SYSTEM APPROACH TO ASSESSMENT OF THERMAL STRESS OF UNITS OF TRANSMISSIONS

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Abstract:
In the article the application of system approach to the study of thermal stress of units of transmissions of transport and technological machines on the example of cardan joints is considered. The authors carried out the analysis of parameters of diagnosing of cardan joints for the purpose of assessment of their technical condition, in particular, assessment methods on bearing clearance in bearing mount assemblies and in vibration parameters. On the other hand, in the transport equipment diagnosing methods on temperature condition of the work of a unit are widely known. For justification of the practical application of system approach to the solution of problems of preliminary treatment of cardan joints and increase in their reliability the consideration of a unit at three hierarchical levels is necessary: the first is defined by working processes in a bearing mount assembly, the second – directly in the cardan joint, and the third – by working processes of the cardan joint as a part of the drive line. Adaptation of system approach in studying of temperature condition of cardan joints allows to prove the modes of increase in reliability of cardan joints by optimization of their thermal conditions.

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1. INTRODUCTION

At the present stage of development of machine-building production of Russia great demands are placed on technological level and operability of transport and technological machines. Achievements of technical progress in the field of transport and agricultural mechanical engineering are directed first of all to improvement of quality of products and resource-saving.

One of the main conceptual directions of ensuring operability of units of transmissions of transport and technological machines at stages of designing, production and operation is justification, realization and forecasting of thermal balance of a product under operating conditions taking into account external and internal factors.

As a critical parameter of thermal balance of the unit we accept the thermal stress determined directly or indirectly by excess amount of heat, given off in the unit in comparison with ambient temperature, related to the surface area or volume of the case.

Temperature condition of drivetrain components, in particular cardan joints, characterizes a mode of behavior and reliability of a product. Amount of heat in details of the cardan joint is the sum of external warmth (the environment, joined heat releasing units) and an internal thermal emission from the work of race ways and rolling elements. It is known that the raised internal thermal emission can cause increase in temperature of details of bearing mount assemblies up to the critical level of a thermorelease that involves drop of hardness of rolling elements, and, respectively, their durability [1]. The internal thermal emission of bearing mount assemblies of cardan joints, along with noise and vibration make losses of mechanical energy, and their level defines efficiency of the cardan joints. Therefore, research and optimization of temperature condition of cardan joints will allow not only to make assessment and forecasting

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of their technical condition, but also to provide increase in reliability.

2. ANALYSIS OF RESEARCH

The existing methods of preliminary treatment of cardan joints have a number of essential shortcomings. For example, methods of measurement of bearing clearance provide the use of measuring devices in bearing mount assemblies of the cardan joint, various for each standard size of the joint and option of its production [2]. Besides, there is no accurate criterion for evaluation of the received sizes of bearing clearances which significantly depend on measuring effort.

Vibration diagnostics method, in relation to propeller shafts, is fulfilled on assessment of technical condition of the bearing of an intermediate bearing part of a shaft, and is of little use for assessment of technical condition of bearing mount assemblies of cardan joints owing to their significant number in the unit. In this regard the problem of diagnosing of bearing mount assemblies of cardan joints is offered to be solved by realization of a thermal method [3].

In A. S. Terekhov's works the application of system approach to the study of temperature condition of units of transmissions of cars [4] was offered. This approach provides the consideration of all factors in a single complex, their features and interrelations with the purpose of optimization of criterion function – typical temperature. Arguments of function of typical temperature are: set of constructive characteristics, characteristics of an internal operating environment, characteristic of an external environment and set of operating modes.

In relation to cardan joints a problem of thermal stress was considered in M.I. Lysov's work [5]. The author offers thermal stress assessment on the basis of a gain of temperature of the cardan joint concerning the environment on condition of the steady thermal balance of the cardan joint. In the work value of a limit of the temperature proportionality as a quantity depending on one of cardan modes of behavior (torque, rotary speed, a break corner) is described, at which sharp temperature increase is observed. The results of tests given in the work allow to use assessment of temperature of the cardan joint for its diagnosing. The specified effect is applied when carrying out the accelerated tests of cardan joints as criterion of a limit condition of the joint [6].

Thus, the development of system approach in assessment of temperature condition of a unit, on the example of the cardan joint, for the purpose of diagnosing, forecasting and ensuring reliability is urgent.

3. RESEARCH OBJECTIVE

Research objective - adaptation of system approach to studying of temperature condition of cardan joints.

4. MAIN MATERIAL OF RESEARCH

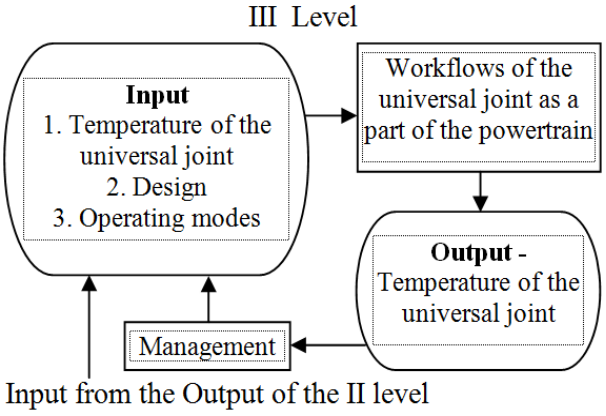
For the solution of a problem of assessment of thermal stress of the cardan joint we will consider its thermal system presented in Figure 1 [7].

At the I (first) hierarchical level of the system the working processes of basic jointing (a pin – a needle roller, a needle roller – a bearing body, a pin butt – a bearing body bottom) a bearing mount assembly of the cardan joint are considered. Input effects at the first level are design data of jointing, their operating modes and operating environment. Design parameters of basic jointing are a form and geometrical sizes, physical and mechanical characteristics, off-contact distances and tightnesses in jointing. Operating modes of jointing are caused by values of forces and speeds arising in jointing. The operating environment (lubricant) exerts considerable impact on working processes of a joint, on the one hand, the operating environment provides reduction in a thermal emission due to friction drop, and on the other hand, provides a heat transfer in a bearing mount assembly. The output of the first hierarchical level is the typical temperature of basic jointing. Management at this level assumes a change of input effects for the purpose of optimization of temperature of basic jointing due to change of design data [8], operating modes and parameters of an operating environment (lubricant).

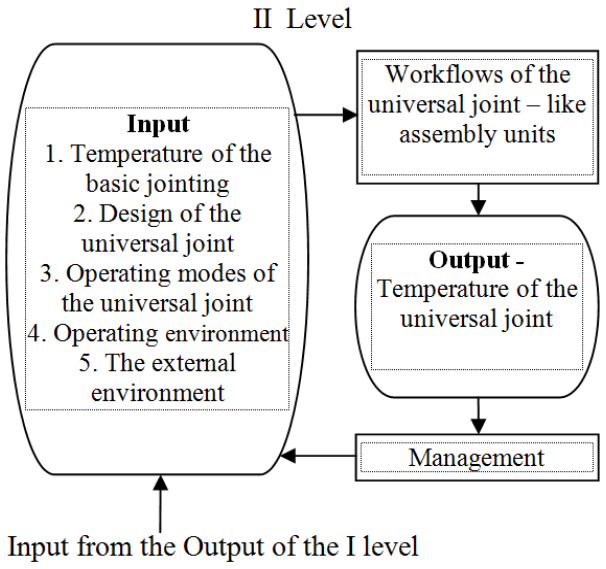
The II (second) hierarchical level assumes consideration of the working processes of the cardan joint (a crosspiece, bearing mount assemblies, u-joint forks) as an object of research. At the second level the input effects are: temperature of basic jointing (output parameter of the first level), design data of the cardan joint, mode of behavior of the cardan joint, internal operating environment and external environment.

The form, sizes and physical and mechanical characteristics of its details defining processes of a heat transfer belong to design data of the cardan

joint. Also it should be noted that the cardan joint structurally unites bearing mount assemblies with basic jointing – sources of thermal stress of the first level.



a)



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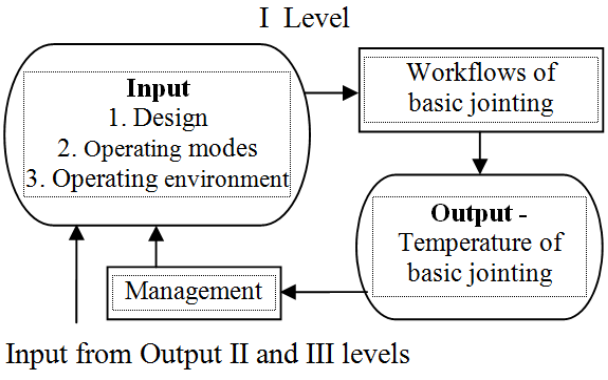

c)

Fig. 1. System of study of temperature condition of the cardan joint

The operating mode of the cardan joint is defined by its rotary speed, the transmitted torque and an angle of breaking. The internal operating environment of the cardan joint is defined by processes of a heat transfer by means of the joint lubricant system of all its bearing mount assemblies. Ability of a heat transfer to the environment of its external surfaces (heat conductivity, the area, volume) belongs to the parameters of the external environment of the cardan joint. The output of the second hierarchical level is the typical temperature of the cardan joint. Possibilities of the control of optimization at this level are presented rather widely. For example, there are constructive decisions providing drop of contact tension of rolling elements (elementary sources of thermal stress) [9], the developments providing an effective internal heat transfer [10], and also a heat transfer to the environment [11].

At the III (third) hierarchical level working processes of the cardan joint used in the drive line installed in transmissions of transport and technological machines are considered. At the same time the temperature of the cardan joint (the output of the second level), design parameters of installation of the cardan joint and the operational modes of transmission of the transport or technological machine belong to the input effects. Design data parameters are installation near heat sources (the exhaust system of the engine, reducers, technological sources). The high-speed mode, road conditions, atmospheric climatic conditions and the load mode belong to the operational modes of a machine. Reserves of optimization of management at this level consist in constructive opportunities of finding of optimum position of the cardan joint providing its heat insulation from external sources of heat, and also the effective heat sink which is provided with the movement of air masses.

The mathematical model of processes of the described levels can be presented in the functionality form,

$$t_i = f(\Sigma K_{ij}, \Sigma T_{ij}, \Sigma E_{ij}), \quad (1)$$

where is:

- t_i – typical temperature in a zone, °C;
- ΣK_{ij} – a complex of design parameters (geometrical parameters of details, material, etc.);
- ΣT_{ij} – a complex of technological parameters (machining, hardening, a roughness, etc.);
- ΣE_{ij} – a complex of operational parameters (the loading modes, frequency of service, introduction of additive compounds, etc.) elementary interfaces, actually cardan joint and

cardan joint as a part of the drive line in transmission;

- *i* – order of hierarchical levels (1, 2, 3);
- *j* - number of factors.

The analysis of the described system of research of temperature condition of the cardan joints (Figure 1) shows that the output of the second level makes impact on the input of the first, and the output of the third level on the inputs of the second and first. It is explained by objective processes of a heat transfer. For example, existence of a powerful external source of heat will lead to temperature increase in a zone of friction of bearing mount assemblies and vice versa, the effective external heat sink will reduce this temperature.

5. CONCLUSION

Practical adaptation and realization of the system approach in studying of temperature condition of units, in particular cardan joints, allows to solve a number of theoretical and applied problems, namely:

1) to establish theoretical dependences between parameters of working processes of cardan joints on the basis of the analysis of the condition;

2) to develop the new methods and technical means of diagnosing of cardan joints focused on an assessment of their thermal stress;

3) to define the directions and to develop modes of increase in reliability of cardan joints by optimization of their thermal condition.

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