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Web application used for multi-criterion optimized selection of most important parameters of single-pass internal cylindrical grinding process

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Abstract

In the paper web application developed for multi-criterion optimized selection of the most important parameters of the single-pass internal cylindrical grinding process is presented. The application was made as website based on a scripting programming language PHP. Exemplary results of optimization are presented and discussed. The material removal rate Q_w as well as the roughness average *Ra* of the machined surface were chosen as main criteria of optimization. The presented web application allows practical use of investigation results and their applying through Internet as a ready-to-use informatics tool.

Keywords: multi-criterion optimization, single-pass internal cylindrical grinding, grinding parameters, web application.

Aplikacja internetowa do wielokryterialnej optymalizacji doboru najważniejszych parametrów procesu jednoprzejściowego szlifowania otworów

Streszczenie

W artykule przedstawiono aplikację sieciową opracowaną w celu optymalizacji doboru najważniejszych parametrów procesu jednoprzejściowego szlifowania otworów ściernicami o strefowo zróżnicowanej budowie. Na podstawie zdefiniowanego przez użytkownika głównego kryterium optymalizacyjnego (np. wydajność ubytkowa szlifowania Q_w lub chropowatość powierzchni obrobionej *Ra)* aplikacja dobiera, z użyciem zaimplementowanych funkcji, wartości najważniejszych parametrów procesu (a_e, v_{fa}, χ). Aplikacja wykonana została jako strona internetowa, którą opracowano z wykorzystaniem skryptowego języka programowania PHP. Zawarto w niej podstawowe informacje dotyczące jednoprzejściowego szlifowania otworów oraz głównych parametrów procesu. Najważniejszą część aplikacji stanowi *Kalkulator* umożliwiający wygenerowanie optymalnych parametrów procesu na podstawie danych wpisanych w formularzu przez użytkownika. Przedstawiona aplikacja sieciowa może stanowić ciekawe narzędzie informatyczne stanowiące praktyczną pomoc w realizacji procesu jednoprzejściowego szlifowania otworów ściernicami o strefowo zróżnicowanej budowie. Największym ograniczeniem opisywanej aplikacji jest bazowanie jedynie na relatywnie wąskim zakresie wyników badań opisywanego procesu, przeprowadzonych w jednym ośrodku badawczym. Rozszerzenie bazy wiedzy o wyniki procesu uzyskane dla innych materiałów, różnych średnic wewnętrznych i długości przedmiotu, a także na odmiennych szlifierkach, pozwoliłoby na rozszerzenie możliwości potencjalnego wykorzystania opracowanej aplikacji.

Słowa kluczowe: optymalizacja wielokryterialna, jednoprzejściowe szlifowanie otworów, parametry szlifowania, aplikacja sieciowa.

1. Introduction

Single-pass grinding is an alternative for the most often applied in industrial practice reciprocating internal cylindrical grinding method [1-3]. Replacement of such kinematics by only one working passage, with significantly reduced grinder table axial feed speed allows obtaining the demanded result of grinding process in shorter time.

It is necessary, however, to apply unconventional abrasive tools with conic chamfer which distribute total machining allowance on a grinding wheel larger surface. Such tools have often stratified construction, which can help to obtain more easily low roughness of the workpiece surface through suitable selection of the characteristic of grinding wheel separate functional zones [4-7].

In the result of experimental investigations conducted in the Department of Production Engineering of Koszalin University of Technology, a grinding wheel with zone-diversified structure were constructed. This grinding wheel was built of microcrystalline sintered corundum SG and glass-crystalline ceramic bond (Fig. 1) [8-12].

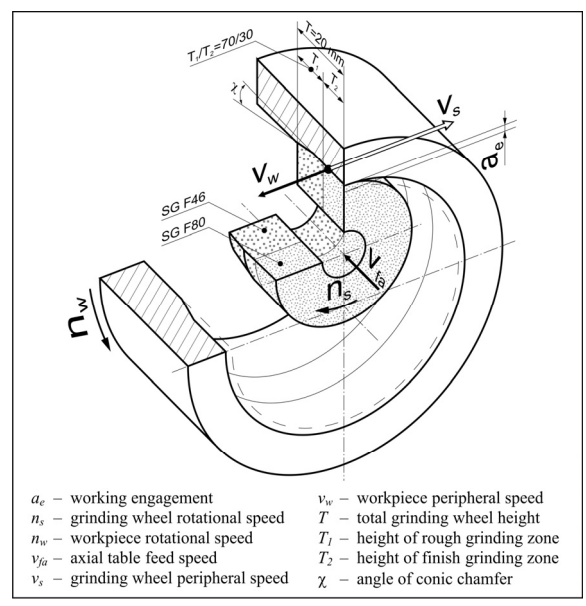


Fig. 1. Single-pass internal cylindrical grinding using grinding wheels with zone-diversified structure
Rys. 1. Schemat procesu jednoprzejściowego szlifowania otworów ściernicami o strefowo zróżnicowanej budowie

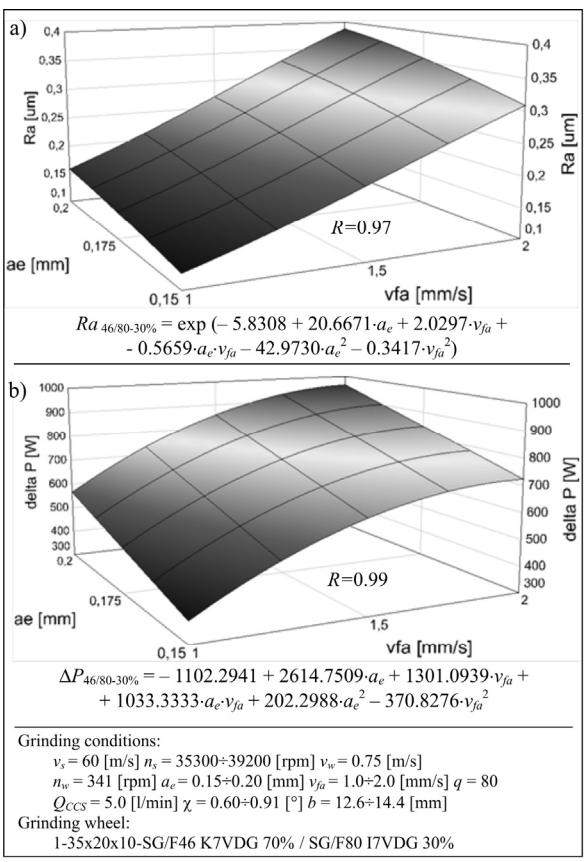
The applied bond is distinguished by fatigue waste mechanism comparable to fatigue crushing up of abrasive grains, because they are materials of about approximate brittleness. Such a feature of bond is particularly significant for grinding wheels of microcrystalline abrasive grains, because glass-crystalline bond in

grinding process wear according to analogous mechanism of destruction.

The application of developed grinding wheels makes possible to obtain the material removal rate of the order of $Q_w \cong 24$ mm^3/s [8-12]. It is, however, very important to form precisely the conic chamfer on the rough grinding zone of the grinding wheel active surface. Both conic chamfer angle χ, and its width b should be matched in dependence on working engagement a_e and width of the grinding wheel coarse-grained zone T_1.

Realization of wide range of experimental investigations of the single-pass internal cylindrical grinding process using grinding wheels with zone-diversified structure enabled developing mathematical models describing changes of the workpiece surface roughness *Ra* (roughness average) [13], as well as changes of grinding power ΔP in dependence on the basic process parameters, which are the working engagement a_e and the grinder table axial feed speed v_{fa} (Fig. 2).

The mathematical models were based on experimental investigations realized according to the three-level experiment design, which enabled determining of a non-linear quadratic model. The number of repetitions for every point of the plan was assumed to be $n = 3$. Selection of a given class of the mathematical model was made on the basis of a criterion which was the best adjustment to the recorded results of experimental investigations, defined by the multidimensional correlation coefficient *R* value [14].



$$Ra_{46/80\text{-}30\%} = \exp(-5.8308 + 20.6671 \cdot a_e + 2.0297 \cdot v_{fa} + - 0.5659 \cdot a_e \cdot v_{fa} - 42.9730 \cdot a_e^2 - 0.3417 \cdot v_{fa}^2)$$

$$\Delta P_{46/80\text{-}30\%} = -1102.2941 + 2614.7509 \cdot a_e + 1301.0939 \cdot v_{fa} + + 1033.3333 \cdot a_e \cdot v_{fa} + 202.2988 \cdot a_e^2 - 370.8276 \cdot v_{fa}^2$$

Grinding conditions:
$v_s = 60$ [m/s] $n_s = 35300 \div 39200$ [rpm] $v_w = 0.75$ [m/s]
$n_w = 341$ [rpm] $a_e = 0.15 \div 0.20$ [mm] $v_{fa} = 1.0 \div 2.0$ [mm/s] $q = 80$
$Q_{CCS} = 5.0$ [l/min] $\chi = 0.60 \div 0.91$ [°] $b = 12.6 \div 14.4$ [mm]
Grinding wheel:
1-35x20x10-SG/F46 K7VDG 70% / SG/F80 I7VDG 30%

Fig. 2. Mathematical models describing changes in the surface roughness of a workpiece *Ra* (a) and grinding power gain ΔP (b) as a function of the working engagement a_e and axial table feed speed v_{fa}. Note: additionally, the grinding conditions of grinding process and technical designation of used grinding wheel are give below

Rys. 2. Modele matematyczne opisujące zmiany chropowatości powierzchni przedmiotu obrobionego *Ra* (a) oraz przyrost mocy szlifowania ΔP (b) w funkcji głębokości szlifowania a_e i prędkości posuwu osiowego stołu v_{fa}. Uwaga: dodatkowo na dole podano warunki dla jakich prowadzono proces szlifowania oraz oznaczenie techniczne używanej ściernicy

2. Web application

The developed model of the change of the grinded workpiece surface roughness *Ra* depending on the working engagement a_e as well as the axial table feed speed v_{fa} (Fig. 2) was used for creation of web application. That application was made to help the selection of parameters of single-pass internal cylindrical grinding process using grinding wheels with zone-diversified structure [14].

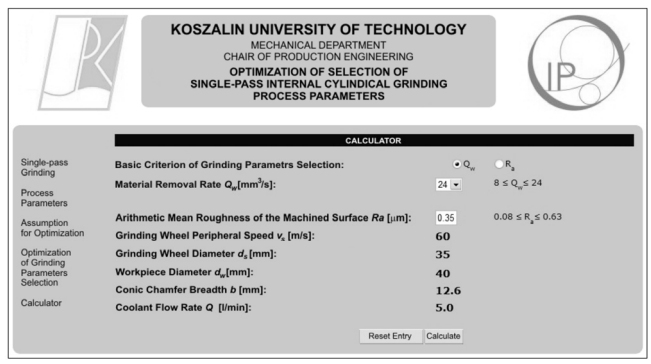


Fig. 3. General view of a *Calculator* worksheet module
Rys. 3. Widok ogólny formularza modułu *Kalkulator*

On the basis of the main optimization criterion (defined by a user), which can be the material removal rate Q_w or the roughness of workpiece surface *Ra*, the application chooses values of the most important parameters of the investigated grinding process (a_e, v_{fa}, χ). To do so, the implemented mathematical models are used. The application of the chosen values allows obtaining the results of the grinding process, which are closest to the values given by a user.

The application was made as website based on a scripting programming language PHP. The basic information about single-pass internal cylindrical grinding as well as the information concerning the main parameters of grinding, were contained in that website. The most important part of the application is a module named *Calculator*, which enables generating the optimum parameters of machining process on the basis of data in a form filled by a user (Fig. 3).

For calculations of the geometrical parameters of a grinding wheel ($d_s = 35$ mm, $T = 20$ mm, $T_1/T_2 = 70/30$, $b = 12.6$ mm), the speed of grinding ($v_s = 60$ m/s), the relation of speed ($q = 80$) as well as the coolant flow rate ($Q = 5.0$ l/min.) were assumed to be constant.

The result of the application work are values of: working engagement a_e, axial table feed speed v_{fa}, angle of conic chamfer χ as well as the value of Q_w and *Ra* which are enumerated for chosen parameters (Fig. 4a) on the basis of the worked out empirical mathematical models.

Choice of the main optimization criterion and defining the demanded values of both optimization criteria (*Ra* and Q_w) cause that the application finds in a set of possible solutions that which will ensure obtainment of the value closest to the given one. The first application finds solutions by the basic criterion, and then by an additional one. This means, that for the same value of the selection criteria, the results of application will change depending on the chosen basic criterion. It can be seen from comparison of Fig. 4a with Fig. 4b.

The developed mathematical models are valid only for the range of parameter changeability used in experimental investigations, because they were created on its basis. That is why the changeability ranges of optimization criteria values given by a user were also limited in such a way, to correspond the investigation results.

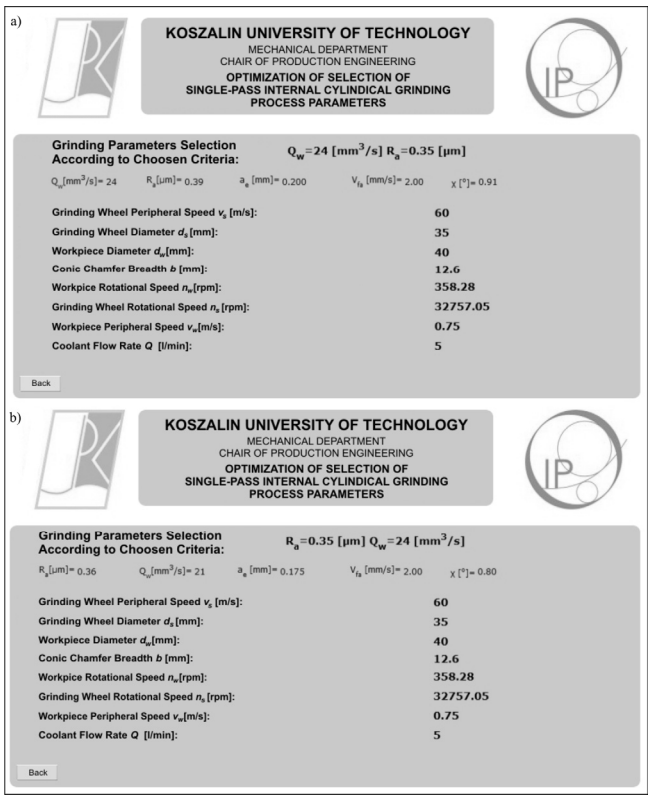


Fig. 4. Exemplary results of optimization carried out with use of the developed web application for Q_w = 24 mm^3/s and Ra = 0.35 µm: a) basic criterion – Q_w, b) basic criterion – Ra

Rys. 4. Przykładowe rezultaty optymalizacji przeprowadzonej z wykorzystaniem opracowanej aplikacji sieciowej dla Q_w = 24 mm^3/s i Ra = 0,35 µm: a) kryterium podstawowe – Q_w, b) kryterium podstawowe – Ra

In the case of existing more than one solution for the demanded value of the main optimization criterion, the application selects from among them that one which is closest to fulfillment also an additional criterion. However, it can happen that the application finds more than one solution fulfilling exactly both conditions. In such a case, all solutions are displayed in order to enable undertaking the decision about choice of one of them, by a user (Fig. 5).

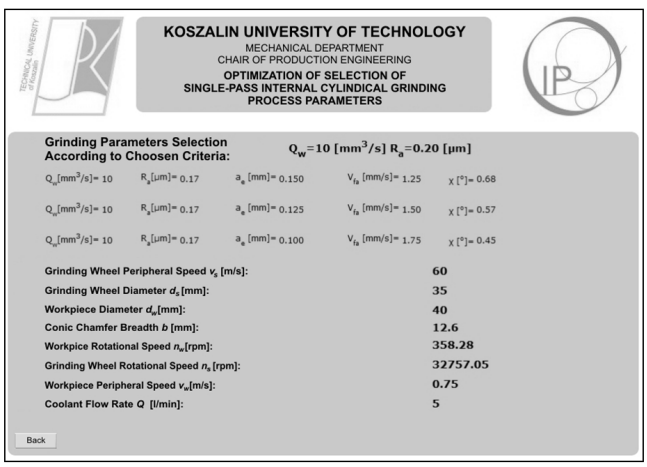


Fig. 5. Exemplary result of process parameter selection for chosen criteria – Q_w = 10 mm^3/s and Ra = 0.20 µm, obtained with use of the developed web application

Rys. 5. Przykładowy wynik doboru parametrów obróbki dla wybranych kryteriów – Q_w = 10 mm$_3$/s i Ra = 0,20 µm, uzyskane za pomocą opracowanej aplikacji sieciowej

3. Summary

The developed web application provides practical assistance in realization of single-pass internal cylindrical grinding process using grinding wheels with zone-diversified structure. It helps to choose the value of the most important parameters of process (a_e and v_{fa}) on the basis of the demanded values of two basic criteria (Q_w and Ra). Automatic calculation of the conic chamfer angle value as well as the peripheral and rotational speeds of the grinding wheel and workpiece are also very helpful. The major limitation of the described informatics tool come from using only the relatively narrow range of the investigation results of the studied process conducted in one research centre. Extending the knowledge based on results of the process obtained for other materials, different internal diameters and lengths of the workpiece, as well as different grinding machines will allow extending the potential use of the developed web application.

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