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

VALERIU V. JINESCU*, SIMONA EUGENIA MANEA1, COSMIN JINESCU1
1 Politehnica University Bucharest, 313, Splaiul Independentei, 060042, Bucharest, Romania
2 Horia Hulubei National Institute of Physics and Nuclear Engineering, 30 Reactorului, 077125, Magurele, Romania

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 cumulative 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, Ai, is characterized by what we call stress, Si. The stress is the carrier of a certain quantity of specific energy, Ei, 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,

\[ S_i \leq S_{i,\text{al}} \]  

where \( S_{i,\text{al}} \) 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 \( S_{i,\text{al}} \) 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 \( \sigma_i \), which is proportional to \( Y_i \):

\[ \sigma_i \approx Y_i \]  

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

\[ \sigma_i \leq \sigma_{i,\text{al}} \]  

where \( \sigma_{i,\text{al}} \) 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 loading/stresses upon a body or upon the environment (fig. 2). For example, mechanical load upon a structure with tensile stress \( o \), 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: \( S_i \) – constant in time; \( S_m \) – varying in time (produces fatigue); \( S_m \) – 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 \( Y \) external generalized load by nature of type \( i \) and \( X \) - the effect of the nature of type \( j \) (except the thermal effect, noted \( X_{th} \)).

The effects of loads \( Y \) 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 \( Y_1, Y_2, \ldots, Y_n \) (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 \( (X) \), the occurrence of electric charges \( (X) \), and thermal effect \( (X_{th}) \), as shown in figure 3, b. It is what is defined as piezoelectricity.

* email: vvjinescu@yahoo.com; Phone: ++4021.402.9193;
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

\[ Y = B \cdot X \]  \hspace{1cm} (4)

- non-linear, power law,

\[ Y = C \cdot X^k \]  \hspace{1cm} (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

\[ E_i = \frac{E}{V} \]  \hspace{1cm} (6)

where \( V \) is body volume stressed by the load \( Y \), carrier of the energy \( E \). Generally, specific energy is calculated with the relation,

\[ E_i = \int Y \cdot dX \]  \hspace{1cm} (7)

which, for linear behavior (4) becomes,

\[ E_i = \frac{1}{2} (B \cdot X)^2 \]  \hspace{1cm} (8)

and for nonlinear (5) is,

\[ E_i = \frac{1}{k+1} (C \cdot X^{k+1}) \]  \hspace{1cm} (9)

By replace \( x = Y/B \) and respectively \( x = Y/C \) \( k \) in equations (8) and (9) obtains,

\[ E_i = \frac{Y^2}{2B} \]  \hspace{1cm} in case of low (4);

\[ E_i = \frac{Y^{k+1}}{(k+1) \cdot C^{k/2}} \]  \hspace{1cm} in case of low (5);

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 [Es] = J/m³), 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:

\[ P' = \frac{E_s(Y)}{E_s(Y_{al})} \delta_Y. \]  (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 \( (Y_{al}) \). This allows to calculate the total effect of the simultaneous loads \( (Y) \), by algebraic summation of individual participations \( P'(Y_i) \); it can be obtained the total participation of the specific energies,

\[ P'_t = \sum P'_t(Y_i). \]  (12)

where \( P'_t(Y_i) \) 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, \( Y_{al} \),

\[ E_{s,al} = \begin{cases} \frac{Y_{al}^2}{2B} & \text{in case of low (4)}; \\ \frac{Y_{al}^{1+1}}{(k+1)C} & \text{in case of low (5)}. \end{cases} \]  (13)

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

\[ P' = \left( \frac{Y}{Y_{al}} \right)^2 \delta_Y \text{ in case of low (4)}; \]

\[ P'(Y) = \left( \frac{Y}{Y_{al}} \right)^{1+1} \delta_Y \text{ in case of low (5)}. \]  (14)

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

\[ P'_t = \sum_i \left( \frac{Y_i}{Y_{al}} \right)^{1+1} \delta_{Y_i} . \]  (15)

where \( \alpha = 1 / k \).

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

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,

\[ P'_t \leq P'_{al} \text{ - the load or the process \ where act the load \( Y \) is allowable}; \]

\[ P'_t > P'_{al} \text{ - the load or the process \ where act the load \( Y \) is not allowable}. \]  (16)

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

\[ P'_{al} = \begin{cases} P'_{t} & \text{for the undamaged materials and without residual stresses}; \\ -D'_t(t) - P'_{res}, & \text{generally} \end{cases} \]  (17)

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

\[ D'_t(t) = \sum D'_t(t). \]  (18)

where \( D'_t(t) \) is the individual deterioration (caused by a certain external stress) in relation with allowable state, which can be calculated using the relation \( D'_t(t) = D(t) / C_o \), where \( C_o > 1 \) is safety coefficient; and \( D(t) \) is calculated corresponding to the critical state of matter deterioration.

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

\[ P'_{res} = \left( \frac{\sigma_{res}}{\sigma_{al}} \right)^2 \delta_{res} . \]  (19)

where \( \sigma = \sigma_{al} \), \( c > 1 \) is the safety coefficient.

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

\[ P'_t(t) = P'_t + P'_t(t) + P'_t(t) \]  (20)

The right part of relation (20) is inscribed the individual participations with respect to the allowable state \( P'_{al} \). 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, \( = \text{const.}, \) 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])

<table>
<thead>
<tr>
<th>No.</th>
<th>Stress</th>
<th>The specific energy participation with respect to allowable state</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Normal stresses in the solid:</td>
<td>- tensile or compression ($\sigma$)</td>
<td>$P^*(\sigma) = \left(\frac{\sigma}{\sigma_{ai}}\right)^{a_{\sigma}+1} \cdot \delta_{\sigma}$</td>
<td>$\sigma = M_{\sigma} \cdot e$ - the behavior law; $M_{\sigma}$, $e$ - material constants; $\sigma_{ai}$, $\sigma_{ai}$ - allowable values of $\sigma$, respectively, $\sigma_{ai}$; $\delta_{\sigma} = 1$, if $\sigma &gt; 0$; $\delta_{\sigma} = -1$, if $\sigma &lt; 0$; $a_{\sigma} = 1/\delta_{\sigma}$.</td>
</tr>
<tr>
<td>1. Normal stresses in the solid:</td>
<td>- bending stress ($\sigma_\beta$)</td>
<td>$P^*(\sigma_\beta) = \left(\frac{\sigma_\beta}{\sigma_{\beta,ai}}\right)^{a_{\sigma_\beta}+1} \cdot \delta_{\sigma_\beta}$</td>
<td>$\sigma_\beta = M_{\beta} \cdot e^k$ - the behavior law; $M_{\beta}$, $k_1$ - material constants; $\sigma_{\beta,ai}$, $\sigma_{\beta,ai}$ - allowable values of $\sigma_\beta$, respectively, $\sigma_{\beta,ai}$; $\delta_{\sigma_\beta} = 1$, if $\sigma_\beta &gt; 0$; $\delta_{\sigma_\beta} = -1$, if $\sigma_\beta &lt; 0$.</td>
</tr>
<tr>
<td>2. Shear stresses in the solid:</td>
<td>- shear stress ($\tau$)</td>
<td>$P^*(\tau) = \left(\frac{\tau}{\tau_{ai}}\right)^{a_{\tau}+1}$</td>
<td>$\tau = M_{\tau} \cdot e^k$ - the behavior law; $M_{\tau}$, $k_1$ - material constants; $\tau_{ai}$, $\tau_{ai}$ - allowable values of $\tau$, respectively, $\tau_{ai}$; $a_{\tau} = 1/\delta_{\tau}$.</td>
</tr>
<tr>
<td>2. Shear stresses in the solid:</td>
<td>- torsion stress ($\tau_t$)</td>
<td>$P^*(\tau_t) = \left(\frac{\tau_t}{\tau_{t,ai}}\right)^{a_{\tau_t}+1}$</td>
<td>$\tau_t$ - time of contact with corrosive substance; $t_{ai}$ - time until the allowable corrosion of wall thickness; $c$ - constant.</td>
</tr>
<tr>
<td>3. Cyclic stress with constant amplitude of stress ($\sigma^2$) [14]</td>
<td>$P^*(n) = \left(\frac{n}{N_{ai}}\right)^{a_{n}+1}$</td>
<td>$\alpha = 1/\delta_{\alpha}$; $n$, $N_{ai}$ - number of effective loading cycles and allowable loading cycles, respectively, with stress amplitude, $\sigma_{ai}$; $m$ is the exponent of the Basquin’s law [14].</td>
<td></td>
</tr>
<tr>
<td>4. Constant corrosion</td>
<td>$P^*(t) = \left(\frac{t}{t_{ai}}\right)^{c}$</td>
<td>$t$ - time of contact with corrosive substance; $t_{ai}$ - time until the allowable corrosion of wall thickness; $c$ - constant.</td>
<td></td>
</tr>
<tr>
<td>5. Action of pollutants</td>
<td>$P^*(c) = \left(\frac{c}{c_{ai}}\right)^{a_{c}+1}$</td>
<td>$c$, $c_{ai}$ - pollutant concentration and its allowable value; $e = a \cdot e^c$ - the effect of pollutant $c$; $a$, $a_e$ - constants.</td>
<td></td>
</tr>
<tr>
<td>6. Radiations flow</td>
<td>$P^*(\Phi) = \left(\frac{\Phi}{\Phi_{ai}}\right)^{a_{\Phi}+1}$</td>
<td>$\Phi$, $\Phi_{ai}$ - radiations flow (UV, thermal, neutrons, X-ray etc.) and its allowable value. The effect, $e$, of radiations flow: $e = b \cdot \Phi^k$; $b$, $a_\Phi$ - constants.</td>
<td></td>
</tr>
<tr>
<td>7. Magnetic field</td>
<td>$P^*(B) = \left(\frac{B}{B_{ai}}\right)^{a_{B}+1}$</td>
<td>Behavior law: $F = M_B \cdot B^2$ - force created by induction $B$; $B$, $B_{ai}$ - the induction of the magnetic field and its allowable value; $M_B$ and $a_B \geq 1$ - constants.</td>
<td></td>
</tr>
<tr>
<td>8. Organisms exposure to electrical fields of a certain frequencies,</td>
<td>$P^*(J) = \left(\frac{J}{J_{i,ai}}\right)^{a_{J}+1}$</td>
<td>$J$, $J_{i,ai}$ - the density ($A \cdot m^{-2}$) of the electrical current induce at frequency $i$ and its maximum allowable effect. Law of behavior: the effect $e_J$ is, $e_J = M_J \cdot J^{2\delta_{J}}$, where $M_J$ and $a_J$ are constants.</td>
<td></td>
</tr>
</tbody>
</table>
Some cases of loads superpositions on mechanical structures were analysed 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 write relationship (22), it was taken into account that $\delta_{F} \sigma_{b} \tau_{b}$. In eqs. (21) and (22) one considered the behaviour of solid material expressed by the following power laws:

$$\sigma = M_{b} \varepsilon^{k} \quad \text{for normal stresses:}$$

$$\tau = M_{b} \gamma^{k_{1}} \quad \text{for shear stress.}$$

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

$$\sigma = M_{b} \varepsilon^{k} \quad \text{for normal stresses:}$$

$$\tau = M_{b} \gamma^{k_{1}} \quad \text{for shear stress.}$$

The factors $M_{b}$, $M_{t}$ and the exponents $k$ and $k_{1}$ by relations (23) are constants of the material. In the relation (21) one noted $a = 1/k$ and $a_{1} = 1/k_{1}$.

**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, where $M(-)$ 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'B1 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.) $\Phi$, a magnetic field by induction $B$, is characterized by the total participation compared to the allowable state [11, 16],

\begin{equation}
P_{F} = \left( \frac{F_{a}}{F_{a,al}} \right)^{a_{1}} + \left( \frac{M_{b}}{M_{b,al}} \right)^{a_{1}} + \left( \frac{M_{t}}{M_{t,al}} \right)^{a_{1}},
\end{equation}

\begin{equation}
\sigma_{b} \left( \frac{\sigma_{b}}{\sigma_{b,al}} \right)^{a_{1}} + \left( \frac{\sigma_{b}}{\sigma_{b,al}} \right)^{a_{1}} + \left( \frac{\tau_{b}}{\tau_{b,al}} \right)^{a_{1}}.
\end{equation}

\begin{equation}
P_{F} = \left( \frac{P_{e}}{P_{e,al}} \right)^{a_{1}} + \left( \frac{M_{b}}{M_{b,al}} \right)^{a_{1}} + \left( \frac{F_{a}}{F_{a,al}} \right)^{a_{1}},
\end{equation}

\begin{equation}
\Phi \left( \frac{\Phi}{\Phi_{al}} \right)^{a_{1}} + \left( \frac{\Phi}{\Phi_{al}} \right)^{a_{1}} + \left( \frac{B}{B_{al}} \right)^{a_{1}},
\end{equation}

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 \( S_{al} \). 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 polluants, 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,

\[
F^*_T(c) = \left( \frac{c_i(t)}{c_{al,i}} \right)^{a_{si}}
\]

where \( c(t) \) is time dependent; for example, decreases to time (fig. 7). \( c_{al,i} \) 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.

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

\[
F^*_T(\Phi) = \left( \frac{\Phi_j}{\Phi_{al,j}} \right)^{a_{\Phi_j}}
\]

where \( \Phi_j \) is the radiation flow of radiation \( j \), in the environment, and \( \Phi_{al,j} \) 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),

\[
F^*_T(B) = \left( \frac{B_k}{B_{al,k}} \right)^{a_{B_k}}
\]

where \( B_{al,k} \) 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,

\[
F^*_T = F^*_T(c) + F^*_T(\Phi) + F^*_T(B)
\]

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>
<thead>
<tr>
<th>Physical or chemical pollutant</th>
<th>Maximum Allowable Concentration (MCA)</th>
<th>The limit value for protection of ecosystems</th>
<th>Limit value for protection of human health</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UM</td>
<td>1 h</td>
<td>24 h</td>
</tr>
<tr>
<td>Sulf dioxide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen dioxide and oxides of nitrogen</td>
<td>µg/m³</td>
<td>200*</td>
<td>40</td>
</tr>
<tr>
<td>Suspensions (PM10)</td>
<td>µg/m³</td>
<td>50 *</td>
<td>40</td>
</tr>
</tbody>
</table>

*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])

<table>
<thead>
<tr>
<th>Global indicators</th>
<th>U.M.</th>
<th>Waste water discharges in sewer networks</th>
<th>Waste water discharges into natural receivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Physical indicators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum temperature of discharge</td>
<td>°C</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>B. Chemical indicators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH of wastewater discharge</td>
<td>pH units</td>
<td>6.5-8.5</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Pollutants discharged Maximum Allowable Concentration (MCA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biochemical oxygen demand in 5 days (BOD5)</td>
<td>mg Oy/dm³</td>
<td>300</td>
<td>25.0</td>
</tr>
<tr>
<td>Phenols coagulable water vapor (C₆H₅OH)</td>
<td>mg/dm³</td>
<td>30</td>
<td>0.3</td>
</tr>
<tr>
<td>Extractable Substances with organic solvents</td>
<td>mg/dm³</td>
<td>30</td>
<td>20.0</td>
</tr>
<tr>
<td>Free residual chlorine (Cl₂)</td>
<td>mg/dm³</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 5
MAXIMUM ALLOWABLE CONCENTRATION FOR ENVIRONMENT FACTORS IN SOIL EXTRACTED FROM [19])

<table>
<thead>
<tr>
<th>Physical or chemical pollutant</th>
<th>U.M.</th>
<th>Normal Values</th>
<th>Maximum Allowable Concentration (MCA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>mg/kg</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>mg/kg</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>B. Elements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanide (free)</td>
<td>mg/kg</td>
<td>&lt;1</td>
<td>5</td>
</tr>
<tr>
<td>Cyanide (complex)</td>
<td>mg/kg</td>
<td>&lt;5</td>
<td>100</td>
</tr>
<tr>
<td>C. Aromatic and polyaromatic hydrocarbons. Petroleum hydrocarbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total aromatic hydrocarbons (AH)</td>
<td>mg/kg</td>
<td>&lt;5</td>
<td>25</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons</td>
<td>mg/kg</td>
<td>&lt;100</td>
<td>200</td>
</tr>
<tr>
<td>D. Organic compounds organochlorine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total chlorobenzenes</td>
<td>mg/kg</td>
<td>&lt;0.1</td>
<td>5</td>
</tr>
<tr>
<td>Polychlorodibenzofurans</td>
<td>mg/kg</td>
<td>&lt;0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>E. Organochlorine pesticides and triazine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Organochlorine pesticides</td>
<td>mg/kg</td>
<td>&lt;0.2</td>
<td>1</td>
</tr>
<tr>
<td>Total triazine</td>
<td>mg/kg</td>
<td>&lt;0.1</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 6
MAXIMUM ALLOWABLE VALUES FOR EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS (EXTRACTED FROM [20 - 22])

<table>
<thead>
<tr>
<th>Frequency, f, Hz</th>
<th>Electric field strength, E (kV/m)</th>
<th>Magnetic field strength, H (Am⁻¹)</th>
<th>Magnetic flux density, B (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational exposure</td>
<td>Environmental exposure</td>
<td>Occupational exposure</td>
<td>Environmental exposure</td>
</tr>
<tr>
<td>1 Hz - 8 Hz</td>
<td>20</td>
<td>5</td>
<td>1.53 x 10⁵/f²</td>
</tr>
<tr>
<td>8 Hz - 25 Hz</td>
<td>20</td>
<td>5</td>
<td>2 x 10⁶/f</td>
</tr>
<tr>
<td>25 Hz - 300 Hz</td>
<td>5 x 10⁴/f</td>
<td>5</td>
<td>8 x 10²</td>
</tr>
<tr>
<td>300 Hz - 400 Hz</td>
<td>2.5 x 10⁵/f</td>
<td>2.5 x 10⁴/f</td>
<td>6.4 x 10⁴/f</td>
</tr>
<tr>
<td>400 Hz - 3 kHz</td>
<td>5 x 10⁴/f</td>
<td>2.5 x 10⁴/f</td>
<td>6.4 x 10⁴/f</td>
</tr>
<tr>
<td>3 kHz - 10 mHz</td>
<td>1.7 x 10⁴</td>
<td>8.3 x 10⁻²</td>
<td>80</td>
</tr>
</tbody>
</table>

### Table 7
MAXIMUM ALLOWABLE VALUES FOR ENVIRONMENTAL RADIOACTIVITY [23]

<table>
<thead>
<tr>
<th>Environmental factor</th>
<th>Measurement</th>
<th>U.M.</th>
<th>Maximum Allowable Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Gross beta radioactivity</td>
<td>Bq/m³</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>External gamma Dose Rate</td>
<td>μSv/h</td>
<td>0.250</td>
</tr>
<tr>
<td>Atmospheric deposition</td>
<td>Gross beta radioactivity</td>
<td>Bq/m³/day</td>
<td>200</td>
</tr>
<tr>
<td>Water</td>
<td>Gross beta radioactivity</td>
<td>Bq/l</td>
<td>2</td>
</tr>
</tbody>
</table>
The synergic effect by superposition external loads

Simultaneous action of several loads 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 action 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 analysed 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).

References

6. JINESCU, V.V., CHELU, A., TEODORESCU, N., NICOLEOF, V.I., Strength of tubular samples and tubular cracked junctions under combined loads, Rev. Chim. (Bucharest), 66, no. 11, 2015, p. 1832.
10. JINESCU V.V., Principiul energiei critice, Rev. Chim. (Bucharest), 35, no. 9, 1984, p. 858.

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

<table>
<thead>
<tr>
<th>Dose limits</th>
<th>Whole body</th>
<th>Extremity of hands and legs</th>
<th>Skin</th>
<th>Lens of the eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1 mSv/year</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Exposed workers</td>
<td>20 mSv/year</td>
<td>500 mSv/year</td>
<td>500 mSv/year</td>
<td>150 mSv/year</td>
</tr>
<tr>
<td>Trainees (16-18 years old)</td>
<td>6 mSv/year</td>
<td>150 mSv/year</td>
<td>150 mSv/year</td>
<td>50 mSv/year</td>
</tr>
<tr>
<td>Women during pregnancy</td>
<td>≤ 1 mSv/year</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
16. JINESCU V.V., NICOLETA TEODORESCU, GEORGE JINESCU, IOLANDA CONSTANTIA 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 inconjurãtor, published in the Official Gazette of Romania no 452/28.06.2011.
20. Ordinul 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.
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
31. JINESCU, V.V., Contribuþii la calculul deteriorãrii materialelor si echipamentelor de proces, I, Rev. Chim. (Bucharest), 59, no. 4, 2008, p. 453
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.

Manuscript received: 15.12.2016