be subjected to one or more actions. Each action, A_i, is characterized by what we call stress, S_i. The stress is the carrier of a certain quantity of specific energy, E_i, and may be of a different or the same nature, but of different types (fig. 1).

When external action is characterized by a single stress, the allowable condition is written as,

$$S_i \leq S_{i,al}, \tag{1}$$

where $S_{i,al}$ is the maximum allowable value of S_i.

When a body or environment undergoes to several loads the question is how it can be determinate if the state of stress is or not admissible. Is considered knew the maximum allowable value $S_{i,al}$, for each stress S_i. Because the actions may be as high variety, they are expressed with different units of measure. Accordingly they can not be summed algebraically!

Sometime, for example, in mechanical engineering, instead of loads Y_i is used mechanical stresses σ_i, which is proportional to Y_i,

$$\sigma_i \sim Y_i. \tag{2}$$

In the is case eq. (1) is replaced by,

$$\sigma_i \leq \sigma_{i,al}, \tag{3}$$

where $\sigma_{i,al}$ is the allowable mechanical stress for the case of load analyzed.

The load superposition

The problem of *superposition of actions or loadings* upon a particular body or upon the environment is analyzed.

Actions or loadings superposition means the simultaneous loading with individual loadings/stresses upon a body or upon the environment (fig. 2). For example, mechanical load upon a structure with tensile stress ó, at a temperature higher than creep temperature [1, 2], or a tubular junction loading at internal pressure and bending stress [3 - 6]. Figure 2 shows the superposition of three loads: S_1 – constant in time; S_2 – variable in time (produces fatigue); S_3 – increases with time.

One or more loads acting on the system/body has at least two effects, one of which is always the thermal effect X_{th}. Considering Y_i external generalized load by nature of type *i* and X_j - the effect of the nature of type *j* (except the thermal effect, noted X_{th}).

The effects of loads Y_i upon a body are represented in figure 3. A single load Y (fig. 3, *a*) or the actions of several loads $Y_1, Y_2, \ldots, Y_n$ (fig. 3, *c*) may have as result the effect X and the thermal effect X_{th}. As well, a single load Y (fig. 3, *b*) or the actions of several loads $Y_1, \ldots, Y_n$ (fig. 3, *d*) may have as result the effects $X_1, \ldots, X_m$ plus the thermal effect X_{th}.

Some examples

– during the tensile loading (Y) of a steel specimen a deformation *(X)* and a thermal effect (X_{th}) is obtained, as shown in figure 3a;

– at various crystalline substances (quartz, borosilicate, aluminum salt Seignette (double tartrate of sodium and potassium etc...) the mechanical stretch, compression or bending have as results a deformation (X_1), the occurrence of electric charges (X_2), and thermal effect (X_{th}), as shown in figure 3, *b*. It is what is defined as piezoelectricity;

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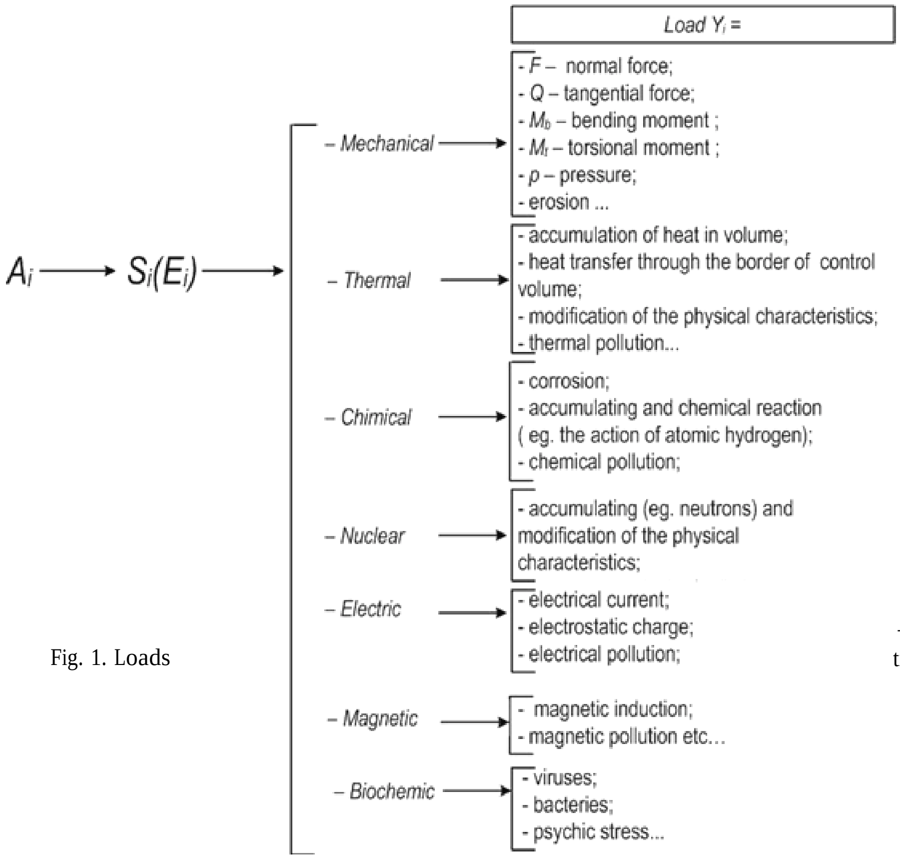


Fig. 1. Loads

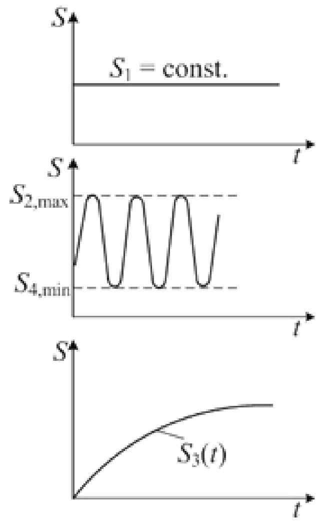


Fig. 2. Simultaneous stress actions: – a constant stress (S_1); – a variable stress in time (S_2); – a stress increases with time(S_3(t))

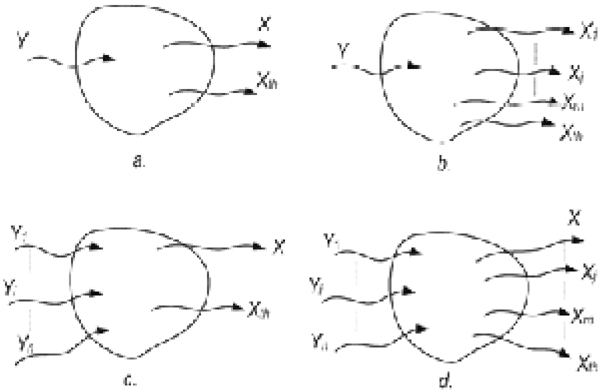


Fig. 3. a – X and X_{th} the effects of the action load Y ;
b – $X_1 \dots X_m$ and X_{th} the effects of the action load Y;
c –X and X_{th} the effects of the action loads $Y_1 \dots Y_n$;
d – and X_{th} the effects of the action loads [7]

– the electric and magnetic properties of rocks are correlated with their state of mechanical stress. A seismic movement changes the status of local mechanical stress (X_1), magnetism (X_2) and electric state of the rock (X_3), accompanied by a thermal effect (X_{th}) etc ...

Allowable state calculation in case of loads superposition

In the case of loads superposition we recourse to the principle of energy critical (PCE) and the general law of matter behaviour [8].

The effect, *X*, depends on the behaviour of matter loaded by load *Y*. The behavior law can be, for example [8, 9],

-linear

$$Y = B \cdot X; \quad (4)$$

-non-linear, power law,

$$Y = C \cdot X^k, \quad (5)$$

where *B*, *C* and *k* are constants of the material.

The energy given by the load *Y* to the body is noted by *E*. The appropriate energy per unit volume (energy density or specific energy) is noted

$$E_s = E/V, \quad (6)$$

where *V* is body volume stressed by the load *Y*, carrier of the energy *E*.

Generally, specific energy is calculated with the relation,

$$E_s = \int Y \cdot dX, \quad (7)$$

which, for linear behavior (4) becomes,

$$E_s = \int_0^X (B \cdot X) \cdot dX = \frac{B \cdot X^2}{2} = \frac{Y \cdot X}{2}, \quad (8)$$

and for nonlinear (5) is,

$$E_s = \int_0^X (C \cdot X^k) \cdot dX = \frac{C \cdot X^{k+1}}{k+1} = \frac{Y \cdot X}{k+1}, \quad (9)$$

By replace x=Y/B and respectively x=(Y/C)$^{1/k}$ in equations (8) and (9) obtains,

$$\left.\begin{aligned} E_s &= \frac{Y^2}{2B} \text{ - in case of low (4);} \\ E_s &= \frac{Y^{\frac{1}{k}+1}}{(k+1) \cdot C^{1/k}} \text{ - in case of low (5).} \end{aligned}\right\} \quad (10)$$

The specific energy contains not only cause *(Y)*, but also its effect *(X)*, correlated by the behavior law. Consequently, recourse to energy concepts and specific energy, allows fully and correctly evaluation of any process or phenomenon.

But not only the energy, but even the specific energy are values which have a certain dimension ([E] = J, and [E_s] = J/m^3), which does not allow solving the problems of superposition or cumulation of loading in case of nonlinear behaviour of matter (5). This is why we recourse to the *concept of participation of specific energy*.

According the principle of critical energy [8-10], generally, participation of the specific energy in relation with allowable state is defined by the relation:

$$P^* = \frac{E_s(Y)}{E_{s,al}(Y_{al})} \cdot \delta_Y , \qquad (11)$$

where $E_s(Y)$ is the specific energy received by a system / body through the load *Y*, specific to the process that is involved; $\delta_Y=1$ if the specific energy $E_s(Y)$ acts in the direction of the respective process or phenomenon; $\delta_Y=0$ if E_s has no effect upon the respective process or phenomenon and $\delta_Y=-1$, if the action of the specific energy E_s opposes the evolution of the process or phenomenon.

The participation of specific energy is a dimensionless value, dependent on the load parameter (Y), on the behaviour of matter involved in the process or phenomenon (*k)* and on the limit imposed by the allowable value of the load (Y_{at}). This allows to calculate the total effect of the simultaneous loads (Y_i), by algebraic summation of individual participations $P_i(Y_i)$; it can be obtained *the total participation of the specific energies,*

$$P_T^* = \sum_i P_i^*(Y_i), \qquad (12)$$

where $P_i^*(Y_i)$ results from eq. (11).

Taking into account the relation between specific energy and the load (10), one obtains the *allowable values of the specific energy corresponding to the allowable load, Y_{al},*

$$\left.\begin{aligned} E_{s,al} &= \frac{Y_{al}^2}{2B} \ \text{- in case of low (4);} \\ E_{s,al} &= \frac{Y_{al}^{\frac{1}{k}+1}}{(k+1)\cdot C^{1/k}} \ \text{- in case of low (5).} \end{aligned}\right\} \qquad (13)$$

From relations (10), (11) and (13) one results specific energy participation in relation to the allowable state,

$$\left.\begin{aligned} P^*(Y) &= \left(\frac{Y}{Y_{al}}\right)^2 \cdot \delta_Y \ \text{- in case of low (4);} \\ P^*(Y) &= \left(\frac{Y}{Y_{al}}\right)^{\frac{1}{k}+1} \cdot \delta_Y \ \text{- in case of low (5).} \end{aligned}\right\} \qquad (14)$$

In case of the power low (5), the total participation of specific energy in relation to the allowable state (12), results from expressions (12) and (14) as,

$$P_T^* = \sum_i \left(\frac{Y_i}{Y_{i,al}}\right)^{\alpha_i+1} \cdot \delta_{Y_i} , \qquad (15)$$

where $\alpha_i = 1 / k_{ii}$.

In case of linear behaviour k=1, in the expression (15) one replace $\alpha_i=1$ so that $\alpha_i+1=2$.

The eq. (15) is used to calculate the total effect of loading with stresses Y_i, where i=1; 2...n (fig. 3).

To determine whether a stress is dangerous or not, one compare P_T^* with its allowable values P_{al}. If,

$$\left.\begin{aligned} &P_T^* \le P_{al} \ \text{– the load or the process where act the load } Y \text{ is allowable;} \\ &P_T^* > P_{al} \ \text{– the load or the process where act the load Y is not allowable.} \end{aligned}\right\} \qquad (16)$$

Generally, the allowable participation has the following values[7, 9]:

$$P_{al} = \begin{cases} \text{, for the undamaged materials and without residual stresses;} \\ -D_T^*(t) - P_{res}^* \text{, generally} \end{cases} \qquad (17)$$

where the total deterioration of matter (time-dependent) in relation with allowable state is,

$$D_T^*(t) = \sum_k D_k^*(t), \qquad (18)$$

where $D_k^*(t)$ is the individual deterioration (caused by a certain external stress) in relation with allowable state, which can be calculated using the relation $D_k^*(t)=D_k(t) / c_D$, where $c_D > 1$ is safety coefficient, and $D_k(t)$ is calculated corresponding to the critical state of matter deterioration

The residual stress participation *integrated* into the material, relative to the allowable state, is:

$$P_{res}^* = \left(\frac{\sigma_{res}}{\sigma_{al}}\right)^2 \cdot \delta_{res} , \qquad (19)$$

where $\sigma_{al}=\sigma_u / c_\sigma$ is the allowable stress (α - ultimate stress); $c>1$ is the safety coefficient.

$\delta_{\sigma\,res}=1$if the residual stress act in the direction of the process and $\delta_{\sigma\,res}=-1$, otherwise.

Some concrete situations of loads superposition in case of solid body

The simultaneous stresses can be constant over time, but can be time-dependent (fig. 4). In consequence in the loading case represented in figure 4, the total participation at the time t_1 is,

$$P_T^*(t_1) = P_1^* + P_2^*(t_1) + P_3^*(t_1) \qquad (20)$$

In the right part of relation (20) are inscribed the individual participations with respect to the allowable state P_i^*. These can be calculated with the relations listed in table 1, for the general case of nonlinear, power law, behaviour (5).

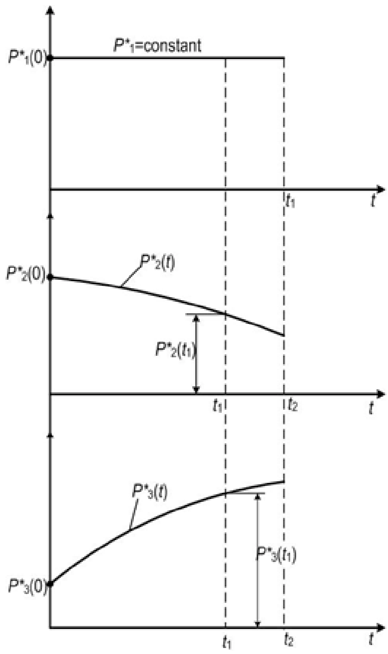


Fig. 4. Simultaneous loading with: time constant participation, = const., time decreases participation and with time rises participation

Figure 5. A cylindrical pipe, simultaneous loaded with axial force, F_a, bending moment, M_b, and torsional moment, M_t

Table 1
RELATIONS FOR SPECIFIC ENERGY PARTICIPATION WITH RESPECT TO THE ALLOWABLE STATE
(ACCORDING TO [11 - 13])

No.	Stress		The specific energy participation with respect to allowable state	Observations
1.	Normal stresses in the solid:	- tensile or compression (σ)	$P^*(\sigma)=\left(\frac{\sigma}{\sigma_{al}}\right)^{\alpha+1}\cdot\delta_\sigma$	$\sigma=M_\sigma\cdot\varepsilon^k$ – the behavior law; M_σ, ε - material constants; σ_{al}; $\sigma_{b,al}$ – allowable values of σ, respectively, σ_b; $\delta_\sigma=1$, if $\sigma>0$; $\delta_\sigma=-1$, if $\sigma<0$; $\alpha=1/k$. $\delta_{\sigma_b}=1$, if $\sigma_b>0$; $\delta_{\sigma_b}=-1$, if $\sigma_b<0$.
		-bending stress (σ_b)	$P^*(\sigma_b)=\left(\frac{\sigma_b}{\sigma_{b,al}}\right)^{\alpha+1}\cdot\delta_{\sigma_b}$	
2.	Shear stresses in the solid:	- shear stress (τ)	$P^*(\tau)=\left(\frac{\tau}{\tau_{al}}\right)^{\alpha_1+1}$	$\tau=M_\tau\cdot\gamma^{k_1}$ - the behavior law; M_τ, k_1 - material constants; $\alpha_1=1/k_1$ τ_{al}; $\tau_{t,al}$ – allowable values of τ, respectively, τ_t;
		- torsion stress (τ_t)	$P^*(\tau_t)=\left(\frac{\tau_t}{\tau_{t,al}}\right)^{\alpha_1+1}$	
3.	Cyclic stress with constant amplitude of stress (σ_a) [14]		$P^*(n)=\left(\frac{n}{N_{al}}\right)^{\frac{\alpha+1}{m}}$	$\alpha=1/k$; n; N_{al} – number of effective loading cycles and allowable loading cycles, respectively, with stress amplitude, σ_a; m is the exponent of the Basquin's law [14].
4.	Constant corrosion		$P^*(t_{cz})=\left(\frac{t}{t_{al}}\right)^c$	t – time of contact with corrosive substance; t_{al} - time until the allowable corrosion of wall thickness; c – constant.
5.	Action of pollutants		$P^*(c)=\left(\frac{c}{c_{al}}\right)^{\alpha_c+1}$	c; c_{al} – pollutant concentration and its allowable value; $e=a\cdot c^{\alpha_c}$ - the effect of polluant c; a; α_c - constants.
6.	Radiations flow		$P^*(\Phi)=\left(\frac{\Phi}{\Phi_{al}}\right)^{\alpha_\Phi+1}$	Φ, Φ_{al} - radiations flow (UV, thermal, neutrons, X-ray etc.) and its allowable value. The effect, e, of radiations flow: $e=b\cdot\Phi^{\alpha_\Phi}$; b, α_Φ - constants.
7.	Magnetic field		$P^*(B)=\left(\frac{B}{B_{al}}\right)^{\alpha_B+1}$	Behavior low: $F=M_B\cdot B^{\alpha_B}$ - force created by induction B; B; B_{al} – the induction of the magnetic field and its allowable value; M_B and $\alpha_B\geq 1$ – constants.
8.	Organisms exposure to electrical fields of a certain frequencies,		$P^*(J)=\left(\frac{J_i}{J_{i,al}}\right)^{\alpha_J+1}$	J_i, $J_{i,al}$ - the density $\left(\mathrm{A\cdot m^{-2}}\right)$ of the electrical current induce at frequency i and its maximum allowable effect. Law of behavior: the effect e_J is, $e_J=M_J\cdot J_i^{\alpha_J}$, where M_J and α_J are constants.

Some cases of loads superpositions on mechanical structures were analised in papers [7, 9,15].

Loading a mechanical structure (for example, a tubular shell), simultaneous with axial force, F_a, bending moment, M_b, and torsional moment, M_t, all constant in time (fig. 5). The total participation is calculated with general relation (21), listed in table 2, where the denominators represent the allowable values of the stresses corresponding in the numerator. $\delta_F=1$ if $F_a>0$ (stretching) and $\delta_F=-1$ if $F_a<0$ (compression); $\delta_{\sigma b}=1$ when bending stress caused by M_b is positive ($\sigma_b>0$) and $\delta_{\sigma b}=-1$when bending stress is negative. To writing relationship (22), it was taken into account that $\delta\sim F_a$;$\sigma_\beta\sim F_b$ and $\tau_\beta\sim M_t$.

In eqs. (21) and (22) one considered the behaviour of solid material expressed by the following power laws:

$$\sigma = M_\sigma \cdot \varepsilon^{\kappa} \text{ – for normal stresses;}$$

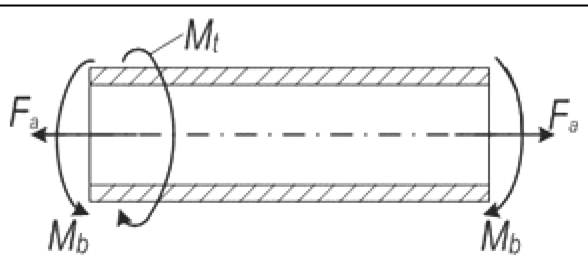
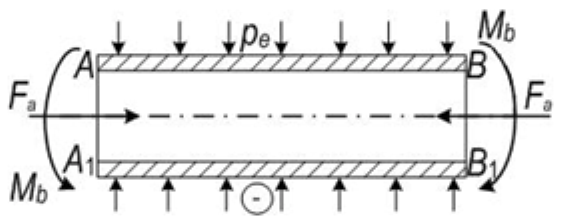
$$\tau = M_\tau \cdot \gamma^{k_1} \text{ – for shear stress.} \qquad (23)$$

where $M_b(-)$ is the bending moment on the compressed fiber $(-)$. Critical loads, in this case refers to areas compressed because buckling is determined by compressive stresses. The total participation in this case corresponds to the most stressed compressed fiber (A_1B_1 on fig. 6).

Result of superposition in case of environmental pollution with only a single pollutant from each kind of pollutants

The simultaneous *environmental pollution* with various external factors such as: a chemical substance of concentration time-dependent c(t), a radiation flow (ultraviolet, thermal, neutrons, X-ray etc.) **Φ**, a magnetic field by induction *B*, is characterized by the total participation compared to the allowable state [11, 16],

Table 2
THE TOTAL PARTICIPATION OF SPECIFIC ENERGIES IN CASE OF MULTIPLE LOADING A SOLID BODY

	Loading	The total specific energies participation with respect to allowable state
1	 Fig. 5. A cylindrical pipe, simultaneous loaded with axial force, F_a, bending moment, M_b, and torsional moment, M_t.	$P_T^* = \left(\frac{F_a}{F_{a,al}}\right)^{\alpha+1}\cdot\delta_F + \left(\frac{M_b}{M_{b,al}}\right)^{\alpha+1}\cdot\delta_{\sigma_b} + \left(\frac{M_t}{M_{t,al}}\right)^{\alpha_1+1}$ (21) $P_T^* = \left(\frac{\sigma}{\sigma_{al}}\right)^{\alpha+1}\cdot\delta_{\sigma_{ax}} + \left(\frac{\sigma_b}{\sigma_{b,al}}\right)^{\alpha+1}\cdot\delta_{\sigma_b} + \left(\frac{\tau_t}{\tau_{t,al}}\right)^{\alpha_1+1}$ (22)
2	 Fig. 6. A cylindrical pipe loaded with compressive stresses $(F_a, p_e, M_b(-))$ which can cause its buckling.	$P_T = \left(\frac{p_e}{p_{e,al}}\right)^{\alpha+1} + \left(\frac{M_b(-)}{M_{b,al}}\right)^{\alpha+1} + \left(\frac{F_a}{F_{a,al}}\right)^{\alpha+1}$ (24)

The factors M_σ, M_τ and the exponents *k* and k_1 by relations (23) are constants of the material. In the relatin (21) one noted a = 1 / k and $_{a1}$=1 / k_1.

The buckling calculation for mechanical structures

One recourse, generally, to the same calculation method, derived from the *principle of critical energy*. For example, for the tubular structure, represented in figure 6, the total participation with respect to allowable state (buckling) is calculated with relation (24) listed in table 2,

$$P_T^* = \left(\frac{c(t)}{c_{al}}\right)^{\alpha_c+1} + \left(\frac{\Phi}{\Phi_{al}}\right)^{\alpha_\Phi+1} + \left(\frac{B}{B_{al}}\right)^{\alpha_B+1}, \qquad (25)$$

where denominators represent the allowable values corresponding to the numerator. Exponents correspond to general nonlinear behaviour listed for each case, on the last column of table 1.

Results of superposition in case of many polluants from each kind of polluants (chemical, radiation and magnetic)

Each action upon the environment is characterized by a specific energy participation. Generally are known and recommended maximum allowable values $S_{i,al}$. Accordingly, the total participation will be determined compared to the allowable state based on the general relation (15).

In case of simultaneous pollution with more pollutants, chemicals 1,...*i*,...*l* by concentrations $c_1(t)$....$c_i(t)$....$c_l(t)$ in the environment, the total participation with respect to allowable state is,

$$P_T^*(c) = \sum_{i=1}^{l} \left(\frac{c_i(t)}{c_{i,al}} \right)^{\alpha_c + 1} \quad (26)$$

where $c_i(t)$ is time dependent; for example, decreases to time (fig. 7). $c_{i,al}$ is the maximum allowable value for pollutan *i.*

At moment $t > t_2(0)$ the environment is influenced only by concentration $c_1(t)$ and $c_3(t)$, but at moment $t > t_1(0)$ remains only concentration $c_3(t)$. At moment $t \geq t_3(0)$ pollution was canceled.

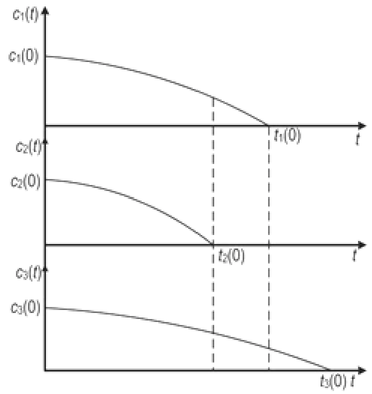


Fig. 7. Pollution by chemicals whose concentrations c_1, c_2 and c_3 decrease in time.

In case of pollution with more action represented by various radiation flows Φ_j, the total participation with respect to allowable state (table 1) is written as,

$$P_t^*(\Phi) = \sum_j \left(\frac{\Phi_j}{\Phi_{j,al}} \right)^{\alpha_{\Phi_j} + 1}, \quad (27)$$

where Φ_j is the radiation flow of radiation *j*, in the environment, and $\Phi_{j,al}$ is the maximum allowable value.

In case of environmental pollution with multiple magnetic fields, *k,* characterized by the induction B_k, the total participation with respect to allowable state is (table 1),

$$P_T^*(B) = \sum_k \left(\frac{B_k}{B_{k,al}} \right)^{\alpha_{B_k} + 1}, \quad (28)$$

where $B_{k,al}$ is the maximum allowable value in the environment.

Some maximum allowable values for environmental pollutants are listed in tables 3÷8.

The total participation of specific energies with respect to the allowable state, in case of the simultaneous action of chemical pollutants, radiations flows and magnetic fields upon environmental has the expression,

$$P_T^* = P_t^*(c) + P_t^*(\Phi) + P_t^*(B). \quad (29)$$

where the particular total participation results from eqs. (26) - (28).

This multiple pollution, in totality, is allowable if is satisfied the first condition (16).

In an analogous manner comes on the problem of the allowable state calculation in case of multiple pollution of living bodies [11; 16].

Other results when PCE application was experimentally verified have been published, for example, in [25-36].

In the case of loading with many loads or external actions (chemical pollutants, electromagnetic radiation, stress, medicines, etc.) a material with nonlinear behaviour, synergic effect is emphasized through the total participation of specific energies corresponding to these loads [16].

Table 3

MAXIMUM ALLOWABLE CONCENTRATION FOR SOME ENVIRONMENT FACTORS IN AIR (EXTRACTED FROM [17])

Physical or chemical pollutant	UM	Maximum Allowable Concentration (MCA)			The limit value for protection of ecosystems			Limit value for protection of human health		
		The period of mediation								
		1 h	24 h	1 year	1 h	24 h	1 year	1 h	24 h	1 year
Sulf dioxide		350 *	125*	-	-	-	20	350*	125*	-
Nitrogen dioxide and oxides of nitrogen	μg/m³	200 *	-	40	-	-	24	140*	-	32
Suspensions (PM10)	μg/m³	50 *	-	40	-	35*	28	-	35*	28

******legislation allows on a case by case. a limited number of overtaking these values during a year*

Table 4

MAXIMUM ALLOWABLE CONCENTRATION FOR SOME ENVIRONMENT FACTORS IN WATER (EXTRACTED FROM [18])

Global indicators	U.M.	Waste water discharges in sewer networks	Waste water discharges into natural receivers
A. Physical indicators			
Maximum temperature of discharge	^0C	40	35
B Chemical indicators			
pH of wastewater discharge	pH units	6.5-8.5	6.5-8.5
Pollutants discharged Maximum Allowable Concentration (MCA)			
Biochemical oxygen demand in 5 days (BOD5)	mg O_2/dm^3	300	25.0
Phenols coachable water vapor(C_6H_5OH)	mg/dm^3	30	0.3
Extractable Substances with organic solvents	mg/dm^3	30	20.0
Free residual chlorine (Cl_2)	mg/dm^3	0.5	0.2

Table 5

MAXIMUM ALLOWABLE CONCENTRATION FOR ENVIRONMENT FACTORS IN SOIL EXTRACTED FROM [19])

Physical or chemical pollutant	U.M.	Normal Values	Maximum Allowable Concentration (MCA)
A. Metals			
Arsenic (As)	mg/kg	5	15
Lead (Pb)	mg/kg	20	50
B. Elements			
Cyanide (free)	mg/kg	<1	5
Cyanide (complex)	mg/kg	<5	100
C. Aromatic and polyaromatic hydrocarbons. Petroleum hydrocarbons			
Total aromatic hydrocarbons (AH)	mg/kg	<5	25
Total petroleum hydrocarbons	mg/kg	<100	200
D. Organic compounds organochlorine			
Total chlorobenzenes	mg/kg	<0.1	5
Polychlorodibenzofurans	mg/kg	<0.0001	0.0001
E. Organochlorine pesticides and triazine			
Total Organochlorine pesticides	mg/kg	<0.2	1
Total triazine	mg/kg	<0.1	1

Table 6
MAXIMUM ALLOWABLE VALUES FOR EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS (EXTRATED FROM [20 - 22])

Frequency, f, Hz		Electric field strength, E		Magnetic field strength, H		Magnetic flux density, B	
		occupational exposure	environmental exposure	occupational exposure	environmental exposure	occupational exposure	environmental exposure
A. exposure to low frequency electric and magnetic fields							
		(kVm^{-1})		(Am^{-1})		(T)	
1 Hz- 8 Hz		20	5	$1.63 \times 10^5/f^2$	$3.2 \times 10^4/f^2$	$0.2/f^2$	$4 \times 10^{-2}/f^2$
8 Hz- 25 Hz		20	5	$2 \times 10^4/f$	$4 \times 10^3/f$	$2.5 \times 10^{-2}/f$	$5 \times 10^{-2}/f$
25 Hz- 300 Hz	25 Hz- 50 Hz	$5 \times 10^2/f$	5	8×10^2	1.6×10^2	1×10^{-3}	2×10^{-4}
	50 Hz- 400 Hz		$2.5 \times 10^2/f$		1.6×10^2		2×10^{-4}
300 Hz- 3 kHz	400 Hz- 3kHz	$5 \times 10^2/f$	$2.5 \times 10^2/f$	$2.4 \times 10^5/f$	$6.4 \times 10^4/f$	$0.3/f$	$8 \times 10^{-2}/f^2$
3 kHz- 10 mHz		1.7×10^{-1}	8.3×10^{-2}	80	21	1×10^{-4}	2.7×10^{-5}
B. exposure to time-varying electric and magnetic fields							
		(Vm^{-1})		(Am^{-1})		(μT)	
10-400 MHz		61	28	0.16	0.073	0.2	0.092
400-2000 MHz		$3 \times f^{1/2}$	$0.0037 \times f^{1/2}$	$0.008 \times f^{1/2}$	$0.0037 \times f^{1/2}$	$0.01 \times f^{1/2}$	$0.0046 \times f^{1/2}$
2 - 300 GHz		137	61	0.36	0.16	0.45	0.20

Table 7
MAXIMUM ALLOWABLE VALUES FOR ENVIRONMENTAL RADIOACTIVITY [23]

Enviromental factor	Measurement	U.M.	Maximum Allowable Values
Air	Gross beta radioactivity	Bq/m^3	10
	External gamma Dose Rate	μSv/h	0.250
Atmospheric deposition	Gross beta radioactivity	Bq/m^2day	200
Water	Gross beta radioactivity	Bq/l	2

Table 8
THE LIMIT OF EFFECTIVE DOSE FOR PEOPLE (EXPOSURE TO IONIZING RADIATION) [24]

Dose limits	Whole body	Extremity of hands and legs.	Skin	Lens of the eye
Population	1 mSv/year	-	-	-
Occupational exposure				
Exposed workers	20 mSv/year	500 mSv/year	500 mSv/year	150 mSv/year
Trainees (16-18 years old)	6 mSv/year	150 mSv/year	150 mSv/year	50 mSv/year
Women during pregnancy	≤ 1 mSv/year			

The synergic effect by superposition external loads

Simultaneous action of several load directed in the same way, represents what is called *synergy*. This means *action or activity;* comes from Greek where *sin* means *with or together with* and *ergon* which translates as a*ction or activity*.

Often by synergistic effect is understood that the total effect of two or more action is higher than the algebraic sum of their individual effects. In the paper [11] has been shown that the result of the loads of several loads may be:

- synergic positive, case where the total effect is higher than the sum of their individual effects;

- synergic negative, case where the total effect is lower than the sum of their individual effects.

The effect from the same group loads depends on the behavior of the loaded matter. That is why synergistic effect depends on the behavior of matter.

At the simultaneously and/or successive loading with multiple loads, especially in the case of non-linear behavior of matter, it imposes the calculation of effects with adequate mathematical relations.

On the other side, the intramolecular reciprocal influence, the intramolecular synergism of molecular fragments was analised using a statistical method in the paper [37].

Conclusions

Solid bodies and fluids and more particularly environment, are often, simultaneous loaded with several external actions/loads. The problem in these cases of loads superposition is to determine if that load is allowable or not?

For this purpose was used critical energy principle on which, for nonlinear behavior, power law (5), have been calculated the total participation of specific energy with respect to allowable state (15) and the allowable participation (17). By comparing the values (dimensionless) of these quantities one can determine if the stress corresponding to the action of several loads is allowable or not.

The result obtained ((15)-(17)) was applied to loads superposition:- upon a solid body ((21),(22) and (24)); in case of environmental pollution with a single sort of pollutants (26); - in case of environmental multiple pollution: chemical, radiations and magnetic (29).

Finally is shown that the load superposition can have synergetic effect and this, according to behavior of loaded matter, can be positive or negative, that means the total effect can be higher or lower than the algebraic sum of their individual effects.

References

1. JINESCU V.V., Calculul si constructia utilajului chimic, petrochimic si de rafinarii, vol. I, Editura Didactica si Pedagogica, Bucuresti, 1983.

2.ZHU S.-P., YANG Z.-J., HUANG H.-Y., LV Z., WANG H.-K., A unified criterion for fatigue-creep life prediction of high temperature components, Journal of Aerospace Engineering 0 – (0)I – 12, DOI:10.1177/0954410016641448.

3.LYNCH M. A., MOFFAT D. G., MORETON D. N., Limit loads for a cracked branch junction under pressure and branch out-of-plane bending, Int. J. Press. Vess.&Piping, **77**, no. 4, 2000, p. 185.

4.LYNCH M. A., Limit loads of piping branch junctions with cracks, Phd. Thesis, The University of Liverpool, 2001.

5.MYEONG M. S., KIM Y. J., BUDDEN P. J., Limit load interaction of cracked branch junctions under combined pressure and bending, Eng. Fract. Mech., **86**, 2012, p. 1.

6.JINESCU, V..V., CHELU, A., TEODORESCU, N., NICOLOF, V.I., Strength of tubular samples and tubular cracked junctions under combined loads, Rev. Chim. (Bucharest), **66**, no. 11, 2015, p. 1832

7.JINESCU V.V., Tratat de Termomecanica, vol. 1, Editura AGIR, Bucureºti, 2011.

8. JINESCU V.V., Energonica, Editura Semne, Bucuresti, 1997.

9.JINESCU V.V., Principiul energiei critice si aplicatiile sale, Editura Academiei Romane, Bucuresti, 2005.

10.JINESCU V.V., Principiul energiei critice, Rev. Chim. (Bucharest), **35**, no. 9, 1984, p. 858

11. JINESCU, V.,V., NICOLOF, V. I., JINESCU, G., ENACHESCU, G. L., Unitary approach of mechanical structures and living organisms lifetime, Rev. Chim. (Bucharest), **67**, no. 9, 2016, p. 1673

12.JINESCU, V..V., Discursuri ºi expuneri academice, Editura AGIR, Bucureºti, 2014.

13JINESCU V.V., Critical Energy Approach for the Fatigue life Calculation under Blocks with different normal Stress Amplitudes, Int. J. Mechanical Sci., **67**, 2013, p. 78-88.

14.BASQUIN OH, The exponent low of endurance tests, Proc. Am. Soc. Test Mater, 1910, **10**, p. 625-630.

15.JINESCU, V.V., NICOLOF, V. I., JINESCU, C.V., CHELU, A., Superposition of Effects in Calculating the Deterioration of Tubular Structures and in Non-newtonian Fluid Flow, Rev. Chim. (Bucharest), **66**, no. 5, 2015, p. 698

16. JINESCU V.V., NICOLETA TEODORESCU, GEORGE JINESCU, IOLANDA CONSTANTA PANAIT, The result of superposition of different actions upon the mechanical structures and living bodies, Rev. Chim. (Bucharest), **67**, no. 12, 2016, p. 2607-2613.
17. ***Legea 104/15.06.2011 privind calitatea aerului înconjurãtor. published in the Official Gazette of Romania no 452/28.06.2011.
18. Hotararea nr. 352 din 21 aprilie 2005 privind modificarea si completarea Hotãrârii Guvernului nr. 188/2002 pentru aprobarea unor norme privind conditiile de descãrcare în mediul acvatic a apelor uzate. published in the Official Gazette of Romania no. 196/22.03.2002.
19. *** Ordinul Ministerului Apelor, Padurilor si Protectiei Mediului, nr 756/03.11.1997 pentru aprobarea Reglementarii privind evaluarea poluarii mediului, published in the Official Gazette of Romania, Parte I no. 313 bis /06.XI.1997.
20 *** Ordin nr. 1.193 din 29 septembrie 2006 pentru aprobarea Normelor privind limitarea expunerii populatiei generale la campuri electromagnetice de la 0 Hz la 300 GHz.
21 *** ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields up to 300 GHz.
22.*** Hotarare nr. 1.136 din 30 august 2006 privind cerintele minime de securitate si sanatate referitoare la expunerea lucrãtorilor la riscuri generate de câmpuri electromagnetice, published in the Official Gazette of Romania nr. 769 din 11 septembrie 2006.
23. ***Ordinului Ministrului nr. 1978/19.11.2010 privind aprobarea Regulamentului de Organizare ºi Funcþionare a Reþelei Naþionale de Supraveghere a Radioactivitãþii Mediului.
24.*** NSR-01 NORME FUNDAMENTALE DE SECURITATE RADIOLOGICA approved by Order of the President of CNCAN no. 14/24.01.2000, published in the Official Gazette of Romania Parte I nr. 404 bis / 29.08.2000.
25.JINESCU, V.V., NICOLOF, V. I., Calculation of deterioration due to cracks in tubular specimens, U.P.B. Sci.Bull., Series D, vol. 76, 2014, p. 149 – 160.
26.JINESCU, V.V., NICOLOF, V. I., TEODORESCU N., Relation for Calculation of Critical Stresses in Pressure Equipment with Cracks, Rev. Chim. (Bucharest), **64**, no. 8, 2013, p. 858
27.JINESCU, V.,V., The Principle of Critical Energy in the Field of Materials Fracture Mechanics, Int. J. Press Vess & Piping, **53**, nr. 1, 1992, p. 39-45.
38.JINESCU, V..V., Stability Determination of Structure under Groups of Loads by Using the Principle of Critical Energy, Int. J. Press Vess & Piping, **48**, nr. 4, 1991, p. 343-375.
29.JINESCU, V..V., Principiul energiei critice în domeniul mecanicii ruperii materialelor, II, Rev. Chim. (Bucharest), **41**, no 4, 1990, p. 305
30. JINESCU V.V., Effects Superposition by Buckling, Fatigue and Creep, Int. J. Press Vess & Piping, **53**, nr. 3, 1993, p. 377-391.
31. JINESCU, V.V., Contribuþii la calculul deteriorãrii materialelor si echipamentelor de proces, I, Rev. Chim. (Bucharest), **59**, no. 4, 2008, p. 453
32. JINESCU, V.V., PETRESCU, ST., JINESCU, C., Energy, Work, Heat and Efficiency in Processes with Gases, Viscos and Viscoelastic Liquids and Solids, I, Rev. Chim. (Bucharest), **64**, no. 5, 2013, p. 457
33. JINESCU, V.V., Contributii la calculul deteriorãrii materialelor si echipamentelor de proces, II, Rev. Chim. (Bucharest), **59**, no. 7, 2008, p. 787-795.
34.JINESCU, V.V., NICOLOF, V.I., CHELU, A., MANEA, S.E., Critical stresses, critical group of stresses and strength of tubular structures without and with cracks, U.P.B. Sci.Bull., Series D, **77**, 2015, p. 165-176.
35.JINESCU, V..V., Fatigue life prediction for simultaneous cyclic loading with blocks of normal stresses and shear stresses, Eng. Sci. and Innovation, **1**, nr. 1, 2016, p. 1-16.
36. JINESCU V.V., Principiul energiei critice II. Aplicatii în cazul solicitarilor variabile izoterme, Rev. Chim. (Bucharest), **40**, no. 1, 1989, p. 67
37.TARKO L., A statistical method for calculation of intramolecular synergy, MATC Commun. Math. Comput. Chem., **75**, 2016, p. 533 – 558.

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