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*grinding, polishing,
interchangeable abrasive discs,
sculptured surfaces*

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GRINDING AND FINISHING SCULPTURED SURFACES USING AN INNOVATIVE MULTITOOL HEAD WITH INDEPENDENT PNEUMATIC DRIVE

The paper presents the concept and prototypes of multitool grinding and polishing head with independent pneumatic drive for grinding and finishing large free form surfaces (FFS). Such a head facilitates selection of elastic abrasive discs, grinding process parameters and conditions, as well as proper shaping of the marks of the workpiece surface geometric structure.

1. INTRODUCTION

A wide variety of technologies and machine tools is offered in cylindrical and flat surface machining, however, machining free form surfaces is still highly troublesome. This refers mostly to large elements such as sheet metal press tools, propeller screws etc., which are required to have low surface roughness. Such surfaces are most often shaped in the machining processes with milling machines and CNC machining centers, while they are smoothed out usually in abrasive machining with tools used for manual machining with electro- or pneumatic drive.

The aim of abrasive machining is to obtain low surface roughness (Ra = 0,1 - 2,0μm), proper shaping of the machining marks' structure, with high dimension – shape precision [1],[2].

To obtain such effects in industrial conditions, such machining may last even up to a few hours and its automation is extremely difficult.

In order to limit such difficulties and increase the free form surfaces finish grinding effectiveness, an innovative method of grinding and smoothing out such surfaces using a multitool head with independent pneumatic drive was developed in the Department of Production Engineering at the Technical University of Koszalin. This method can be applied both in milling machines and numerically steered machining centers, as well as in conventional machine tools such as milling machines and lathes.

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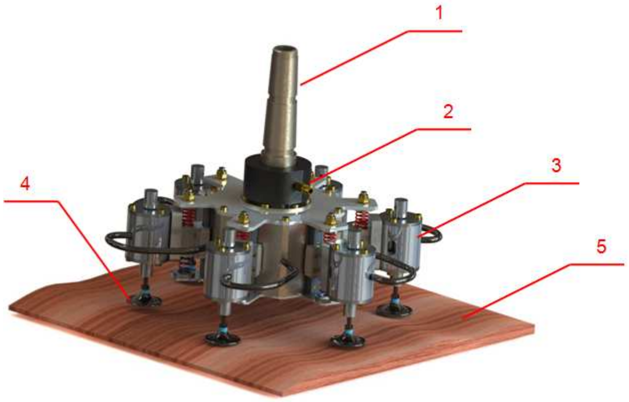
2. MULTITOOL GRINDING – POLISHING HEAD

The multitool grinding – polishing head is composed of 6 tool groups, in which abrasive discs designed for grinding and polishing are embedded opposite the mounted axis.The axes are driven using pneumatic turbines with adjustable pressure, to which the compressed air is provided through cords connected with the central air intake (Fig. 1).



1 – head grip (Morse's cone),
2 – sleeve providing compressed air,
3 – 6 spindles spaced on the hexagonal body
4 – elastic backing for abrasive discs,
5 – workpiece.

Fig. 1. Multitool grinding – polishing head

The particular tool groups can relocate independently on slideways in the axial direction, as a result of which their temporary position can be adjusted to the machined surface shape. Moreover, particular tool groups can be rotated at a specific angle, as a result of which the machining zone size and location, as well as its heat – mechanical strain can be adjusted. The particular tools are pressed against the machined surface using springs with adjustable pressing power. This facilitates controlling the power value in the grinding zone and the grinding depth. The machining zone is additionally cooled with compressed air directed in the proper way after leaving the turbine.

The advantages of the multitool head are the following:
- performing grinding and smoothing out procedures using one tool,
- possible adjustment of the size and shape of the machining zone depending on the machined surface shape and the machined material properties,
- its own independent drive using compressed air from industrial network with pressure 5 - 8 bar,
- the possibility of application on conventional machining tools such as milling tools, lathes, grinders, machining centers, as well as industrial robots [3],[4],[5],[6].

3. TECHNICAL CHARACTERISTICS OF THE MULTITOOL HEAD

A pneumatic turbine with diameter 35mm with 6 vanes of concave outline R10 and height 20mm (Fig. 2) was used in the grinding – polishing head developed.

a) b)

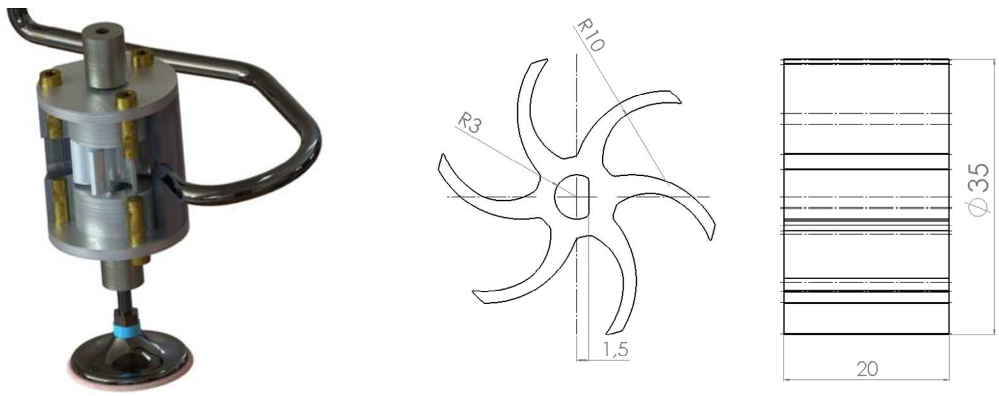


Fig. 2. Tool group (a) and the pneumatic turbine (b)

The characteristics of the rotational speed of the head drive unit spindle were examined using vertical milling machineFYF32J produced by Jafa company while compressed air, pressure 5 - 8 bar, was provided from the external industrial network.

PHANTOM V210 high speed camcorder with special external illumination system were used to determine the rotational speed (Fig. 3).

Fig. 3. Research arrangement used to determine the characteristics of the rotational speed of the head drive unit spindle

The tests were conducted in the applied pressure function, which determined the spindle rotational speed and the grinding speed for abrasive discs with 50 mm diameter (Table 1).

Table 1. Technical characteristics of the multitool head

Pressure, bar	The time of 10 rotations, ms	The time of 10 rotations, s	Rotational speed n, rot/s	Circumferential speed v, m/s
5	82,3	0,0823	121	18,997
6	40,8	0,0408	245	38,465
7	37,4	0,0374	467	41,919
8	35,8	0,0358	279	43,803

The results obtained prove that the dependence of the head spindle rotational speed of the working pressure is not linear and makes it possible to control the grinding speed on the grinding tool circumference within the range of approximately 19 - 44m/s.

4. RESEARCH ON THE GRINDING PROCESS

The tests were conducted on a knee-type milling machine, type FYF32J, in whose spindle the multitool grinding – polishing head was mounted. The workpiece was made from NC6 steel, hardness 60 HRC and it was mounted in a vice on a sliding table (Fig. 4) [10],[11],[12].

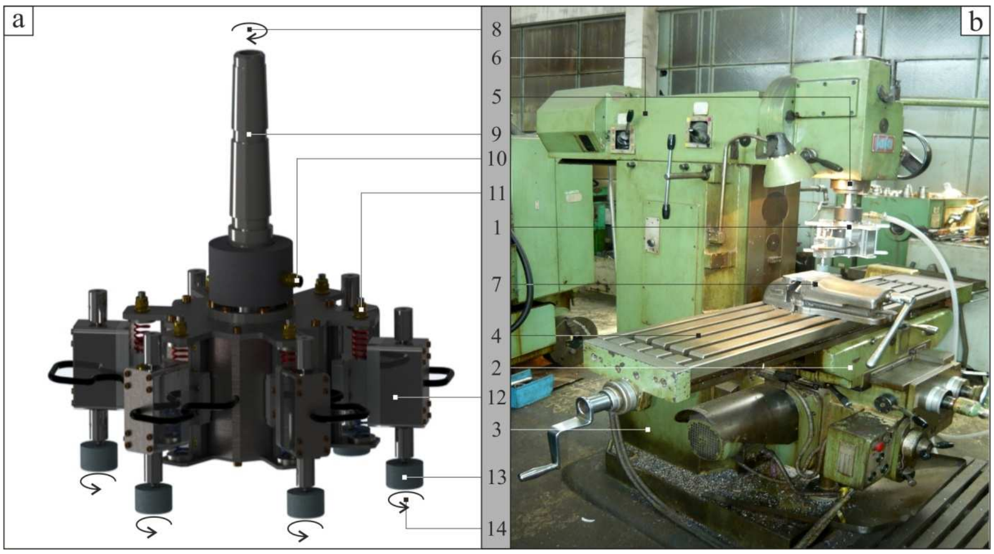


Fig. 4. Research post: a) grinding – polishing head, b) knee-type milling machine TYP - FYF32J with mounted head, 1–grinding head, 2–cross slide, 3–knee-type milling machine(Jafa, TYP - FYF32J), 4–table, 5–spindle, 6–cantilever slide beam, 7–vise with the workpiece, 8–head rotation direction, 9–Morse's cone 4, 10–compressed air inlet, 11–spring stretching adjustment, 12–spindle, 13–dish-type grinding wheel, 14–grinding wheel rotation speed

Interchangeable elastic abrasive discs of Roloc system, produced by 3 M, with various technical features and types of abrasive grains, were used as abrasive tools. These included:

- cubitron II P36+ grains which were the abrasive on the fiber discs of 984F type with reinforced edges,
- trizact A30 grains which were the abrasive on the abrasive discs,
- abrasive non-woven fabric 3M SC-DR, which was the abrasive on the discs with 3M Surface Conditioning backing,
- universal felt 3M finesse - it with "Extra Life" TYPE - T.

The tools' active surfaces can be viewed in Fig. 5.

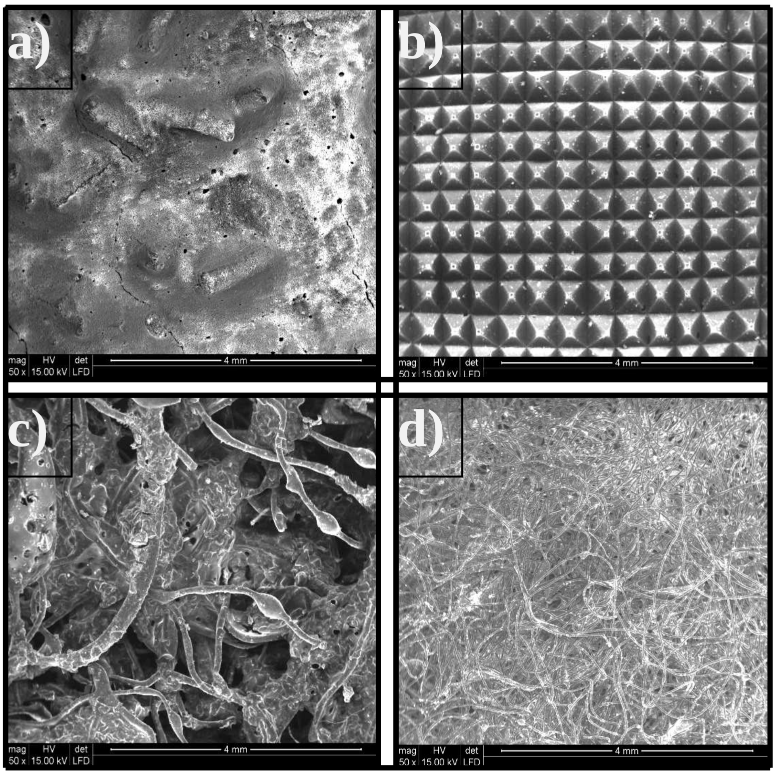


Fig. 5. View of the active surfaces of abrasive discs with Cubitron II 36+ (a), Trizact A30 grains (b), abrasive non-woven fabric 3M SC-DR (c), universal felt 3M Finesse - it "Extra Life" TYPE - T (d)

Abrasive grains of Cubitron II type are constructed from microcrystalline sintered corundum and are characterized by regular apex and edge shape. Moreover, they undergo the process of self-sharpening during the grinding process. They are electrostatically oriented on talus surfaces of the abrasive surfaces.Tools with such grains are designed for grinding carbon, stainless steel, alloys of color and hard-to-machine metals. Trizact grains are shaped like regular three-dimensional pyramids, composed from a large number of precisely fractioned abrasive, in the microreplication process.As a result of the progressing active grains wear process, new micrograins apexes are revealed during work, which allows for ongoing self-sharpening process that renews their cutting capacity. This stabilizes the talus tools' operating conditions and guarantees repeatability of the machined surface structure over a considerable period of time. These grains are destined for grinding carbon and stainless steels, as well as nickel, cobalt and titanium alloys.

Abrasive non-woven materials of 3M SC-DR type are characterized by spatial structure, thus creating surfaces of talus tools for finish grinding with considerable structure openness. In consequence, they do not overheat the workpieces' surfaces. They are designed for finish grinding of practically all types of metal materials.

The influence of different types of abrasive materials on the machined surface roughness was examined with grinding speed v_c= 44m/s (compressed air pressure 8 bar) and axial table feed speed v_{ft} =1120mm/min in a single pass.The results of such tests are presented in Fig. 6 in relation to the initial roughness of surface after grinding assessed at three measurement points.

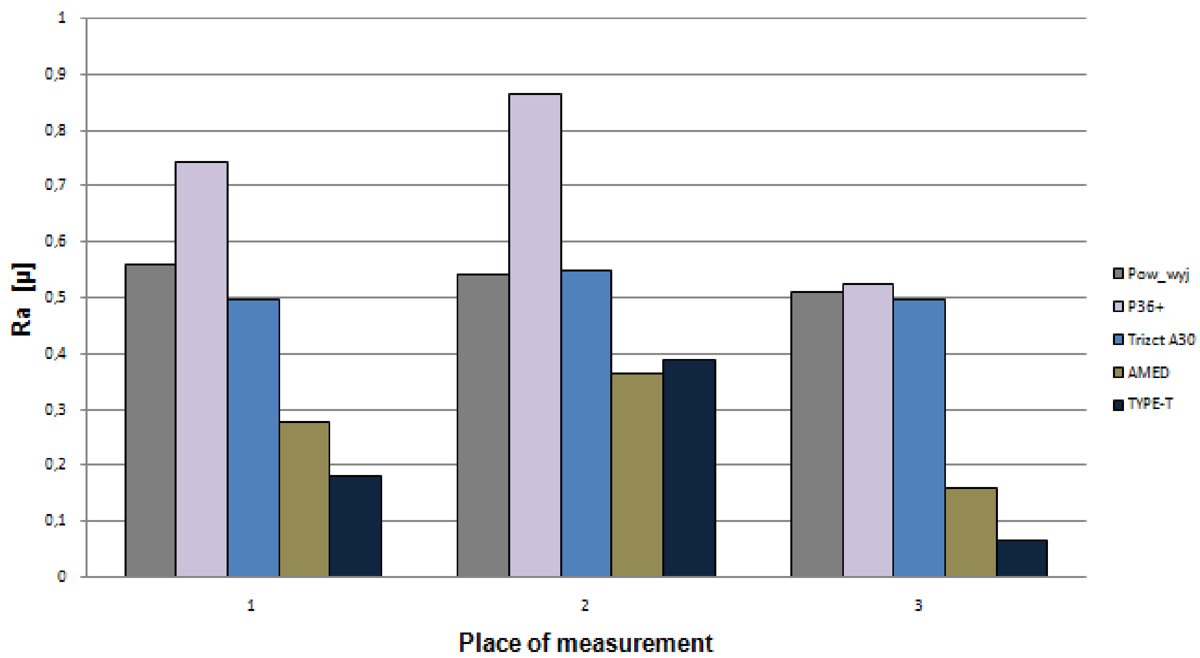


Fig. 6. Roughness of surface made from tool steel NC6 (60HRC) after grinding and finishing with abrasive discs from different types of abrasive materials

On basis of their analysis, it can be concluded that in the presented kinematic system and machining conditions, the abrasive grains with grains guarantee surface roughness comparable to the one obtained after grinding (initial surface). Discs with non-woven materials with abrasive felt, on the other hand, are capable of decreasing it considerably.

The worst effects in this system are provided by discs with Cubitron II P36+ grains which deteriorate the initial surface roughness. Therefore, on order to obtain decent effects of the process of finishing a surface with the multitool grinding – polishing head, the process should be carried out in stages.

First of all, discs with Trizact grains of regular shape should be applied, which should be followed by usage of discs with non-woven materials with gradual gradation and the fiber discs.

The second stage of the tests included examination of the grinding and finishing process of the free form surface using discs with Trizact grains with gradual granulation, i.e.: A160, A100, A65 and A45 [7]. Their active surfaces are presented in Fig. 7.

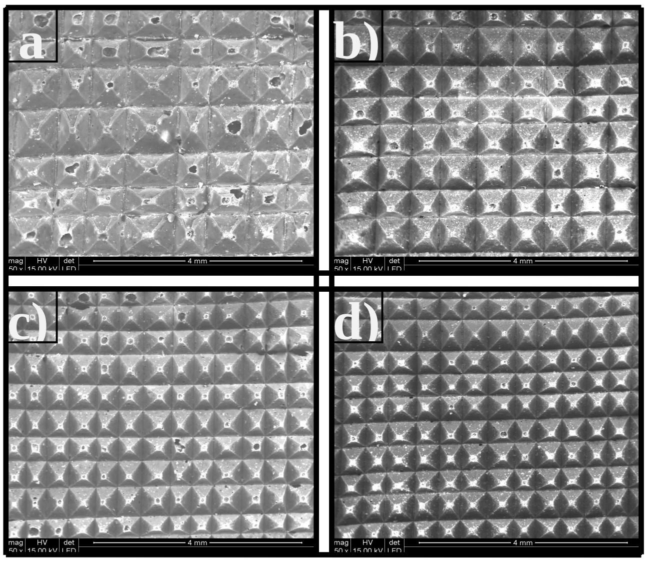


Fig. 7. View of active surfaces of abrasive discs with Trizact grains: A160 (a), A100 (b), A65 (c), A45 (d)

The influence of the granulation of Trizacton the surface roughness was examined with grinding speed v_c = 44m/s and axial table feed speed v_{ft} =1120mm/min in a single pass. The results of these tests are presented in Fig. 8 in reference to the output surface roughness.

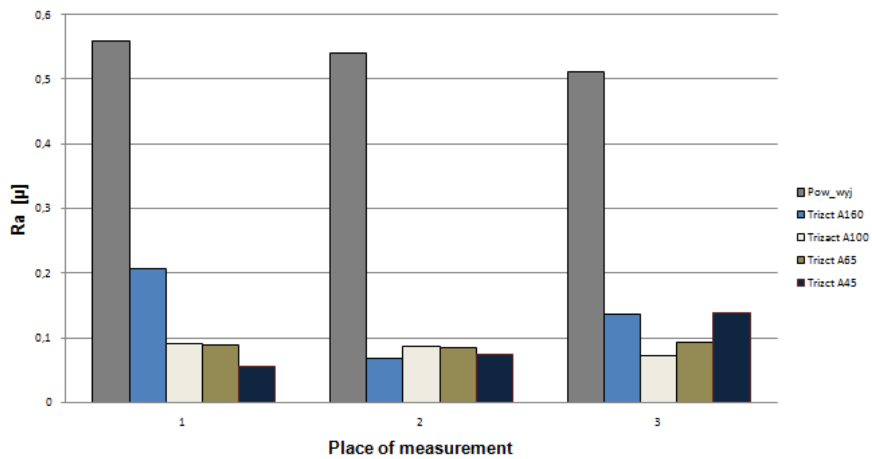


Fig. 8. Roughness of surface made from tool steel NC6 (60HRC) after grinding with abrasive grains with Trizact grains of different granulation

The results of these tests show that roughness values can be considerable decreased, down to approximately Ra = 0,1μm with proper combination of discs' granulation. This result is comparable, even better, in relation to the surface smoothed out with the non-woven material with felt.It must be, however, noticed that due to high compliance of the tool spindles in the axial direction, it was not confirmed that the lower the abrasive grains' granulation, the lower the machined surface roughness [8],[9],[10].

Grinding with abrasive discs with Trizact grains may, however, constitute a competitive alternative to grinding and smoothing out with abrasive non-woven material. This results from their better self-sharpening capacity, as well as long durability periods, which guarantees repeatability of the machining marks and homogeneity of the machined surface structure.

5. SUMMARY

The results of the research show that the designed multitool grinding – polishing head with independent pneumatic drive facilitates effective machining of free form surfaces. Due to application of discs with Roloc Scotch – Brite mounting system using thread connection, it makes machining both with abrasive and polishing tools, with various technical characteristics, possible. The head can be successfully used in milling tools and machining centers, both in machining metal and non-metal materials. It will be also used for manual grinding of large stationary objects with changing shape, e.g. boat/yacht hulls etc.

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