

Determination of high-strength materials diamond grinding rational modes

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Abstract. The analysis of methods of high-strength materials abrasive processing is carried out. This method made it possible to determine the necessary directions and prospects for the development of shaping combined methods. The need to use metal bonded diamond abrasive tools in combination with a different kind of energy is noted to improve the processing efficiency and reduce the complexity of operations. The complex of experimental research on revealing the importance of mechanical and electrical components of cutting regimes, on the cutting ability of diamond tools, as well as the need to reduce the specific consumption of an abrasive wheel as one of the important economic indicators of the processing process is performed. It is established that combined diamond grinding with simultaneous continuous correction of the abrasive wheel contributes to an increase in the cutting ability of metal bonded diamond abrasive tools when processing high-strength materials by an average of 30% compared to diamond grinding. Particular recommendations on the designation of technological factors are developed depending on specific production problems.

1. Introduction

High-strength materials based on compounds of carbon and nitrogen with tungsten, titanium, tantalum, niobium and others, characterized by a number of unique properties, can be used in modern technology when manufacturing the parts of machines and mechanisms subjected to increased wear, as structural acid-resistant and heat-resistant materials, as well as in the tool industry [1-3].

However, the wide application of high-strength materials, in some cases, is limited due to the difficulties associated with its processing and the provision of specified quality parameters. It is advisable to use in this case methods based on a combination of different processes and technologies [4-7]. In this case, the diamond grinding tools are the most effective, but in the production environment, resinoid bonded diamond grinding wheels are usually used and metal bonded diamond grinding wheels are used less often [8, 9].

It is known that metal bonded grinding wheels are superior in many respects to resinoid bonded grinding wheels, but it has a significant drawback – a tendency to become greasy and, as a result, to reduce or lose its cutting ability completely, so there is a need for constant or periodic dressing [10, 11].

When considering the cutting ability of grinding wheels as a whole, under certain assumptions, it can be represented as the g-ratio, that is, the ratio between the volume of the material and the volume of the depleted abrasive. In this case, the g-ratio will be determined by the characteristics of the grinding wheel itself (grain size, hardness, structure, etc.), as well as the mechanical components of



the cutting regimes. A similar trend is maintained for metal bonded diamond grinding wheels, but only without the use of combined methods.

It is preferred to use the metal bonded diamond grinding wheels in combination with different kinds of energy (electrical, chemical, etc.), which makes it possible to increase processing efficiency and reduce the laboriousness of individual operations [10-12].

The widespread introduction of combined technologies and its improvement leads to the need for clarification of the technological parameters in each particular case [8, 9, 11, 13].

For that matter, it is of considerable interest to evaluate the influence of technological factors of combined diamond grinding of high-strength materials on the specific consumption of metal bonded diamond grinding wheels.

2. Materials and methods research

In this paper, the specific consumption of diamond abrasive tools as one of the important economic indicators of the processing during combined electrochemical grinding with simultaneous continuous correction of the metal bonded diamond grinding wheel is estimated. This method combines the anodic dissolution of grinding products that are formed on the surface of the grinding wheel, ensuring the work of the wheel in the self-sharpening mode, and simultaneous electrochemical softening of the working area of the processed material.

To implement the complex of experimental research, a laboratory facility based on a surface grinding machine 3E711 was designed and created.

The analysis of various methods of combined diamond grinding allowed one to reveal the following factors that affect the processing: dressing current density i_{st} [A/cm²], etching current density i_{et} [A/cm²], wheel speed V [m/s], the depth of cut t [mm] and feed S [m/min]. In the conditions of the same implementation process, these factors quite fully reflect the proposed technology.

For research, the experiment design, necessary to minimize the number of experiments during the determination of the mathematical model of the process under study with the aim of reducing labor intensity and material costs was carried out.

A study of the dependence of the combined processing conditions and parameters on the mechanical and electrical components of the hard alloys processing modes (depth of cut t [mm] and feed rate S [m/min]; the dressing current density i_{st} [A/cm²] and the etching current density i_{et} [A/cm²]) was undertaken. Thus, 4 factors were taken into account and 16 experiments were carried out.

Factor levels and its variation intervals were chosen in accordance with the recommendations developed earlier [13]. The speed of wheel V [m/s] was constant.

The specific consumption of diamond grinding wheel q [mm³/mm³] is adopted as the output parameter.

After each series of experiments, the wheel was removed from the laboratory facility and, using a special device, the specific consumption of the wheel was measured linearly as a ratio of the volume of the depleted diamond wheel [mm³] to the volume of the removed material [mm³].

The surface condition of the diamond wheel and the processed products was controlled using modern techniques of visual and structural analysis.

The results of the output parameter study by the example of hard alloy WC8 are given in the paper, due to wide use of this alloy in production as a structural and tool material.

In the studies, metal bonded diamond grinding wheels of the 1A1 form with a grain size of 80/63 were used. Metal conductive binder of grade M2-01 was used. Salt solution containing 0.5% Na₂CO₃ and 1% NaCl dissolved in water was used as the electrolyte.

3. Results and Discussion

At the first stage of the study, a full factorial experiment was set up. The results of the experiment showed that investigated output parameter q does not obey the normal law, therefore, the investigated dependence can not be approximated with sufficient accuracy by the first-order equation.

Therefore, the experiment was set up on the program of central compositional planning of the

second order. Sixteen complete factorial experiments were conducted, and seven experiments in the center of the plan were supplemented by eight experiments in “star” points.

As a result, it was established that the parameter under study can be adequately approximated by the regression equation of the form:

$$q = 0.45 + 0.09S + 1.55t + 0.03i_{et} + 1.44i_{st} + 0.01S^2 + 38.6t^2 - 0.002i_{et}^2 - 3.59i_{st}^2. \quad (1)$$

At the second stage, the mathematical analysis of the study results of dependence of diamond wheel specific consumption q [mm³/mm³] during processing of the WC8 alloy on the mechanical components of the regimes (depth of cut t [mm] and feed S [m/min]) was performed, and the following dependence was obtained:

$$q = 0.694 + 0.09S + 1.55t + 0.01S^2 + 38.6t^2. \quad (2)$$

The response surface of the parameter under study is shown in Figure 1.

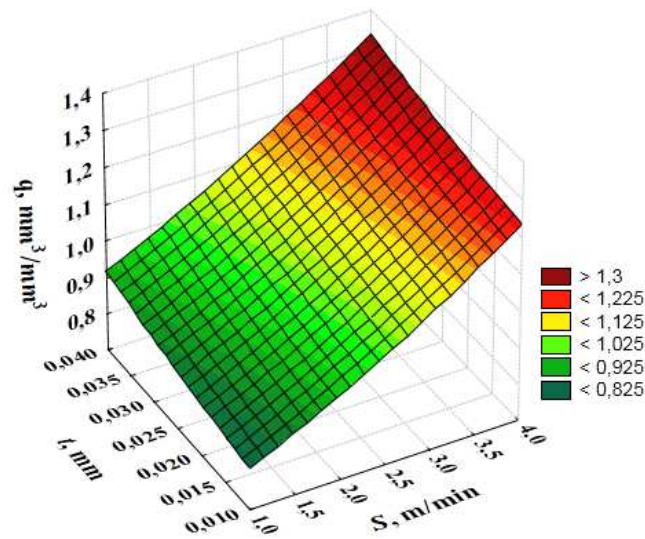


Figure 1. Dependence of the specific consumption of the wheel on the mechanical components of the combined diamond grinding modes.

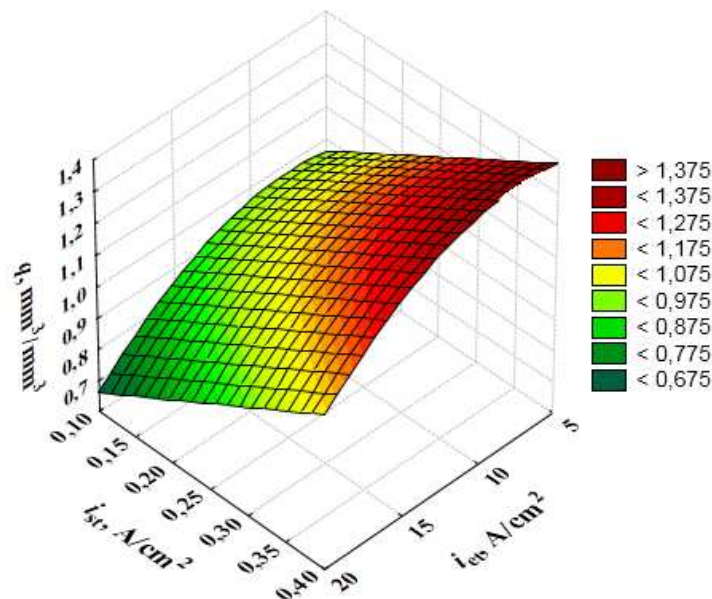


Figure 2. Dependence of the specific consumption of the wheel on the electrical components of the combined diamond grinding modes.

At the third stage, the statistical analysis of the dependence of the diamond wheel specific consumption on the processing modes electrical components (dressing current density i_{st} [A/cm²], etching current density i_{et} [A/cm²]) was conducted and the following dependence was obtained:

$$q = 0.716 + 0.03i_{et} + 1.44i_{st} - 0.002i_{et}^2 - 3.59i_{st}^2. \quad (3)$$

The response surface of the parameter under study is shown in Figure 2.

At the next stage, a number of experimental studies were conducted aimed at identifying rational regimes for combined diamond processing, providing satisfactory cutting properties and a minimum specific consumption of metal bonded diamond grinding wheels.

Taking into account the data obtained at the previous stages, it should be noted that with minimum values of the constant electrical components of the combined diamond processing modes, the values of the sought parameter are in the range of $q = 1.4 \dots 1.6$ mm³/mm³, which does not exceed 10% error when compared with theoretical data.

Analyzing the results obtained, it should be noted that the maximum values of the modes mechanical components (depth of cut $t = 0.04$ [mm] and feed $S = 4$ [m/min]) should be used in roughing operations where maximum productivity is required when removing the allowance. But in this case, an additional periodic dressing of the diamond wheel is required in view of fouling, which leads to an increase in its consumption.

To ensure satisfactory cutting properties and minimum consumption rate, the depth of cut $t = 0.02$ [mm] and feed rate $S = 2.0$ [m/min] should be assigned.

At the final stage, an experimental study of the influence of the electrical components of the processing modes (dressing current density i_{st} [A/cm²], etching current density i_{et} [A/cm²]) on the specific consumption of the diamond wheel under unchanged mechanical conditions was made.

When the etching current density is varied within $i_{et} < 10$ [A/cm²] and the dressing current density is varied within $i_{st} < 0.1$ [A/cm²], the cutting ability of the diamond wheel is low because the dissolution products of the treated surface form a greasy layer that prevents the worn out grains from being changed. For this reason, additional periodical dressing of the wheel is required while the specific consumption rate is $q = 1.2 \dots 1.4$ mm³/mm³.

The increase in the etching current density in the range of $i_{et} = 10 \dots 15$ [A/cm²] and dressing current density $i_{st} = 0.15 \dots 0.3$ [A/cm²] contributes to a decrease in the specific consumption rate of the wheel to $q = 0.6 \dots 0.8$ [mm³/mm³]. Under these conditions, the diamond tools have stable cutting properties due to the self-sharpening effect; there is no fouling on the surface of the wheel.

When etching current density $i_{et} = 15$ [A/cm²] and dressing current density $i_{st} = 0.35$ [A/cm²], the specific consumption rate is stabilized at the level of $q = 0.8$ [mm³/mm³]. In this case, due to effective removal of processing products, the wheel has a high cutting ability, and electrochemical softening reduces the intensity of plastic deformations and internal stresses in the surface layer of the workpiece, which leads to an improvement in the quality of the finished product.

An increase in the etching current density to more than $i_{et} > 20$ [A/cm²] and dressing current density $i_{st} > 0.4$ [A/cm²] contributes to an increase in the electrochemical softening of the surface of the part leading to a decrease in quality, and due to the high density of the dressing current, the working surface of the wheel dissolves intensively, which leads to an increase in the consumption rate of the wheel. Therefore, this mode can be used in roughing operations to increase productivity. Comparing the experimental data obtained by the influence of the modes electric components on the specific consumption of the wheel with the theoretical data, the error did not exceed 10%.

4. Conclusions

Based on the results of the planning and statistical analysis of the data obtained, a regression equation is found, which adequately approximates the investigated output parameter of the specific consumption of metal bonded diamond grinding wheels q [mm³/mm³] on the mechanical and electrical components of the proposed method for combined diamond processing of high-strength materials.

It is established that combined diamond grinding with simultaneous continuous dressing of the wheel contributes to an increase in the cutting ability of metal bonded diamond tools when processing

high-strength materials by an average of 30% compared to diamond grinding.

For the production use of the considered method for high-strength materials processing, the following recommendations are proposed:

To ensure a minimum specific consumption of metal bonded diamond grinding wheels and satisfactory surface quality of high-strength materials, the following rational regimes should be used: depth of cut is $t = 0.02$ [mm], feed is $S = 2.0$ [m/min], etching current density is $i_{et} = 15$ [A/cm²] and the dressing current density is $i_{st} = 0.35$ [A/cm²].

On preliminary and roughing operations, in order to ensure a high cutting ability of the diamond wheel and with low requirements to the quality of the treated surface, it is recommended to set the depth of cut in the range of $t = 0.02 \dots 0.04$ [mm], feed - $S = 2.0 \dots 4.0$ [m/min], etching current density - $i_{et} = 20$ [A/cm²] and the dressing current density - $i_{st} = 0.4$ [A/cm²]. It should be noted that processing in elevated modes entails an increase in specific consumption to an average of 20%.

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