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The Influence of Abrasive Paste on the Effects of Vibratory Machining of Brass

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Abstract

The article presents the results of research on the finishing of M63 Z4 brass by vibratory machining. Brass alloy was used for the research due to the common use of ammunition elements, cartridge case and good cold forming properties on the construction. Until now, the authors have not met with the results of research to determine the impact of abrasive pastes in container processing. It was found that the additive for container abrasive treatment of abrasive paste causes larger mass losses and faster surface smoothing effects. The treatment was carried out in two stages: in the first stage, the workpieces were deburred and then polished. Considerations were given to the impact of mass of workpieces, machining time and its type on mass loss and changes in the geometric structure of the surface. The surface roughness of machining samples was measured with the Talysurf CCI Lite optical profiler. The suggestions for future research may be to carry out tests using abrasive pastes with a larger granulation of abrasive grains, and to carry out tests for longer processing times and to determine the time after which the parameters of SGP change is unnoticeable.

Keywords: Surface treatment, Product development, Vibratory machining, Surface roughness, Brass finishing

1. Introduction

Brass are copper alloys with zinc [1]. Based on the phase diagram on the copper side there is a wide range of alpha isomorphic solid solution with copper. The maximum solubility of zinc is 39% at 456^0 C. Peritectic transformation results in a secondary solid beta solution with approx. 37% Zn. In alloys with a higher zinc content up to approx. 56%, the beta phase is separated directly from the liquid. Alloys with a content of about 35-46% zinc are two-phase (alpha + beta), and alloys with 46-50% Zn are single-phase beta.

The alpha solution is characterized by good plasticity at room temperatures, worse in the temperature range of 300-700^0 C and therefore these alloys are cold worked. The hardness and strength of the alpha brass increases with increasing zinc content [2]. The Beta phase has high strength - Rm around 420 MPa, but is less plastic than in the case of solid alpha solution - extension by approx. 7%. It is difficult to plastically cold [3]. That's why the alpha + beta brass are plastically machined.

In the article [4] a study was undertaken on the influence of vibratory machining on the effects of smoothing the surface of small-caliber ammunition. The treatment was carried out in two stages: deburring using ceramic media and polishing using steel balls. Papers [5] confirm the possibility of achieving a lower average arithmetic surface roughness when using two-stage processes. The test results [4] refer to the linear and spatial parameters of the geometric structure of the surface. Only the processes of using aqueous solutions of chemical liquids were considered without the use of abrasive pastes. In this work, it was decided to use polyester profiles that have larger deburring properties. Surface smoothing results were compared to similar tests using a slightly abrasive paste.

2. Vibratory machining

Devices for vibratory machining were introduced for common use in the 1850s, and thanks to improvements they became the basic construction of the industry [6]. The devices usually consist of a drive unit forcing the vibrating motion connected to the working container [7]. The tank mounted using spring susceptible to the fixed base [8]. The movement of machining media is usually controlled by adjusting the engine speed. In the literature, you can find terms synonymous with the term "mass finishing" such as loose abrasive media treatment, container finishing, vibratory machining, and superfinishing [9-11]. Anglo-Saxon literature often uses the terms micro mass finishing, rotofinish, tumble finishing or vibratory tumbling [12].

Vibratory machining, alongside the processing of erosion and cutting, is one of many the production techniques of the finished products with low surface roughness. Vibratory machining is one of the manufacturing processes providing finished products characterized by low surface roughness [13]. Vibratory machining is an example of unconventional machining, as are microwelding, electrical discharge machining, electrochemical machining and laser cutting [14,15]. Conventional machining methods include milling, drilling, turning and grinding.

Vibratory tumbling is a mechanical and chemical surface conditioning process during which elements are polished with abrasive media [16]. Abrasive media are commonly used for the material-removing surface treatment [17]. The material-removing, the unevenness of the workpieces surface is removed as a result of abrasion with abrasive media [18]. As a result of the process the workpiece, lose very little original mass [19].

The whole load of the parts to be finished and the finishing material is set into motion by the vibration of the container; they rub against one another until the required surface is obtained. The helical motion about the tumbler axis causes the tumbling material to micro-machine the workpieces [13]. If metal media are used, the parts may be surface conditioned by micro-kneading [5]. All the processes taking place inside the tumbler change the surface texture of the parts [6]. The principle of operation of the vibratory tumbling equipment used for the experiments is shown in Figure 1. Tumble finishing is commonly used, for example, in jewellery to polish metal items with a complex macro-geometry and semi-precious stones or in medicine to polish implants and natural bones [6]. It is also suitable for brightening plastic elements, deburring or degreasing.

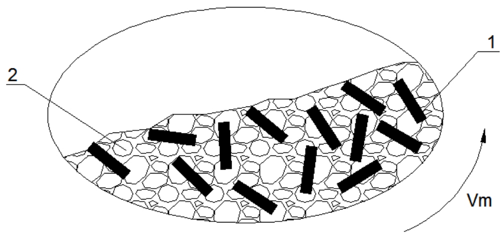

Fig. 1. Diagram of the process flow vibratory machining: 1) abrasive media, 2) workpiece, v_m - the direction of movement of charge [6]

3. Experimental procedure

The objects of the study were made of M63 brass cartridge case (after drawing and redrawing process) with a diameter of 9.5 mm, length of about 45 mm and a wall thickness of 0.2 mm, and bushings M63 Z4 brass with a diameter of 10 mm, length 45 mm and wall thickness 2 mm. Higher wall thickness of the sleeve allowed to obtain about threefold increase in the mass of processed details. Chemical composition is shown in Table 1. Brass M63 are executed of sheet metal, pipes, belts, rods and other sections. It is a common material used for cartridge case of ammunition, for cold forming and hot forming for deep drawing. This alloy is characterized by its resistance to corrosion and, due to its good thermal conductivity properties, it is commonly used as a material for coolers and other heat exchangers.

Table 1.
Chemical composition of brass alloy M63, % [20].

	Cu	Pb	Al.	Fe	Ni	Zn
min	62.0	-	-	-	-	-
max	64.0	0.1	-	0.1	0.3	Rest

The test was carried out on a Rollwasch SMD-25-R vibratory tumbler with a working volume of 25 liters. The first part of the research included preliminary deburring using polyester media PB 14KR - Figure 2. These media are dedicated to deburring processes. The processing time was 30, 60 and 90 minutes. In the second part of the research, the polishing process was carried out using metal fittings - SB 3.1 lotto metal media - Figure 3. Circular media of stainless steel is recommended for polishing steel and non-ferrous metals [6]. The smoothing and polishing processes were carried out wet with 200 ml of liquid adjuvant ME L100 A22/NF, due to the good properties, recommended by the manufacturer in the case of polishing, smoothing copper alloys.

Fig. 2. Polyester media, cone with dimensions: diameter 14 mm, height 14 mm

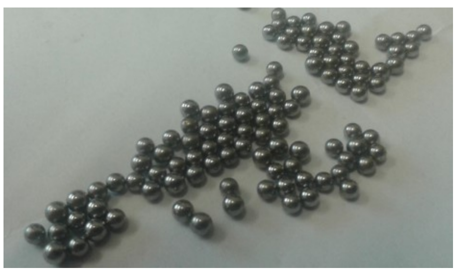

Fig. 3. Polishing media SB 3.1 lotto (round)

In addition, analogous processes were carried out using Tempo (Druchema) abrasive paste. The paste contains C9-C11 hydrocarbons, n-alkanes, isoalkanes, cyclic, less than 2% aromatics and morpholine. In the case of deburring with polyester media, about 75 grams of paste was added, and in the case of polishing with metal media also about 75 grams of paste. Tempo is abrasive paste commonly used for varnishing painted surfaces and to finishing decorative metal elements.

4. Results and discussion

Cartridge case and bushings of M63 brass have been deburred with polyester media for 30, 60, 90 minutes and polished with metal fittings for 30, 60, 90 min without the use of abrasive pastes and with added abrasive paste. The samples were marked and weighed in order to determine the mass loss.

The next step was to take measurements of the geometric structure of the surface. The surface roughness was measured using a device from Taylor Hobson a Talysurf CCI Lite optical profilometer. The measurement resolution was 1024x1024 points. 3D surface topography analysis for all samples was performed. The obtained data allowed to draw the Table 2- measurements for cartridge case and Table 3- measurements for brass bushing.

Among the height parameters of the geometric structure of the surface, it is necessary to replace arithmetic average surface height – parameter *Sa* [21]. Parameter Sp is the maximum height of surface peaks, Sv the maximum depth of surface depressions and Sz the maximum surface height [21].

Table 2.
Results of measurements of cartridge case

	Type and duration of machining	Mass loss, μg	*Sa*, μm	*Sz*, μm	*Sv*, μm	*Sp*, μm
without abrasive paste	before machining	-	0.24	5.15	2.13	3.03
	deburring 30 min	2.9	0.40	10.07	6.68	3.40
	deburring 60 min	6.7	0.40	7.09	4.56	2.53
	deburring 90 min	11.5	0.39	6.20	3.44	2.76
	deburring 90 min & polishing 30 min	12.4	0.29	4.96	2.86	2.10
	deburring 90 min & polishing 60 min	13.0	0.28	4.05	2.17	1.88
	deburring 90 min & polishing 90 min	14.9	0.25	5.06	3.11	1.95
with abrasive paste	deburring 30 min	5.1	0.49	5.05	2.50	2.56
	deburring 60 min	9.0	0.41	4.86	2.45	2.40
	deburring 90 min	12.9	0.41	4.58	2.36	2.21
	deburring 90 min & polishing 30 min	13.6	0.31	4.48	2.78	1.70
	deburring 90 min & polishing 60 min	16.0	0.26	3.80	1.88	1.93
	deburring 90 min & polishing 90 min	16.2	0.26	4.01	1.93	2.08

Table 3.
Results of measurements of brass bushing

	Type and duration of machining	Mass loss. μg	*Sa.* μm	*Sz.* μm	*Sv.* μm	*Sp.* μm
without abrasive paste	before machining	-	0.58	11.69	6.67	5.01
	deburring 30 min	5.9	0.76	8.50	5.48	3.02
	deburring 60 min	14.0	0.58	7.32	3.55	3.78
	deburring 90 min	22.8	0.55	6.79	3.77	3.01
	deburring 90 min & polishing 30 min	23.5	0.44	7.32	3.53	3.79
	deburring 90 min & polishing 60 min	26.2	0.40	6.48	3.48	3.00
	deburring 90 min & polishing 90 min	27.9	0.37	4.65	1.95	2.70
with abrasive paste	deburring 30 min	12.1	0.66	9.45	6.48	2.97
	deburring 60 min	22.3	0.57	7.89	5.01	2.88
	deburring 90 min	23.4	0.51	6.06	3.18	2.88
	deburring 90 min & polishing 30 min	23.8	0.41	7.77	4.34	3.43
	deburring 90 min & polishing 60 min	27.3	0.37	6.00	3.80	2.20
	deburring 90 min & polishing 90 min	29.9	0.35	4.64	2.32	2.32

When considering mass losses, it should be mentioned that the average weight of the cartridge case is about 6.8 grams whereas the copper bushing with a similar length weighs 18.6 grams. Triple increase in the mass of processed details of similar geometry moved to twice as large mass losses of brass sleeves in relation to the cartridge case of ammunition.

Moreover, the addition of abrasive paste in the case of machining of the cartridge case caused larger mass losses from 1.2 μg to 3.0 μg. However, processing of heavier details (bushing) caused an increase in mass loss from 0.3 μg to 8.3 μg. In addition, in both cases it should be emphasized that the largest mass losses occur in the first stage of processing - deburring with polyester media. For 90 minutes of deburring, the mass loss of the cartridge case is about 11.5 μg without paste and approximately 13 μg with a slightly abrasive paste. However, for the brass bushing, the deburring treatment for 90 minutes gives a mass loss of about 22.8μg without paste and about 23.4 μg with a slightly abrasive paste. Mass losses decrease with the duration of the process. The second stage - polishing treatment with metal fittings no longer causes such significant changes in mass losses. Correspondingly for the cartridge case, the mass loss is approximatly. 3.4 μg and for brass bushing 5.1 μg. The perennial nature of the burnishing of steel balls contributes to this.

Figure 5 was created on the basis of the collected data of mass loss from the machining time. There were two cases applied: the first effect of deburring with the loose polyester media, second impact deburring and then polishing with steel balls.

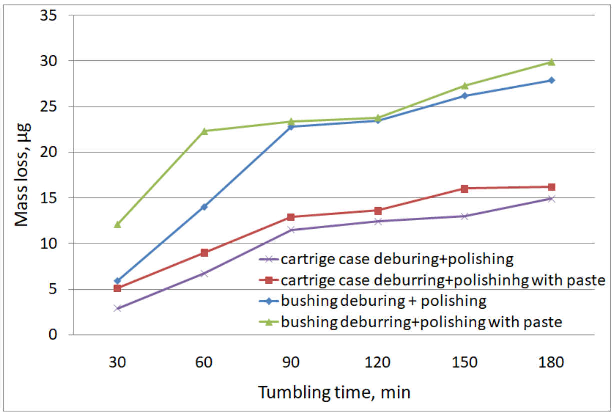

Fig. 5. Graph of mass loss dependence on duration of vibratory machining

Analyzing the measurements of the geometrical structure of surface it can be concluded that the cartridge case has a smaller arithmetic average surface roughness Sa 0.24 µm than the copper bushings where the Sa parameter is twice as large and amounts to 0.58 µm. This is due to the process of forcing semi-finished products from which ammunition cartridge case are made. This requires greater accuracy of tools and much more stringent parameters of plastic forming processes than in the case of brass tubes.

On the basis of the research, it can be unequivocally stated that deburring with the use of polyester profiles increases the arithmetic mean of surface roughness in the first period of treatment - the first 30 minutes. In the case of an cartridge case, Sa increases from 0.24 µm to 0.40 µm after 30 minutes of deburring and in the case of brass bushing from 0.85 µm to 0.76 µm. The longer the deburring machining time, the Sa parameter decreases to 0.31 µm in the case of cartridge case and 0.35 µm in the machining of the bushing.

The largest changes in the arithmetic mean surface roughness occur in the second processing stage - polishing with metal media. It was possible to reduce the Sa from approximatly 0.40 µm to 0.26 µm after 90 minutes of cartridge case and for the brass bushing from approx. 0.58 µm to approximatly 0.35 µm after similar 90 minutes of vibratory machining.

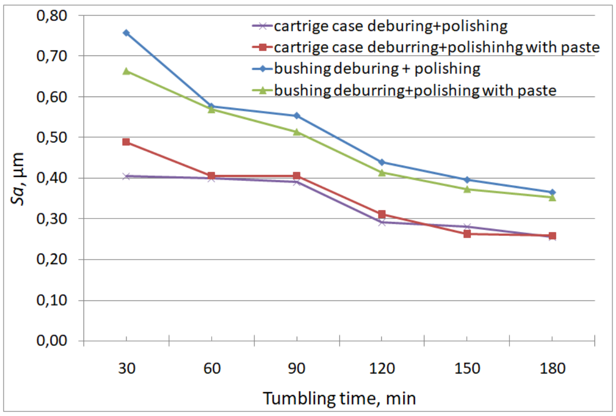

Fig. 6. Graph of the Sa average surface roughness on the duration of vibratory machining

The graph of the correlation between the change in the arithmetic mean of surface roughness and the duration of the treatment is shown in Figure 6.

Deburring treatment reduces the largest surface heights (Sp). In the case of a cartridge case redrawing, this parameter behaves similarly to the Sa parameter, i.e. during the first minute of deburring treatment the most intense impacts on the treated surfaces occur, therefore it increases to 3.40 µm in relation to samples not yet processed from 3.03 µm. The process is different for a rougher sleeve, which in the initial state has a Sp equal to approx. 5 µm and after deburring Sp decreases to approx. 3 µm. Finishing with metal fittings for 90 minutes in both cases reduces the Sp parameter to respectively 1.9 µm and 2.7 µm

Vibratory machining with abrasive pastes does not cause significant surface roughness changes in relation to analogous processes carried out without the use of abrasive pastes. Despite the surfaces are characterized by higher brightness of the surface – Fig. 7

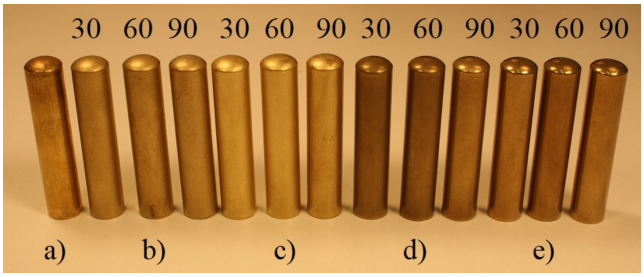

Fig. 7. The samples of ammunition scales a) before machining, b) after deburring on 30, 60, 90 min, c) after deburring with abrasive paste on 30, 60, 90 min, d) after polishing on 30, 60, 90 min, e) after polishing . with abrasive paste on 30, 60, 90 min

The results confirm [5] that it is best to lead the vibratory machining process in two stages using abrasive liquid media or pastes that assist container processing. That is, the abrasive-polishing media for the treatment of deburring, smoothing, and the process of using the media for strengthening the surface.

The three-dimensional (3D) optical surface of the samples before and after vibratory machining are shown on Figure 8-11.

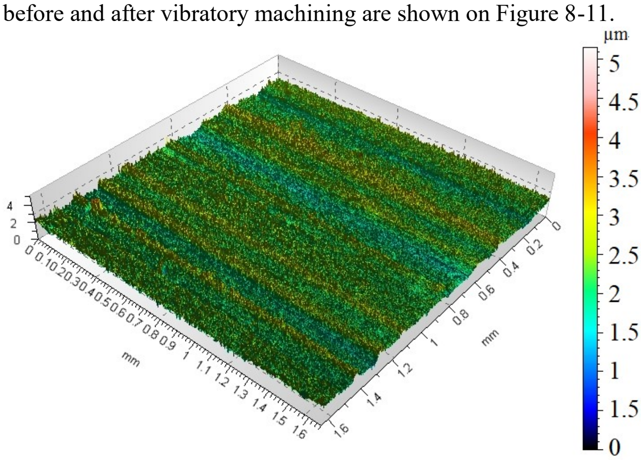

Fig. 8. Three-dimensional optical surfaces of the cartage case before machining. *Sa* = 0.2421 µm

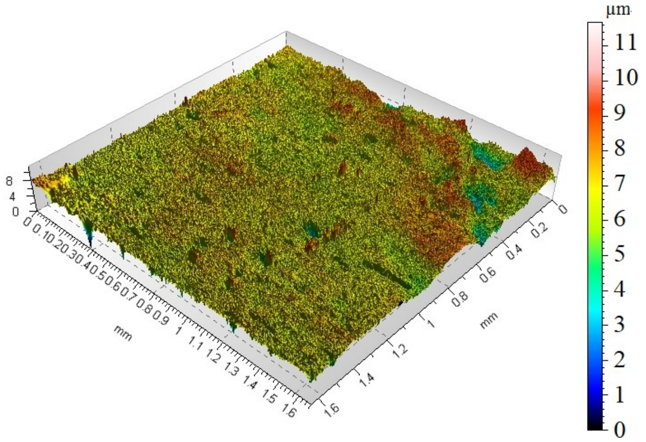

Fig. 9. Three-dimensional optical surfaces of the brass bushing before machining. Sa = 0.5752 µm

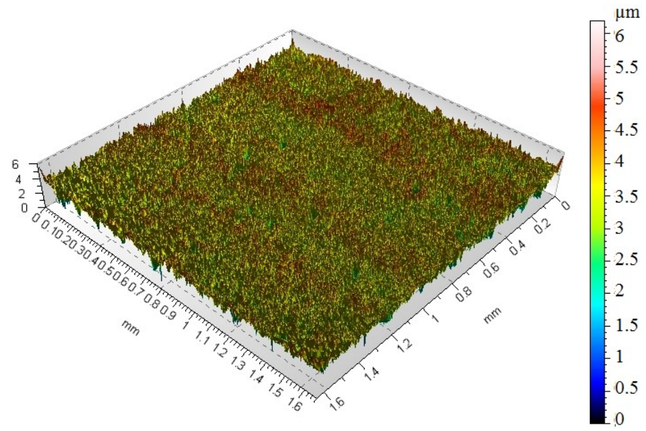

Fig. 10. Three-dimensional optical surfaces of the cartage case after vibratory deburring with abrasive paste on 90 min; *Sa* = 0.41 µm

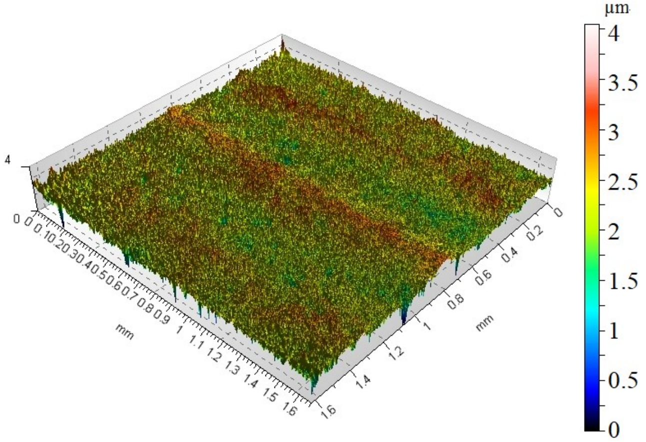

Fig. 11. Three-dimensional optical surfaces of the brass bushing after vibratory deburring and polishing with abrasive paste on 90 min; *Sa* = 0.26 µm

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4. Conclusions

Vibratory machining allows to effectively carry out finishing and shine on the surface.

The greatest effects are observed in the case of a two-stage treatment. First step deburring and then followed step of polishing.

The addition of abrasive paste results in larger mass losses compared to analogue vibratory machining processes without abrasive pastes.

The addition of abrasive paste results in a smaller mean arithmetic surface roughness Sa in comparison to analogue vibratory machining processes without abrasive pastes.

Vibratory machining with the addition of abrasive paste results in a lower surface roughness compared to similar processes carried out without abrasive pastes.

Observations of the directivity of the geometric structure of the surface allow to state that after vibratory machining the surface has the anisotropic structure. There are no traces of the previous drawings and redrawing processes.

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