Improving the quality of crane wheels machining

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Abstract. One of the most common types of damage to cranes is wear of the working surface and/or the ribs of the running wheel. When the maximum permissible wear is reached, the wheel is machined to restore its geometry. During production and repair of running wheels of load-lifting cranes, the problem of increasing the efficiency of the technological machining process on the rolling profile of the running wheels is a component of the general problem of increasing dependability of hoisting and transport machines. The technological process of restoring the profile of the surface of the crane wheels has a number of features. If the change in the depth of the cut can be estimated and then during processing to adjust the modes, then to measure and consider the hardness of the material to be removed are practically impossible. The lack of proper control over the change in the depth of the cut and the hardness of the treated surface often leads to the fact that the crane wheels turn in the understated modes, which adversely affects the performance. This causes the expediency of regulating the process according to such criterion as the optimal cutting temperature. The article describes the methods of experimental determination of the optimal cutting temperature. A new method of determination based on shear thermocouples is proposed. The authors obtained and compared dependences for thermo-EMF, corresponding to the optimum temperature, on the cutting speed, obtained with the help of shear and natural thermocouples.

1. Introduction

One of the most common types of damage to cranes is wear of the working surface and/or the ribs of the running wheel [1, 2]. In the process of operation, the working surface of the crane wheel in the circle of rolling is subjected to significant contact loads, which leads to intense wear and the appearance of various defects on its surface. When the maximum permissible wear is reached, the wheel is machined to restore its geometry. During production and repair of running wheels of load-lifting cranes, the problem of increasing technological process efficiency of machining on the rolling profile of the running wheels is a component of the general problem of dependability increase of hoisting and transport machines [3-5].

Interaction of a mode and mechanism of movement of the crane is carried out through the top layers of metal of a wheel and a rail [6]. In the area of the wheel contact spot with the rail there is a large specific pressure. The loads to which each section of the wheel's surface is subjected, especially during the start of movement and when stopped, cause wear, plastic deformation and various types of contact fatigue damage [7]. In general, the faults and defects of crane wheels in many ways are the same defects of railway wheel sets for fixing the developed classifier ITM1-B [8].
The influence of these factors adversely affect the durability of the cutting tool, so that the technological process of restoring the profile of the surface of the crane wheels has a number of features. If the change in depth of the cut can be estimated and then in the process of processing adjusted to the modes, then we can measure and consider the hardness of the material to be removed as practically impossible. The lack of proper control over the change in the depth of cut and the hardness of the treated surface often leads to the fact that the turning of the crane wheels is made on the understated modes, which adversely affects the performance [9-11].

The above factors suggest the feasibility of adjusting the cutting process according to the value of the selected criterion. Attempts were made to control the process by the value of the vertical component of the cutting force $P_z$. The dynamics of its change when turning the profile of the worn wheel is shown in figure 1.

![Figure 1. The change of cutting force in the recovery worn wheel profile.](image)

The main disadvantage of the power parameter control is the delay of the control signal in the presence of local areas with high hardness. At present, it is proved that for each pair, the tool material - the processed material, there is an optimal temperature value in the cutting zone $\theta_0$, the work at which will provide the tool with the greatest dimensional stability, and on the treated surface, the maximum residual compression stresses [12].

2. **Experimental installations for determination optimal cutting speed and temperature**

We created a laboratory plant to study the temperature parameters of the process of processing of wheel steels, the scheme of which is shown in figure 2. The studies were carried out during end turning with a constant depth and cutting feed.
Figure 2. Scheme of the experimental installation for determination optimal cutting speed.

The value of residual stresses was determined by the electromagnetic device ERION-1B at the end of the processing, while the thermo-EMF corresponding to the cutting temperature was fixed in the process of turning using a natural thermocouple cutter-disc.

After processing with the help of the device ERION-1B determined by the value of residual stresses and the diameter, the maximum compressive stresses are realized. The analysis of the results was carried out with the help of digital oscilloscope AKIP-4115 and videographic recorder ViER M7. Using the developed method, the values of the optimal cutting speed $V_0$ for different grades of wheel steels and cutting tools, as well as the corresponding thermo-EMF of the natural thermocouple, were obtained.

With non-stationary cutting, which is typical for the process of restoring the surface of the crane wheels, changing the conditions of turning along the wheel profile significantly complicates the definition of rational cutting conditions and cutting speed. Based on this, the adjustment modes should be carried out directly in the process of turning, based on information about the cutting temperature. To use temperature as an optimization criterion, it is necessary to know its absolute value.

The complexity and lack of accuracy of existing methods of determination $\theta_0$ limit the possibility of their practical use.

For the experimental determination of the absolute value of the optimal cutting temperature in the processing of wheel steels, it is proposed to establish the radius of the disc thermocouples cut through the current collector connected to the recording equipment. The experimental installation was developed to implement this method (Figure 3), which produced a record of thermo-EMF shear thermocouples, as well as the value of thermo-EMF natural thermocouple cutter – disc for further comparison of the results. A distinctive feature of this method is the use of a shear thermocouple with a junction, calibration of which with different length of the latter was performed using a standard thermocouple. After the end turning, the point with the maximum compressive residual stresses was determined using the ERION – 1B device. According to the results of the research, the temperature values obtained by means of natural and shear thermocouples, respectively, as well as the dependence of residual stresses on the treated surface were plotted.
3. Research results

The absolute value of the optimal cutting temperature and the corresponding EMF value of the natural thermocouple were determined graphically by the value of the maximum compressive residual stresses as shown in figure 4.

Knowing the value of the optimal cutting temperature and the corresponding value of the thermo-EMF of the natural thermocouple, there is a possibility to control the cutting process by adjusting the feed or cutting speed, maintaining the thermo-EMF of the natural thermocouple in a certain range.

Based on this, the adaptive control system (ACS) was developed for the process of restoring the profile of the surface of the crane wheels, the block diagram of which is shown in figure 5.
The thermal receiver D, which uses a natural thermocouple, is connected in series with the amplifiers U in the measuring diagonal of the bridge IM, and the power diagonal includes a stabilized power supply IPS, ensuring the constancy of the operating current in the measuring circuit. The output of the amplifier is connected to a reversible asynchronous electric motor RAE, which, in turn, affects the motor of the reechord in IM and the control device of the RU. The regulating device is connected through the control unit RU to the actuator M, which is used as an asynchronous reversible motor. The actuator is connected to the regulating body of the RO system, which is used to regulate the value of the caliper feed or the speed of rotation of the workpiece.

Cutting temperature control is carried out in the following sequence. If the measured thermo-EMF is equal to the voltage drop at the extreme points of the measuring diagonal of the bridge (IM), the circuit is in equilibrium and the cutting is carried out with a constant supply. When changing the thermo-EMF at the input of the amplifier, U receives a DC signal, which is converted into an AC signal and amplified to a value sufficient to drive the motor RAE. Depending on the magnitude and sign of the misalignment signal in the block IM, the regulating device transmits a signal to M through the control unit (BU), which, acting on the regulatory body, regulates the longitudinal feed of the caliper or cutting speed. Regulation lasts as long as there is a signal caused by the imbalance of the system.

4. Conclusion
As a result of the research, a new method of experimental determination of the optimal cutting temperature using shear thermocouples was proposed, including a promising adaptive control system that allows adjusting the temperature in the cutting zone in a certain range.

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