Intelligent technologies in process of highly-precise products manufacturing

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Abstract. One of the main control methods of the surface layer of bearing parts is the eddy current testing method. Surface layer defects of bearing parts, like burns, cracks and some others, are reflected in the results of the rolling surfaces scan. The previously developed method for detecting defects from the image of the raceway was quite effective, but the processing algorithm is complicated and lasts for about 12 ... 16 s. The real non-stationary signals from an eddy current transducer (ECT) consist of short-time high-frequency and long-time low-frequency components, therefore a transformation is used for their analysis, which provides different windows for different frequencies. The wavelet transform meets these conditions. Based on aforesaid, a methodology for automatically detecting and recognizing local defects in bearing parts surface layer has been developed on the basis of wavelet analysis using integral estimates. Some of the defects are recognized by the amplitude component, otherwise an automatic transition to recognition by the phase component of information signals (IS) is carried out.

The use of intelligent technologies in the manufacture of bearing parts will, firstly, significantly improve the quality of bearings, and secondly, significantly improve production efficiency by reducing (eliminating) rejections in the manufacture of products, increasing the period of normal operation of the technological equipment (inter-adjustment period), the implementation of the system of Flexible facilities maintenance, as well as reducing production costs.

1. Introduction

In the technological process of highly-precise products manufacturing in the grinding stage, there are many destabilizing factors affecting both the processing results and the process itself, which leads to necessity of multiple monitoring during the working shift. The solution to this problem is seen in the use of automatic control of grinding modes with the control of the current stock, as well as in the application of means for monitoring the geometric parameters of accuracy and physical and mechanical properties of the surface layer of machined parts and to be machined, measurement data...
processing and adopting a control solution for adjusting the technological regime and readjustment of lathes.

To control the uniformity of the surface layer structure of bearing parts raceways (rings and rollers), as its defects reduce the reliability of the bearings, an automatic recognition of rolling surfaces defects is suggested as an important component of the intellectual part of intelligent technologies.

Taking into account that recognition of images is one of the branches of artificial intelligence, and the recognition system should consist of appropriate equipment and software, the elements of intellectualization are introduced into the monitoring system (Figure 1.) as an attempt to make an automated production system autonomous and adaptable as much as possible.

![Figure 1. The structural diagram of intelligent monitoring in the manufacturing process of bearings production](image)

2. **Intelligent technology of the bearing manufacturing process**

In the monitoring system at OJSC Saratov Bearing Plant, one of the main control methods of the surface layer of bearing parts is the eddy current testing method. Surface layer defects of bearing parts, like burns, cracks and some others, are reflected in the results of the rolling surfaces scan, each type of defect gives its unique "trace" character on the image obtained by means of device for eddy current image control (DECC-K2M) (Figure 2.)
The previously developed method for detecting defects from the image of the raceway [5] was quite effective, but the processing algorithm is complicated and lasts for about 12 .. 16 s. The real non-stationary signals from an eddy current transducer (ECT) consist of short-time high-frequency and long-time low-frequency components, therefore a transformation is used for their analysis, which provides different windows for different frequencies (narrow for high frequencies and broad for low frequencies). The wavelet transform meets these conditions.[6].

The local inhomogeneities of the surface layer (Figure 2) correspond to sharp fluctuations in the amplitudes of the signal components in comparison with the average value of the amplitudes of the signal (ECT) obtained when controlling the part with an acceptable level of quality, the most frequently encountered defects in the surface layer of the bearing parts have a different form of the signal (ECT) (the signal has two components - phase and amplitude), i.e. the changes in the physico-mechanical state of the surface layer of the grinded part are identified. Based on aforesaid, a methodology for automatically detecting and recognizing of local defects in bearing parts surface layer has been developed on the basis of wavelet analysis using integral estimates. Some of the defects are recognized by the amplitude component, otherwise an automatic transition to recognition by the phase component of information signals (IS) is carried out. A generalized algorithm for recognizing defects is shown on Figure 3.

When using the method of automatic detection and recognition of defects in bearing parts surface layer the process of monitoring, a training experiment is preliminarily conducted: the defect type for

Figure 2. Scans of defects obtained by means of the device (DECC-K2M) (1), its localization in the signal (2) and approximation of the selected signal, from which the classification characteristics (3) are allocated, where the y-axis is represented by the amplitude in relative units of wavelets, and along the x-axis, the time interval in conventional units.
recognition is established on the basis of a special classifier KZ-2005, and details are selected, the presence of defects in which is confirmed by alternative defect management methods. [1]

Then quantitative estimates of the quality of the surface layer from the initial array of values for the amplitude and phase components of the (EST) signal are calculated for each part, i.e. the classification characteristics are determined (Figure 3).

The extraction of the defect "trace" by finding its boundaries in an information signal (IS) is realized automatically on the basis of an estimate of the mean square deviation (MSD) of the signal when the total array of values is divided into several segments (about 20). If the IS MSD in one or more segments differs significantly from the IS MSD in segments without defects, for example, not 30%, then it is considered that the IS contains a "trace" of the defect.

Recognition of a local defect is based on applying of wavelet transformations to an array of IS data with a "trace" of the defect, according to which the signal is decomposed into the spectrum according to Daubechies basic wavelets. The resulting spectra of coefficients have different length and amplitude, since defects differ in geometric dimensions: depth, square (Figure 2).

Subsequently, the array of data of the selected segment is scaled and used to recognize the type of local defect based on the integrated estimation of the spectra (IES) of wavelet coefficients by the algorithm (Figure 3). At the first stage, the amplitude component produces defects, integral estimates of the spectra (IES) of wavelet coefficients which differ significantly. If the IES from some defects almost coincide, then the transition to the recognition of the phase component of the signal is performed. Thus, the use of two classification features allows us to separate defects in the feature space and provide all the basic local defects of the rolling surfaces (probability of recognition is \( \approx 95 \ldots 98\% \)) [2].
Figure 3. The algorithm for recognizing defects according to classification criteria

3. Conclusion
The ability to identify and quantify periodic local residual inhomogeneities of the surface layer of polished parts makes the system suitable for use as an information channel of an intelligent monitoring system.

The use of intelligent technologies in the manufacture of bearing parts will, firstly, significantly improve the quality of bearings, and secondly, significantly improve production efficiency by reducing (eliminating) rejections in the manufacture of products, increasing the period of normal operation of the technological equipment (inter-adjustment period), the implementation of the system of Flexible facilities maintenance, as well as reducing production costs.

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