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EXPERIMENTAL RESULTS ON SIMULATION MODELS OF HYDRO ENERGETIC EQUIPMENTS DYNAMIC BEHAVIOUR

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Abstract The paper deals with the applied side of the models of simulation of the dynamic behavior of the hydro energetic equipments by generating some autoregressive models (ARX and ARMAX) which, applied to some bearing systems, show that the model approximates with a reasonable error the experimental results, allowing, at the same time, the comparative analysis of the results.

1. INTRODUCTION

Simulations were made based on the values measured experimentally of the sliding bearing and in the case of the bearing with hydraulic sustenation. In both cases we generated ARX and ARMAX models testing the functioning for some sets of parameters. As a simulation program we used the module „System Identification Toolbox" of the programming environment MATLAB of MathWorks. Excitation signals were sinusoids generated by a computer program, taking into account the amplitude and frequency of a real excitation.

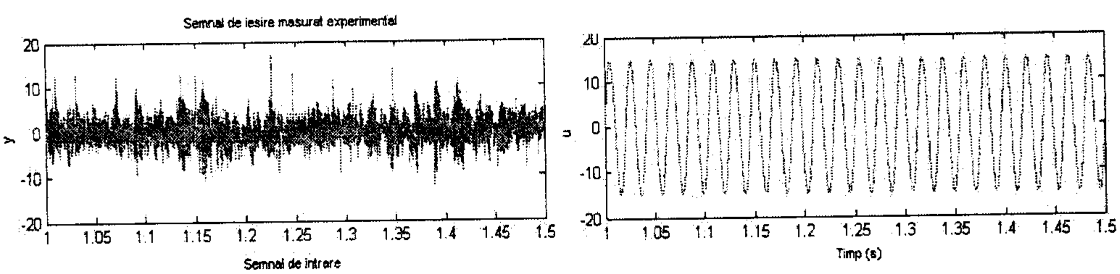

Fig. 1. The input and output signals of the model.

2. RESULTS OF SIMULATION IN THE CASE OF USING SLIDING BEARING

The input and output signals from this case are presented in fig. 1.

Usage of ARX model. Results of simulation and the experimentally measured signal are presented in fig. 2. One may notice that the model approximates relatively correct the experimental results, except for the random peaks.

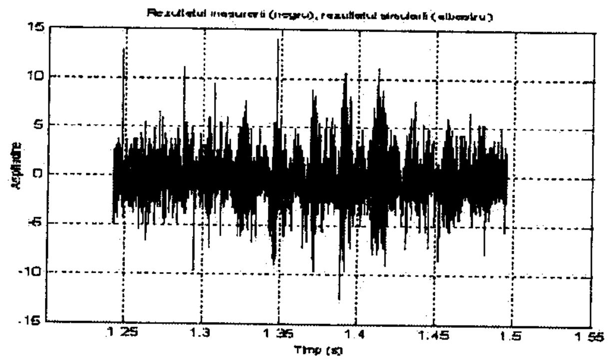

Fig. 2. Results of simulation using the ARX model. The blue zone represents the simulation; the black zone represents the experimentally measured signal.

The equation for the model is given by $A(q)y(t) = B(q)u(t) + e(t)$ where: $A(q)$ is the coefficient of the input value; $B(q)$ is the coefficient of the output value; $e(t)$ is the error.

The identification procedure leads to the model given by equations

$$\begin{aligned} A(q) &= 1 - 0,6599q^{-1} + 0,1429q^{-2} + 0,1537q^{-3} - 0,1683q^{-4} \\ &\quad -0,1946q^{-5} - 0,038q^{-6} - 0,009411q^{-7} + 0,1326q^{-8} + 0,04448q^{-9} \\ B(q) &= -4,985 * 10^{6}q^{-2} + 1,495 * 10^{7}q^{-3} - 1,495 * 10^{7}q^{-4} + 4,983 * 10^{6}q^{-5} \end{aligned}$$

where the coefficients $A(q)$ and $B(q)$ are automatically determined numerically by the aforementioned computer program. In figs. 3, 4 we present the results of testing the model with an excitation of type step and with an excitation with sinusoid signal of different frequency. The diagram of the response at step signal shows that the system is amortized, coming back to the equilibrium position after an interval of two milliseconds from the excitation.

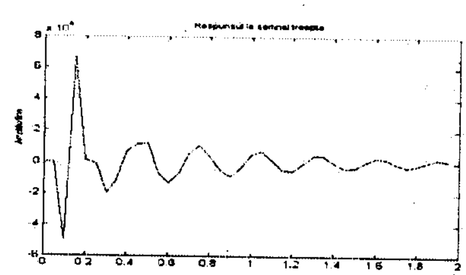

Fig. 3. The response of the model to a step type excitation.

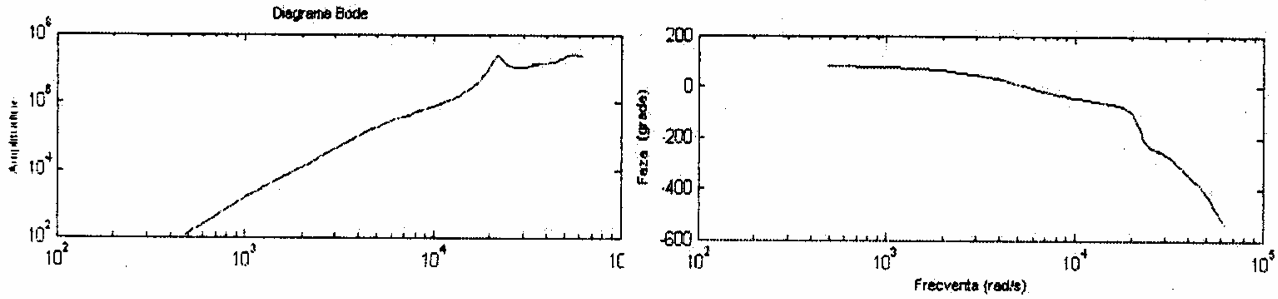

Fig. 4. The response of the model to an excitation with sinusoid signal.

Usage of ARMAX model. The result of the simulation measured experimentally are presented, comparatively in fig. 5. One may notice that the simulated results do not differ very much from the ones obtained with the ARX model. Even if we increase the order (accuracy) of the model, the results do not improve significantly. As a consequence, we recommend using the ARX model for this type of bearing.

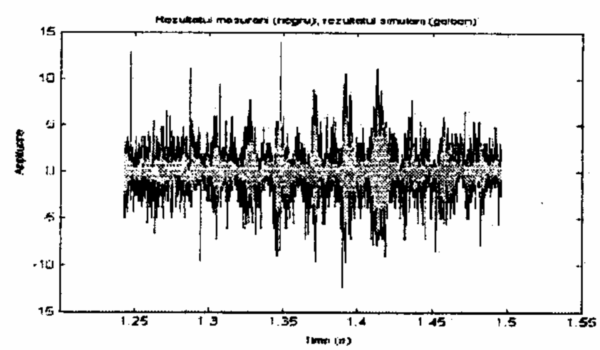

Fig. 5. The result of simulation using the ARMAX model. The yellow zone represents the simulations. The black zone represents the experimentally measured signal.

The equation of the model is given by $A(q)y(t) = B(q)u(t) + C(q)e(t)$.The identification procedure leads to the model given by the relations

$$A(q) = 1 - 1,632q^{-1} + 1,603q^{-2} - 0,664q^{-3},$$
$$B(q) = -0,06334q^{-1} + 0,06356q^{-2}, C(q) = 1 - 0,9315q^{-1} + 0,7581q^{-2},$$

In figs. 6 and 7 we present the results of the testing of the model with step excitation and with sinusoidal signal excitation of different frequencies. The response diagram at step signal shows that the system is less amortized that the one for the amortized ARX model, the tendency to enter in a resonance regime being quite big. We do not observe that with the experimental system.

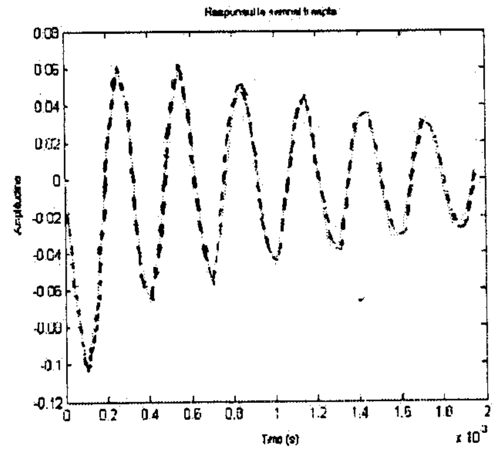

Fig. 6. The response of the model to a step like excitation.

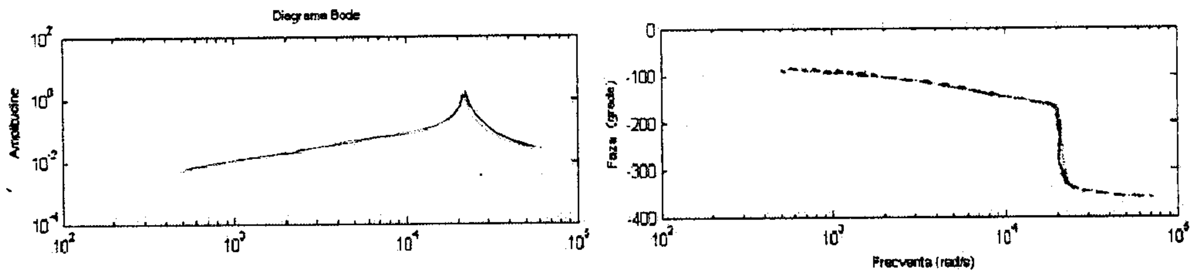

Fig. 7. The response of the model to a sinusoid signal excitation.

3. RESULTS OF SIMULATION IN THE CASE OF USING BEARING WITH HYDRAULIC SUSTENATION

The input and output signals for this case are presented in fig. 8. We notice a functioning smoother than in the case of using sliding bearing. The exaggeratedly large peeks, that denote the presence of shocks in the case of sliding bearing, are not present in this case. Also, we notice an important diminution of the periodic frequency variances that induce in the preceding case the phenomenon of „beating".

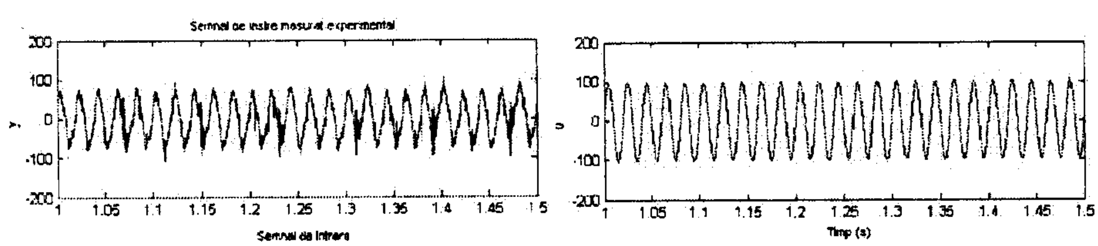

Fig. 8. Input and output signal of the model.

Usage of ARX model. The result of the simulation and the measured signal are presented in fig. 9. One may notice that in this case, the model approximates correctly the experimental results, the differences between the output value of the model and of the physical system is approximately 10% (amplitude).

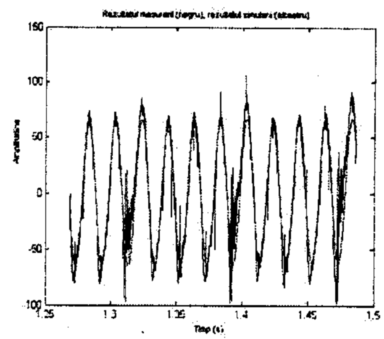

Fig. 9. Results of the simulation using the ARX model.

The equation of the model is given by $A(q)y(t) = B(q)u(t) + e(t)$The identification procedure leads to the model

$$A(q) = 1 - 0,8875q^{-1} + 0,3177q^{-2} + 0,06909q^{-3} - 0,4121q^{-4},$$
$$B(q) = 8,649 * 104q^{-1} - 2,594 * 105q^{-2} + 2,594 * 105q^{-3} - 8,645 * 104q^{-4}.$$

In figs. 10 and 11 we present the results of the testing of the model with excitation of step type with sinusoid signal of different frequencies. The response diagram at step signal shows that the system is thoroughly amortized, coming back to the balance position after an interval of 1, 2 milliseconds from the excitation.

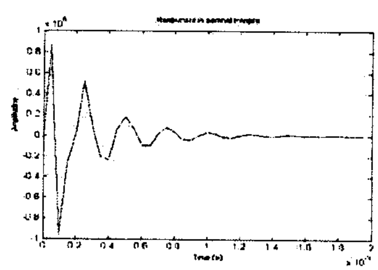

Fig. 10. The response of the model to excitation of type step.

The more powerful amortization from this case is due to the hydro-static sustenation, the oil under pressure taking a significant part of the generated vibration energy in the bearing. Since a great amount of that energy is transformed in heat, it is recommended to cool the oil in the hydraulic circuit.

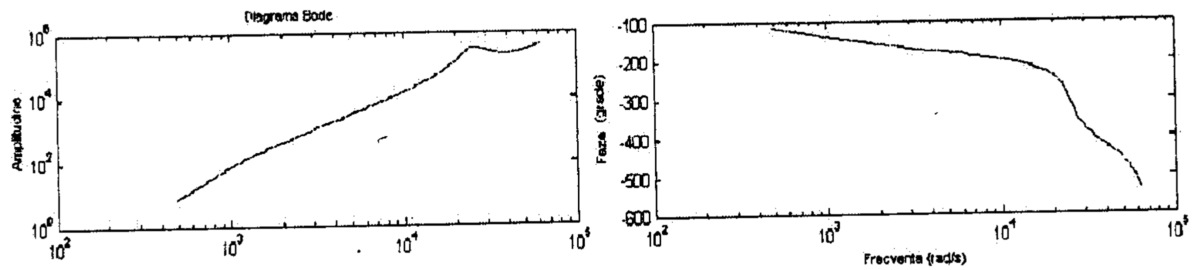

Fig. 11. The response of the model to an excitation with sinusoidal signal.

Usage of ARMAX model. The results of the simulation and the experimentally measured signal are presented in fig. 12. We notice that the ARMAX2221 model used in this case approximates better the physical system, the differences between the output signal of the model and the output signal of the real system being of only 5%.

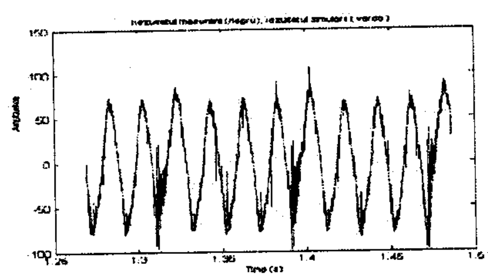

Fig. 12. The result of the simulation using the ARMAX model.

The equation of the model is given by the relation $A(q)y(t) = B(q)u(t) + C(q)e(t)$.The identification procedure leads to the model

$$A(q) = 1 - 1,254q^{-1} + 0,2719q^{-2},$$
$$B(q) = 0,829q^{-1} + 0,823q^{-2}, C(q) = 1 - 0,3559q^{-1} + 0,3224q^{-2}.$$

In figs. 13, fig. 14 we present the results of testing the model with excitation of type step and with sinusoidal signal of different frequencies. The response diagram at step signal shows that the ARMAX model used has the most important characteristic of amortization, being close to the values of viscous amortization parameters.

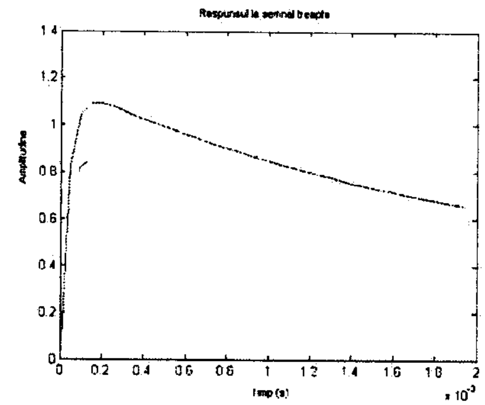

Fig. 13. The response of the model to a step like excitation.

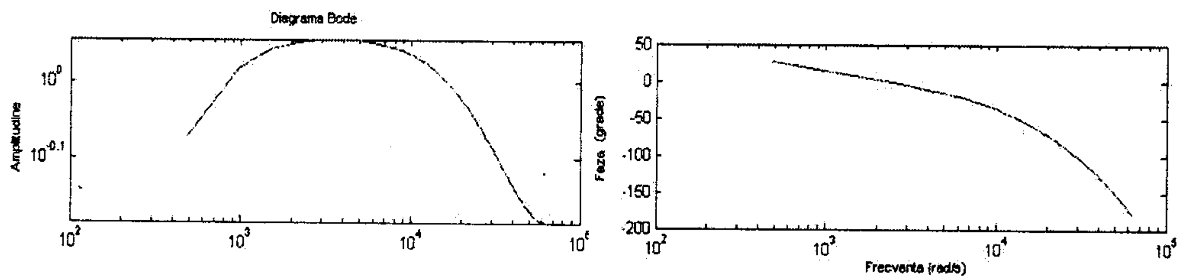

Fig. 14. The response of the model to a sinusoid signal excitation.

4. CONCLUSIONS

The modelling of the function of the experimental system in the case of using sliding bearing and, respectively, of bearing with hydrostatic sustenation, allows, in the case that we obtain a correct model, the prediction of the functioning of the system and in different conditions that the ones tested experimentally. With the aid of the models we can establish the response of the system in limit situation that can lead to major a malfunction. For simulation we must use an adequate software, for example the simulation program „System Identification Toolbox" from the modelling program MATLAB of MathWorks and sinusoidal excitation signals generated by a computer program; in correlation with the amplitude and the frequency of the real excitation. In order to identify the characteristic dynamic processes AHE, we recommend using the Auto Regressive Models (ARX, ARMAX), tested for an adequate number of sets of values for the functioning parameters. The result of the simulation and the experimentally measured signal in the case of using the ARX model, shows that the model approximates with an acceptable error the experimental results, with the exception of random peaks. In the case of the ARMAX model, the results do not differ very much from the results obtained with the ARX model, even if we increase de order (accuracy) of the model. As a consequence, we recommend using the ARX model, for sliding bearing with film of autoportant lubricant.

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