Controlling the periodicity of grinding wheel dressing with the application of expert decision support system

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Abstract. The article considers the influence of the grinding wheel dressings frequency on the end product quality after processing; it describes developing of smart algorithms for CNC grinding unit as a part of Expert Decision Support System with software implementation.

1. Introduction
In terms of improving grinding quality and performance, the high standards applied to grinding wheel dressing are associated with batch production of component parts. It requires to use an Expert System (ES) for provision of immediate recommendations on processing parameters with the consideration of such technical aspects of grinding process as a processing mode, equipment condition and its accuracy, condition of machine-tool attachments, properties of the material being processed, tolerance value, elastic deformations of the manufacturing system and thermal impacts.

2. Investigation of the influence made by the grinding wheel dressing frequency on the processing quality
Grinding process is accompanied by gradual decrease in cutting force of the wheel due to irregular load received by the abrasive grains and, consequently, due to irregular wear. It results in deformation of the instrument, increase of the vibration level and decrease in quality of the processed surface. If the load on the abrasive grains is large, the grinding wheel can sharpen itself in a way that it takes irregular geometric shape due to partial destruction or full breakdown of the dull grains. It leads to decrease in quality of the processed surface and increase of vibration levels in the dynamic system (DS).

At finishing stages with less load on the grain, there is a gradual dulling of the abrasive grains of the grinding wheel working part; rounding radius of the cutting grain faces increases and the wheel pores get clogged with fine pieces of metal and binding substances. Dull grinding wheel results in increased pressure received by the workpiece in the zone of cutting, burn marks and unwanted facets on its surface.

At the same time, we shall consider that the condition after processing of the previous workpiece influences the processing quality of the next one; the wheel wear, in its turn, depends on the quality of the previously processed workpiece and actual cutting margin, i.e. the grinding wheel dressing frequency is determined by many factors and has a great impact on the processing quality [1, 3].
2.1. Investigation of vibration levels
Experimental study has proven that the vibration level is one and a half times lower when grinding the workpieces using a newly sharpened wheel (figure 1a) compared to the results given by a worn wheel (figure 1b). Such vibration unavoidably affects the quality of the workpiece surface and wheel wear [4].

![Figure 1](image1.png)

**Figure 1.** Vibration level recorded (noise & vibration meter VSHV-003M3) in the process of workpiece grinding: a) after wheel dressing; b) with worn wheel.

2.2. Determining the moment of a wheel dressing on the basis of the DS stability factor
For our experimental study, we observed the work of CNC cylindrical grinding machine WeissWKG-05 in production environment for processing small-size shafts. The purpose of the experiment is to determine the moment of wheel dressing based on the machine DS stability factor. This will allow for developing ES in order to increase the capacity of a grinding machine. 30 workpieces were analyzed for such parameters as their ovality, surface roughness, and DC oscillation index for the recommended wheel dressing frequency period. Then 3 experiments were conducted for 85 processed shafts with corresponding numbers. Figure 2 shows the results of the analysis and measurements taken.

As the study has shown [8], DS stability factor determines an appropriate periodicity of the grinding wheel dressing for the observed machine, and ring and wheel materials. Actual periodicity of the dressing can be increased by 2-2.5 times, thus saving grinding wheel and dressing instrument and increasing the capacity of workpiece production by 4%.

3. Smart algorithm for CNC grinding unit
On the basis of the above study, we developed the algorithm to optimize the periodicity of grinding wheel dressing. This algorithm is developed to be a part of ES of technological process monitoring; it analyses values of vibration parameters array measured within an allowed range of up to 2,900 Hz in the real-time mode and makes decisions on correcting the periodicity of grinding wheel dressing or its replacement.

As production practice shows, the number of workpieces between wheel dressings is set at the extreme and amounts to 30 (figure 2), as grinding rejects are often irreparable. The average amount of workpieces between grinding wheel dressings and maximum permitted (working) value of vibration parameter are stored in the database (DB) of ES of technological process monitoring. The correction is made depending on the last vibration measurement cycle after grinding wheel dressing. Stable vibration value in the process will allow for increasing the periodicity of wheel dressing by more than two times without substantial damage to the grinding quality (figure 2). This can be done by gradual transition to less frequent wheel dressing (by means of decreasing the number of workpieces between the dressings by 5) under the monitoring of ES in the real-time mode [4].

The development of smart control tools facilitates implementation of the above algorithm for determining the moment of grinding unit dressing based on the actual condition of the wheel. Measuring the amplitude of vibration acceleration and cutting time in the process of each workpiece processing will allow for correction (increasing or decreasing) of the number of workpieces between the wheel dressings in the process of grinding. At the same time, it is reasonable to set the initial number of workpieces between the dressings so that it is bigger than the number at the extreme, with the
consideration of the previous value of this parameter. Under unfavorable conditions the set number will be decreased based on the measurements [6,7,9].

**Figure 2.** Analysis of measurements on precision of workpieces processing on CNC cylindrical grinding machine WeissWKG-05 (workpieces are numbered 1-85 around the circle). 1 – recommended moment of grinding wheel dressing (30 workpieces), 2 – moment of grinding wheel dressing in accordance with established technological process (75 workpieces).

4. **Development of ES software unit as per the algorithm**

To implement ES as technological process monitoring system, we developed Schlif software unit and DB (figure 3) [5], which are aimed to visualise, collect, store and perform smart processing of the data related to the grinding. It applies the algorithm of parameter optimization for correction of controlling action based on recommendations by ES.

Initial values are represented in the form of digital data received from CNC sensors (manual input is possible). The data is reflected on the run screen and added in the ES database. Initial values can also be represented in the form of reference data with the possibility to correct and reenter them. Output values are visualized in the real-time mode. We introduced interactive buttons for correction values...
input for the manual mode of the program. In case of emergency, an alarm signalling is activated and the equipment switches to a holding mode for further ES recommendations.

5. Conclusions
The smart algorithm for CNC grinding unit developed to be a part of ES of technological process monitoring determines appropriate periodicity of the grinding wheel dressing for the observed machine, and ring and wheel materials, thus saving grinding wheel and dressing instrument and increasing the capacity of workpiece production by 4%.

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