Increase in efficiency of electric powered diamond grinding of conductive material by regulating longitudinal profile of grinding wheels

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S u m m a r y . The method of increasing the efficiency of electric powered diamond grinding of hard-to-machine materials which provides the reduction of vibration by forming rational longitudinal profile of working wheel's surface is presented. The prerequisites and peculiarities of vibration absorbing, technological equipment for implementing the suggested method are described.
K e y w o r d s . Electric powered diamond grinding, wheel's working surface, longitudinal profile, vibration absorbing.

INTRODUCTION

Abrasive-diamond processing of hard-to-machine materials is widely used both at intermediate and final stages of producing essential components. Using diamond wheels for processing hard-to-machine materials is determined by unique physical, mechanical, thermal, electrical and chemical properties of diamonds grains. High hardness, stiffness, durability, cutting ability, elastic limits of diamond grains, homogeneity and density of their structure, low coefficient of thermal expansion, high thermal conductivity, low coefficient of friction [13] predetermine effective final processing of conductive materials.

At the present stage abrasive-diamond processing is characterized by searching the ways to increase the performance and economical efficiency of the process, quality and precision of parts-in-process. One of the factors, which in a great measure conditions the effectiveness of grinding is vibrational stability. The matters of increasing vibrational stability are of great importance due to development of flexible automated unmanned manufacturing. There is a new tendency in tool-making manufacturing – development of electromechanical devices and technological equipment that in their characteristics and functionality will conform to contemporary computer equipment [29].

The results of the investigation [3] prove that in the process of diamond grinding in due course the height of grain protrusion lowers, which leads to reduction of a tool's cutting abilities and decrease of processing performance; specific consumption of diamonds and vibrational amplitude increase. The waves of longitudinal profile of working surface, appearing as a result of processing and increasing in due time, negatively affects the process efficiency. It is fair to assume that by purposeful change of the waviness of working wheel's surface longitudinal profile, it is possible to regulate the outcome measures of grinding.

RESEARCH ANALYLSIS

The efficiency of grinding is to a large extent determined by rational choice of the scheme and method of processing [6, 22]. Among the most advantageous ones are high speed [7], forced [8], cryogenic precision [19, 20], deep [14, 39], profile grinding [5, 39] etc. However, the choice of efficient kind of grinding not always guarantees the steadiness of working wheel's surface's relief and conditions of processing.

Stability of grinding process, as a part of its efficiency, is determined by stability of outcome measures of part processing during the whole period of operating. An important source of increasing the stability of processing is improvement of the equipment performance characteristics, defined by necessary stiffness, damping capacity, vibration resistance [1, 2, 15].

Grinding wheels with interrupted working surface are of big interest [18, 37], because they make it possible to increase significantly stability and the rate of the process outcome data [26, 36].

Introducing additional power in the cutting area [12, 21, 23, 33, 35] in some cases allows increasing the efficiency of grinding by means of keeping high cutting ability of a wheel. The increase in performance and quality of the processed surfaces in cases of imposing longitudinal vibration on the grinding wheel, while processing, is found out [34].

The systems of automated regulation of processing are used to consider changing conditions of grinding [38]. The most frequently regulated parameters are cutting force [32] or power [25], vibration level of the machine's parts [27]. Using such systems contributes to increasing stability of the quality of processed parts, but does not avoid the necessity for restoring the wheels' shape and cutting surface.

One of the main demands that establish the grinding efficiency is high cutting ability of diamond wheels. It can be reached by controlling the cutting relief by means of proportioned impact on the wheel's bond while grinding. It predetermines the wheel's operation in the mode, equivalent to the mode of self-sharpening in the absence of direct bond-to-processed metal contact, which contributes to reducing the cutting force and grinding temperature. However, in most cases the wheel's self-sharpening is insufficient for conducting high-efficiency processing, because the geometric form of its working surface does not remain unchanged.

Deviations of the working surface profile from the correct geometric form can appear in two mutually perpendicular directions. There are longitudinal waves and transverse waves. Longitudinal waves generally appear as a result of the technological system vibration. Transverse profile is defined by the inequality of the wheel wearing [13]. It was experimentally proved [28], that in cases of flat face grinding of the plates of hard-to-machine steels, longitudinal waviness is 15-20% bigger than transverse one.

The main factors that cause appearing the waviness in the course of grinding include: poor input shape precision and material of the part-to-process, characteristics and waviness of the grinding wheel's working surface, acquired as a result of tool dressing, the rate of its wearing and dulling, imbalance of the wheel and other machine units, damping capacity of the zone of wheel-to-part contact, stiffness and vibration stability of a technological system, grinding mode and cycle. Reducing negative impact of all the factors listed contributes to increasing the precision of the part's form [13]. Dead-stop grinding at the end of the operation cycle significantly reduces form defects [10]. The experiments proved [28], that thick grinding oil, got to the zone of tool-to-part contact, is able to reduce the amplitude of grinding pressure oscillations, lower the vibration rate in the technological system, which leads to decrease in waviness of the surface-to-process.

Controlling the working surface waviness in operation [10] means agreement of intensities of forced bond removal and linear wear of diamond wheels, as well as defining the conditions which exclude avalanchine falling of inactive grains out of bond. However, in such cases it is impossible to avoid changes in initial form of its working surface.

Reduction of waviness height can be reached by means of periodic changes of own vibration frequency in tool-to-part system [30]. The analysis of differential equations of cutting [16] proves, that the general solution is the process with momentum application of the force. A new notion of vibration insensitive cutting process was first introduced.

Direct relation between a pitch of waves t_B of longitudinal profile and a dynamic coefficient of the system μ, [3]. which indicates how many times the amplitude of forced oscillations with excitation force is bigger than the system deviation, formed from the impact of pulsation of normal cutting force, was found μ coefficient intensively decreases in case t_B lowers. Therefore, with the constant stiffness of the system *machine – equipment – tool – part*, providing rather short pitch of waves, it is possible to achieve a considerable reduce in vibration amplitude.

RESEARCH OBJECT

Taking into account a considerable correlation between the parameters of the waves of longitudinal wheel profile and the oscillations of elastic cutting system, there are prerequisites for developing the method of grinding with the directional formation of longitudinal profile of the tool's working surface relief [4] with the parameters, that provide vibration reduction and continuous maintenance of its cutting characteristics.

In the course of investigations the method of reducing the oscillation amplitude of the cutting system by means of forming desired waves of grinding wheel's longitudinal profile was suggested. The theory of mechanical oscillation says that oscillation frequency of vibrating system deviates from the frequency of own oscillations in case if the forcing frequency has bigger value [16, 31]. Rational pitch of waves with pre-set grinding modes must provide additional pulsation of excitation force with the frequency, exceeding the frequency of the own vibration of the system. Electric discharge destruction of metal bond [17] by integrated grinding mode [4, 24] was chosen as the method of forming the wheel's working surface.

The choice of electric discharge impact on the wheel's bond (compared with electrochemical one) is determined by the following features:

- possibility to use ordinary cooling liquids instead of electrolyte, which lowers demands for corrosion resistance of materials,
- absence of oxide layer on the processed surface,
- high performance of electric diamond grinding with continuous electric discharge trueing of the wheel during the whole period of processing.

To implement the suggested method, the mechatronics system of regulating rational longitudinal profile of wheels' working surfaces on conductive bonds was developed. Block diagram of the system is presented in the figure.

Grinding wheel is electrically isolated from the machine. While processing the cutting zone is supplied with grinding oil. A voltage from impulse current source is applied to the grinding wheel and conductive part-to-process. In this case there is electric discharge impact on the wheel metal bond and the part. Vibration measuring module records amplitude and frequency of grinding wheel vibration, an analog signal is generated and after digitizing DAC/ADC by m-DAQ12/DAC converter is sent to the computer and analyzed by a special program module. If the values of vibration amplitude and frequency exceed the

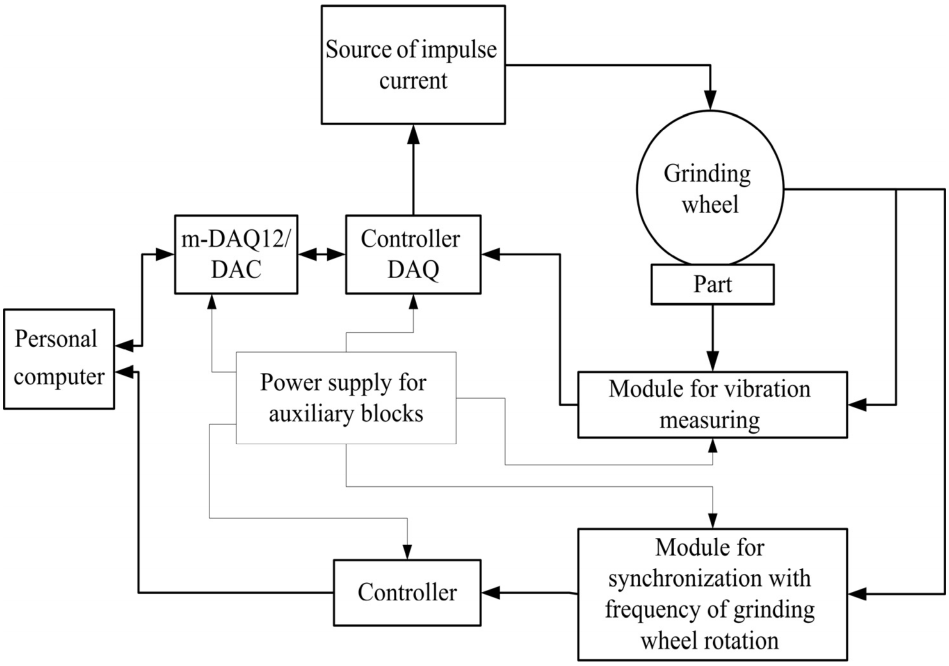

Fig. 1. Block diagram of mechatronics system of regulating grinding vibration

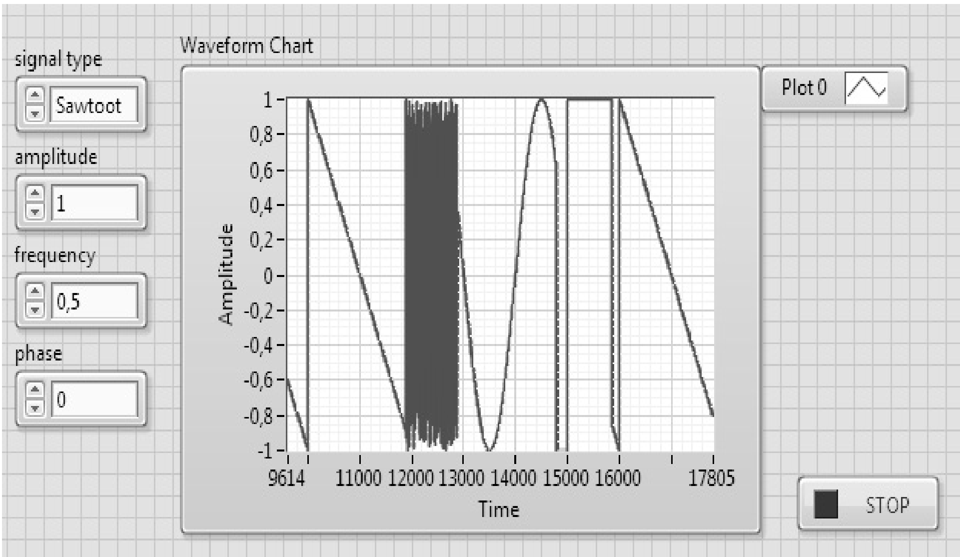

Fig. 2. The program of generating impulses of various forms

limits of pre-set range, the program generates digital control signal (Fig. 2), which is converted by m-DAQ12/DAC to analog one. It corrects the work of generator for changing current intensity and control impulse frequency.

The level of electric discharge impact on the grinding wheel bond must provide the height of longitudinal profile wave, significant for the influence on the vibrating cutting system, and is adjusted experimentally.

RESULTS OF RESEARCH

On the considered theoretical grounds, a universal sharpener 3Д641E was modernized to implement the suggested ideas. In Fig.3 you can see electric isolation of the machine working parts and dielectric shell for the diamond wheel with four channels for current collector (Fig. 3).

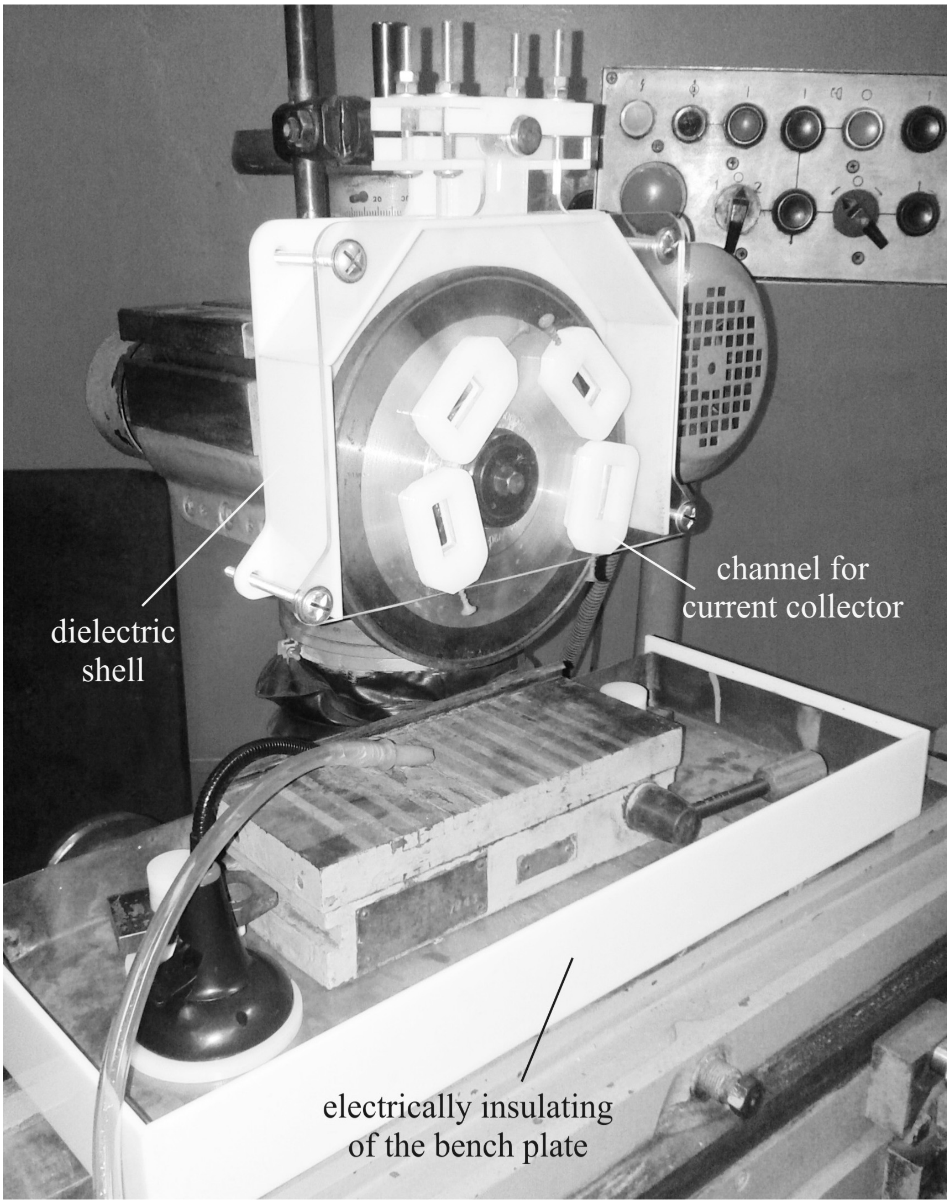

Fig. 3. General view of the experimental machine

The synchronization module (Fig. 4) provides pre-set correlation of control impulse frequency and the wheel rotation for achieving desired pitch of longitudinal profile waves.

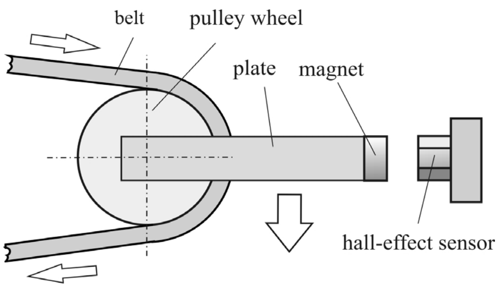

Fig. 4. The module for synchronizing frequency of current source impulses and frequency the grinding wheel rotation

The scheme of the module for measuring grinding vibration is presented in Fig. 5. This module is a springy cantilever beam with the fixed slide assembly for pattern and sample for treatment. The value of stiffness is regulated by moving the slide assembly along the spring beam. In the base plate there is a variable reluctance pickup of linear movements, which measures the vibration of cantilever beam while processing. Such scheme helps to evaluate the influence of pulsating component of cutting force, caused by processing with the diamond wheel with wavy working surfaces.

An original source of impulse technologic current was developed for an experimental machine (Fig. 6).

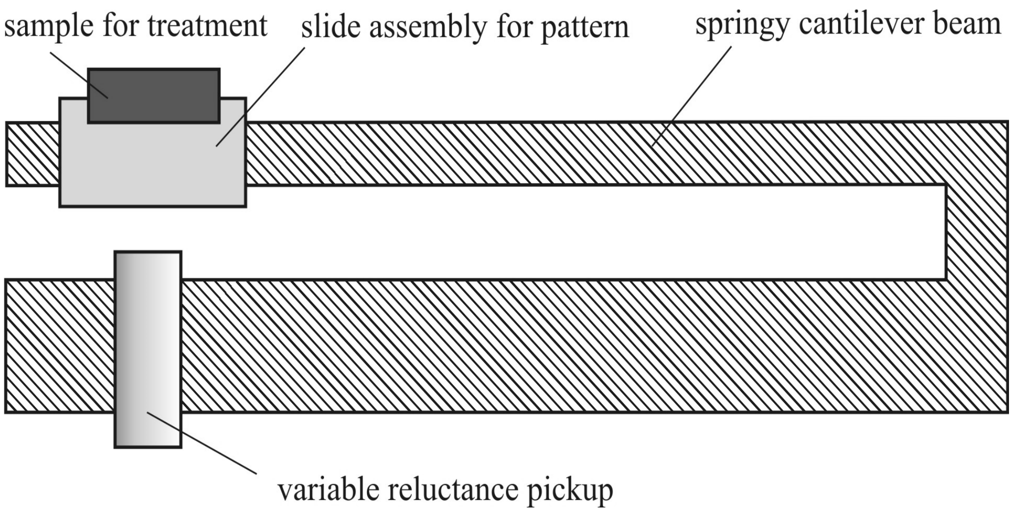

Fig. 5. Module for measuring grinding vibration

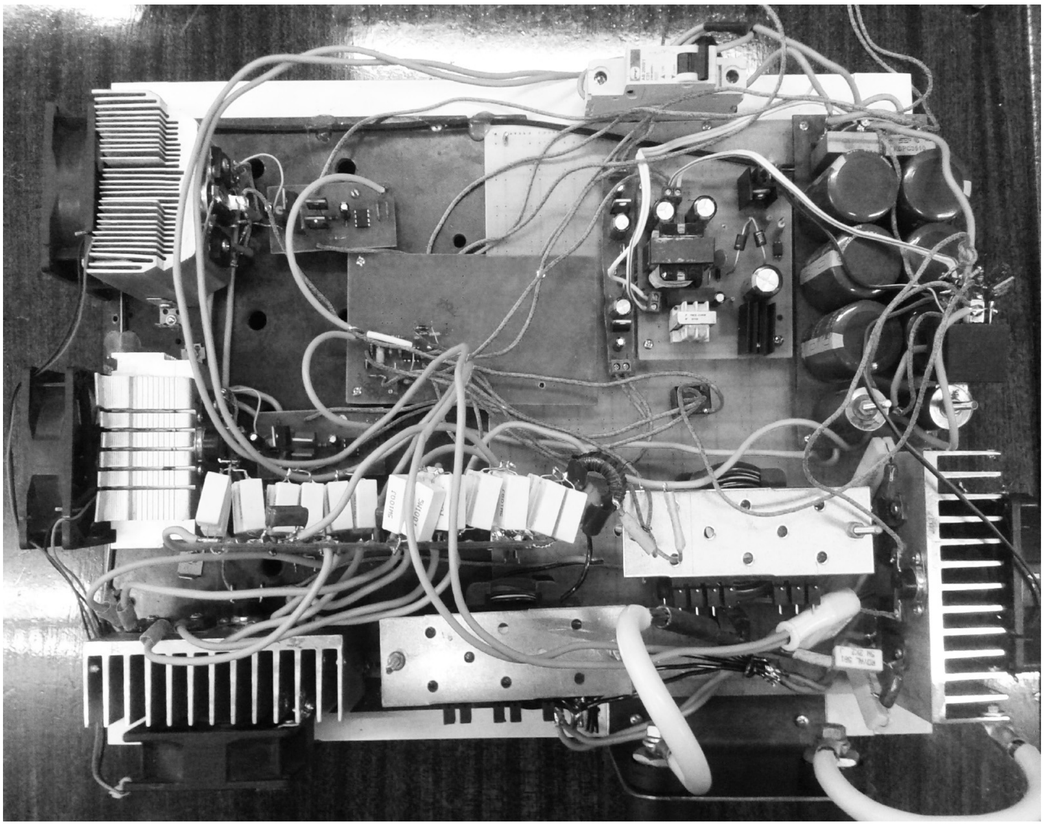

Fig. 6. The source of impulse technologic current

CONCLUSIONS

1. The suggested method of increasing the efficiency of diamond grinding of hard-to-machine materials provides reduction of grinding vibration by forming rational longitudinal profile of working wheel's surface. It helps to increase stability of grinding, reduce the tools wearing, improve dimensional accuracy and quality of processed parts' surface. The effect is achieved by electric discharge impact of electric impulse, synchronized with frequency of the wheel rotation on conductive diamond wheel's bond.

2. The existing level of mechatronics allows fulfilling the task of automated regulation of the rational vibration level for

pre-set conditions of diamond grinding of hard-to-process materials.

3. Conducted modernization of universal sharpener 3Д641E provides implementation of the suggested method. The developed devices measure grinding vibration and synchronize frequency of technologic current control impulses and frequency the grinding wheel rotation.

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ПРОЦЕССА ЭЛЕКТРОАЛМАЗНОГО ШЛИФОВАНИЯ ТОКОПРОВОДЯЩИХ МАТЕРИАЛОВ ПУТЕМ РЕГУЛИРОВАНИЯ ПРОДОЛЬНОГО ПРОФИЛЯ КРУГОВ

Владимир Доброскок, Андрей Шпилька,
Марина Морнева, Николай Шпилька

Аннотация. Представлен метод повышения эффективности процесса электроалмазного шлифования труднообрабатываемых материалов, обеспечивающий снижение вибраций путем формирования на круге рационального продольного профиля рабочей поверхности. Рассмотрены предпосылки и особенности гашения вибраций, технологическое оборудование для реализации предлагаемого метода.

Ключевые слова: электроалмазное шлифование, рабочая поверхность кругов, продольный профиль, снижение вибраций.