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REDUCING THE DYNAMIC LOAD OF MECHANICAL WATER-JET DRIVE OF AMPHIBIOUS MACHINES

СНИЖЕНИЕ ДИНАМИЧЕСКОЙ НАГРУЖЕННОСТИ ПРИВОДА ВОДОМЕТНОГО ДВИЖИТЕЛЯ АМФИБИЙНОЙ МАШИНЫ

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Abstract: *The article provides an analysis of the excitation conditions and the results of the detuning of parametric resonance in mechanical drive amphibious water-jet machines. The paper substantiates the possibility of solving the problem of reducing the dynamic load on the basis of the synthesis filter low-frequency vibrations.*
Index words: *dynamic loading, oscillations, analysis, transmission, water-jet, frequency.*

Introduction

Transport vehicle power plant durability is limited largely to fatigue failure of the components due to the resonant mode excitation at a deficient level of vibration protection.

In machines, the method for resonance elimination is widely applied by reducing transmission natural frequency due to reduction in spring and friction damper rigidity [1,2]. However, the possibilities of rigidity reduction are restricted because angular compliance does not exceed 2 … 3 degrees in case of the required 8 … 12. When using springs of the Swedish company "Oteva", the compliance reaches 5 … 8 degrees [3]. The value of the required compliance can be reached when using, as a damper, a Centa elastic coupling (with angular compliance up to 15 degrees) [4]. However, the possibility of wide application of such couplings is defined by durability limited by biological aging of elastic details, by stability of their properties in the wide range of temperatures.

In mechanical engineering, while solving engineering problems, the method of eliminating resonant modes stated in A.N. Grishkevich's reference book [5] is widely known and applied. This method deals with performing the following operations:

1) Determination of transmission natural frequencies according to rigid body drawings of the components.

2) Computation of the function for the polyharmonic excitation of the engine torque according to the indicator diagram of a single cylinder, considering an operating procedure and construction features, based on spectrum analysis of the acquired function for determination of major harmonicas.

3) Creation of the superimposed frequency response characteristic of the engine and transmission. Forecast of the resonant mode according to the crosspoints of lines of the system natural frequencies and engine motor harmonicas, as well as determination of a corresponding range of engine shaft speeds.

4) Definition of the acceptable speed range of engine shaft speeds, beyond which the resonance should be removed.

5) When forecasting the resonant mode, it is necessary to calculate required parameters of elastic and dissipative characteristics (rigidity, friction torque, preloading forces) eliminating the resonant mode; and to build an elastic and dissipative characteristic. Depending on required angular rigidity, it is necessary to choose a damper type (spring and friction, torsion, in the form of an elastic coupling) which is to be established on the flywheel of the heat engine. However, the efficiency of a damper synthesized on the known method can be sufficient only to eliminate some local resonance, for example, in pretorque converter zone, but at the same time, the conditions of exciting resonances at other frequencies remain.

The results of research

The object of the experimental research is dynamic loading of the transport vehicle transmission ramified dynamic system. According to the modal analysis of the mechanical system, which turns on the YaMZ-780 engine, the GTK-430 hydraulic torque converter, inertial mass of a divider of the transmission gear, inertial masses and compliances of drive components of support equipment, for example, of the track water propulsion unit of the amphibious vehicle, the resonant modes according to the ramified frequency characteristic (Fig. 1, Table 1) caused by the main motor harmonics of the engine (3,6,9,12) can arise at all natural frequencies of the system.

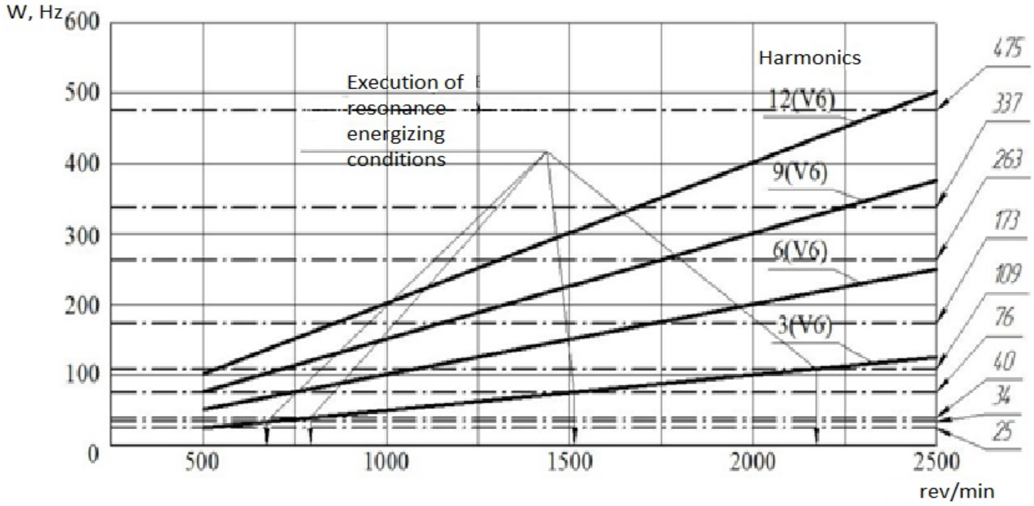

Fig. 1 - Ramified characteristic of the engine and dynamic system

Table 1. Natural frequencies of the dynamic system

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Motion mode	Natural frequencies, Hz								
	1	2	3	4	5	6	7	8	9
D	25	34	40	76	109	173	263	337	475
R	27	33	39	81	100	173	263	337	475

According to the kinematic scheme, the dynamic model of the system (Fig. 2) is developed, the elastic and inertial parameters of which are determined according to the drawing technical documentation.

While creating this model, the possibility of regulating the frequency of engine shaft rotation within the working range is provided. The results of the harmonic analysis of the engine torque, considering gas and inertial forces, are given in Fig. 3, from which it follows that the main harmonicas forming excitation in the dynamic system are the third and sixth.

The results of modeling the dynamics of the system, executed in LMS AMESim software package [6] are shown in Fig. 4. Analysis of the results shows that all the inertial mass of the system are loaded with essential dynamic torque. As an example, analyzes the change of the dynamic torque is given to the mass Ja during acceleration from minimum to maximum sustainable revolution. The graph shows the 3D-spectrum of amplitudes and frequencies of the engine torque, with dependence on its rotation. The maximum values of torque amplitudes up to 3 kNm are fixed at frequencies of 25, 40 and 76 Hz and are excited by the third motor harmonica. The entire population of high value of amplitudes and recurrence of loading the water-jet drive components restricts their durability.

To reduce dynamic loading of the drive, the option of the low frequency oscillation filter design and optimization of its parameters are worked over. Filter parameters are selected from a condition of reducing a variable component of an engine torque, providing a dynamic response factor at the transmission inlet to be no more than Kd=0,2. At the same time, the given dynamic response factor is provided with a necessary value of a detuning factor [7]. The results of modelling the system dynamics with the optimized low frequency filter are given in Fig. 5. It follows from the calculated data that the filter provides a considerable (up to 3 times) reduction of torque amplitudes in the water-jet drive.

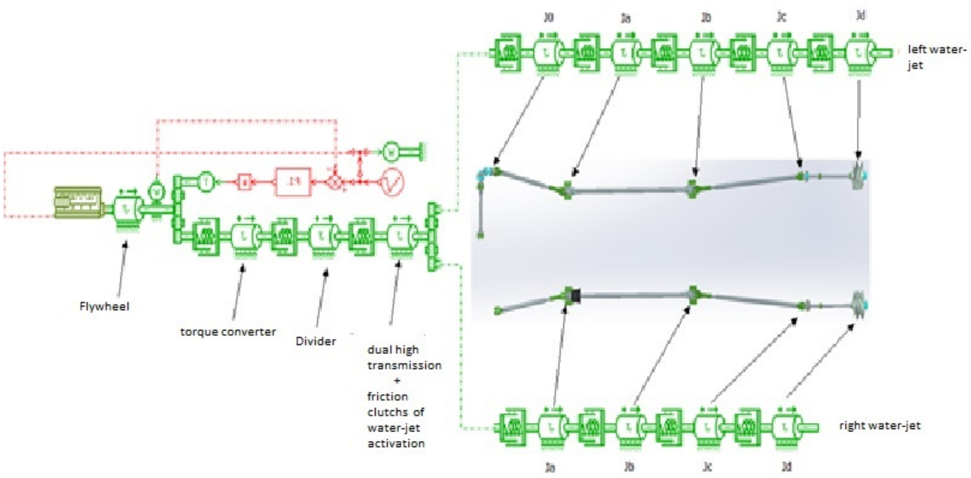

Fig. 2 –Dynamic model of the system "Engine – HTC –Divider - Water-jet Drive"

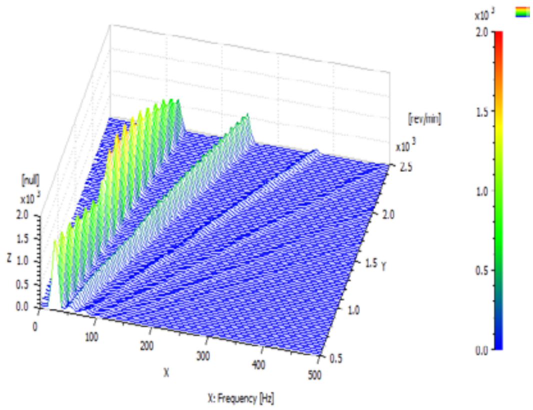

Fig. 3 Results of the harmonic analysis of the engine torque.

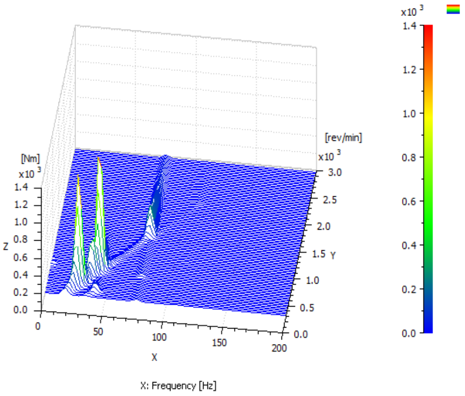

Fig. 4 Results of modelling the dynamics of the experimental system "Engine – HTC –Divider - Water-jet Drive"

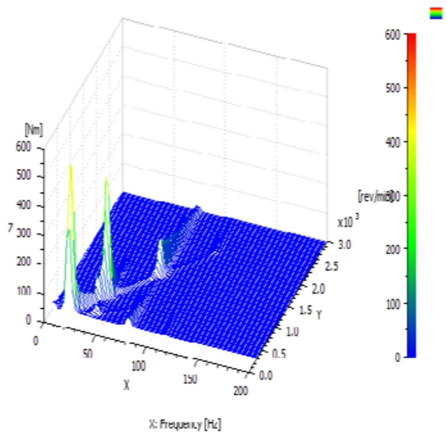

Fig. 5 Results of modelling the dynamics of the experimental system "Engine – HTC –Divider - Water-jet Drive" with a low frequency filter

Limitations

The results of the research are received for the linear system though existence of shaft drives in the driving gear and gear backlashes leads to emergence of nonlinear dynamic effects, such as parametrical oscillations, sub - and super-harmonic oscillations. Research of nonlinear system dynamics can be an object of follow-up studies

Conclusion

As a result of the research, the following has been established.

1) 1) The developed computational scheme and mathematical model of the system "Engine – HTC –Divider - Water-jet Drive", the results of modeling the polyharmonic excitation of the engine and defining modal characteristics of the system show that dynamic loading in many respects is defined by a condition of a resonance excitation

2) 2) Novelty of the research findings is in using a modern software package [*] for detailed research of harmonic components of the internal combustion engine torque, which are the source of oscillation system excitation.

3) 3) Introduction of a low-frequency filter to the system provides three-fold decrease of the magnitude of the dynamic torque that creates opportunities for ensuring the required durability of drive components.

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