A Study of Abrasive Media Effect on Deburring in Barrel Finishing Process

Ali Vakili Sohrforozani[1], Masoud Farahnakian[1], Mohammad Sajjad Mahdieh[2*], Amir Masoud Behagh[3], Omid Behgh[3]
[1] Department of Mechanical Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2] Department of Mechanical Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[3]Arshan Sanat Jam Co. ltd, Isfahan, Iran
[*]Email of Corresponding Author: s.mahdieh@scu.ac.ir
Received: November 6, 2019; Accepted: January 27, 2020

Abstract
Formation of the burrs in the industrial parts after manufacturing processes such as blanking, punching, machining, cutting and etc. is inevitable. The burring phenomenon decreases the geometrical and dimensional tolerance and makes assembling parts together difficult. Radiusing the corners of workpieces is a common technique to reduce the stress concentrations at corners and also facilitate their assembly. By means of barrel finishing, a number of workpieces undergo deburring and radiusing coincidently in one process. In barrel finishing which is one of the mass finishing techniques, many workpieces with abrasive media are loaded in a rotary barrel. By rotation of the barrel, the parts and abrasive media are collided to each other and rub themselves, resulting in deburring and polishing the workpieces. The working time of this process is normally long. The aim of this study is to decrease the working time by using proper abrasive media. Here, a number of experiments is designed on combination of three abrasive media: steel balls, ceramics and aluminum oxide particles, in different working periods, to achieve appropriate radius and reducing burrs height of CK45 steel alloy samples in reduced working time.

Keywords
Mass finishing, Barrel finishing, Deburring, Radiusing, Design of experiments.

1. Introduction

Although, in a few machining processes such as electrical discharge machining, the acceptable surface quality can be achieved [1-6], the proper finishing processes such as grinding, polishing, burnishing and mass finishing are required to have a desired surface finishing [7-9]. The burr is plastically deformed material which is formed in the manufacturing processes such as metal forming, machining and casting [10]. Barrel finishing is a common technique in deburring and polishing the industrial parts. In addition, by this technique, the sharp corners can be rounded [11]. The abrasive media and the workpieces are loaded in a rotary barrel and because of relative flow of abrasive media to the surfaces of the workpieces, eventually the height of the burrs is eroded and the sharps edge are rounded [10]. Low labor skill requirements, capability of processing a large volume of work pieces at one time, capability of processing complicated work pieces and low processing cost are the advantages of barrel finishing [12]. There are a lot of industrial parts such as crank shaft, cam shaft, chains, and gears and jewels which can be deburred through barrel finishing technique [13-17].

As mentioned, several effective factors such as type of abrasive media, working time and machining parameters (i.e. rotational speed, dimension, geometry and etc.) and mechanical properties of the workpiece are effective on the barrel finishing process [18, 19].

To investigate the effects of these factors, the statically methods are generally used and by trial and errors, the effects of each factor is determined [10, 12]. Although many studies have been developed on the mathematical model for the movement of abrasive particles and workpieces, but exact prediction of the final results (height of the burrs and radius of corners) is still under study [20-23]. A number of researchers have been tracked the particles and analyzed the particles trajectory. They have observed the particles movement by common techniques such as magnetic resonance imaging, positron emission method and imaging processing [24-27]. By these techniques, they could approximately calculate the working time, the surface roughness, the height of the burrs and the strain stress; however, these calculations were not completely accurate [28].

The working time of this process is high [29]. To decrease the working time, the rotational speed of the barrel can be increased; but high rotational speeds may damages the workpieces. In additions, the optimum result in this process is achieved when the barrel is rotated at a speed just below the cascade point [30-32]. Another approach to decrease the working time is using effective abrasive media, as discussed in the present paper. The shape, hardness and size of the abrasive particles are the important parameters in defining capability of the abrasive media [33]. In this study, decreasing the burrs height and radiusing the corners of CK45 steel alloy samples, via combinations of three types of abrasive media including, steel balls, ceramics and aluminum oxide particles, in the different working times has been investigated. Several experiments are designed and the proper abrasive media, which deburrs and radiuses the samples in minimum working time is determined.

2. Experimental procedures

The samples in this study are made of CK45 steel alloy, because of its widespread industrial applications. The chemical composition of CK45 steel alloy is shown in table 1.

The samples have cylindrical shape and produced by a Tabariz TN50 turning machine in 10mm diameter and 30mm height. To make the burrs on the samples, each sample is drilled with a 5mm drill bit. Fig. 1 shows the created burrs on samples. To measure the radius of the corners and the height of the samples burrs, each sample is symmetrically cut into two identical parts after barrel finishing process, then carefully polished and their corners and the burrs measured. Fig. 2 shows half of a samples which was cut and polished and ready for measurement.

Table1. Chemical com positions of CK45 steel

C (%)	Si (%)	Mn (%)	P (%)	S (%)
0.42-0.50	0.15-0.35	0.50-0.80	0.035	0.35

Figure1. The burrs on three samples

Figure2. Half of a samples which is cut and polished and ready for measurement.

The barrel finishing machine used in this study was horizontal and hexagonal barrel, formed by PVC sheets in the workshop. The diameter and the length of the barrel are 230mm, with 9 litter capacity. The rotational speed of barrel was 54 rev/min. Fig. 3 shows the utilized barrel finishing machine.

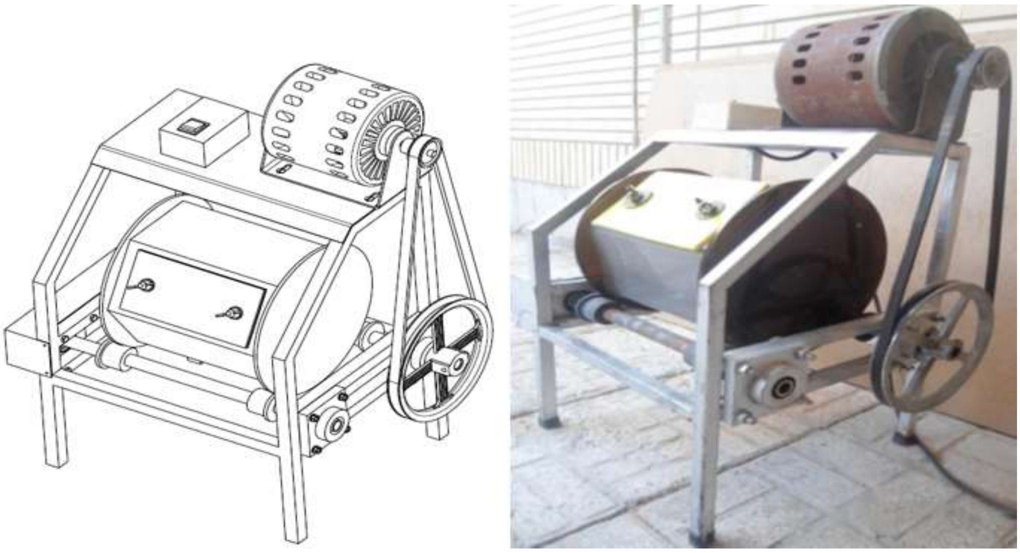

Figure. 3. Applied barrel finishing machine

Steel balls, aluminum oxide grit and ceramics particles are the three types of abrasive media which were used in the experiments. The ceramics has cylindrical shape with a 5mm diameter and 10mm length and 2.9 g/cm^3 density. Steel balls are in 3mm diameter and with 7.8 g/cm^3 density. The mesh of aluminum oxide (Al_2O_3) is 80 and the density is 1.8 g/cm^3. Fig. 4 shows these abrasive media. It should be noted that after each experiment, the abrasive media was washed and cleaned with water and nitric acid.

Figure 4. Three types of used abrasive media

To measure radius of the corners and the height of the burrs, a Dino Lite AM3013T digital microscope was used. This apparatus is connected by DinoCapture 2.0 software to the computer and has the magnification ×200. In Fig. 5 and Fig. 6, measurement of the radius of a corner and measurement of the height of burrs of a sample with the digital microscope are shown respectively.

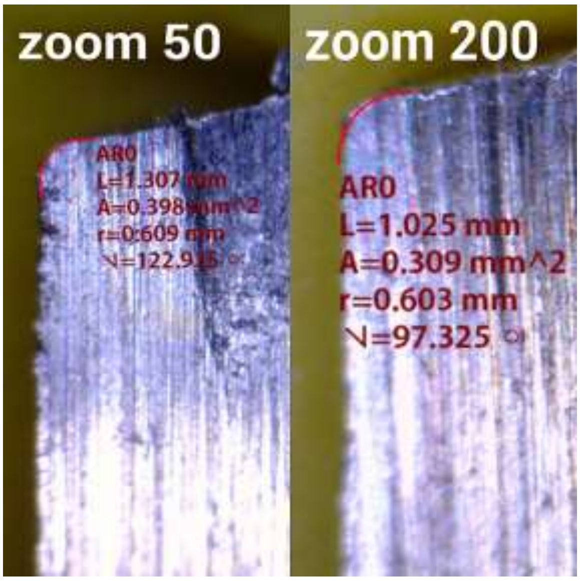

Figure5. Measuring the radius of the corner via digital microscope

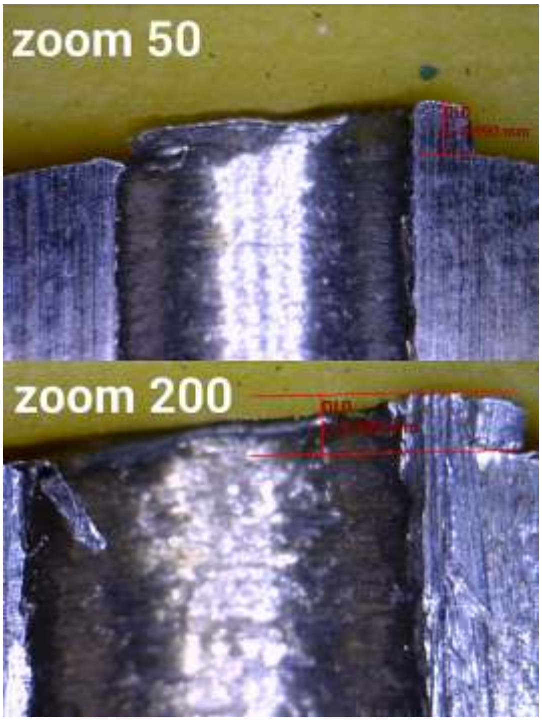

Figure6. Measuring the height of the burrs via digital microscope

3. Design of experiments

There are two input factors: working time and type of abrasive media in the designed experiments. The working time has four levels as 1 hour, 2 hours, 3 hours and 4 hours. There are nine levels for the combinations of the abrasive media out of three abrasive particles: steel balls, aluminum oxide and ceramics particles. The total weight of the abrasive media which is loaded in each experiment in the barrel is 5kg and the combinations is set as the percentage of each media in the total weight. These two factors and their levels are shown in table 2.

Table2. The factors and their levels

Input Factors		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
Working time (hrs)		1	2	3	4	-	-	-	-	-
Abrasive media (%wt of total weight)	Al_2O_3	-	100%	-	50%	-	75%	50%	25%	33%
	Steel balls	100%	-	-	-	50%	25%	50%	75%	33%
	Ceramics	-	-	100%	50%	50%	-	-	-	33%

The experiments were performed in the full factorial method and the influence of all factors was investigated on the height of the burr and radius of the corners of the specimens. In table 3 and 4, the measured height of the burr and the reduction of burr's height is presented respectively. In table 5, the measured radius corner of the specimens for each experiments is shown. Five samples were selected for each experiments and their height of the burr and radius of the corners were measured and averaged. Totally 48 experiments were performed in this study.

Table3. The measured burr's height of the samples in the experiments

Working time (level)	Abrasive media								
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
	Burr height (mm)	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**	**Burr height (mm)**
1	1.46	.73	1.29	1.36	1.01	1.31	1.20	.98	1.20
2	1.42	.50	1.20	1.27	.89	1.25	1.11	.81	1.12
3	1.38	.37	1.11	1.18	.79	1.19	1.03	.68	1.07
4	1.35	.26	1.03	1.11	.70	1.12	.95	.54	1.00

Table4. The reduction of burr's height in the experiments

Working time (level)	Abrasive media								
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
	Burr Reduction (%)	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**	**Burr Reduction (%)**
1	2.66	51.33	14	9.33	32.66	12.66	20	34.66	20
2	5.33	66.66	20	15.33	40.66	16.66	26	46	25.33
3	8	75.33	26	21.33	47.33	20.66	31.33	54.66	28.66
4	10	82.66	31.33	26	53.33	25.33	36.66	64	33.33

Table5. The radius of the corner of the samples

Working time (level)	Abrasive media								
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9
	Corner radius (mm)	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**	**Corner radius (mm)**
1	0.411	–	0.235	–	0.340	–	–	–	–
2	0.755	–	0.345	–	0.527	–	–	–	–
3	0.975	–	0.427	–	0.685	–	–	–	–
4	1.109	–	0.481	–	0.830	–	–	–	–

4. Results and discussion

The effects of these factors (working time and abrasive media) on the burrs height and corners radius is investigated as following.

4.1 The effect of the working time on the burrs height and corners radius

By increasing the working time, the height of the burrs is reduced and the edges and corners become rounder. In fact, by increasing the working time, the more abrasive particles can be collided with the specimens and consequently, the burrs height is considerably decreased and the radius of the corners increased. In Fig. 7 and 8 the burrs height and burrs height reduction are plotted against working time for four different conditions. Fig. 9 shows the increase of the radius of the corners by increasing the working time for three conditions.

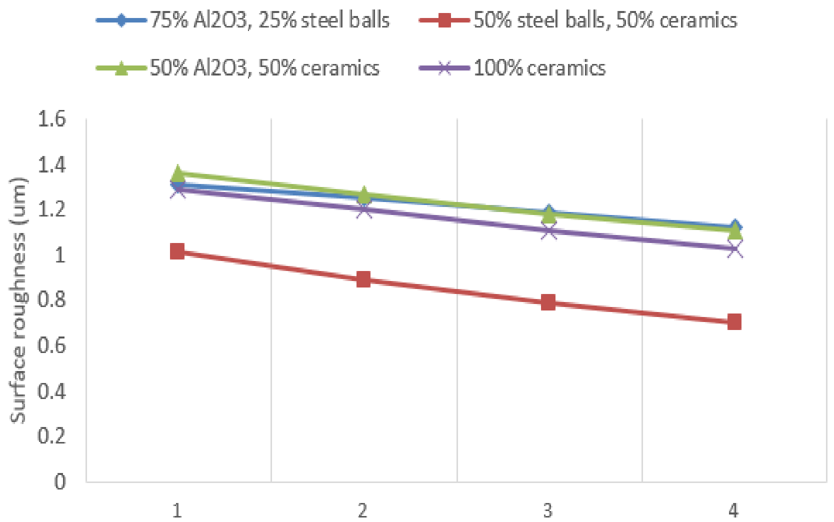

Figure7. Burrs height by increasing working time

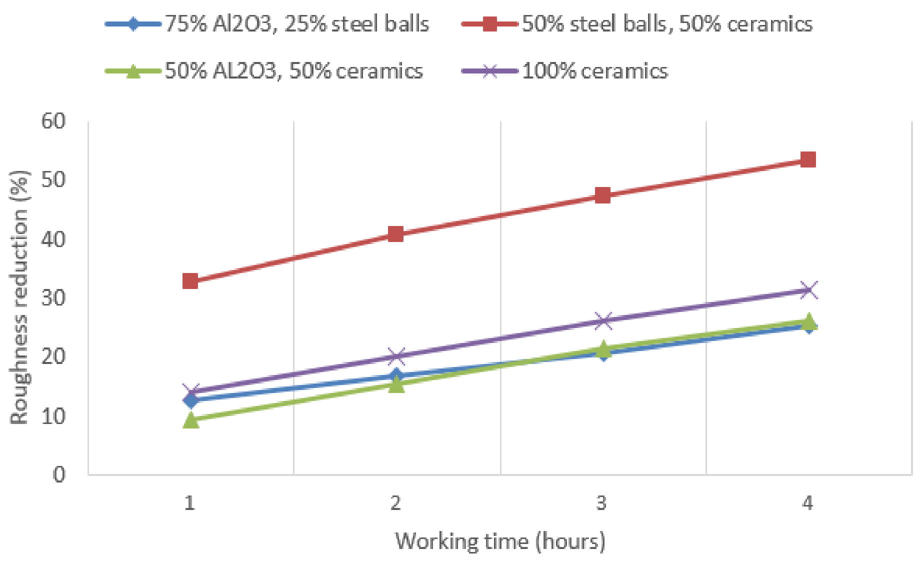

Figure8. Burrs height reduction by increasing working time

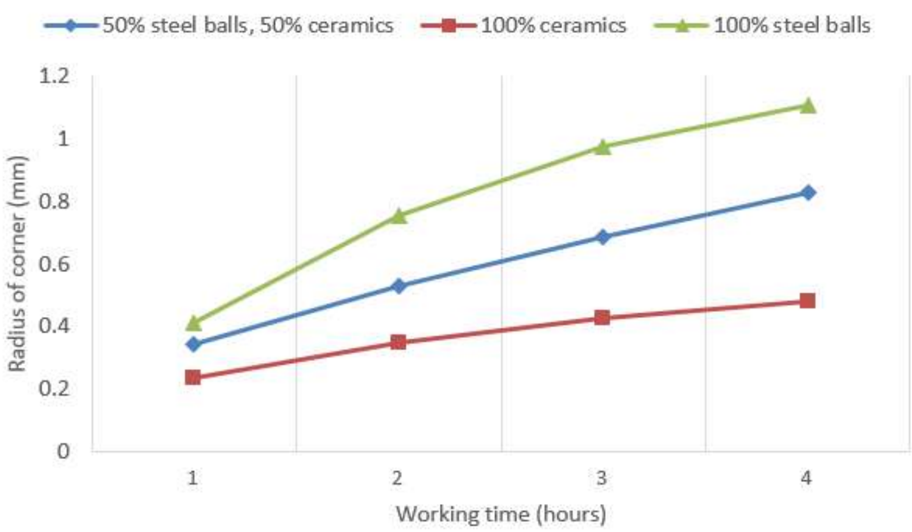

Figure9. Radius of the corners by increasing the working time

4.2 The effect of abrasive media type on the burrs height

The effect of the type of abrasive media on the burrs height for all the nine levels of abrasive media for four conditions is shown in Fig. 10. Fig. 11 shows the burrs height and the reductions of the burrs height for those conditions. As Fig. 10 and 11 show, the least height burrs or the maximum reduction of burrs height is achieved when using level 2 (100% aluminum oxide) as the abrasive media. By applying level 8 (25% aluminum oxide and 75% steel balls) and level 5 (50% steel balls and 50% ceramics) successively, proper results also can be observed but the 100% aluminum oxide is the most effective abrasive media for reducing the burrs height. Therefore, during deburring process, the working time can be reduced noticeably by using 100% aluminum oxide as the abrasive media. The capability of 100% aluminum oxide is more than other combinations of abrasive particles. It can be explained by high abrasive characteristic of aluminum oxide. Fig. 12 shows three samples before and after deburring when using aluminum oxide as the abrasive media.

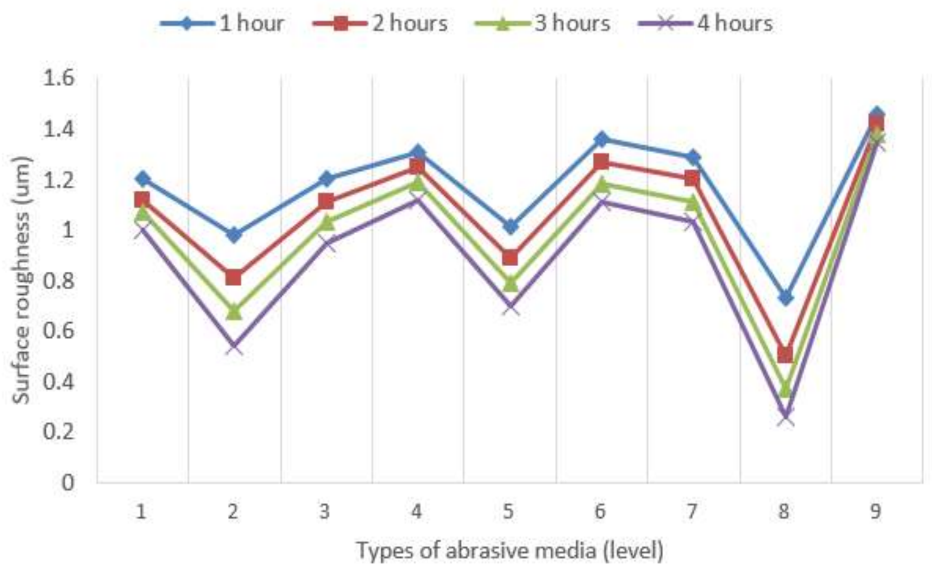

Figure10. Burrs height by using 9 levels of abrasive media

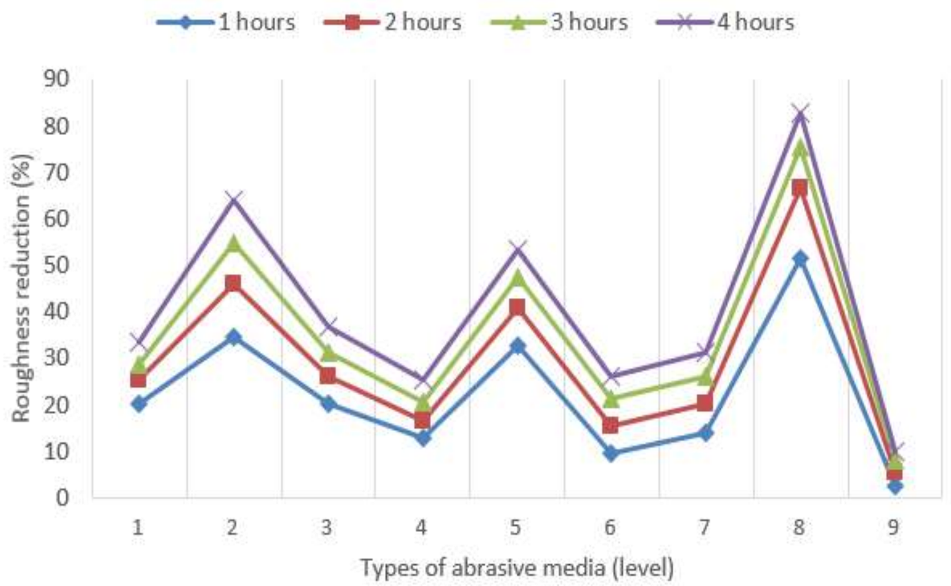

Figure11. Reduction of the burrs height by using 9 levels of abrasive media

Figure12. Samples before and after 3 hours deburring with aluminum oxide as the abrasive media

4.3 The effect of abrasive media type on the radius of corners

Radiusing the edges and the corners of the samples is also investigated in this paper. The best results has been attained while using level 1 (100% steel balls), level 3 (100% ceramics) and level 5(50% steel balls and 50% ceramics); thus, the other results has not shown in the table 5. The radius of the sample's corners while using these three types of abrasive media is plotted in Fig. 13. As it is observed from Fig. 13, the radius of the corners is considerably increased while using 100% steel balls as the abrasive media. It may because of the high density and weight of steel balls, in comparison with aluminum oxide and ceramic particles. This property plays significant role when steel balls impact the corners of specimens. The high impact energy leads to best results for radiusing the corners. By using the steel balls, the working time can be decreased as well.

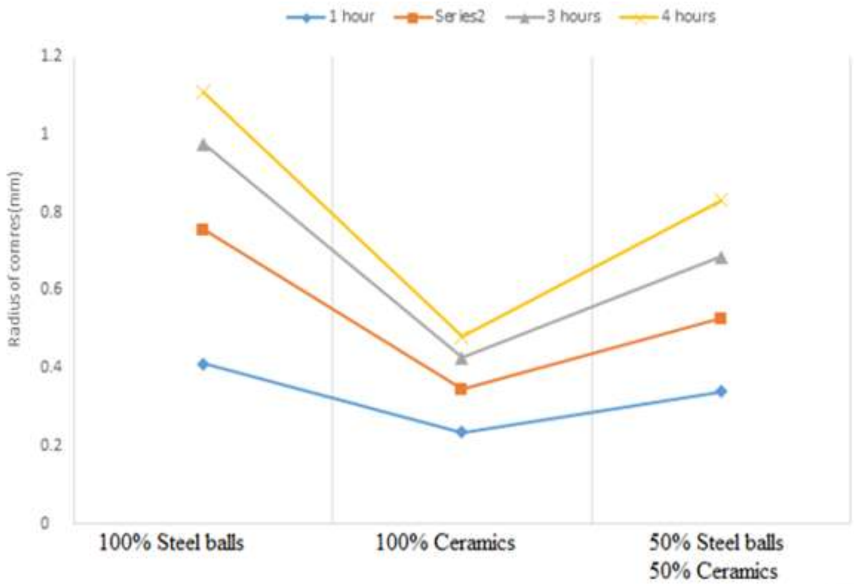

Figure13. Radius of the sample's corners by using these three types of abrasive media

5. Conclusions

In this paper, the abrasive capability of different combinations of three types of abrasive particle including steel balls, ceramics and aluminum oxide, have been investigated in deburring and radiusing the samples and reduction of the working time of the process. The results are:

- By increasing the working time, the height of the burrs is decreased and the radius of the corners is increased.
- By using 100% aluminum oxide as the abrasive media, the samples have the minimum burrs height. Hence, the working time can be remarkably reduced while using this type of abrasive media. By Applying 25% aluminum oxide and 75% steel balls and also 50% steel balls and 50% ceramics, proper results can be attained as well.
- To have the roundest edges and corners, using 100% steel balls as the abrasive media is suggested, by which the working time can be considerably reduced. 100% ceramics and also 50% steel balls and 50% ceramics as the abrasive media can yield appropriate results as well.
- To have the least height of the burrs and the proper round corners in the minimum working time, applying 50% steel balls and 50% ceramics as the abrasive media, is suggested.

References

[1] Mahdieh, M.S. and Mahdavinejad, R. 2016. Recast layer and micro-cracks in electrical discharge machining of ultra-fine-grained aluminum. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 0954405416641326.

[2] Mahdieh, M.S. and Mahdavinejad, R.A. A study of stored energy in ultra-fined grained aluminum machined by electrical discharge machining. 2016. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. 0954406216666872.

[3] Mahdieh, M.S. 2019. Recast layer and heat-affected zone structure of ultra-fined grained low-carbon steel machined by electrical discharge machining. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 0954405419889202.

[4] Mahdieh, M.S. and Mahdavinejad, R. 2016. Comparative Study on Electrical Discharge Machining of Ultrafine-Grain Al, Cu, and Steel. Metallurgical and Materials Transactions A. 47:6237–6247.

[5] Mahdieh, M.S. and Zare-Reisabadi, S. 2019. Effects of electro-discharge machining process on ultra-fined grain copper. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. 0954406219844802.

[6] Mahdieh, M.S. 2020. The surface integrity of ultra-fine grain steel, Electrical discharge machined using Iso-pulse and resistance–capacitance-type generator. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications.1464420720902782.

[7] Mahdieh, M.S., Rafati, E., and Sichani, S.K. 2013. Investigation of Variance of Roller Burnishing Parameters on Surface Quality by Taguchi Approach. International Journal of Advanced Design and Manufacturing Technology. 6(3):77-81.

[8] Boschetto, A., Ruggiero, A. and Veniali, F. 2006. Corner shaping by barrel finishing. ASME 8th Biennial Conference on Engineering Systems Design and Analysis. American Society of Mechanical Engineers. Paper No: ESDA2006-95683:877-881.

[9] Saraeian, P., Gholami, M., Behagh, A., Behagh, O., Javadinejad, H. R. and Mahdieh, M. S. 2016. The Influence of Vibratory Finishing Process by Incorporating Abrasive Ceramics and Glassy Materials on the Surface Roughness of CK45 Steel. International Journal of Advanced Design and Manufacturing Technology. 9(4):1-6.

[10] Boschetto, A., Ruggiero, A. and Veniali, F. 2007. Deburring of sheet metal by barrel finishing. Key Engineering Materials. 344:193-200.

[11] Bottini, L., Boschetto, A. and Veniali, F. 2014. Estimation of Material Removal by Profilometer Measurements in Mass Finishing. Key Engineering Materials. 611-612: 615-622.

[12] Boschetto, A., Bottini, L. and Veniali, F. 2013. Microremoval modeling of surface roughness in barrel finishing. The International Journal of Advanced Manufacturing Technology. 69(9-12):2343-2354.

[13] Li, W.H., Yang, S.Q. and Yang, S.C. 2008. Theoretic Analysis and Experimental Research on Barrel Finishing Uniformity of Crank Shafts with Larger Size. in Key Engineering Materials. Trans Tech Publ. 852: 573-577.

[14] Li, W. H., Yang S. C., Yang S. Q., and Chen, H.L. 2008. Process Characteristics Research on Horizontal Spindle Barrel Finishing. in Advanced Materials Research. 53-54: 15-19.

[15] Li, W.H., Chen, H. and Yang, S.Q. 2009. Surface Integrity Research on Barrel Finishing of Crankshafts' Part.. Key Engineering Materials. 392-394: 655-660.

[16] Li, W.H., Yang, S.Q., Yang, S.C. and Chen, H. 2009. Theoretic Analysis and Simulation on Horizontal Spindle Barrel Finishing. Key Engineering Materials. 416: 332-336.

[17] Li, W.H., Yang, S.Q, Yang, S.C. and Chen, H. 2010. Research of Uniformity and Effect on Crankshaft Barrel Finishing. Advanced Materials Research. 97-101: 4120-4123.

[18] Nityanand, N., Manley, B. and Henein, H. 1986. An analysis of radial segregation for different sized spherical solids in rotary cylinders. Metallurgical Transactions B. 17(2): 247-257.

[19] Boschetto, A. and Veniali, F. Radial segregation of workpiece in barrel finishing. 2002. AMST'02 Advanced Manufacturing Systems and Technology, Proceedings of the 6th International Conference. 499-505.

[20] Mellmann, J. 2001.The transverse motion of solids in rotating cylinders—forms of motion and transition behavior. Powder Technology. 118(3): 251-270.

[21] Boateng, A. 1998. Boundary layer modeling of granular flow in the transverse plane of a partially filled rotating cylinder. International Journal of Multiphase Flow. 24(3): 499-521.

[22] Boschetto, A., Marchetti, E. and Veniali, F. 2001. Analysis of the charge movements in barrel finishing. Engineering. Technology Conference on Energy. 69: 2343–2354.

[23] Cantelaube, F., Bideau, D. and Roux, S. 1997. Kinetics of segregation of granular media in a two-dimensional rotating drum. Powder technology. 93(1):1-11.

[24] Parker, D.J., Dijkstra, A.E., Martin, T.W. and Seville, P.K. 1997. Positron emission particle tracking studies of spherical particle motion in rotating drums. Chemical Engineering Science. 52(13): 2011-2022.

[25] Bbosa, L.S., Govendera, I., Mainza, A.N., and Powell, M.S. 2011. Power draw estimations in experimental tumbling mills using PEPT. Minerals Engineering. 24(3):319-324.

[26] VanPuyvelde D.R., Young, B.R., Wilson, M.A. and Schmidt, S.J. 1999. Experimental determination of transverse mixing kinetics in a rolling drum by image analysis. Powder Technology. 106(3): p. 183-191.

[27] Nakagawa, M., Altobelli, S. A., Caprihan, A. and Fukushima, E. 1997. NMRI study: asial migration of radially segregated core of granular mixtures in a horizontal rotating cylinder. Chemical Engineering Science. 52(23):4423-4428.

[28] Boschetto, A. and Veniali, F. 2009. Workpiece and media tracking in barrel finishing. International Journal of Machining and Machinability of Materials. 6(3-4):305-321.

[29] Boschetto, A., Veniali, F. and Miani, F. 2004. Mass Finishing of Parts Produced by Direct Metal Laser Sintering. ASME 7th Biennial Conference on Engineering Systems Design and Analysis. American Society of Mechanical Engineers.

[30] Ding, Y., Seville, J.P.K., Forster, R. and Parker, D.J. 2001. Solids motion in rolling mode rotating drums operated at low to medium rotational speeds. Chemical Engineering Science. 56(5):1769-1780.

[31] Boateng, A. and Barr, P. 1996. Modelling of particle mixing and segregation in the transverse plane of a rotary kiln. Chemical Engineering Science. 51(17):4167-4181.

[32] Henein, H., Brimacombe, J. and Watkinson, A. 1983. Experimental study of transverse bed motion in rotary kilns. Metallurgical transactions B. 14(2):191-205.

[33] Chiancola, M. 1995. Choosing the right media to meet mass finishing goals. Metal Finishing. 93(12):37-39.