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MACHINING OF HARD NON - METAL MATERIALS

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ABSTRACT

Plastic deformation and chip formation machanisms form the basis of material removal processes and according to that all materials can be separated into two groups. The first group encompasses materials with plastic properties (metals, plastic materials, composites, etc.) and the second group consists of hard and brittle materials, i.e. materials with low plasticity (glass, ceramics, stone, etc.). Due to their low plasticity, machining of brittle materials has some specific characteristics. Considering that data on the machining of these materials can be rarely found in literature, this paper gives some investigation results in the machining of glass as a representative of hard and brittle materials. Glass is primarily a decorative material and its purpose depends on the visual effect of machined surface. A comparison of the surface quality obtained by different material removal processes is presented using the example of glass machining. The paper also presents the investigation of the influence of cutting parameters (cutting speed and feedrate) on surface quality in final machining phase, i.e. the polishing of glass.

Keywords: glass, surface roughness, polishing

1. INTRODUCTION

Engineering materials are the substances which are used for the manufacturing of engineering products and which possess the combination of favourable physical properties called engineering properties. In order to become an engineering material, a substance, in addition to possessing good engineering properties, must be easily worked and shaped into the desired shape by a suitable treatment (casting, deformation, material removal processes, welding, etc.). Engineering materials can be listed according to [1] as: metals and alloys, ceramics and glasses, polymers and composites. Ceramics and glasses are good insulators, resistant to high temperatures, and extremely hard materials. On the other hand, they belong to the group of materials which are brittle, which means that the fracture in general loading conditions occurs without noticeable permanent deformation.

The material removal process is based on the mechanism of chip formation, i.e. creation of separate particles. According to this, materials can be divided into two major groups: materials with the properties of plasticity (metals, plastic materials, composites, etc.), and a group of materials which are hard and brittle, or the materials with poor plasticity (glass, ceramics, stone, etc.). Due to their low plasticity, the machining of these hard and brittle materials has specific characteristics since the mechanism of chip formation is different from the common ones. The different chip formation mechanism of the machined workpiece materials can be attributed to their different mechanical properties. According to [2, 3], hardness and thermal conductivity are basic properties of workpiece materials since they affect the mechanism of chip formation. Materials with very high hardness, and

therefore, low deformation ability, are characterized by a change of the chip formation mechanism from continuous chips to serrated (segmented) chips [2, 3, 4]. It is also known that hard materials may be worked in the most efficient manner by high speed machining. In that case the chip formation mechanism differs clearly from the chip formation mechanism at conventional cutting speeds because, by applying higher cutting speeds, the shear angle increases. Chip formation mechanisms and chip form influence the machining process, i.e. have the effect on cutting forces, generated heat and also the quality of machining [5, 6].
Since the data on the machining of hard and brittle non-metallic materials can rarely be found in the relevant literature, this paper presents the research results of the machining of glass as a representative of these materials.

2. GLASS MACHINING

According to [7, 8, 9, 10], various machine tools are used for glass machining, and the processes most often used are: cutting, edge grinding and bevelling, making of bores, coining, polishing, sandblasting, etc. The cutting of the original glass plate to the required workpiece dimensions is performed by a cutter in the form of a steel disc, a circular saw, water jet or a diamond milling cutter on a numerically controlled machine tool.
What is meant by glass machining in this paper is the edge grinding of glass plates which can have different thickness. The given examples are the manufacturing of glass doors, mirrors, glass shelves and cupboards, and similar components. The edge machining process is always divided into four phases in which different chip removal processes are used. The first phase is the cutting of the glass plate to the required dimensions and profiles. The next phase is rough grinding followed by fine grinding and final polishing. The 200x500mm samples of transparent glass 12 mm thick were tested with respect to the achieved quality of the machined surface. The test samples were machined on the INTERMAC PRO 5C grinding centre installed in the public liability company «Staklo Piletić», Zagreb, Velikopoljska 3.
In the first phase of machining, a “Diamut” FR 06445 standard diamond cutter, with the diameter of 20 mm, with six segments and with T20/8 quality, Figure 1, was used [11]. This tool simply follows the contour of the machined surface, and it is the tool most often used in the phase of edge cutting and machining on the NC machines. Table 1 gives an overview of cutting parameters recommended by tool manufacturers and used in this research.

Figure 1. A diamond cutter and a combined tool for glass edge machining.

In order to reduce the time of tool changing on the grinding centre, a standard procedure is to use a combined tool, Figure 1, in the second, third and the fourth phase of machining, i.e. for rough grinding, fine grinding and polishing of edges. Such a combined tool has the diameter of 100mm and consists of a rough grinding wheel with the granulation of 80/100 (identification P00247), a fine grinding wheel with the granulation of 230/270 (TR06253) and a plate for the final polishing of glass edge (L13172). The used cutting parameters recommended by the combined tool manufacturers are also given in Table 1. The "Perthometer C5D" measuring device was used to measure the roughness of edge surfaces, and the roughness results of the obtained surface were expressed by R_a , R_y and R_z parameters presented in Table 1.

Table 1. Surface roughness obtained by glass machining using different cutting tools

workpiece	cutting tool	v_c m/s	v_f m/min	a_p mm	R_a μm	R_y μm	R_Z μm
a	diamond milling cutter	13,1	0,7	5	11,3	47,00	61,5
b	rough segment wheel	24,6	3	0,7	6,21	44,04	34,46
c	fine wheel	27,35	1,875	0,2	2,02	13,93	11,56
d	polishing plate	19	1,82	-	1,99	10,75	8,74

Figure 2 presents the visual aspect of glass workpieces machined in four different phases. The workpiece "a" shows the look of the surface obtained by a diamond milling cutter, the workpiece "b" shows the glass surface machined by a rough segment wheel, the workpiece "c" shows the surface machined by a fine wheel, and the workpiece "d" shows the surface machined by a polishing plate.
Comparing the results of measured roughness of the samples given in Table 1 and the visual effect of the sample surfaces given in Figure 2, one can clearly see that the surfaces of samples "a" and "b" are very rough and machining tracks can be noticed. Sample "c" has significantly lower roughness and, visually, its surface is much smoother compared to the previous two samples, but its surface is matt and has the characteristic frosted white look. The last sample, i.e. sample "d", has no significant change in the surface roughness compared to sample "c", according to Table 1, since the surface roughness parameters have similar values. However, from Figure 2, it can be clearly noticed that sample "d" is the only sample with the required property of being decorative, i.e. that it has a glittering and clear surface as a result of polishing.

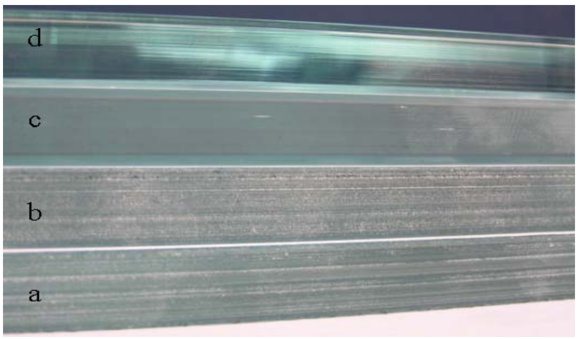

Figure 2. Surfaces of glass samples machined by different cutting tools

3. FINAL PHASE OF MACHINING – GLASS POLISHING

In order to obtain by polishing both the lower surface roughness and the decorative property of a glass sample, further research aimed at determining the effect of parameters affecting the surface roughness of samples machined by a polishing plate. Since the depth of cut cannot be varied during the polishing process, the object of research was to investigate the dependence of polished glass arithmetic mean of the surface roughness profile (R_a) on the change of cutting speed (v_c) at the recommended feedrate (v_f), and the dependence on the change of feedrate (v_f) at the recommended cutting speed (v_c). Diagrams are given in Figures 3 and 4.

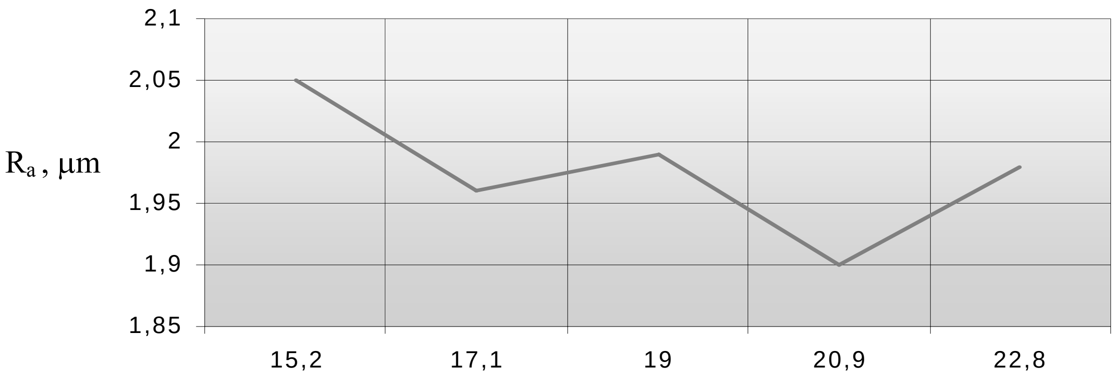

Figure 3. Dependence diagram $R_a = f(v_c)$ for v_f = 1,82 m/min

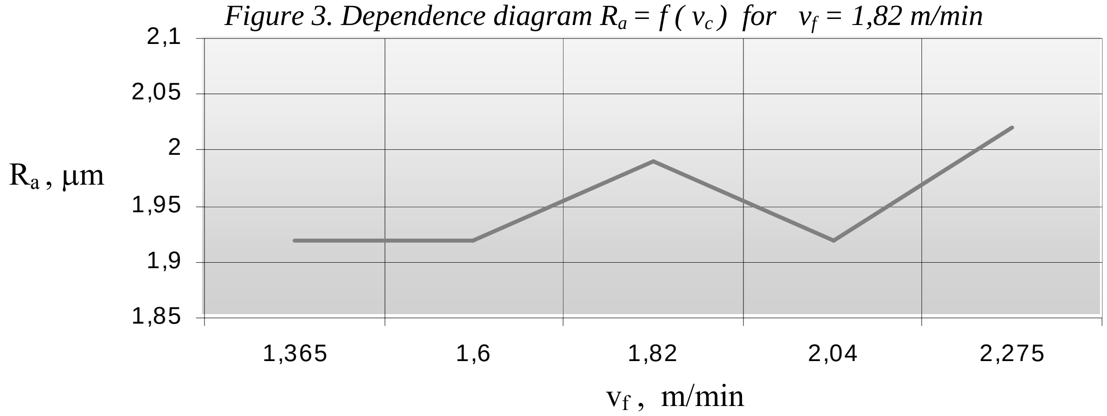

Figure 4. Dependence diagram $R_a = f(v_f)$ for v_c = 19 m/s

The diagram in Figure 3 shows that the arithmetic mean of the surface roughness profile (R_a) decreases with the increase of the cutting speed during polishing, but the change is within the value of 0.15 µm, which can be neglected. The diagram in Figure 4 shows that the arithmetic mean of the surface roughness profile (R_a) decreases with the decrease of feedrate. However, the deviation of roughness from the maximal and minimal measured values is negligible as it is only 0.1 µm.

4. CONCLUSION

This research has shown that there is an expected difference in the obtained glass surface roughness when different machining procedures are applied. When a diamond milling cutter is used, the surface rougness is at the highest level. By using a rough segment wheel the surface roughess is reduced, while the use of a fine continuous wheel and a polishing plate results in the lowest level of roughness. The comparison of measuring results of the finely ground and polished samples does not give a significant difference in the obtained roughness, but it can be noticed that the decorative property has been achieved only in the case when polishing was applied. This is the only case in which the machined surface is clear and there are no machining tracks.

Further research into the possibility of reducing the obtained glass surface roughness by applying the polishing process has shown that polishing cannot significantly improve the glass surface roughness neither in the case when the cutting speed is increased nor in the case when the feedrate is reduced since the effects can be neglected. It is planned for the future research to investigate the possibility of reducing the glass surface roughness by applying a fine continuous wheel for grinding that would precede the final polishing procedure. It is predicted that this procedure could affect the quality obtained by final polishing.

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