Comparative research on abrasive blasting of 145Cr6 steel for various working media

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Abstract. This paper deals with the influence of testing elements made of 145Cr6 steel after heat treatment. The elements have been machined with various abrasive materials using abrasive blasting. The abrasive materials were: quartz sand, two corundum sizes and two sizes of Brown Fused Alumina. The treatment of all types of abrasives took place at the same working pressure of 0.55 MPa. The 2D and 3D roughness parameters obtained after the abrasive blasting were analyzed. Roughness measurements were made using the Talysurf CCI Lite optical profilometer. Microscopic observations were performed on a Nicon Eclipse MA 200 inverted microscope.

1 Introduction
Modern technology development confronts many engineers with problems that they have to solve. The development of modern technologies is associated with the emergence of modern construction materials. There are also modifications and improvements of materials known for a long time [1,2,3]. Advances in materials engineering have resulted that currently produced materials are characterized by: increasingly higher strength properties, increased hardness, abrasion resistance, etc. For the processing of modern materials, modifications of well-known methods of their processing are often used, such as microwelding [4,5,6,7]. One of the types of known machining methods are surface treatments. Surface treatments are widely used in modern production processes. Due to their diversity and versatility, it is possible to use complicated technologies such as laser technology [8] or relatively simple thermal methods to implement them. Their diversity means that surface treatments are used in many cases, for example, changes in the functional properties of the native material [9,10] (eg surfacing) [11], applying various coatings (protective, decorative, technical, etc.) or as finishing treatment [12]. Abrasive blasting is used in the processing of metal elements and it can be also used as a treatment aimed at preparing the surface before the next stages of the technological process or to remove oxides, lacquer coatings, prior to gluing processes to develop the surface in relation to the surface nominal as well as finishing treatment of the surface of workpieces [13,14].

2 Blasting - abrasive - characteristics
In the blasting process, the prepared abrasive grains suspension in the working medium (which may be liquid or gas) is sprayed onto the workpiece surface of the object. If water is used as the carrier medium, it is advisable to add corrosion inhibitors. The reinforced abrasive grit, due to its properties, allows machining of complex shapes. It also allows one to process large surfaces. The technological parameters of processing (such as process efficiency, roughness) are influenced by
many factors. These are: the type and size of grains of the working medium, the distance of the spraying device from the work surface, working pressure, treatment time, an angle of the abrasive stream relative to the surface to be machined and the type of workpiece. Abrasive blasting is used mainly in cases where there are no excessive requirements as to the dimensional accuracy of the workpieces.

In the abrasive blasting section, the working fluid pressure which is usually applied is in the range 0.2 - 1.2 MPa. The abrasive jet sprayed by the nozzle at the given pressure range reaches the speed of 200 - 800 m / s. During the process, the material layer being removed is usually 0.01 - 0.1 mm. Typically, the angle of the nozzle axis of the spray device relative to the work surface (κ) is in the range of 15 - 90°. At κ angles above 30º, we obtain an additional effect of strengthening the surface layer to a depth of a few micrometres. In addition, for the described values of the angle κ, a favorable distribution of compressive stresses is obtained.

3 Experimental research

The tests were carried out on cylindrical samples made of 145Cr6 steel after heat treatment. This steel is a tool steel for a cold work. It is characterized, inter alia, by a high abrasion resistance. The chemical composition of steel is shown in Table 1.

| C    | Si   | Mn  | P    | S    | Cr   | Ni   | Mo   | Al   | Cu   | V    | W   | Ti  | Co  |
|------|------|-----|------|------|------|------|------|------|------|------|-----|-----|-----|
| 1.33 | 0.25 | 0.49| 0.018 | 0.005 | 1.42 | 0.02 | 0.032| 0.14 | 0.11 | 0.01 | 0.04| 0.01|

The samples before the experimental tests were heat treated (hardening, low tempering - the obtained hardness of the samples was 62 HRC). The front faces of the samples have been sanded. The blasting process was carried out in the PK-700 sandblasting machine.

Prior to the actual tests, preliminary tests were performed in which machining parameters used in further experimental work were determined as follows:

• air stream pressure p = 0.55 MPa, the distance of the nozzle of the element gushing from the surface of the processed sample equals 80 mm;
• the angle of the nozzle axis of the gushing element relative to the work surface κ ≈ 45°;
• the nozzle diameter of the spout element equals 6 and 7 mm;
• processing time up to 40 s.

There were five different working materials used in the study. Their summary is presented in Table 2.

| Quartz sand | Brown Fused Alumina A-20B | Brown Fused Alumina A-20B | Corundum | Corundum |
|-------------|---------------------------|---------------------------|----------|----------|
| the size of the abrasive grains | 0.2-0.8 mm | F10 | F24 | 0.2-0.5 | 0.5-1.4 |
| diameter of the nozzle | 6 mm | 7 mm | 6 mm | 6 mm | 6 mm |
4 Results and discussion
After the abrasive blasting process, all samples were cleaned and subjected to observations, using light microscopy techniques and roughness measurements. The observations were made on a Nicon Eclipse MA 200 micrograph of an inverted type microscope. In Figure 1, there is shown an example of a photo of the surface of a C45 steel element after blasting.

![Figure 1](image-url)

Figure 1. Surface of the sample of 145Cr6 steel after abrasive blasting (working medium - Corundum 0.2 - 0.5 mm, diameter of the nozzle 6 mm)

The table 3 presents examples of 2D and 3D roughness parameters.

|                  | Quartz sand | Brown Fused Alumina A-20B | Brown Fused Alumina A-20B | Corundum | Corundum |
|------------------|-------------|---------------------------|---------------------------|----------|----------|
| Ra, μm           | 1.095       | 3.703                     | 3.850                     | 0.884    | 0.851    |
| Rz, μm           | 8.529       | 23.622                    | 22.753                    | 8.177    | 6.943    |
| Sa, μm           | 1.173       | 5.085                     | 5.324                     | 0.899    | 0.891    |
| Sz, μm           | 13.102      | 66.967                    | 39.846                    | 16.105   | 9.235    |

The surface roughness and a 3D surface profile was measured for all the samples. Roughness measurement was carried out using a Talysurf CCI Lite 3D non-contact surface profiler. The measured and analyzed 2D roughness parameters were: $R_p$ (μm) – Maximum peak height of the roughness profile, $R_v$ (μm) – Maximum valley depth of the roughness profile, $R_z$ (μm) – Maximum height of the roughness profile elements, $R_t$ (μm) – Total height of roughness profile, $R_a$ (μm) – Arithmetic mean deviation of the roughness profile, $R_q$ (μm) – Root-Mean-Square (RMS) Deviation of the roughness profile, $R_sk$ – Skewness of the roughness profile, $R_ku$ – Kurtosis of the roughness profile, $R_{mr}$ (%) – Relative Material Ratio of the roughness profile, $R_{dc}$ (μm) – Roughness profile Selection Height difference,
RSm (mm) – Mean Width of the roughness profile elements, Rdq (deg) – Root – Mean – Square slope of the roughness profile.
The measured and analyzed 3D roughness parameters were: Sq (μm) – Root mean square height, Ssk (μm) – Skewness, Sku (μm) – Kurtosis, Sp (μm) – Maximum peak height, Sv (μm) – Maximum pit height, Sz (μm) – Maximum height, Sa (μm) – Arithmetic mean height [15]
Figure 2 presents an example of a graph of the polar roughness distribution for sample No. 3, (a variant of an abrasive blasting using A-20 B ordinary corundum, size F24). One can see no roughness directionality – randomness.

Figure 2. The graph of the polar roughness distribution for sample No. 3

Figure 3 presents exemplary roughness results for sample no. 3 (a variant of abrasive blasting using A-20 B ordinary corundum, size F24).

Figure 3. The 3D roughness results for sample no. 3

The tests carried out and the analysis of the obtained results show that depending on the working medium used, abrasive grains obtain different energy at the same working pressure. It results directly from the dependence on the kinetic energy of the particle, which depends on the mass of the particle and its velocity. It was found that it is necessary to select the machining parameters, such as: type and size of abrasive grains, air working pressure, the angle of the sprinkler nozzle to
the work surface and the distance of the device gushing from the work surface depending on the type of material and the assumed technological effects of the process. By an appropriate selection of the size of abrasive grains, one can regulate both the intensity of the layer remove from the surface of the workpiece and the degree of surface development of the workpiece. The analysis of 3D surface topography and the polar graph of roughness distribution for all samples shows the lack of directivity of the geometric structure of the surface.

The use of abrasive grains with low granulation results in a reduction in the intensity of interactions with the treated surface. As a result of the treatment with low granulation grains, an even distribution of roughness on the work surface is obtained. In the case of using larger sizes of abrasive grains, due to their relatively high kinetic energy, they may be formed as a result of their interactions with the surface treated with deep craters. Abrasive blasting can also be used for relatively hard materials, such as heat-treated cast iron, etc., but this is associated with a much greater wear of the working medium in the form of abrasive grains.

Conclusions

The size of abrasive grains regulate both the intensity of the layer remove from the surface of the workpiece and the degree of surface development of the workpiece. The surface roughness after the abrasive blasting process is undetermined - is random. As a result of the treatment with low granulation grains, an even distribution of roughness on the work surface is obtained. The using larger sizes of abrasive grains on the surface may be make deep craters. The surface after blasting is more susceptible to corrosion, hence the abrasive slurry should contain corrosion inhibitors.

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