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# VIBRATION CHARACTERISTICS OF THE TECHNICAL DEGRADATION PROCESS OF AN OBJECT

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## Abstract

The mechanical system is modelled as an energy processor, which transforms the input power into effective power, destruction power of its elements and external dissipation power (noise). The elements of the mechanical object are subject to wear with different intensity. This is reflected in the dynamic characteristics of the object and the vibration load power characteristics causing the destruction of the machine. The paper presents the concept of an energy-based vibration identification method of the degradation of a reinforced concrete beam, subjected to static loads until failure. The method is used in testing the energy propagation and the structural changes in mechanical objects.

## ANALYSIS OF DEGRADATION PROCESS OF MECHANICAL OBJECT

According to the nature of processes, the phenomenon of mechanical structures' degradation is described by power quantities. The work of external exciting force equals the work of damping force in the system which is the measure of destruction. The value of the realized work is the function of damping measures and vibration amplitude. It reaches maximum values in resonance.
The method of dynamic load power distribution analysis [1] has been used in testing the degradation process and the evaluation of object life time. This method is a modern, power method of the object life time analysis. It allows for spatial power change in individual subsystems and the flow of energy between the subsystems.
The main idea of this method is the fact that the object load condition can be represented by accumulated, dissipated and transferred energy.

In the frequency domain, the machine load condition holistic model is described by the matrix of power spectral density of the dynamic load power in a mechanical system [1]:

$$\left\{G_{N_{ik}}\left(j\omega,\Theta\right)\right\} = \mathbf{H}_{V_{ik}}\left(j\omega,\Theta\right)\cdot \mathbf{G}_{F_k F_k}\left(j\omega,\Theta\right) \qquad (1)$$

where: $\mathbf{H}_{V_{ik}}\left(j\omega,\Theta\right)$ – the matrix of the dynamic mobility,

$\mathbf{G}_{F_k F_k}\left(j\omega,\Theta\right)$ – the matrix of the spectral density of forcing actions.

The elements of the matrix of dynamic characteristics [1]:

$$\mathbf{H}_{ik}\left(j\omega,\mathbf{D}(r,\Theta)\right) = \begin{Bmatrix} H_{11}\left[j\omega, D_{11}(\Theta)\right] & \dots & H_{1n}\left[j\omega, D_{1n}(\Theta)\right] \\ \hdotsfor{3} \\ H_{n1}\left[j\omega, D_{n1}(\Theta)\right] & \dots & H_{nn}\left[j\omega, D_{nn}(\Theta)\right] \end{Bmatrix} \qquad (2)$$

are the functions of the spatial destruction measure of the mechanical system.

The real part of the load power is the measure of the internal dissipation, causing the destruction. The cumulative results of the occurrence of vibration loads manifest themselves in destruction of the structure elements. The fatigue destruction is mainly caused by the elastic or plastic strain at the edges of material defects. The quantity of dissipated energy and material volume distribution decide on the life time of the elements.

## EXAMPLES

### Power characteristics of the structural degradation of objects' elements

The comparative tests of two pretensioned prestressed concrete beams have been made (Fig.1).

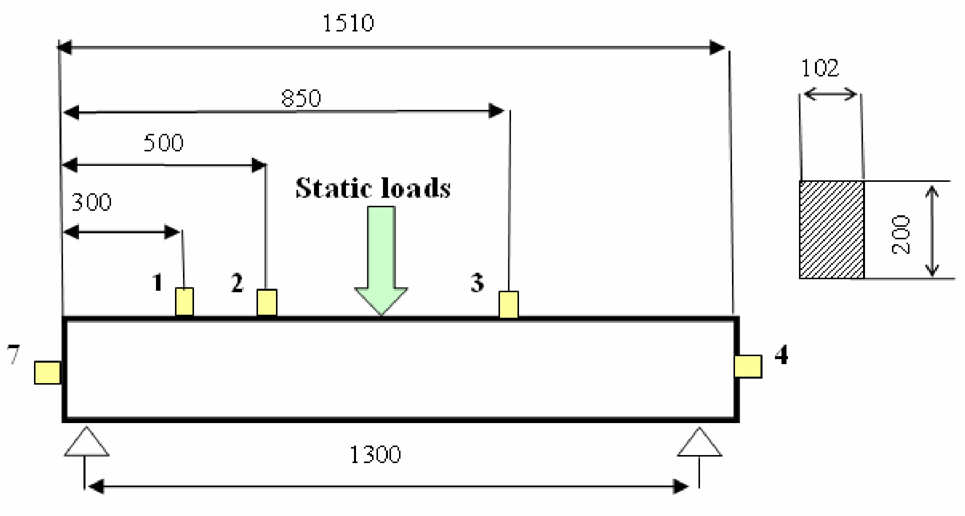


*Figure 1- Pretensioned prestressed concrete beam.*
*Distribution of the application points of the testing forcing actions of the impulse character and the vibration registration points [7]*

The beams differed in compression ratio of concrete. The diagnostic tests have been made concerning the technical condition of the beams subjected to forcing actions applied in sequence in escalating degradation stages as a result of successively succeeding static loads **F**, put in the middle of the beam: 5,10,…75 kN.
The figures below present the comparison of the modules of the power spectral density of the testing load impulse power GN of the beams, determined in particular conditions of the technical degradation of the object. The dynamic characteristics and the testing load vibrating power values reflect the intensity of beams' degradation (cracking).

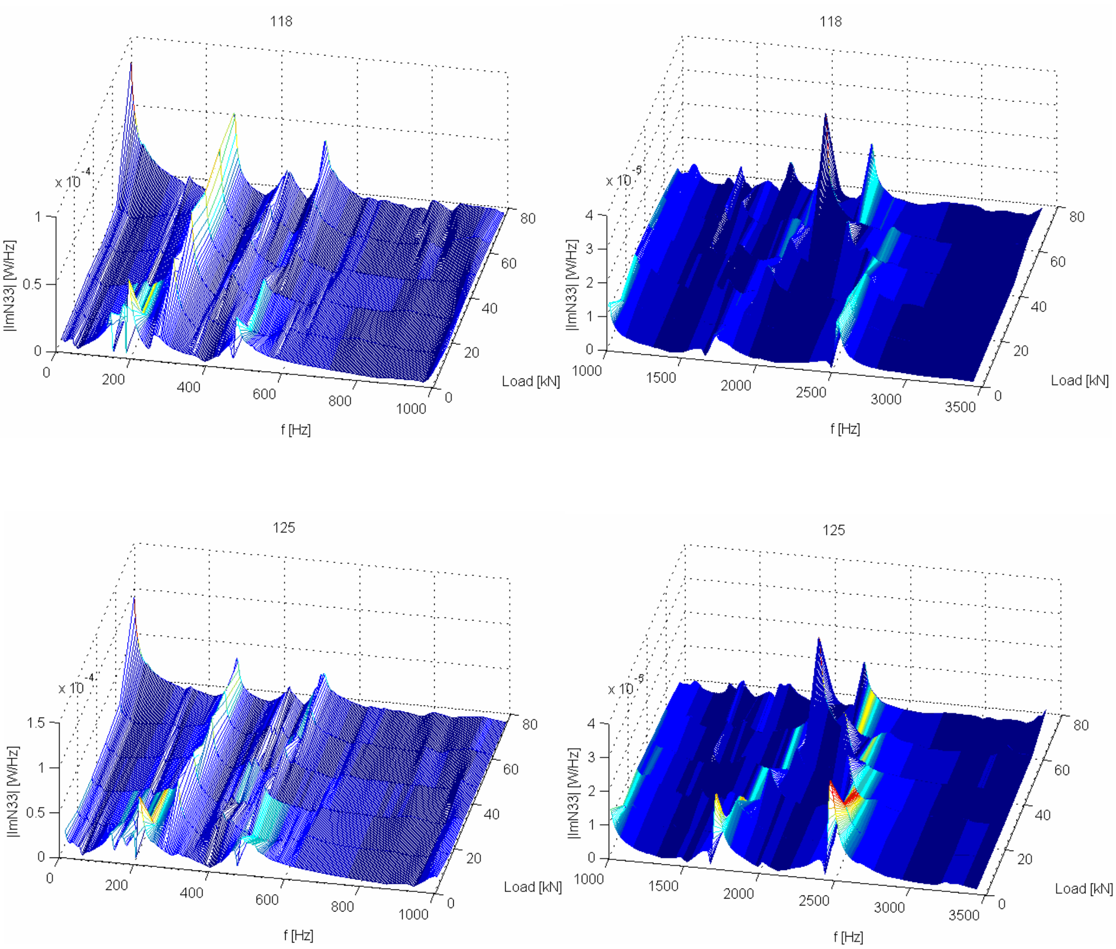


*Figure 2 - The comparison of the power spectrum density of the dynamic rigidity force power in different conditions of the beams' degradation*

Figures 2 and 3 present the imaginary parts modules and the real parts modules of the power spectral density of the dynamic load power $GN_{33}(f)$ of both beams. $GN_{33}(f)$ symbol is the power spectral density of the testing load power of the beam determined when applying forcing actions in point 3 and the measurement of responses in point 3. The characteristics have been determined in different conditions of their degradation when applying testing forcing action. The real parts of the power density spectrum of the power determine the force power testing the beams' destruction process. However, the imaginary parts $GN_{33}(f)$ of the power density spectrum of the power are the functional estimates of the dynamic rigidity force power and the beam inertia forces of the testing forcing actions.

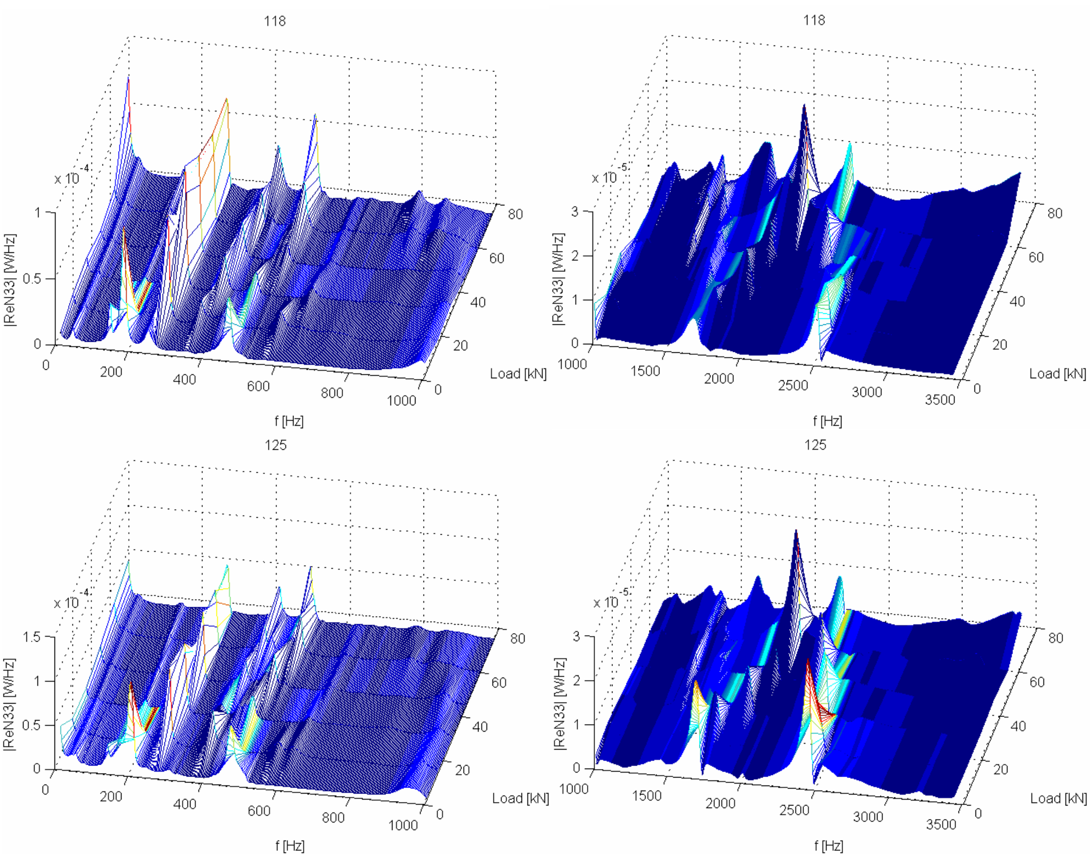


*Figure 3 - The comparison of the power spectral density of the vibration damping force power in different conditions of the beams' degradation*

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The state of beams degradation, caused by the increase of the static load, manifests itself in reduction of characteristic maxima frequency which means reduction of vibration frequency of the beams as a result of reduction of their dynamic rigidity (fig.2) and change of the internally dissipated energy (fig.3).

Analyzing the diagrams of the imaginary parts and the real parts of the testing force powers in the frequency function, remarkable changes (of maxima) in the run of these functions have been noticed, different for each beam, which means that the degradation processes of different frequency occurred altogether with the increase of the statistic load of the beam. Particularly, at the final stage of the testing the increase of the degradation processes occurred. Figures 4 and 5 present the amplitude estimates of the dissipated powers (fig.4) and of the dynamic rigidity force powers (fig.5) of the testing signals, determined from the following formula:

$$\int_{\omega} GN_{ik}(\omega)d\omega$$

Analyzing the function characteristics (fig. 2 and 3) and the diagrams of power amplitudes (fig. 4 and 5) of the testing loads in the beams' load function, higher values of dynamic rigidity and energy transfer of beam No. 125 shall be stated. Beam No. 118 has been destroyed at the load of approx. 50 kN, while beam No. 125 at the load of approx. 70 kN. In both beams the changes of the energy transfer function at the static load of approx. 40-45 kN have been noticed.

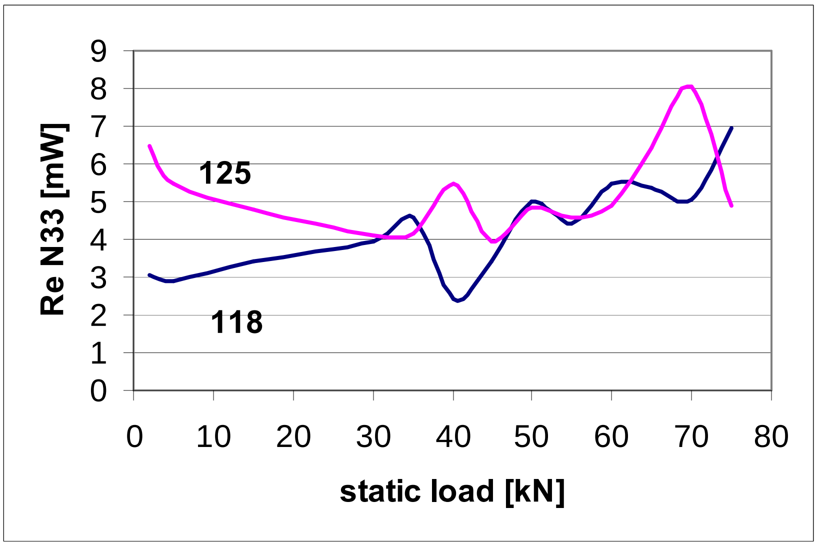


*Figure 4 - Forcing action force power characteristics describing scattering of energy*

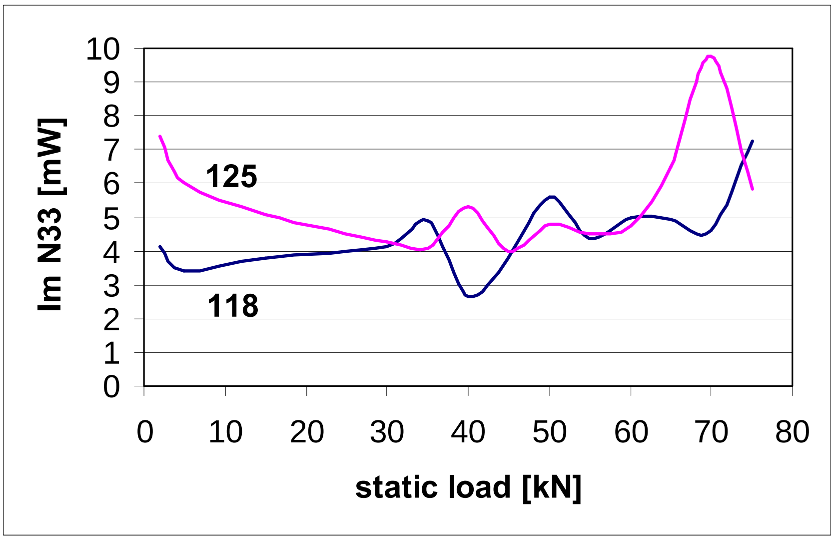


*Figure 5 - Characteristics of the inertia force power and dynamic rigidity of the testing forcing actions*

The real part of the testing forcing action power (fig. 4) is the scattered power in the structure. The scattered power maxima in the static load function inform about the initiation of the beam cracking process: for beam 118 it occurs at the load of approx 35 kN, for beam 125 at the load of approx. 42 kN.
The changes of the inertia force power and dynamic rigidity of the forcing actions (fig. 5) of beam 118 occur at the load of approx.35 kN and beam 125 at the load of approx. 40 kN. Maxima for high static loads characterised the process of cracking and breaking of beams.

## Structural changes in the process of welding of machine element (cultivator spring)

The tests of the cultivator spring structural characteristics (fig. 6) in two states have been made: a) a new spring, b) after cutting and welding. The spring has been subjected to the testing forcing actions. The figures below present the comparison of the modules of the power GN spectral density of the testing dynamic loads, determined when applying impulse testing forcing action at the accelerated test stand.

*Figure 6 - Cultivator spring at the test stand*

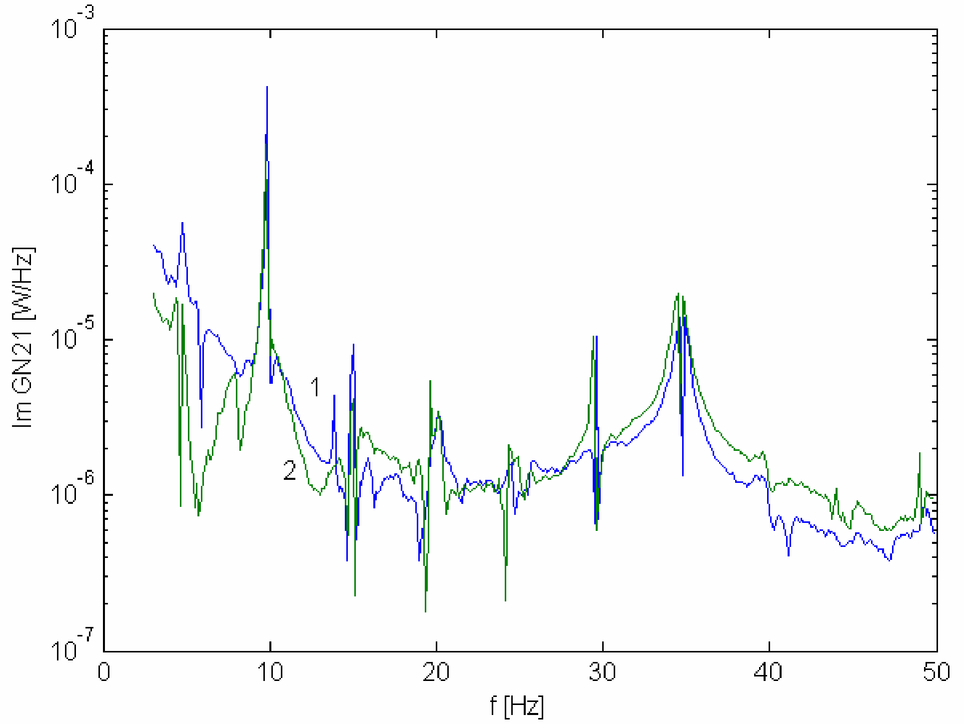


*Figure 7 - Modules of the real parts of the power spectral density of the load testing cultivator springs (1- without changes, 2-after welding)*

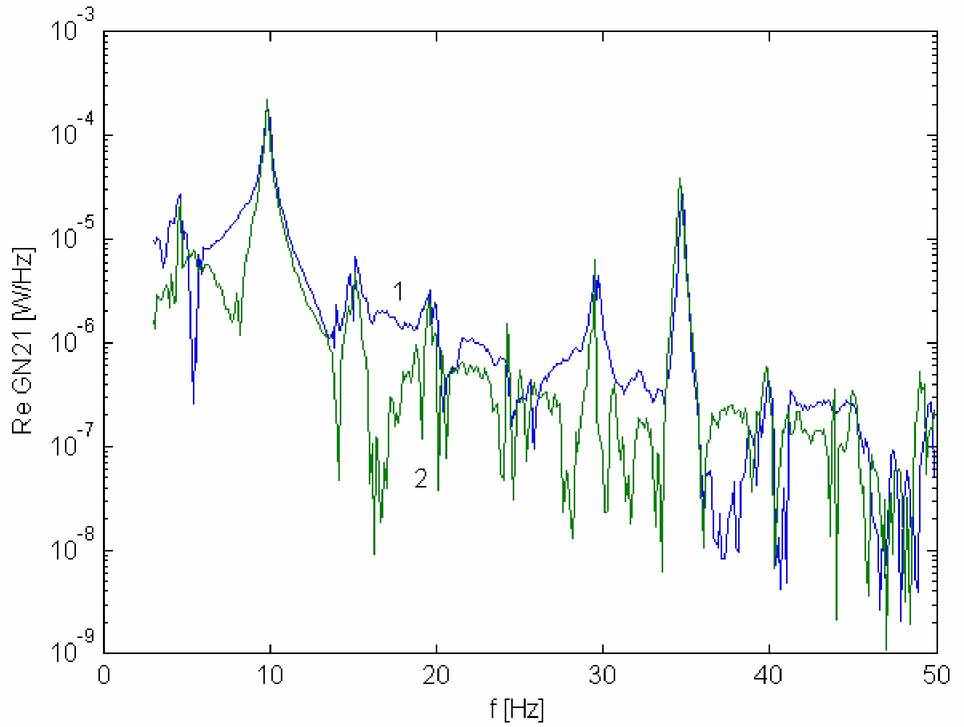


*Figure 8 - Modules of the real parts of the power spectral density of the load testing cultivator springs (1- without changes, 2-after welding)*

The shift of characteristic extremes and the occurrence of minima (anti-resonance) in power characteristics constitute the confirmation of the degradation state of the machine element in the process of welding.

## CONCLUSION

1/ The dynamic load power distribution analysis method in mechanical systems makes it possible to determine the characteristics of technical degradation process of mechanical objects and the description of their technical condition.
2/ The analysis of the life time tests' results by means of the impulse test method makes it possible to determine the loads initiating the process of the construction structure damage.

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