RESEARCH ARTICLE OPEN ACCESS

Extrusion Honed Surface Characteristics of Inconel 625 Fabricated By EDM for Square Shape

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ABSTRACT:
Extrusion Honing (EH) is also known as Abrasive flow machining (AFM) is an effective method that is used to deburr, clean, polish, remove recast layer and micro cracks by flowing pressurized semisolid abrasive laden visco-elastic media over those surfaces. Inconel 625 is one of the most difficult-to-cut materials because of its low thermal diffusive property, high hardness and high strength at elevated temperature. In this paper, the influence of the process parameters on surface roughness is investigated on Inconel 625 material of square shape fabricated by Electric discharge machining (EDM). The processed surfaces were measured and analyzed with the help of surface roughness tester and Scanning Electron Microscope (SEM). Results show a significant improvement in surface finish and EH/AFM is capable of removing the micro cracks and recast layer.
Key words: Extrusion honing, Inconel, EDM, Surface finish, Abrasive Flow Machining, Silicone, SiC.

I. INTRODUCTION

The growing need for precision parts in today's industries has brought an increase in the need for finishing operation that can satisfy the demand. Finishing operations in the metal working industries represent a critical and expensive phase of manufacturing process. The quality of surface finish is taken care of by manufacturing processes. Most of existing finishing operations are performed manual, conventional, or non-conventional machining processes. A new process called Extrusion honing (EH) also known as Abrasive Flow Machining process (AFM) promises to provide the accuracy, efficiency and economy of surface finish on wide verities of metals, ceramics and other materials.

Several researches have studied the application of finishing surface by abrasive flow machining. Rhoades [1-2] developed Abrasive flow machining which is an automatic finishing process that can be applied to a wide range of applications, from critical aerospace and medical components to high production volumes of parts. This process consists of two vertically opposed cylinders extrude a semisolid abrasive media back and forth through passages formed by the work piece and tooling. In this study author compares machining action as grinding operation of the abrasive media which gently and uniformly hones the surface or edges of the materials ranging from soft aluminum to tough nickel alloys, ceramics, and carbides.

Abrasive flow machining process provides a wide range of predictable, repeatable results. In this process media is composed of a pliable semisolid carrier and concentration of abrasive grains. Authors observed that the surface finish increases as the number of cycle increases with variety of viscosity and the abrasive grain size media. Author suggested the guidelines for media viscosity selection for different diameter of holes assuming that passage length is two times the diameter. AFM can be used to process injector nozzle to enhance engine performance and to improve emission through the improved quality of the nozzle characteristics [3].

Loveless et al. [4] experimentally investigated the effects of AFM on surfaces produced by turning, milling, grinding and wire-EDM. In particular, all of the wire-EDM surfaces were improved greatly by AFM. They observed that Media viscosity significantly affects the surface improvement, while extrusion pressure did not have significant effect. Cheng Wang et al. [5] reported that AFM is an effective method to remove the recast layer produced by wire-EDM. However, the surface roughness will not be uniform when a complex hole is polished by this process. Their proposed method reveals that shear forces in the polishing process and the flow properties of the medium in AFM plays an important role in controlling the roughness on the entire surface. According to Perry [6] AFM is a non-traditional finishing, method used for precision deburring, radiusing, surface improvement and thermal recast removal. Jain and Adsul [7] carried experimental investigations into abrasive flow machining process for determining the surface characteristics of brass and aluminum. The results obtained by the experiments were compared with theoretical results, the machined surface texture produced were studied by using scanning electron microscope. Sehijpal Singh and Shan [8] reported that the possible improvement in surface roughness and material removal rate by applying a magnetic field around the workpiece in Abrasive flow machining. Authors developed the set-up for composite process termed magneto abrasive flow machining process (MAFM) and the effect of surface roughness and metal removal rate were studied. The results obtained by the experiments indicate significant improvement on the performance of MAFM over abrasive flow machining. Gorana et al. [9] has carried out a study on cutting force and active grain density, on surface roughness and helped in developing a more realistic theoretical model. For measuring axial force and radial force components during abrasive flow machining process, authors have used two-component disc dynamometer. The experiments were conducted to select the ranges of variables by using single–factor experimental technique.

Some of the researches have studied the effects of process parameters like extrusion pressure, abrasive concentration, grain size and number of cycles with respect to surface roughness and material removal of ferrous and non ferrous metal work piece. Inconel alloy 625 has 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 Inconel 625.
In the present study, extrusion honing operations were performed on super alloy Inconel 625 at laboratory using indigenously built EH set up. A selected grade, polymeric material as medium and silicon carbide as abrasive particles has been used for finishing process. The extrude honed surface of Inconel 625 have been evaluated in terms of surface finish parameters and SEM photographs were taken from the work pieces before and after the EH process and the results show positive response.

II. EXPERIMENTAL PROCEDURE

Extrusion honing experimentation was conducted in an indigenously built EH set up at laboratory and the surface parameters were evaluated after each trial. Surface roughness measurements were taken at different positions both at entry and exit sides. Finally, SEM photographs of work pieces before and after the EH process were taken.

2.1 Material details

2.1.1 Work material

Inconel® (nickel–chromium–iron) alloy 625 (UNSN06625/W.Nr.2.4856) is a standard engineering material for applications which require resistance to corrosion and heat. The alloy also has excellent mechanical properties and presents the desirable combination of high strength and good workability. The chemical composition and mechanical properties of Inconel alloy 625 is shown in Table 1. The versatility of Inconel 625 has led to its use in a variety of applications involving temperature from cryogenic to above 1350ºC. The alloys strength and oxidation resistance at high temperature make it useful for many application in the heat–treating industry. In the aeronautical field, it is used for a variety of engine and airframe components. The alloy is a standard material of construction for nuclear reactors.

Table 1: Chemical Composition of Inconel 625 and Mechanical Properties.

Element	**Concentration [wt.%]**
Nickel	58.0 Min
Chromium	20-23
Molybdenum	8-10
Niobium + Tantalum	3.15-4.15
Iron	5 Max
Aluminum	0.4 Max
Ti	0.4 Max
Carbon	0.1 Max
Manganese	0.5 Max
Silicon	0.5 Max
Copper	0.5 Max
Phosphorus	0.015 Max
Sulfur	0.015 Max
Mechanical properties	
Density	8.4 g/cm^3
Tensile strength	760N/mm^2
Yield strength	365 N/mm^2
Brinell Hardness	≤ 220
Melting point	1350^{o}C

2.1.2 Carrier medium

In the present study, a selected grade of polymer was used as working medium and commercially available silicon carbide of 36 grit size was used as abrasive. Silicon carbide (50% vol.) was thoroughly mixed with polymer medium using a laboratory built abrasive mixing machine. The details of carrier medium are shown in table 2.

Table 2 Extrusion honing process parameters

Parameters	**Details**
Pressure	60 bar
Volume fraction of abrasive	50%
Temperature	Ambient
Stroke length	650 mm

2.2 Specimen preparation

Inconel 625 specimens of Ø25 mm and length of 12 mm were used for experimentation. The specimens were initially prepared by EDM for square shape. Surface parameters were measured initially and the R_a values found in the range of 6-8 µm. After washing the specimen with acetone, extrusion honing trials were conducted.

2.3 Experiment trials

The experiment setup was designed and fabricated in the laboratory to perform extrusion honing. This set up is a one way type of EH process that is the medium flows in only one direction. It consists of an abrasive media cylinder coupled to a hydraulic cylinder; to control the actuation the directional control valve has been utilized. Abrasive media cylinder is a piston cylinder arrangement with end cap which has a fixture for housing the workpiece. The fixture is designed to mount the workpiece easily to the end cap of the extrusion cylinder. Abrasive media enters the workpiece 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. The specimen was honed for 15 passes under similar conditions and after each pass surface was cleaned with acetone and surface finish parameters were measured at four different locations on the workpiece. The surface roughness measurements were taken with skidless 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 the experiments. SEM photograph were taken by JEOL model JSM-6490 LV for surface analysis.

III. RESULTS AND DISCUSSION

Typical observed parametric influence of surface characteristics of extrusion honed Inconel 625 specimen is illustrated through Fig.1 to Fig.4. Fig.1 and 2 shows the surface roughness in terms of R_a, R_z, R_t and R_{pk} at entry and exit sides respectively. Fig. 3 and Fig.4 illustrates the percentage improvement of surface roughness at entry and exit side respectively. It is seen that there is a visible and drastic reduction in R_a, R_z, R_t and R_{pk} values during early passes of extrusion honing and there will be significant improvement in surface roughness till 11^{th} pass after that there will be reduction in surface roughness.

3.1 Observation of surface roughness

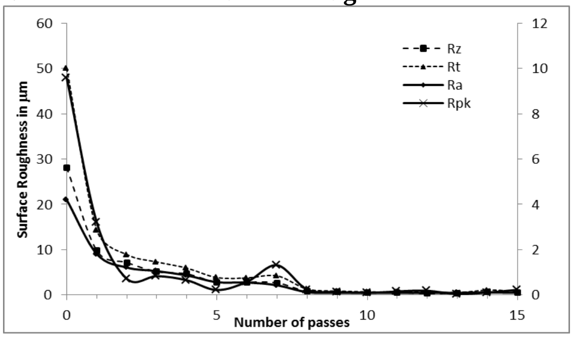

Fig.1 : Surface Roughness v/s Number of passes at entry point

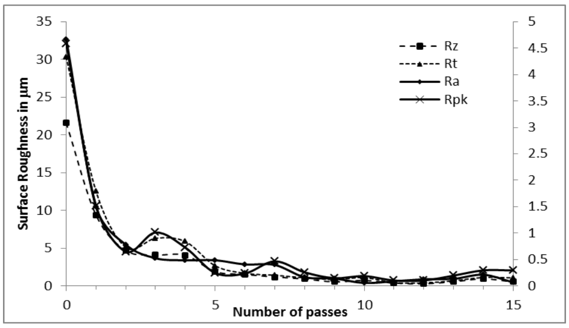

Fig.2 : Surface Roughness v/s Number of passes at exit point

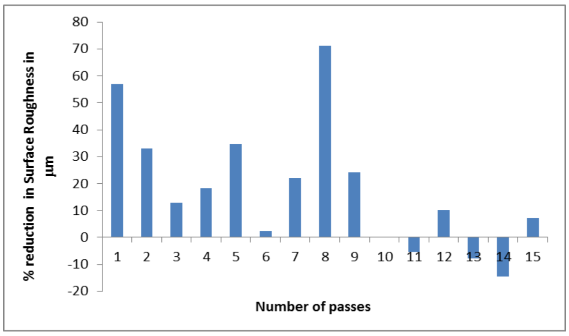

Fig.3 :Percentage of reduction in Surface Roughness v/s Number of passes at entry side

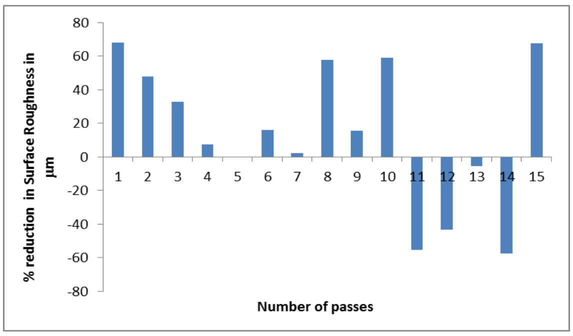

Fig.4 :Percentage of reduction in Surface Roughness v/s Number of passes at exit side

3.2 Scanning Electron Microscope Observation

For understanding the nature of the texture produced by extrusion honing, surfaces of EDMed and extrusion honed were observed through scanning electron microscope. Typical SEM photographs of EDMed and EH honed surfaces are presented. Microstructure of EDMed surfaces is illustrated in the Fig.5. Micro cracks and recast layer produced during the EDM process can be seen clearly.

After fifteen passes, a lay pattern of the abrasive marks can be seen as illustrated in Fig.6. SEM photograph shows that rubbing and ploughing are the possible mechanisms of material removal.

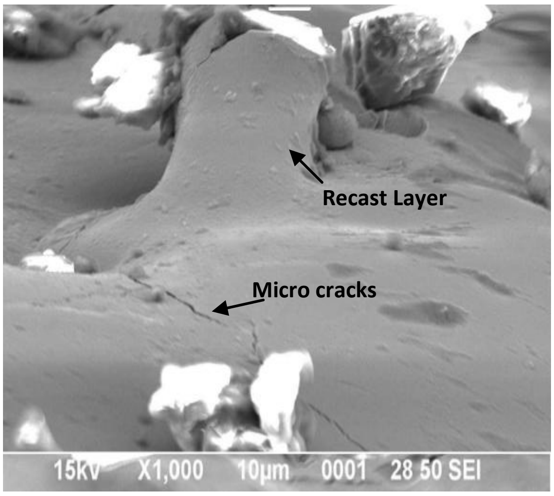

Fig.5 : SEM photograph of EDMed work piece surface before extrusion honing process (x1000)

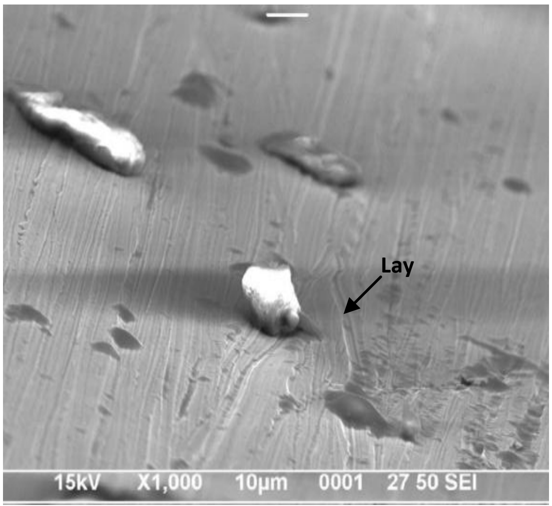

Fig.6 : SEM photograph of extrusion honed surface after 15th pass (x1000)

IV. CONCLUSION

In this paper, an investigation has been made on Inconel 625 work piece to study the surface characteristics of the material using EH process. The samples that were processed with EH have been pre-machined by EDM process. Basic one-way extrusion honing was performed using a silicone polymer with SiC abrasive particles. The surface finish parameters were measured on workpiece at four different locations on entry side and exit side of the abrasive media flow. The conclusions drawn from the study are:

1. The extrusion honing process with 60 bar pressure, abrasive particle size of 36 and 15 EH passes shows good results in finishing of Inconel 625.
2. At the entry side of the specimen drastic reduction in surface finish parameters occurs at early stage within 3rd pass, after that there was continuous improvement in surface finish parameters up to 11th pass, beyond which the surface starts deteriorating.
3. It was observed that the EDM recast layer is removed successfully.
4. It was also observed that the surface finish deteriorates after the 11th pass at entry side, but at the exit side the core roughness is obtained.
5. Surface finish at the exit side is better than the entry side which shows better contact of the abrasive particles in the media at the exit.
6. SEM photographs of extrusion honed surface revealed that the micro cracks and recast layer has been successfully removed by EH process.
7. It can be concluded that with the application of EH process, the surface integrity induced by EDM can be significantly improved.

V. Acknowledgment

The authors acknowledge the financial support provided by AICTE New Delhi, project entitled “Micro Finishing of Internal Primitives through Extrusion Honing Process” project No.8023/BOS/RPS-123/2006-07. Authors also acknowledge Mr. K.Ravi, Foreman, Department of Industrial and Production Engineering, for kind help during experimentation and UVCE, Bangalore institute for providing the SEM facility to analyze the material structure.

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