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RESEARCH ARTICLE

A STUDY OF THE EFFECTSOF EXTRUSION HONING ON HASTELLOY C22 USING SiC ABRASIVE OF DIFFERENT MESH SIZES

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ABSTRACT

The traditional finishing processes are incapable of producing required surface finish and other characteristics in difficult-to machine materials like Nickel based super alloys and also complex geometrical shapes of engineering components. Hence non-traditional micro-machining processes have been developed to achieve these goals. Extrusion honing (EH) is one of the non-traditional micro-machining process to debur, radius, polish, and remove recast layer of components in a wide range of applications. Material is removed from the work-piece by flowing abrasive laden medium under pressure through or past the work surface to be finished. Components made up of complex passages having surface/areas inaccessible to traditional methods can be finished to high quality and precision by this process. Hastelloy C22offers resistance to both aqueous corrosion and attack at elevated temperatures and it is a difficult metal to machine using traditional techniques. In this study, extrusion honing of Hastelloy C22 material having passage diameters 7, 8, 9, and 10mm have been performed in an indigenously built hydraulic operated extrusion honing setup using patented polymer as a carrier medium and SiC grit of threegrit sizes (46, 54, and 60) as abrasive at volume concentration of 35%. The internal surface finish results obtained with the use of extrusion honing process are discussed.

Key words: Abrasive, carrier medium, extrusion honing, Hastelloy C22, surface finish.

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INTRODUCTION

Finishing operations in the metal working industries represent a critical and expensive phase of manufacturing process. The quality of surface finish depends on type of manufacturing processes. Most of the existing finishing operations are labour intensive conventional, or non-conventional machining processes. Extrusion honing **(**EH**)** also known as abrasive flow machining (AFM) is a process for the production of excellent surface qualities of inner profiles that are difficult to access and outside edges for deburring and edge rounding. EH process removes small quantity of material by flowing abrasive-laden semisolid compound called 'media' through or across the surface of the work piece to be finished. The EH setup consists of two vertically opposed cylinders which extrude media back and forth through passages formed by the work piece and tooling (Fig.1.1). Abrasive action occurs wherever the media enters and passes through the most restrictive passages. The media is composed of semisolid carrier and abrasive grains. Most commonly used abrasive grains are silicon carbide, boron carbide, aluminium oxide and diamond. The most commonly used carrier is polyborosiloxane. The unique features of EH such as versatility, efficiency, economy makes the process useful to perform a wide range of precision machining operations in the aerospace and automobile industries, manufacture of dies and medical instruments. Some of the components machined by EH include fuel injector nozzles, turbine blades, combustion liners, dies etc. It can simultaneously process multiple parts or many areas of a single workpiece. Inaccessible areas and complex internal passages can be finished economically and effectively. Hastelloy C22is one of the difficult to machine material using traditional techniques.It has higher corrosion-resistance, particularly regard to localised corrosive attack. This makes the alloy an attractive candidate in chemical and aerospace industries application. Rhoades (Lawrence and Rhoade, 1988; Lawrence *et al.,* 1989) experimentally investigated the basic principles of AFM process and identified its control parameters. He observed that when the medium is suddenly forced through restrictive passage, its viscosity temporarily rises. Significant material removal is observed only when medium is thickened. Jain and Adsul (Jain and Adsul, 2000) reported that initial surface roughness and hardness of the work-piece affects material removal during

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AFM process. Material removal and reduction in surface roughness values are reported higher for the case of softer work-piece material as compared to harder materials. Perry (Perry, 1985) reported that abrasion is high where medium velocity is high. An increase in pressure and medium viscosity increases material removal rate while surface finish value (R_a) decreases. (Loveless *et al.,* 1994) reported that metal removal and surface finish in AFM are significantly affected by the medium viscosity. (Jain and Jain, 1999) also reported that reduction in surface roughness (Ra Value) increases with increase in extrusion pressure and abrasive concentration, but they also observed that reduction in surface roughness (R_a value) is higher with increase in average grain size. (Jain and Adsul, 2000) reported that MRR is high in the first few cycles due to higher initial coarseness of work-piece surface, and thereafter, it starts slightly decreasing in every cycle. (Gorana et.al. 2004) reported that percentage of abrasives in the medium, grain size and viscosity of the base medium are important parameters that influence stock removal and medium velocity. They also reported that depth of penetration of abrasive particle depends on extrusion pressure, abrasive medium viscosity, and grain size. Due to the combined effect of radial force and axial force, the material is removed in the form of microchip. (Manas Das *et al.* 2011) highlighted that R-MRAFF process possesses the ability to correct roundness error of hard cylindrical stainless steel tubes by controlling finishing forces. Some of the researchers have studied the effects of process parameters like extrusion pressure, abrasive concentration, grain size, number of cycles etc. with respect to surface roughness and material removal of ferrous and non ferrous metal work-piece. Hastelloy C22has wide application areas like chemical industry, heat treatment plant and aeronautical field. Hardly any information is available in the literature regarding the effect of EH process parameters on surface finish of Hastelloy C22. In the present study, extrusion honing operations were performed on super alloy Hastelloy C22at laboratory using indigenously built EH setup. A select grade of low cost polymeric material as medium and silicon carbide as abrasive has been used for finish process experimentation. The extrude honed surface of Hastelloy C22have been evaluated in terms of surface finish parameters and the results show positive response.

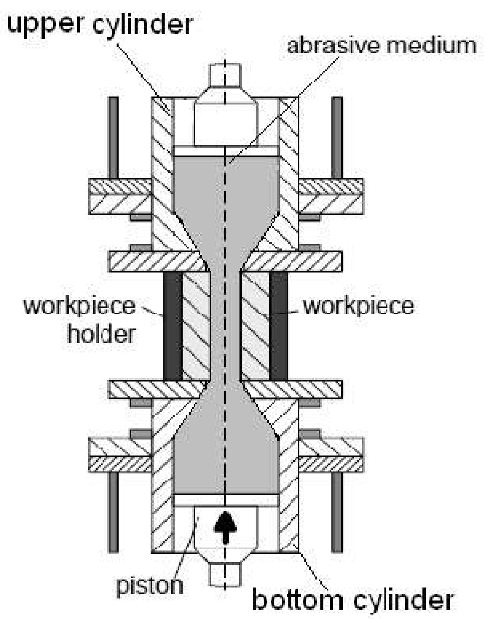

Fig. 1. Two-Way Extrusion process

Experimental procedure

Extrusion honing experimentation were conducted in an indigenously built EH setup at laboratory and the surface finish parameters were evaluated after each trial.

Work material: Hastelloy C22 (nickel-chromium-iron) alloy 600 (UNS NO. N06022 / WERKSTOFF NR2.4602) HASTELLOY® C-22® alloy is a versatile nickel-chromium molybdenum-tungsten alloy with better overall corrosion resistance than other Ni-Cr-Mo alloys available today. C-22 alloy has exceptional resistance to a wide range ofchemical process environments. The chemical composition of Hastelloy C22 is shown in Table 1. The versatility Hastelloy C22 has led to its use in a variety of applications involving temperatures from cryogenic to above 1360°C. The alloy is used extensively in the chemical industry owing to its strength and corrosion resistance. The alloy's strength and oxidation resistance at high temperatures make it useful for many applications in the heat-treating industry. In the aeronautical field, it is used for a variety of engine and airframe components. This alloy is a standard material of construction for nuclear reactors. (*Haynes International*)

Table 1. Chemical composition of hastelloy c22wt % andmechanical properties

Element	Concentration [wt. %]
Ni	50.015 min*
Mo	12.50 – 14.50
Cr	20.00 – 22.50
Fe	2.00 – 6.00
W	2.50 – 3.50
CO	2.50 max
C	0.015 max
Si	0.08 max
Mn	0.50 max
V	0.35 max
P	0.02 max
S	0.02 max
Mechanical Properties	
Density	8.69 g/cc
Hardness, Rockwell B	93
Ultimate TensileStrength	800 MPa
Yield Tensile Strength	407 MPa
Young Modulus	223 GPa
Melting Point (°C)	1351 – 1387

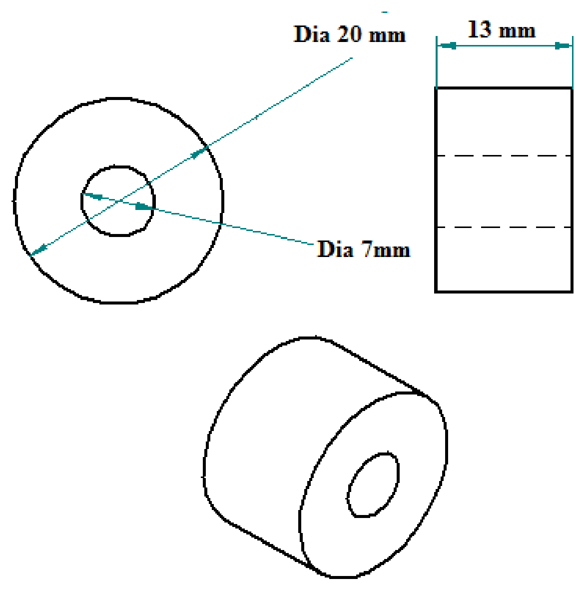

Fig 2. Hastelloy C22 workpiece

Carrier medium: In the present study, a select grade of polymer was used as working medium and commercially available silicon carbide of three grit sizes. (M46, M54, and M60) were used as abrasive. Silicon carbide of each grit size (45vol.%) was thoroughly mixed with polymer medium using a laboratory built mixing device. The details of EH process parameters are shown in Table 2.

Specimen preparation: In this research work Hastelloy C22specimens of 20mm outer diameter and length 13mm having predrilled passage diameter 7, 8, 9,and 10mm were used (Fig 2). Extrusion honing was conducted for ten passes and after each pass the specimens we rewashed with acetone.

Experiment trials: The experiment setup was designed and fabricated in the lab to perform extrusion honing. Fig.3. shows the schematic diagram of the setup for the EH process. This set up is a one way type of EH process, i.e. the medium flows in only one direction. It consists of an abrasive media cylinder coupled to a hydraulic cylinder and to control the actuation suitable directional control valve has been utilized. Abrasive media cylinder is a piston cylinder arrangement with end cap which has a fixture for housing the specimen. The fixture helps to mount and dismount specimen easily from the cylinder. Abrasive media enters the specimen from one side and extrudes out at the other side. The extruded abrasive media is collected in the collector. The parameters used in the trials are presented in Table. 2.

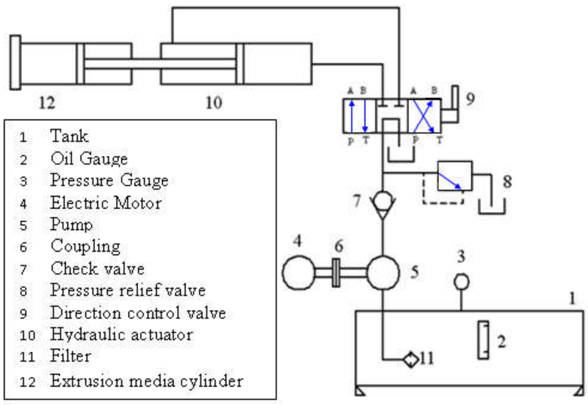

Fig. 3. One Way Extrusion Honing Setup

Each specimen was honed for 10 passes under similar conditions and after each pass surface finish parameter R_a was measured at three locations of entry side of media (side 1)and at three locations of exit side of media (side 2) of the specimen using skid less surface roughness tester Surfcom 130A with a stylus of tip radius 2µm. The cut-off length chosen for measurement was 0.8mm with 4 mm traverse length. Care was taken to measure the roughness at the same location before and after each experiment. The weight of the workpiece was measured after each EH trial by an electronic balance Afcoset FX 400 having least count of 0.001gm.A video measuring device Easson EV2515 (Fig.4.) with resolution one micron and repeatability two microns was used to measure diameter and out of roundness at entry side and exit side of passages after every two EH trials.

RESULTS AND DISCUSSIONS

The objective of this experiment is to investigate the effect of different mesh sizes of silicon carbide at 45% concentration in viscous media on surface parameters R_a, weight loss and change in diameter at entry and exit side of EH processed components having predrilled passage of Ø 7 mm, Ø 8 mm, Ø 9 mm, Ø 10mm.

Table 2. Extrusion honing process parameters

Parameters	Details
Pressure	60 bar
SiC abrasive mesh size	46, 54, 60
Volume fraction of abrasive	45%
Temperature	Ambient
Stroke length	650 mm
Number of passes	10

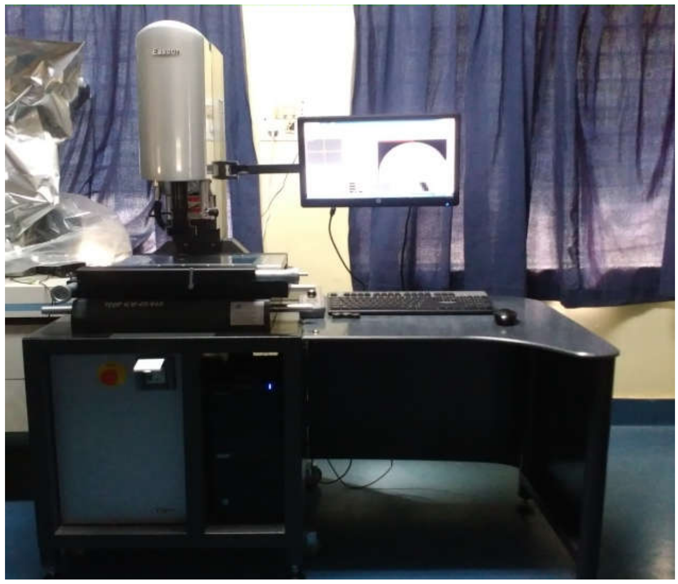

Fig. 4. Video Measuring Machine Easson EV2515

Surface roughness R_a

Fig.5. to Fig.6. illustrates the effect of mesh size of abrasives on surface roughness R_a value at entry side and exit side of passage ϕ7mm, ϕ8mm, work pieces extrusion honed at 45% volume fraction of abrasives. It can be observed from the graph that up to 3rd pass of honing there is a visible / drastic reduction in R_a values, from 4th pass to 7th pass progressive reduction of R_a values can be seen. Later surface deterioration sets in after 8th pass hence there is slight increase in R_a values. It is evident from the graphs that surface finish R_a value at the exit side is better than the entry side. However 54 mesh size shows better R_a value in both entry and exit sides for all passage diameters. The sluggish movement of abrasive medium at entry side may form dead zone which results in ineffective abrasion as the abrasive media travel along the passage it relax quickly as a result abrasive particles makes better contact at the exit side and removes more surface peaks hence better surface finish.

Total material removal (MR)

The effect of mesh size of abrasives on total material removed from all passage diameters is depicted in Fig. 8. It can be seen that the total amount of material removed (MR) is high at smaller passage diameter and it is less at bigger passage diameter. The 54 mesh size abrasives indicates higher total MR in all passage diameters compared to other two mesh sizes. The abrasive particles in 46 mesh size are bigger and fewer cutting edges are exposed for metal removal hence less total

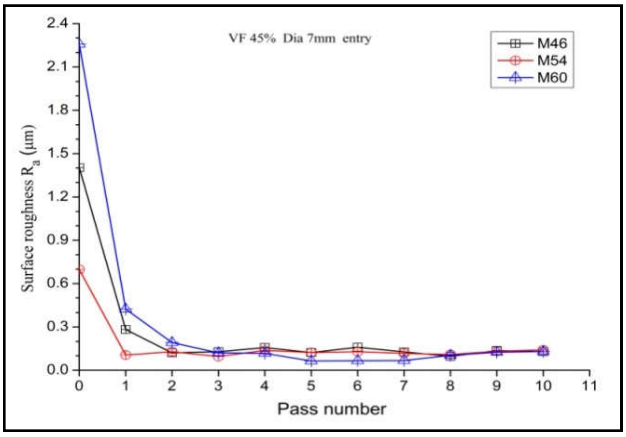

Fig. 5. Effect of mesh size on entry side R_a value of Ø 7mm

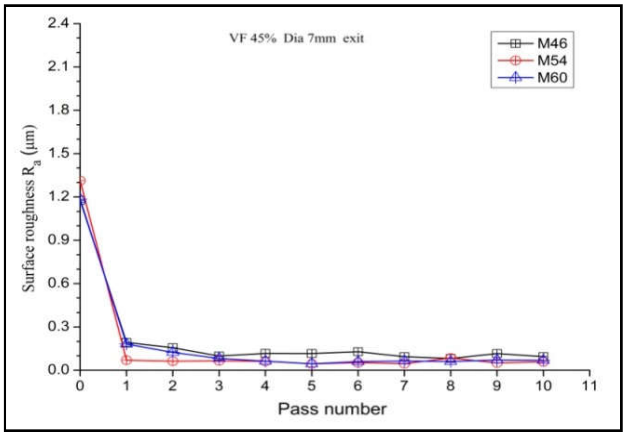

Fig. 6. Effect of mesh size on exit side R_a value of Ø7mm

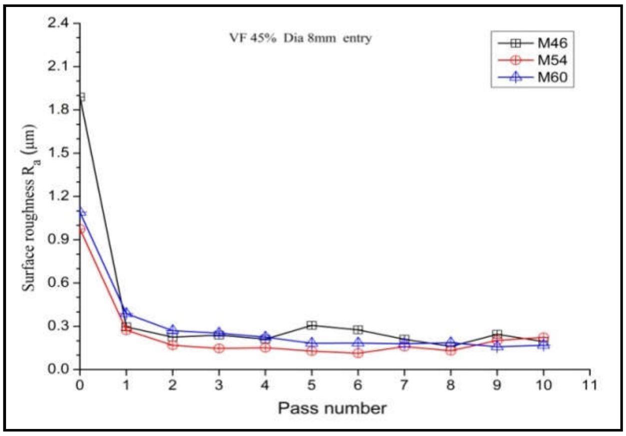

Fig. 7. Effect of mesh size on entry side R_a value of Ø8mm

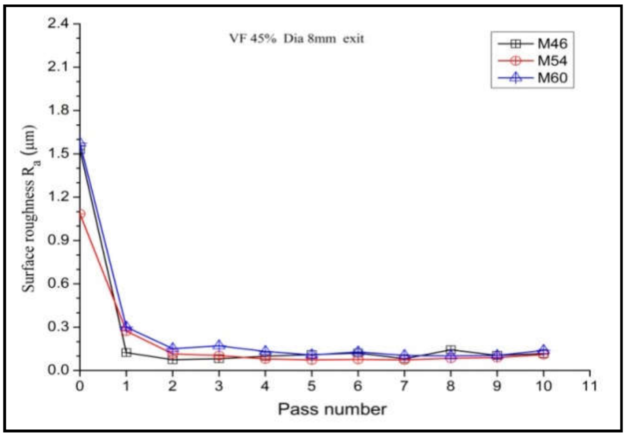

Fig. 8. Effect of mesh size on exit side R_a value of Ø 8mm

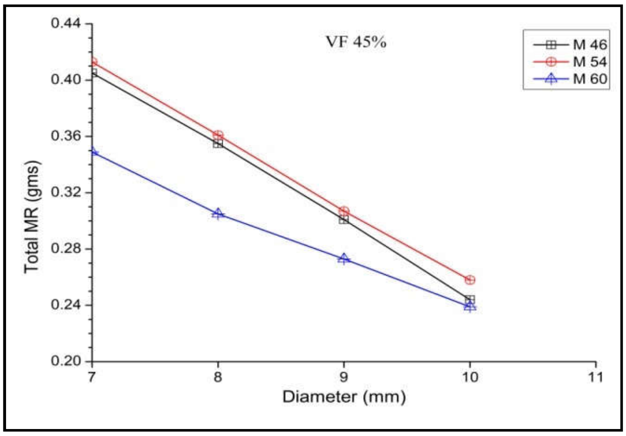

Fig. 9. Effect of abrasive mesh size on total material removed in each passage diameter

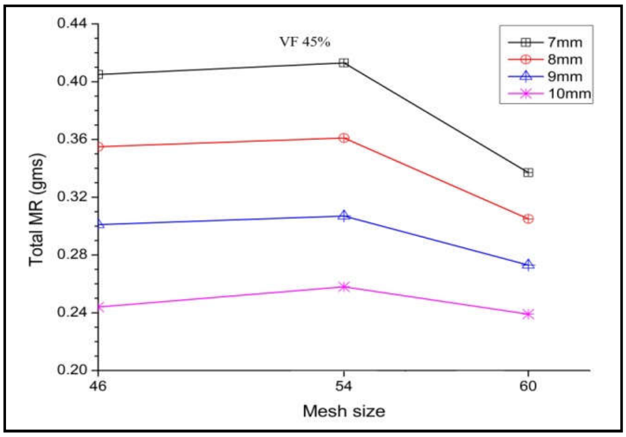

Fig. 10. Total material removed in each passage diameter with respect to mesh size

MR, whereas in 60 mesh size the abrasive particles are much smaller and it may not protrude from the media to perform abrasion of material therefore less material removal. In 54 mesh size, a brasive particles have more cutting edges available for abrasion and hence it shows better metal removal. The total material removed from each passage diameters with respect to mesh size of abrasives is depicted in Fig. 9. There is a slight increase in total MR from 46 mesh size to 54 mesh size in all the passage diameters, however there is a reduction in MR at 60 mesh size. Smaller diameter shows drastic reduction in total MR than bigger diameterat 60 mesh size. It can be attributed to smaller grains in 60 mesh size causes less abrasion to cause metal removal.

Variation of passage entry and exit diameters

The variation of entry and exit side passage diameters at 46, 54 and 60 mesh sizes are shown in Fig. 10. to 12.The predrilled passages show variation of diameter at entry and exit sides, after EH experimentation it can be observed that the diameter on both sides also increases proportionally with increase in number of trials.At the end of tenth pass there exist a gap between entry and exit side of each passage diameter. This gap increases with mesh size as depicted in Fig.10. to 12. At 46 mesh size, as Fig.10. illustrates that the gap is inversely proportional to diameter, there is no gap in but the gap increases with decrease in passage diameter.

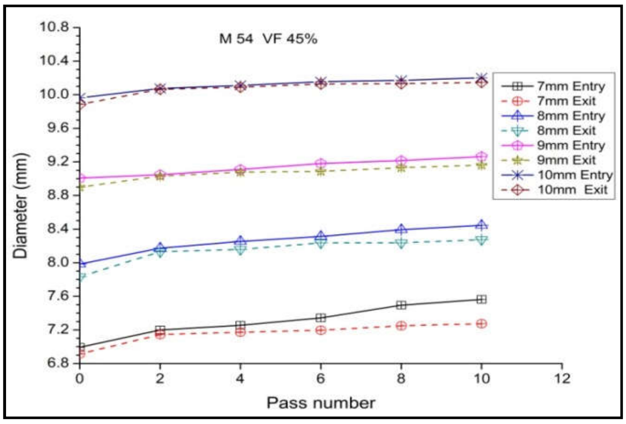

Fig 11. Effect of 54 mesh size on entry and exit side of passages

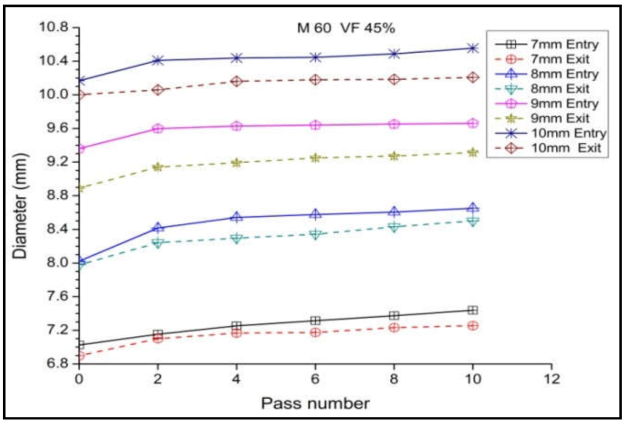

Fig 12. Effect of 60mesh size on entry and exit side of passages

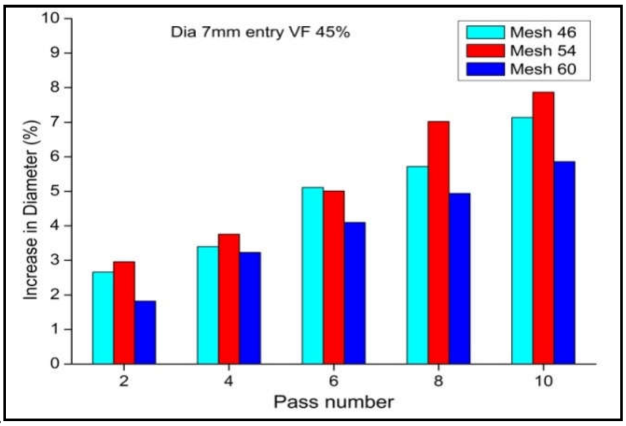

Fig. 13. Effect of mesh sizes on % of increase in diameter at entry side of ø7 mm

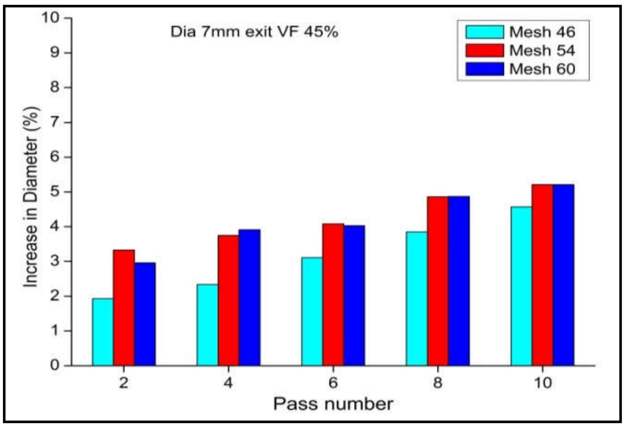

Fig. 14. Effect of mesh sizes on % of increase in diameter at exit side of ø7 mm

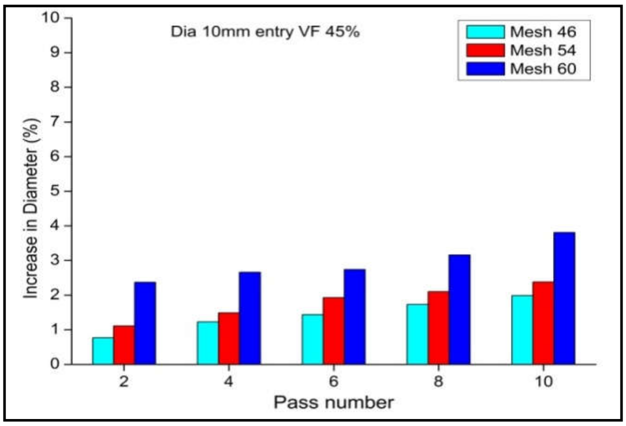

Fig. 15. Effect of mesh sizes on % of increase in diameter at entry side of ø10mm

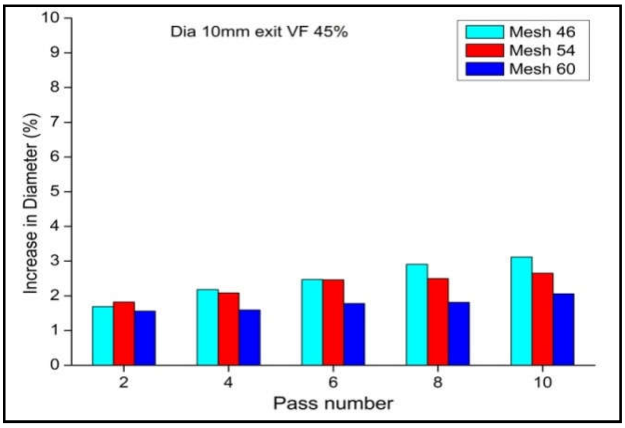

Fig. 16. Effect of mesh sizes on % of increase in diameter at exit side of ø10mm

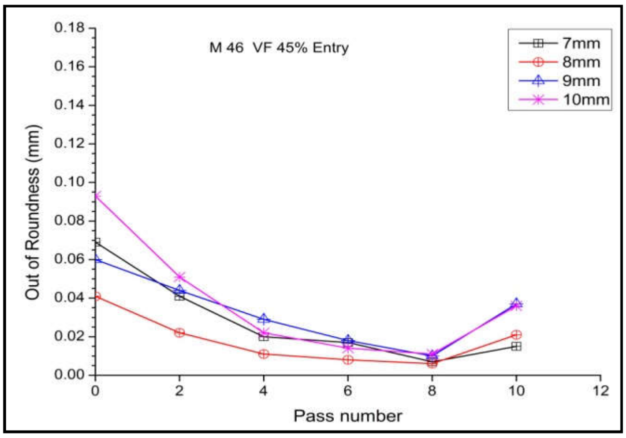

Fig. 17. OOR at entry side of passages

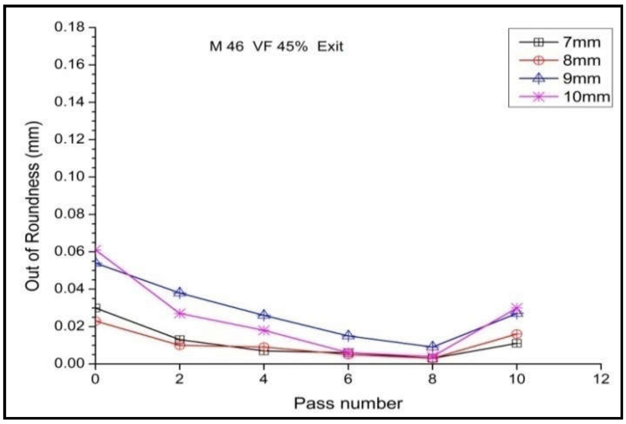

Fig. 18. OOR at exit side of passages

The enhancement of diameter is correlated to MR, in above case total MR is higher at Ø7 mm passage therefore slope is higher in both cases. The slopeis less forbigger diameter because of less total MR. The same variaton is also indicated in Fig.11. with abrasives of 54 mesh size. It shows slight gap in Ø10mm passage. Fig 12. shows gap between entry and exit side of all passage diameters but the gap is wider in Ø9 mm and Ø10mmcompared to other two diametrs, it also exhibit almost horizontal lines after second trial with abrasives of 60 mesh size. this is due to the fact that the total MR for bigger diameter is less. These graphs highlight that eventhough the surface finish is high at exit side major amount of metal removal takes place at entry side itself as the medium as to enter the restricted passage diameter at 60 bar pressure. The effect of mesh sizes on percentage of increase in diameter at entry and exit side of Ø7 mm and Ø10mm are shown in Fig 13. to Fig 16. The percentage of increase in diameter increases with increase in number of EH trials. The percentage of increase in diameter at entry side of Ø7 mm is below 8% and at exit side it is below 6% as shown in Fig.13. and 3.10. Mesh size 54 has a predominant role in increasing the diameter at entry side of Ø7 mm as compared to 46 mesh size, but at exit side of Ø7 mm both 54 and 60 mesh size has almost similar effect. The percentage of increase in diameter at entry side of Ø10 mmis below 4% and at exit side it is below 3% as shown in Fig.15. and Fig 16 Mesh size 60 plays a major role in increasing the diameter at entry side of Ø10 mm as compared to 46 and 54 mesh sizes. The smaller abrasive grains of 60mesh size abrade metal at entry side hence there is less increase in diameter. Where as at the exit side 46 mesh size has more effect compared to other twomesh sizes. Slightly bigger abrasive grains of 46 mesh abrade metal at the exit side since total MR is less for Ø10 mm the increase in diameter is also less.

Out of roundness

Out-of-roundness (OOR) is an importantproperty of components used for criticalgeometric conditions such as air bearings, and they mustexhibit precise form accuracy in addition to the fine surfaceroughness (Jain and Jain, 1999). The effect of 46 mesh on OOR at entry and exit side of each passage diameter is shown in Fig 17. and Fig 18 There is a gradual reduction in OOR as the number of trial are increased however it tends to increase after 8^{th} pass at both entry and exit sides.

Conclusion

At higher abrasive mesh size(60mesh), due to the lesserdiameter of abrasive particles, the number of abrasivespresent in the medium increases for its fixed concentrationin the medium. In this paper, an investigation has been made to study the effect of effects of extrusion honing on Hastelloy C22 using SiC abrasive of different mesh sizes. Basic one-way extrusion honing was performed using a silicone polymer with SiC abrasive of 46, 54 and 60 mesh sizes at 45% concentration. The workpices used for experimentation were predrilled to obtain passage diameter of 7, 8, 9, and 10mm. The surface finish parameter was measured on workpiece at three different locations on entry and exit side of the abrasive media flow. The weight of the workpiece was measured after each EH trial. The diameter and out of roundness at both sides were recorded after every two EH trials.

The conclusions drawn from the study are:

1. The extrusion honing process with 60 bar pressure, abrasives of 46, 54 and 60 mesh sizes at 10 EH passes shows good results in finishing of Hastelloy C22.
2. At the entry and exit side of the specimen drastic reduction in surface finish parameters occurs at early stage within 3^{rd} pass, after that there was continuous improvement in surface finish parameters up to 8^{th} pass, beyond which the surface starts deteriorating.
3. Surface finish R_a at the exit side is better than the entry side which shows better contact of the abrasive particles in the media at the exit.
4. All the diameters show better $R_a$values at 54 mesh size
5. Total MR for all passage diameters is higher at 56 mesh.

But at 60 mesh the total MR decreases

6. The percentage of increase in diameter is less at exit side than entry side.
7. OOR is better at exit side than entry side.
8. From this study, it can be concluded that EH process possesses the ability to correct roundness error of Hastelloy C22 workpices by using SiC abrasive of suitable mesh size.

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REFERENCES

Davis Editor J R. "ASM Specialty Handbook: Nickel, Cobalt, and Their Alloys" ©2000ASM International®PP 235-244.

Gorana, V.K., V.K. Jain and G.K. Lal, 2004. "*Experimental Investigations into cutting forces and active grain density during Abrasive Flow Machining*", *International Journal of Machine Tools and Manufacture,* vol.44, pp.201-211.

Jain V.K.and S.G. Adsul, 2000. "*Experimental Investigations into Abrasive Flow Machining*", International Journal of Machine Tools and Manufacture, vol.40, pp.1003-1021.

Jain, R.K., V.K. Jain, 1999. *"Simulation of surface generated in abrasive flow machining",* Robotics and Computer Integrated Manufacturing 15, 403-412

Jung D., W.L.Wang, A. Kanfl, T.J. Jacobs, S.J. Hu and D.N. Assanis, 2008. "*Experimental Investigation of Abrasive Flow Machining Effects on Injector Nozzle Geometries, Engine Performance, and Emissions in a DI Diesel Engine*", *International Journal of Automotive Technology,* vol.9, No.1, pp.9-15.

Lawrence J. Rhoades and Hilary A. Clouser, 1989. "*Abrasive Flow Machining*", ASM Handbook, vol.16, pp.514-519.

Lawrence J. Rhoades, 1988. "*Abrasive Flow Machining*", Manufacturing Engineering, November, pp.75-78.

Loveless, T.R., R.E. Willams and K.P. Rajurkar, 1994. "*A Study of the Effects of Abrasive-Flow Finishing on Various Machined Surfaces*", *Journal of Material Processing Technology,* vol.47, issues 1-2, pp.133-151.

Manas Das , V. K. Jain and P. S. Ghoshdastidar, 2011. *"The Out-of-Roundness of the Internal Surfaces of Stainless Steel Tubes Finished by the Rotational–Magnetorheological*

Abrasive Flow Finishing Process" Materials and Manufacturing Processes, 26: 1073–1084.

Perry, W.B. 1985. "*Abrasive Flow Machining: Principal and Practices",* Nontraditional Machining, Cincinnati, Ohio, USA, pp.121-127.

Raju, H.P., K. Narayanasamy, Y.G. Srinivasa and R. Krishnamurthy, 2005. "*Characteristics of extrude honed SG iron internal primitives*", *International Journal of Materials Processing Technology,* vol.166, pp.455-464

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