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TECHNOLOGICAL DEFECTS OF CYLINDRICAL GEAR WHEELS AND THEIR DIAGNOSTICS ON A PARAMETER OF KINEMATIC ERROR

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Kinematics error of cylindrical gear wheels

1 Introduction

At the last years there were modern instruments on the basis of PC, ensuring a possibility of diagnostics of toothed drives of machines and mechanisms without their disassembly. These instruments permit to receive the necessary information about state of an item at any moment of its operation by employing indirect methods. Diagnostics on a signal of a kinematics error [Berestnev et al.1996] concerns to such methods, which satisfies to the indicated requests, and also ensures high efficiency and reliability of outcomes. For its realisation it is necessary to understand precisely where and how to discover in an inspected signal the necessary information permitting with a high degree of reliability to evaluate a condition of object and, if necessary to reveal and to recognise the appeared defects. The practical realisation of the given problem is possible at the availability of a data bank of diagnostic indications of possible errors and defects of gear wheels.

2 Means of a research of a kinematics error

For a measurement and analysis of toothed drives with many shafts of various machines and mechanisms on a kinematics error the special inspection-diagnostics complex was developed in INDMASH of NAN RB together with Belorussian State university. It represents a unit of the hardware, executed on modern element basis and high-power high-speed personal computer, integrated and controlled by the common program system working in the medium WINDOWS. The hardware makes deriving signals from photoelectric gauges of angular transitions and their preliminary treatment. The obtained information is transmitted to PC, where it is subjected to main processing with the help of software and it is represented to the user in a kind, convenient for the analysis.

The researches were conducted on the special stand with a braked force outline. It ensures the stepless adjustment of frequency of rotation on input in an examined reduction gearbox from 0 up to 3000 rev/min and various moment of loading on the output shaft.

3 Objects and directions of researches

For fulfilment of works on forming diagnostic indications of defects of gear wheels on a parameter of a kinematics error the special samples of gear wheels with a strict regulation of error types and their magnitudes were made. In particular, the gear wheels have been investigated with the following errors:

- Deviation of a tooth profile,
- Radial deviation of a toothed ring,
- Deviation of a base pitch,
- Non-parallelism of wheels axes ,
- Error of a tooth direction,
- Nicks on working tooth surfaces.

The influence of frequency of rotation and transmitted load on a kinematics error was investigated too. This problem is actual because of obvious divergences between outcomes of monitoring in conditions close to static, and real working conditions. The outcomes of a measurement of a kinematics error of gear meshing in quasi-static conditions do not allow evaluating their operational qualities with required accuracy. This is takes place because at the operation loads and rotation rate there are some dynamic phenomena in gear meshing stipulated by a number of the reasons, including by deformation of teeth. All this results to a modification not only magnitude of a kinematics error, but also it of frequent structure.

Thus, the designer of toothed gearing had the tool, which allows at the stage of completion of a design to optimise geometry of a tooth profile and other elements of gear wheels with the purpose of maintenance specific vibroacoustical requirements of performances, and at the consumers - tool permitting to diagnose technological and operational defects of toothed gearing in real conditions of their operation without disassembly of the mechanism.

4 Symptoms of various defects of toothed wheels in a signal of a kinematics error

4.1 Deviation of a tooth profile

At the investigation of frequency spectra of tooth gearing with a deviation of a tooth profile it was established that on a comparison with a spectrum of “standard” gearing amplitude turnaround component (f_{rot} = n/60, where n - frequency of rotation) vary insignificantly, while amplitude of tooth frequency (f_z = nz/60, where z - number of teeth of a considered wheel) (Fig.1) will increase sharply. Some magnification of amplitudes on multiple tooth frequencies ($f = lf_z$, where l = 1, 2, 3 … - factor) is observed too. In an initial signal of a kinematics error it is easily possible to detect essential departures on a comparison with a signal of “standard” pairs (Figs. 2 and 3). Such errors of a tooth as a cutting of working surfaces expresses in violation of smoothness meshing of working structures and it is fixed precisely in a signal of a kinematics error.

4.2 Radial deviation of a toothed ring

In an results of conducted tests it is established, that on small turnovers and transmitted loads the magnification of radial deviation at one from gear wheels results, first of all, in sharp growth (more than in 5 times) amplitudes on turnaround fr and multiple to it (k = 2) frequencies. The growth of amplitudes component is marked also on toothed and multiple to

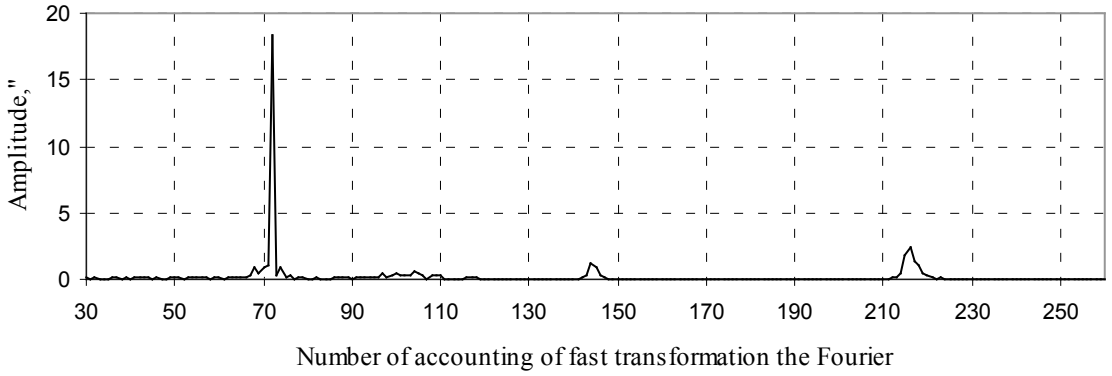

Fig.1 Difference of kinematics error spectra of toothed gearing at availability on a wheel of deviation of tooth profile and with a normal structure

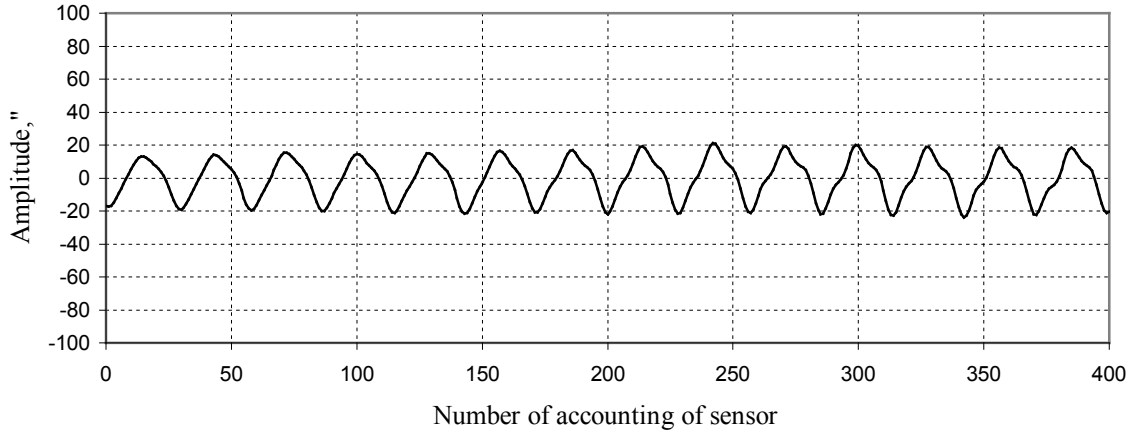

Fig.2. A fragment of a kinematics error signal of toothed gearing, having a tooth profile without obvious deviations

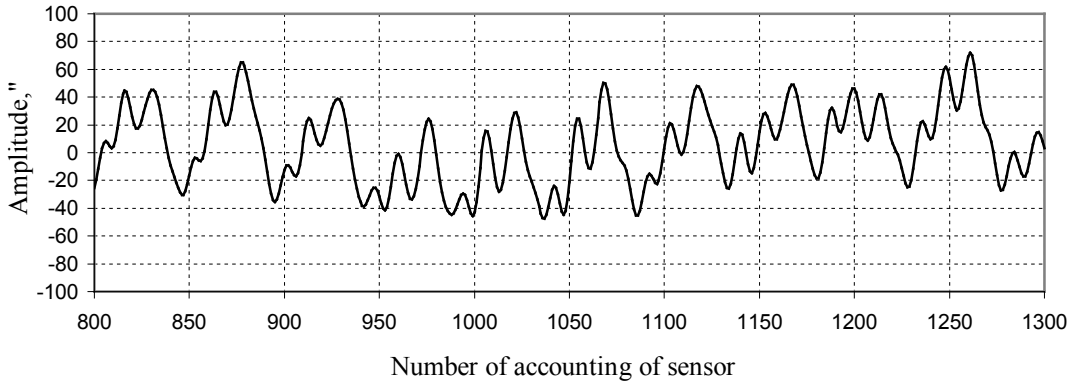

Fig.3. A fragment of a kinematics error of toothed gearing, having a tooth profile with obvious deviations

it frequencies. Growth on frequencies f_z and $2f_z$ is swept up especially. Besides in a spectrum the availability of the modulated frequencies $lf_z \pm kf_{rot}$ of conjugate "standard" wheel is marked. At that, as a rule, component to the right of basic frequency has more values of amplitude.

It is necessary to mark also, that mentioned diagnostics indications of the given kind of an error are looked through in frequent spectra of a kinematics error and at working loads, frequently more clearly.

4.3 Deviation of a base pitch

The availability of defect in a gear wheel as an error of its base pitch calls sharp growth of amplitudes of a kinematics error components, on tooth and multiple to it frequencies (up to l=5). But the greatest growth of amplitude is marked on tooth frequency. At increasing of a transmitted load magnitude the amplitudes component decrease, that allows to make a conclusion about "increase" accuracy of an experimental gear wheel (diminution of an error of a base pitch) at the expense of its partial compensation by elastic bending of teeth. So, the increase of a kinematics accuracy of gearing takes place.

Comparing an obtained information about influence of "positive" and "negative" errors of a base pitch on a kinematics error of gearing it is possible to make a conclusion, that the "positive" error has the greatest negative effect on it. In this case amplitudes component of a kinematics error on tooth and multiple to it frequencies in some times exceed amplitudes component, obtained for similar on magnitude error, but opposite on a sign. It is possible to explain such character of a modification of amplitudes that in the first case the "edge" impact happens, and in second – "middle" impact at the tooth input into meshing. The obtained information once again confirms that fact, that "edge" teeth contact is more harmful, than "middle".

4.4 Non-parallelism of wheels axes

Comparing "standard" spectrum of a kinematics error of toothed transfer with that, received for a driving wheel with this kind of defect, it is possible to mark, that the availability in gearing of the indicated defect is exhibited as magnification of amplitudes of tooth and multiple to it frequencies (up to l = 4). At that, than magnitude of non-parallelism is more, than the grow amplitude on tooth frequency of a defective wheel becomes more appreciable. To marked it is possible also to add, that in a spectrum the availability of the modulated frequencies about basic frequency $8f_z$ of a defective sprocket is observed. The magnification of frequency of rotation of the leading shaft can result in emerging complementary domains of the modulated frequencies.

4.5 Error of a tooth direction

The analysis of frequency spectra, obtained during experiments, allows to make a conclusion, that the given kind of an error is enough precisely diagnosed on quasi-static modes and is exhibited in significant (in tens time) magnification of amplitudes of tooth and second tooth (l=2) frequencies of a defective wheel and additional emerging of the modulated frequencies about basic frequency 8fz ($8fz \pm kf_{rot}$) of the same wheel. Will convert per itself attention and that fact, that the diminution of amplitude of tooth component happens at the magnification of a transmitted load, i.e. has a place effect "self-installations" or increase of an accuracy of "defective" teeth. It is necessary to mark; that in this case speech goes about a kinematics error fixed on the shaft, on which "defective" wheel is installed immediately.

4.6 Nicks on working tooth surfaces

As a rule, the information about toothed gearing r can be received not only from the analysis of magnitude of a kinematics error, but also from a character of a curve of its alternation. The availability on it of sharp overfalls is an effect of availability on a wheel of separate local errors, which can reduce in violation of smoothness of a meshing and noise in gearing [Ionack 1981]. Such at the meshing of a standard wheel with defective, at which at external survey is detected significant nick on a working surface of a tooth is detected, the signal (Fig.4) is obtained, on which the jump for one turn-over caused by availability of the given defect is shown clearly. The similar defects of a wheel don't call any qualitative modifications of a spectrum of a kinematics error.

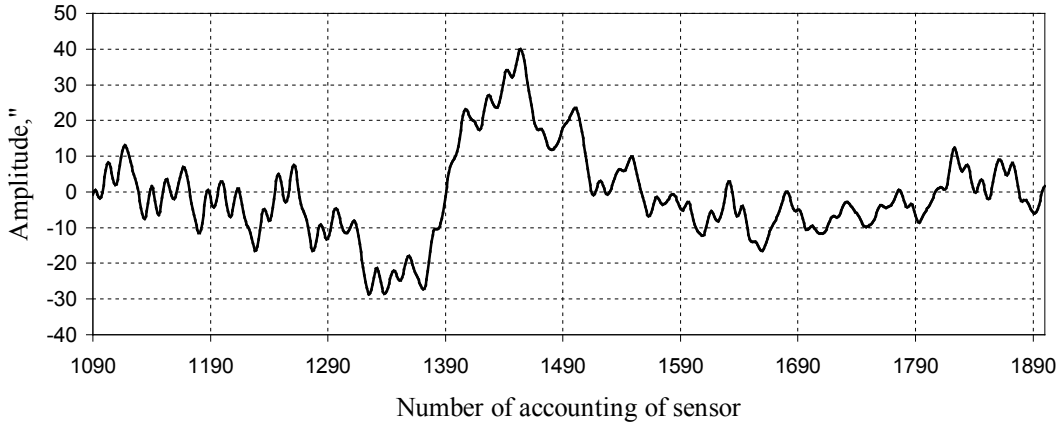

Fig.4. Fragment of a signal of a of toothed gearing kinematics error at the availability of nick on working surface of a tooth of one gear wheel

5 Conclusions

In an outcome of conducted researches the diagnostic indications of the different kinds of errors in a signal of a kinematics error are revealed, and also the evaluation of their influence on qualitative and quantitative performances of frequency of rotation and transmitted load of gearing is conducted. It is established that the kinematics error saves the qualitative kind in the certain area of frequencies of rotation of gear wheels. But, dynamic processes happening in toothed gearing may impose great influence on the kinematics errors out the borders of this area. The similar phenomena are observed and in case of modification of a transmitted load. It is established also, that the signal of a kinematics error, can be used for revealing and recognition not only technological defects of gear wheels, but also defects, which arise from the service of gearing.

References

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