Journal of Manufacturing Engineering, December 2023, Vol. 18, Issue. 4, pp 118-129
DOI: https://doi.org/10.37255/jme.v18i4pp118-129

EVALUATION OF INDUCED SURFACE INTEGRITY IN EXTRUSION HONING PROCESS

Murali Krishna N L[1], *Jayasimha S L N[2] and Raju H P[3]

[1]Department of Industrial and Production Engineering, P.E.S College of Engineering, Mandya, Karnataka-571401, India
[2,3]Department of Mechanical Engineering, P.E.S College of Engineering, Mandya, Karnataka-571401, India

ABSTRACT

It is vital to achieve the desired level of surface texture on the exterior surfaces of pre-machined components. Conventional deburring processes like grinding and honing can obtain the required surface quality on the outer surface. However, difficulty arises while processing the interior surface of components such as micro bores and inlet/outlet valves. It's a revolutionary micro-finishing method that eludes the pressurised flow of media mixed with SiC into the restricted passage to achieve the appropriate range of surface texture. Micromachining in this novel technique results from abrasion by removing a minuscule quantity of stock material. The current investigation attempts to know the effect of several passes at the media's specimen entry and exit side and develop a semi-empirical model for evaluating Ra by applying Buckingham's π theorem. The generated surface produced by process factors such as number of passes, volume fraction, and grit size of abrasives is studied by SEM analysis.

Keywords: *Extrusion Honing (EH), Surface finish (SF), Material removal (MR), Carrier media, Abrasives.*

1. Introduction

Abrasive flow finishing (AFF) is a deburring technique that develops compressive residual stresses while removing burrs and recasting white layers in the pre-machined component. This approach can process multiple passages in one or more components and tapered and stepped parts. This process is now known as extrusion honing and, in some cases, abrasive flow machining (AFM). This technology covers broad applications that include manifolds, impellers and orthopaedic implants.

Finishing is due to the abrasion reaction of the flow of pressurized polymeric media infused with SiC particles across the constrained path. Throughout this process, the abrasive dough is made to flow across the substrate to be processed. The AFM technology is regulated by variables such as extruding force and media flow speed, distribution of SiC in the media, and the number of carrier media passes.

This finishing approach guarantees the process's geometric precision, applicability, and effectiveness, which are crucial for mechanisation. This technique accomplishes significant development in surface morphology with changing dimensions for the first pass itself. Finishing methods generally acquire 15 % of machining costs in the production cycle. While the finishing value reduces below one micron, the marginal cost ramps up.

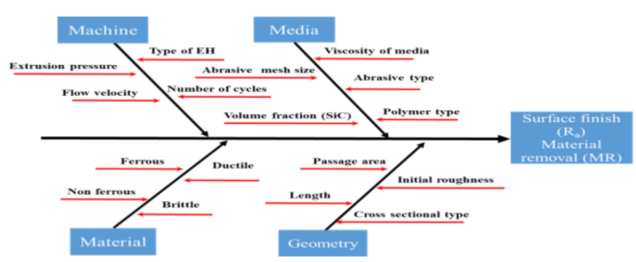

Fig. 1 Extrusion honing process parameters

2. Literature

The present study investigates surface finish R_a, surface texture and quantification of R_a by dimensionless modelling by considering passes, grit value and VF of abrasive in the flow media as process parameters.

Larry Rhoades., (1991) developed AFM for processing inaccessible surfaces by the flow of abrasive-laden media and obtaining the desired surfaces. The finished surface is due to the abrasion process, while the improvement in consistency is around 90 %, with only 10 % of the removal of parent material.

Corresponding Author - E- mail: jysmh29simha@gmail.com

Jain et al. (2000) investigated AFM, which improves the surface texture of unreachable areas, and the effect of parameters like distribution and abrasive grain size with media flow velocity were performed on brass and aluminium. The investigated SF and MR responses were in agreement with the experimental values. Extrusion honing (EH) is an excellent method for processing stiffer materials with complex profiles. From the available literature, several researchers have tried this method for processing the class of materials.

Ravi Sankar et al. (2010) studied abrasion on Al/SiC MMCs using the R-AFF method. Ra is considerably improved when extruding pressure, rotational speed, cycles and range of lubricating oil (wt %) in carrier media are considered. Sudhakara et al. (2020) experimented with AFM on hollow cylindrical civilities. These specimens were made of Al 7075/SiC NMMCs produced by stir casting. Yunus Mohammed et al. (2020) sought to anticipate the impact of factors like extruding pressure, grit size and number of cycles on responses R_a and MR. Al/SiC particulate MMC with a high SiC % has been considered by constructing the Box Behnken design of RSM. Several scholars repeatedly tried AFM processing on a variety of softer or harder materials. For instance, Singh et al. (2015) carried out studies on Al-6061, Ibrahim et al. (2014) on low carbon steel and stainless steel by Sachin Singh et al. (2015)

Raju et al. (2005) studied from the material viewpoint of this deburring technology which has polished a wide range of materials. Furthermore, out-of-roundness, bearing area and residual stresses of spheroidal graphite iron have been investigated by the authors and also MR by Raju et al. (2003). Murali Krishna et al. (2014) validated using this EH approach, revealing that irregularities of the EDM process such as the recast layer were removed. While evaluating the responses, this technique gives consistent results that align with the experimental and theoretical results. Several scientists have attempted to model the EH process, which is still in the early stage. This is owing to the need for more information on the viscoelastic nature of media and the type of MR during micro machining. Also, the performance of micromachining process was monitored by the acoustic emission technique by Murali Krishna et al. (2014)

Despite this, Jain et al. (2003) achieved considerable results using finite element methodologies, stochastic simulation by Jain et al. (2004), neural networks by Jain et al. (1999), and genetic algorithm by Jain et al. (2000) technique for evaluating the performance of the abrasive based finishing method. Patil et al. demonstrated the use of dimensionless modelling for developing an algebraic model. Assess the material removal in wire EDM by considering the thermal and physical properties of WP material and process factors on aluminium metal matrix composite. Finally, a comparison study between experimental, empirical and RSM models was put forwarded by Patil et al. (2010).Kumar et al. (2010) studied ultrasonic machining on titanium by developing the dimensionless model. The author emphasized on material removal by considering tool material, power rate, concentration of slurry, type and size of abrasive. The experiments were planned, performed and examined by applying the Taguchi method. In addition, author probed the mode of MR and input energy for different conditions by capturing SEM images.

Ravindranadh Bobbili et al. (2015) investigated MRR and surface roughness in WEDM on aluminium 7017 and RHA steel by employing Buckingham's π theorem and developed a suitable Taguchi as a design methodology to conduct the experiments. ANOVA analysed the influencing parameters. SEM analysis was done to understand the impact of thermo-physical factors such as input power, flushing time, thermal diffusivity, etc. Singh et al. (2019) explored the application of the DA method for studying the quality features of Al matrix composites by FDM assisted by investment casting. The study's effort is to develop a model employing dimensionless modelling. Also, estimate mechanical properties with dimensional accuracy and hardness of fabricated composite. Taguchi L18 OA was developed to perform and study the experiments.

Zhang et al. (2021) investigated cryogenic based micro-abrasive jet machining on polydimethyl siloxane. A dimensionless model for predicting the MR for factors such as jet pressure, erosion angle and speed were considered in the present study. The required levels of experiments were conducted using L25 OA and ANOVA to know the influencing parameters. Pei-Jen et al. (2001) evaluated MR and tool wear in EDM with process parameters such as peak current, pulse duration, electric polarity and material properties. The trials are executed by formulating a suitable Taguchi experimental design. The tool materials are CU, Gr and Ag-W, while the work is supposed to be AISI grade steel. In this case, nonlinear optimization methods such as Gauss-Newton and David-Fletcher-Powell method has been utilized to evaluate coefficients and power terms of the developed dimensionless model. Some authors prefer linear estimation methods, such as the least square method. By adopting the same procedure, the author determined surface roughness Ra similarly to Kuo-Ming et al. (2001).

Table 1 Literature on the application of DA in other non-conventional machining process

Researcher	Material	Factors	Process	No of Trials	Responses	Prediction method
Ali Abdolahi et al (2018)	Hard alloy steel	Electrical pulse, dielectric fluid flow rate, Electrode diameter and rotation speed,	EDM	-	R_z, R_t, and R_{max}	Non-Dimensional process evaluating function (NPEF)
Mangesh et al., (2015)	Ferrous material	cutting tool used to remove the material, workpiece, and cutting process parameters, such as cutting speed, feed rate, depth of cut	Dry Turning	330	MRR and power consumption	Dimensional and sensitivity analysis
Ajiboye et al., (2010)	Al, Cu and AISI steel	contact pressure, ram velocity, viscosity of the lubricant, load, surface roughness and shear friction factor	Cold forging		Shear friction factor	DA
Roy et al. (2006)	Al and steel of different grades	Peak temp, Heat i/p, angular velocity. Translational velocity and initial temp.	Friction stir welding		Dimensionless peak temperature	DA
Chen Tian Xiang et al. (2012)	40CrMnMo7 steel	Nozzle dia, pump pre, SOD, Jet angle, Traverse speed	Abrasive water jet machining	18	R_a and R_z	DA
Mahendra et al.,(2020)	NiTi60	Voltage, current, pulse ON, pulse OFF	EDM	9	R_a	DA
Nishanth Singh et al. (2019)	Die steel	Current, Pulse ON, Rotation, Gas Pre, duty cycle,	Argon assisted EDM	RSM	Surface roughness	DA SEM XRD

Mohankumar et al., (2020)	Al MMC (B_4C)	Mesh size, mass flow rate, water pressure, traverse speed	Abrasive water jet machining	Box-Behneken	Depth of cut	DA SEM Regression ANOVA
Bhaumik, Munmun et al., (2016)	AISI 304 WC	Density, Melting temperature, Thermal conductivity Coefficient of thermal expansion	EDM	9	MRR Radial overcut	DA
Rupesh Chalisgaonkar et al. (2014)	Pure Ti	pulse on time, pulse off time, peak current, wire feed, wire tension and servo voltage	WEDM	27	MRR, Surface roughness, wire weight consumption	DA Grey-fuzzy logic SEM XRD
Kushwah et al. (2018)	AA6082 (Architectural alloy)	Pulse on time, pulse off time, wire feed rate, Spark voltage	WEDM	Full factorial design 16	MRR	DA, ANN ANOVA
Kumar et al. (2017)	Ti alloy	pulse on time, pulse off time, peak current, dielectric material, electrode material, Cryo of WP and electrode.	EDM	Taguchi 18	Tool wear rate	DA, SEM XRD, Energy dispersive X-Ray spectrometer
Kumar et al., (2017)	Grey cast iron	Cutting conditions, surface finish, Bore size cutting time, load on the spindle, Coolant pressure and conc. Etc.	Tool wear in a boring machine	120	Tool life	DA, ANN
Hajiahmadi et al.,(2019)	Stainless steel sheet	Blank dia, punch dia, sheet thickness, punch edge radius, die edge radius, tensile strength of sheet, friction coefficient27	Deep drawing	27	Estimation of drawing force	DA ANOVA FE Simulation

Kumar et al., (2015)	Titanium	Pulse on time, pulse off time, Peak current, spark gap voltage, wire feed rate, wire tension	WEDM	54	MRR, overcut	DA, Desirability function
Dariusz Poroś et al., (2009)	WC-Co B40 Ti6Al4V	Discharge time, Average working voltage	WEDM	-	Volumetric efficiency	DA
Nishant et al., (2020)	Die steel	Discharge current, Pulse on time, Duty cycle, tool rotation, gas pressure	Gas assisted EDM	RSM	Surface roughness	DA, ANOVA, SEM ANN, ANFIS
Yahya et al., (2004)	-	Pulse on time, Gap voltage, sparking frequency, gap current	EDM	-	MRR	DA

Patel et al. (2019) deduced a semi-empirical model to evaluate MRR in Al MMC reinforced with SiC, B4C and ZrO2 in all the materials processed by WEDM. The tool materials were copper, brass, and molybdenum, and the experiments were designed suitably using L27 OA. The constants, coefficients and power terms were determined by the Quasi-Newton method.

Wang et al. (2007) adopted this DA technique to evaluate the penetration depth of abrasive water jet in alumina ceramics by using AWF. The parameters of the study were supposed to be SOD, H_2O pressure, abrasive flow rate, nozzle speed, oscillation angle and frequency. A predictive model was established using the DA method to determine the insertion depth by water jet. The constants and power factors are found in the experimental data.

The available literature reveals the application of the DA approach for predicting the performance of the NTM process. Due to ANN's vast application, several authors have combined the DA method with ANN for estimating the output response.

Singh et al. (2020) suggested the processing of AA6351 alloy using AWJ. Also, efforts to develop a model to assess MRR and R_a by opting for suitable factors of the abrasive water jet process. The constant of the developed equation is identified by the Levenberg-Marquardt method.

Mangesh et al. (2019) attempted DA with ANN in the WEDM process. They experimented on Al/SiCp MMC by suitably creating the design matrix, selecting the process factors, and contrasting the responses between experiment, DA, ANN and regression techniques.

Nishant et al. (2020) applied the DA procedure to estimate the MRR in the case of a gas-assisted electrical discharge drilling process. The WP material was selected to be high carbon-chromium steel by considering factors like gas pressure, tool rotation, pulse on time and discharge current for five levels. The experiments were planned using the CCRD method and influenced ANOVA-ranked factors. Finally, the experiment's results, regression and DA model were contrasted. The available papers on the application of DA in estimating the responses in EDM, WEDM and other processes are listed in Table .1.

3. Methodology

The EH passes were executed in an in-house developed experimental arrangement. The various constants and parameters considered in the present investigation are recorded in Table 2. The resulting EH surfaces were finally studied.

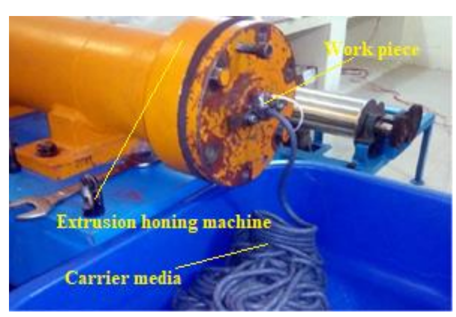

Fig. 2 Equipment for performing extrusion honing

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The EH equipment is depicted in Fig.2, which incorporates a longitudinal cylinder carrying abrasive dough, a flow-regulating valve and a hydraulically controlled actuator. The current setup is irreversible, and the media flows only in one direction. The drum at the acute end is connected to a fixture to fit WP, and fastening is made to grip the specimen so that it can be attached and removed smoothly. Roughness characteristics were measured on the samples after EH experimental trials.

The carrier media in the EH process is a blended mix of silicone polymer and silicon carbide grains, as shown in Fig.3. The transporting media is prepared with known VF and grit size of abrasives. Media is proportionately blended and prepared using a developed media mixing machine, as shown in Fig.3.

Inconel-625 is a Ni-based alloy that is widely applied in elevated temperatures and corrosive environments because of its high resistance to heat and corrosion. The working temperature spans from cryogenic to 1350°C and is commonly employed in thermo-mechanical units. The chemical elements of Inconel-625 alloy are in Table 3. The influence of EH trials were performed on the Inconel alloy specimens having the geometry, span 13 mm, bore dia 7 mm, outside dia 20 mm and pre-drilled R_a of 2-3 µm.

The resultant surface from the EH trials was wiped and decontaminated using compressed air and acetone. Consequently, the surfaces were subjected to SEM analysis, and the surface finish was measured using Surfcom 130A, as illustrated in Fig.4.

Table 2 Extrusion honing process parameters considered in the present study

S. No	Parameters	Value
1	Extruding pressure (bar)	60
2	Flow speed of media(m/min) Fs	0.3
3	Stroke length (mm)	600
4	Number of passes N	15
5	Volume fraction (Abrasive %) Ca	35
6	Grit size of abrasive (microns) Me	36
7	Temperature	Ambient
8	Dynamic viscosity of media (Pa. S)	20250
9	Density of media (Kg/m^3) ρ_m	1.13 ×10
10	Modulus of elasticity(Kg/m^3) E	Two ×10^{11}

Table 3 Chemical composition of Inconel-625

Elements	Ni	Cr	Mo	(Nb+Ta)	Fe	Al	Ti	C	Mn	Si	Cu	P	S
Conc. (% Wt.)	58	23	10	4.15	5	0.4	0.4	0.1	0.5	0.5	0.5	0.015	0.015

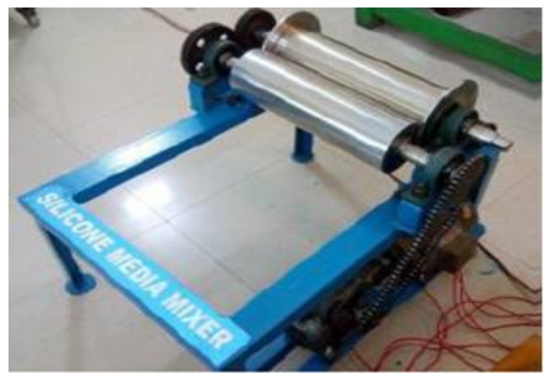

Fig. 3 Carrier media mixing machine.

Fig. 4 Surfcom130A

2.4 Impact of number of passes on surface roughness

The specimens were pre-machined by drilling, having a bore diameter of 7 mm. The EH passes were performed on these passage diameters using the carrier media, a blended mix of SiC in silicone. The media comprises an abrasive of 36 grit size, and a VF of 35 % is utilized for experimentation. The pilot tests were executed to identify the effective process parameters for all factors at different levels, resulting in a better surface finish. The results of these preliminary trials revealed

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that finishing values after the fifteenth pass exhibit higher roughness values. The EH passes were restricted to fifteen passes for all parameters.

The impact of parameters such as volume fraction and particle size of abrasive, number of passes and hole diameter for change in roughness characteristics is presented by plotting the corresponding graphs. The consequence of considered process parameters is evaluated regarding the influence of process factors on roughness parameter R_a. The extrusion-honed surface is analysed under SEM under suitable magnification. The studies revealed that significant improvement in surface morphology is observed as extrinsic features (surface parameters and texture).

As several factors decide the quality of the surface in the current study, R_a is considered for evaluation. The surface roughness parameters were measured using Surfcom 130A at the carrier media's entry and exit side. The surfaces of the specimen after each pass were measured regularly. The surface roughness values were noted initially, before, and after each pass till the fifteenth pass of carrier media. Fig. 5 depicts changes in R_a at both entry/exit regions of carrier media in WP of bore dia 7 mm for the considered process parameters. From the plots, the zero passes indicate the bore dia produced by drilling, while the consequent passes are the EH trials. It is evident from the same plots that the drilled surface has high roughness values. Fig.5 also illustrates the influence of 36 grit size of SiC in 35 % volume fraction of SiC on surface roughness parameters at both entry/exit sides of passage diameter. It's noticed that when contrasted to the entry side, the surface roughness parameters for all passage dia reduce at exit side significantly, as shown in Fig. 5.

The initial surface induced due to the drilling process has a peak level of surface roughness. The surface with enough peaks offers more resistance to the flow of carrier media, and hence, most of the peaks get abraded at the early stage of extrusion honing passes. Consequently, it results in a high rate of reduction in surface values. Abrasives with higher mesh size means fine abrasives, while smaller abrasives yield lower scratch level, and the intensity of abrasion is also less. Irrespective of VF and mesh size of abrasives, R_a reduces at first pass itself due to macro irregularity correction. It is presumed that it is because of the elimination of leading peak asperities, wear debris, and burrs across the passage length.

The slow progress of carrier media at entry creates a dead zone and dull abrasion. As carrier media traverse the passageway, the media rapidly relaxes the abrasives, makes enough contact at the exit side and yields an improved surface finish. It is concluded from Fig.5 that a significant surface finish is achieved on both WP's entry and exit sides. WP of Φ 7 mm by 36 mesh size in 35 % VF at exit side of 0.01 µm and entry side of 0.0064 µm is achieved.

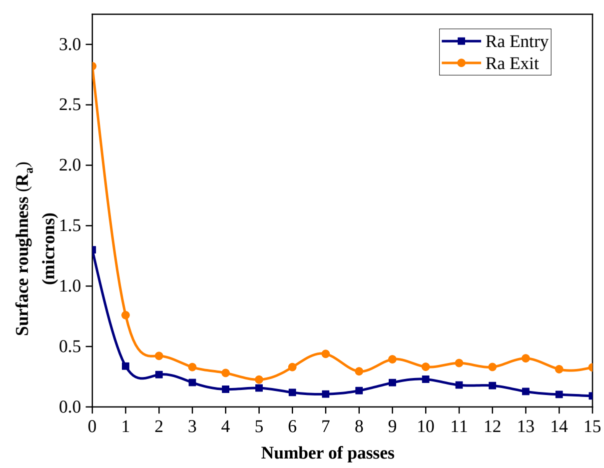

Fig. 5 Influence of the number of passes on R_a at both the entry and exit side

4. Surface roughness prediction model

The resulting response factor, i.e. surface finish (R_a) on the specimen, is rely on the following factors,

$$R_a = f(M_e, N, C_a, F_s, \rho_m, E) \quad (1)$$

Or

The equation (1) can also be expressed as below,

$$f(R_a, M_e, N, C_a, F_s, \rho_m, E) = 0 \quad (2)$$

According to the law of power indices on either side of equation,

$$\pi_1 = M_e^a . F_s^b . \rho_m^c . R_a \quad (3)$$

According to the law of dimensional homogeneity, each π term,

$$\pi_1 = M^0 L^0 T^0 = (L)^a . (LT^{-1})^b . (ML^{-3})^c . (L)$$

By comparing the power terms of M, L, and T on either side,

$$a = -1, \ b = 0, \ c = 0$$

By replacing a, b and c in π_1

$$\pi_1 = M_e^{-1} . F_s^0 . \rho_m^0 . R_a$$

$$\pi_1 = \frac{R_a}{M_e}$$

Similarly, π2, π3 and π4 are,

$$\pi_2 = N \qquad \pi_3 = \frac{C_a}{\rho_m} \qquad \pi_4 = \frac{E}{\rho_m F_s^2}$$

Substituting values of π_1 , π_2, π_3 and π_4 in equation (2)

$$R_a = k\left[M_e \cdot N \cdot C_a \cdot \frac{E}{\rho_m^2 F_s^2}\right] \quad (4)$$

$$R_a = k\left[M_e^{\alpha} \times C_a^{\beta}\right] \quad (5)$$

A dimensionless surface polish equation R_a was developed by considering the number of passes, flow speed, media density, grit number, VF of SiC and modulus of elasticity of WP. The model in this work links the response surface finish (R_a) with the process parameters by taking Young's modulus. The rationale of the developed equation is validated by carrying out associated experiments and determining the equation's constants and power terms using regression modelling. The primary goal of creating a dimensionless equation is identifying a relation between process parameters and responses.

Fig.6 depicts the surface roughness achieved through experiments and projected by the developed model for various numbers of passes with 0.35 volume fraction and mesh size 36. The plot shows a progressive decrease in R_a as the number of passes enhances. The curve indicates an error between the experimental and projected outcomes. R_a reduces during early EH passes due to the reduction of peaks from the pre-bored surface. After six passes, there is a small improvement in R_a, but the surface texture deteriorates.

k is proportionality constants "α" and "β" are dimensionless model's power terms. The coefficient and power indices values must be established. As a result, a series of appropriate experimental trials are carried out. The current study employs regression analysis to determine unknown proportionality constant and power term values based on the acquired results. The effect of pass number, grit size and volume fraction of abrasive on R_a is investigated in this study. While performing EH trials, the parameters ρ_m and F_s of carrier media are constants. The concluding equation with the value of proportionality constant and power terms is given by eqn (6).

$$R_a = 2.4056[M_e^{-1.5047} \times C_a^{-2.4552}] \times N \quad (6)$$

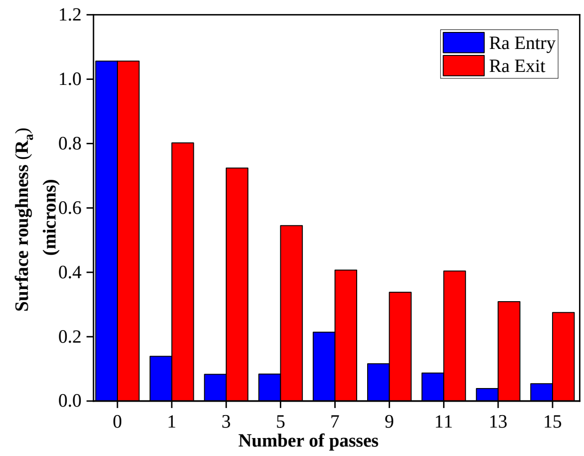

Fig. 6 Plot of experiment and predicted R_a for different EH trials.

It is observed from Fig.6 that there is a deviation between experimentation and forecasted R_a. This is due to the stochastic nature of the abrasion process. Knowing the number of abrasives involved in the shearing operation is complicated. It's presumed that not all abrasives are involved in the micro-machining process. Fine finishing is obtained at the initial pass itself due to the shearing of peaks by the abrasives, as indicated in Fig.5, and the majority of the peaks are abraded at the first pass itself. With continuous deburring of stock material, the abrasives tend to become blunt and scratch the previously finished surface. In the present study, it's perceived that irrespective of volume fraction and size of abrasive the carrier media surface attains a fine finish at the initial pass of EH. It is speculated that this is due to corrections in macro irregularity and removal of dominant peak asperities, debris due to wear and micro burrs by the EH trials. The rapid improvement in surface finish can be visualized from Graph 5 as there is a sudden reduction of R_a from 1.3 to 0.3 in the case of entry and 2.75 to 0.75 microns at the exit section of media, respectively. From available research papers, it is witnessed that there is a gap in developing a relevant empirical relation and modelling of the EH process. There is no proper understanding of the MR mechanism and shearing in this finishing technique. As a result, it raises a difficulty in making appropriate postulates for developing a mathematical relation.

DOI: https://doi.org/10.37255/jme.v18i4pp118-129

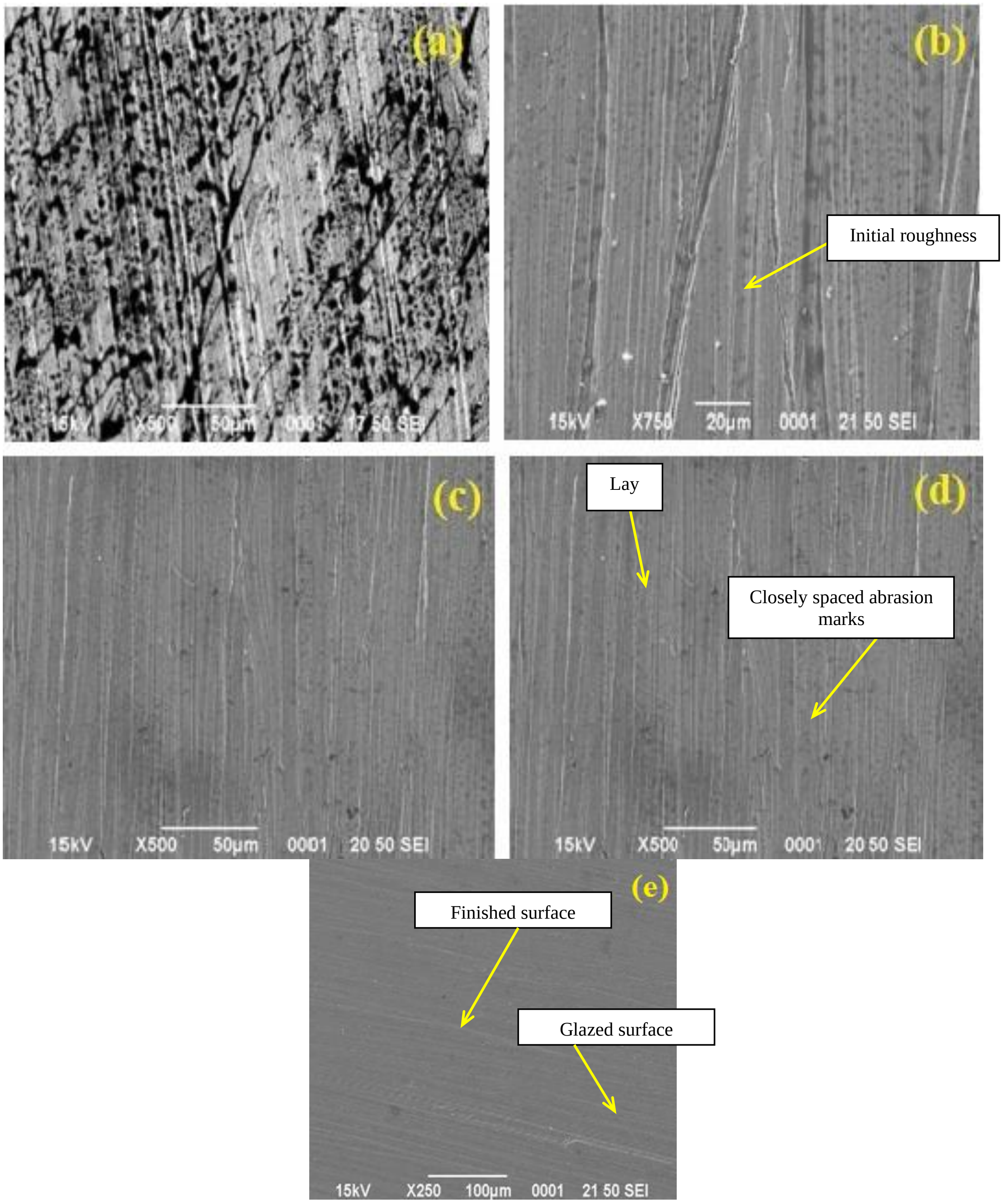

Fig. 7 SEM images of EH textures (a) pre-drilled surface (b) after 5 passes (c) After 10 passes and (d) After 12 passes (e) After 15 passes

As there are no other alternatives, the DA method seems to be a solution for such kinds of problems having a deficiency in a thorough understanding of the problem. However, it is anticipated that in addition to experimental studies for differences in results, the type of regression model opted for also contributes to the dissimilarity in compared results. In the current model, coefficients and power terms are evaluated by assuming they are linear instead of non-linear. Other nonlinear methods need to be employed to determine the equation's constant. Moreover, due to limitations in experimentation and lack of information on fluid properties of the visco-elastic polymer, all of them are assumed to be accountable for the predicted results lagging with the experimental results.

2. SEM analysis

As drilled and EH textures are investigated for SEM analysis to identify the effect of the extrusion honing technique on the surface texture generated. Fig.8 shows the typical SEM illustrations acquired before and

after EH. A machined mark caused by drilling is apparent and illustrated in Fig.7(a). The macrograph after five passes can be seen in Fig.7(b), which also notifies scrubbing of boring lay, path of abrasive particle movement and abrasion dents. Additional trials of this abrasive-based process are shown in Fig.7(c), the glazing pattern can produce a fairly consistent texture with a steady lay pattern. With additional EH trials, as seen in Fig.7(d), these materials acquire a unique smooth finished-like structure and uniform texture after the twelfth pass. With a further number of passes, i.e. at the fifteenth pass, the considered material gets a superior glazy surface, as shown in Fig.7(e).

3. Conclusion

Challenging stiff material like Inconel-625 alloy is finish-machined using the EH process by a select grade polymer. The R_a reduces significantly at the early phase of the EH process, i.e., at the first and second passes. This is due to the shearing of asperities and surface irregularities.

The EH process at a pressure of 60 bar, abrasive grit size of 36, 35 % VF and 15 passes of carrier media in 7 mm bore dia reveal appreciable results when the interior surface of the alloy is extruded honed.

EH trials are carried out for the given grit number and VF of abrasive for the given passage diameter on both entry/exit sides of carrier media. There is an extreme decline in surface finish. This happens from the second pass, after which there is a stable improvement in surface roughness up to the fifteenth pass, with a diminishing surface and a further number of passes.

After the first pass, surface roughness at both the entry and exit sides exhibits extensive abnormality in the surface texture generated by pre-honing. The sudden reduction in surface quality is because of the removal of principal peak asperities at early EH phases. The exit side of the abrasive media exhibits a better surface finish than the entry side. It is due to the formation of a dead zone at entry while there is better contact of abrasive with the work surface at the exit side.

Efforted to develop a dimensionless expression to evaluate R_a with the process parameters considered. It is observed that the results predicted with the developed equation are in accord with the experimental results. The sudden decline in R_a at both exit and entry clearly at early passes depicts the performance of the EH process.

SEM photographs of EH surfaces illustrate progress in surface texture quality and a uniform lay pattern of surface texture can be visualized.

Abbreviations

All	aluminium
ANFIS	artificial neuro-fuzzy interface
ANN	artificial neural network
ANOVA	analysis of variance
AWJ	abrasive water jet
C_a	abrasive concentration
DA	dimensional analysis
E	Youngs modulus
EH	extrusion honing
EDM	electric discharge machining
F_s	flow speed of media
FDM	fused deposition modelling
FE	finite element
The	mesh size of abrasives
MMC	metal matrix composite
MR	material removal
MRR	material removal rate
N	number of passes
NTM	non-traditional machining
OA	orthogonal array
RSM	response surface methodology

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