Research on the use of zeolite for smoothing surfaces in tumbler machining

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Abstract. The article presents the proposal of using grounded zeolite rocks for container processing. The hardness of 5-6 according to the Mohs scale classifies this material as medium hard. Which is applicable for roughing of elements and deburring and polishing processes. The aim of the research was to assess the quality of zeolite application as a cutting material. Effectiveness of removing corrosion and geometric structure of the surface changes of objects made of carbon steel were investigated. Specified mass losses depending on the length of the vibratory machining process and changes in the geometric structure of the surface. The results were compared to analogous processes carried out with the use of ceramic abrasive media.

1 Introduction

Finishing works are a significant challenge in the manufacturing of small objects and with extended geometry, what in many traditional methods of finishing treatment often presents many problems [1-2]. The machining of sharp edges and hard-to-reach places is particularly problematic. Opposite to the requirements of machining of objects with complex spatial structure, they enable their use by loose abrasive machining. Most of all, we should understand here all treatments using high pressure abrasive particles - sandblasting, shot peening, soda treatment, etc. but also container machining with using loose abrasive media [4-6]. Literature data gives [3] a significant dominance of vibratory machining over rotary due to significantly lower machining times required to achieve analogous results as with rotary machine tools only – figure 1.

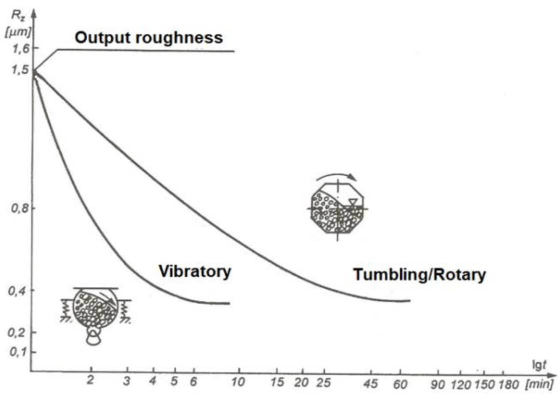

Figure 1. Change of surface roughness of St10 steel samples depending on the time of finishing in the container smoothing machines [3]

Vibratory machining is a finishing process of the object surface to the most optimal form, removing the material allowance and burrs, rounding the edges, smoothing the surface and cleaning it thoroughly [7-9]. The process takes place in containers containing workpieces, the working medium in the form of appropriately selected abrasive or polishing media and the working fluid [10-12]. The process consists in moving the workpieces to the abrasive media [13-15].
Ceramic shapes used in the tests consist of irregularly shaped grains of ceramic cullet connected by a binder [16]. In ceramic shapes there are also pores, ie empty space. It should be noted that the most important role of the binder is the deposition of abrasive grains and keeping them for a suitable time on the active surface of the grinding wheel [17-18]. The pores present in the volume are important, because allow to supply the protective and lubricating agent to the microcutting zone and they hold in their volume and remove products of processing, i.e. chips, from this zone [19]. In grinding wheels with ceramic binders, the pores are formed in an intrinsic way in the process of firing the grinding wheel body [19].

2 Zeolite

Zeolites are a large group of natural hydrated aluminosilicate minerals with different chemical compositions and properties. These are sodium and calcium aluminosilicates, to a lesser extent barium, strontium, potassium, magnesium and manganese. Zeolites were formed as a result of volcanic eruptions in millions of years under the influence of high temperature and pressure, when the volcano lava came into contact with the saltwater. The reaction of volcanic ash with the salts present in the lakes has transformed the solidified lava into various groups of aluminosilicates with unique physicochemical properties. These properties result from their specific crystalline structure, characterized by the existence in the spatial aluminosilicate skeleton of canals and chambers with strictly defined molecular dimensions. The total volume of empty spaces is 24 - 32%. The hardness of 5-6 according to the Mohs scale classifies this material as medium hard. Which is applicable for roughing of elements and deburring and polishing processes. The aim of the research was to assess the quality of zeolite application as a cutting material.

Figure 2. Zeolitic shapes with gradation 4-8 mm and ceramic media CB 20T

3. RESEARCH OBJECT

In order to test the cutting properties of zeolite, i.e. a natural mineral, it was decided to compare the results of the treatment with loose shapes in the form of crushed zeolite rock in a vibrating machine. A fraction of fine particles of zeolite rocks with gradations from 4 to 8 mm was used for the tests. The results of the obtained tests were referred to the results of vibro-abrasive treatment using the shapes with similar abrasive abilities - triangular ceramic shapes CB 20 T (with a size of approx. 20 mm). It should be emphasized that ceramic shapes are a typical composite consisting of ceramics and a binder.

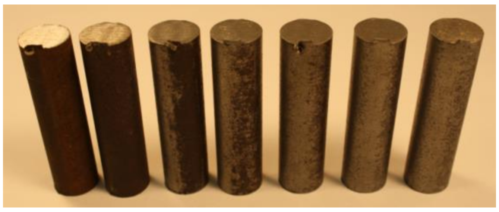

Figure 3. Steel samples a) without machining, b) after 60 min of treatment, c) 120min, d) 180 min, e) 240min, f) 300min and g) 1000 min

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In the research, attention was paid to the possibility of using zeolite for finishing steel (corrosion removal of steel). The samples (figure 3) were made of carbon steel in the form of rods with a diameter of 12 mm, length approx. 45 mm, which as a result of long-term storage were affected by the environment – corrosion.

The tests were carried out on a machine dedicated for vibro-abrasive machining of Rollwasch SMD-25-R with a working tumbler capacity of 25 dm^3. Before the tests, the process parameters were determined. The vibration frequency of the tank (tumbler) was rated at 2400Hz. In order to have a reference to the zeolite's cutting ability, it was decided to examine how the mass loss and the basic parameters of the geometric structure of the surface change along with the duration of the treatment time. The tests were carried out for 0, 60, 120, 180, 240, 300 and 1000 minutes of treatment duration. A charge in the form of crushed zeolite rock (4-8mm) in an amount of approx. 13 kg was filled into the machine tank. The treatment was carried out wet with the addition of about 200 ml ME L100 A22 / NF processing aid and about 400ml of demineralised water. As a result of the zeolite's properties, i.e. the tubular structure of the mineral, all of the liquid part of the charge was absorbed almost immediately by a fixed part of the charge. Too much liquid addition leads to complete soaking of the zeolite, which in turn leads to a solidified mass and the inability to process. Therefore, based on the experience, the authors decided to use a limited amount of supplementary support.

4. RESULTS AND DISCUSSION

The samples were marked and weighed before being placed in the working tumbler. Then, after an appropriate duration of treatment the samples were pulled from the tumbler. They were thoroughly cleaned in an ultrasonic cleaner. Then the mass was re-measured. As a result of the obtained results, it was possible to determine mass losses depending on the length of time of the vibratory machining. Data of mass loss are presented in table 1. In addition, mass losses for analogous processing times using ceramic shapes were compared. A mass loss with the use of zeolites media was applied to a mass loss using ceramic shapes, which was expressed as a percentage value.

Table 1. Comparison of mass losses and the basic parameters of the geometric structure of the surface for the treatment with fittings made of zeolites and ceramics

Tumbling time, min	Weightloss, milligrams		Weightloss Zeolites/ ceramic %	Sa, µm		Sz, µm	
	Zeolites media	Ceramic media		Zeolites media	Ceramic media	Zeolites media	Ceramic media
0	0	0	0	2.024	2.024	39.037	39.037
60	47.2	80.7	58.5%	5.803	2.039	40.522	32.613
120	70.9	89.5	79.2%	3.838	1.881	37.739	22.893
180	88.2	107.9	81.7%	2.362	1.852	30.759	21.315
240	89.6	114.4	78.3%	1.802	1.547	22.52	19.537
300	96.1	115.5	83.2%	1.841	1.282	23.028	17.943
1000	97.4	164.3	59.3%	2.236	0.768	22.258	15.728

On the basis of measurements of mass losses of corroded steel samples subjected to vibratory machining using crushed zeolite and ceramic media it can be clearly stated that processing media in the form of zeolite molds causes mass losses however smaller than those considered with the use of ceramic media. Based on the measurements. it can be concluded that vibratory machining with finely divided zeolite rocks leads to approx. 80% of the mass losses of analogous processing times as in the case of ceramic media. The exception is the shortest - 60 min and the longest processing time - 1000 min where the discrepancies are different from the other machining times and amount to approx. 60%.

Long-term studies of smoothing for 1000 minutes with zeolitic media resulted in a much smaller loss of sample mass equal to 97.4 mg. i.e. about 60% weight loss of samples as in the case of ceramic media. The reason for this situation may be the fact that in the case of long-term processing the sharp edges of the zeolite media become rounded and lose their cutting properties. The weight loss in the case of processing for 300 minutes amounted to approx. 96.1 mg. whereas the treatment for 1000 min approx. 97.4 mg. Therefore, it can be concluded that longer processing times than 5 hours do not bring significant changes in the loss of mass of processed details. It is not advisable to use longer treatment times using the zeolitic media. It should be emphasized that the discrepancies in the results of mass losses can be determined by the fact that ceramic media are composite shapes consisting of a ceramic cullet and a binder - a binding material that keeps individual abrasive shapes in a uniform form. The zeolite moldings are finely crushed zeolite rock which is not a typical example of abrasive shapes dedicated to container processing.

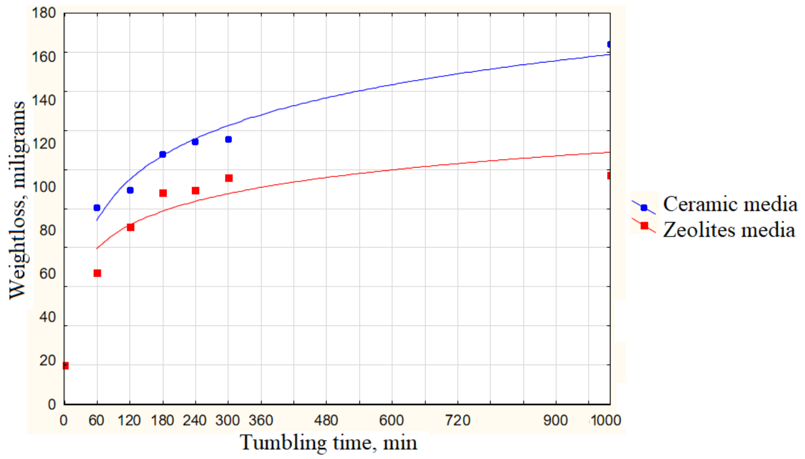

Figure 4. Diagram of the mass loss dependence on the treatment time for ceramics and zeolites

In order to obtain knowledge on which way the mass of the processed samples is reduced measurements of the geometric structure of the surface were carried out using the Taylor Hobson Talysurf CCI Lite 3D optical profilometer. As a result of the conducted analyzes 3D maps of the examined surfaces were obtained along with the SGP parameters. The results of measurements for different tumbling times of the basic surface roughness parameters are included in Table 1. According to Janecki [20] the 3D area surface texture parameters were defined. Sa is the arithmetic mean height of the surface. Parameter Sz is the maximum height of the surface. Parameter Sv is the maximum height of valleys. And parameter Sp is the maximum height of peaks (difference between Sz and Sv) [20].

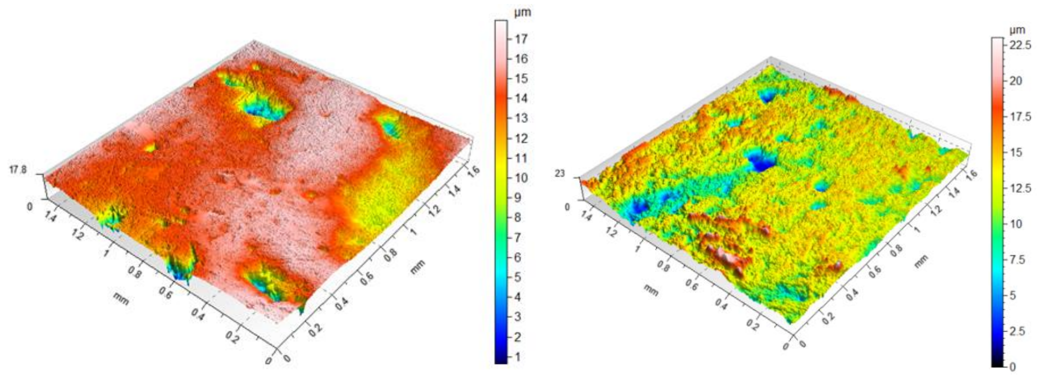

Figure 5. 3D surface texture of steel surface a) processed with ceramic media for 300 min. Sa = 1.841 μm b) processed with zeolit media for 300 min. Sa = 1.282 μm

The undetermined geometry of the media made of zeolite rock translates into a large number of sharp edges that draw surfaces causing the formation of many micro-dimples. In comparison to triangular ceramic shapes having a homogeneous construction surfaces for vibratory machining are characterized by lower surface roughness. This is confirmed by photographs of the obtained surfaces from the Talysurf CCI optical microscope. The obtained data allows to propose the use of fine fractions of zeolite fittings for surface preparation processes for coating application and removal of significant surface irregularities. In order to obtain very smooth surfaces with a low surface roughness should be carried out a two-step treatment. In the first stage of deburring with the use of e.g. zeolite and in the second stage smoothing and brightening with the use of polishing media. On the basis of graph 6, it can be concluded that the treatment with ceramic media allows to achieve smaller average arithmetic surface roughness – *Sa* than the media made of zeolite. Longer working times with ceramic media reduce Sa. The situation is similar with the zeolite media but only up to 300 minutes of treatment. However, machining for 1000 min does not reduce the surface roughness of Sa compared to machining for 300 minutes.

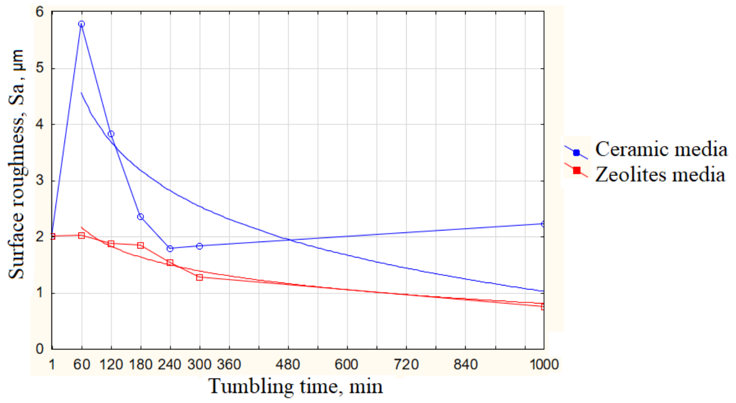

Figure 6. Graph of the dependence of changes in the arithmetic mean surface roughness *Sa* from the duration of the treatment time for ceramic and zeolite media.

Conclusions

On the basis of the conducted research it can be concluded that the shredded zeolite rock has cutting properties.

Visual observations already allow to conclude that the signs of corrosion are removed after approx. 4-5 hours of vibratory machining.

Mass losses of processed corroded parts made of steel with the use of zeolite account for approx. 80% of the mass losses for processing with ceramic media.

Extending the vibratory machining time over 5 hours is pointless due to slight changes in the weight loss of the processed workpieces.

Microscopic observations and measurements of the geometrical structure of the surface allow to state that vibro-abrasive machining with the use of zeolite rock media results in obtaining a surface with a higher average arithmetic surface roughness than analogue vibratory machining with ceramic media. The reason for this state of affairs may be a much smaller size of zeolitic media than ceramic media. Ceramic media are a combination of a binder and a ceramic pestle that plays the role of abrasive grains while the zeolite is pure mineral rock. This translates into a smaller mass of a single piece and the number and type of sharp edges responsible for the effects of machining.

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