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Experimental investigations on AL7075 gear in abrasive flow finishing

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Abstract

Abrasive Flow Finishing (AFF) is a novel Surface Finish (SF) technique that prevents the reshaping of parts' internal surface layers in a wide range of exercises. Semisolid silicon oil with abrasive particles is flowed through the workpiece tooth to achieve a smooth finish. Abrasion occurs over the AL7075 gear tooth while medium passes through the highly closed passage. Flow pressure, number of passes, abrasives mesh size composition and type of tooling, and fixture designs all impact AFF and are studied using optimal process output like SF and Material Erosion Rate (MER). Due to sufficient and a wider range of cycle levels for a larger erosion rate, the greatest level of material erosion rate was reached at 125 bar pressure, mesh size of 100#, and 6 cycles. SF and MER are used as outcomes in the optimization approach. The Taguchi method, planted L9 orthogonal array, has been established for experimental design and machining performance.

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INTRODUCTION

Relative tool motion issues should be avoided for precision machining and fine surface quality in complex shapes. To resolve this concern, some novel approaches based on chemical abrasion or the joining of multiple cutting edges either with Pressure and flow or magnetically presented. One of these methods is abrasive flow machining (AFM) which finishes a surface by the flow of an abrasive medium. Another example could be chemical mechanical polishing (CMP), which uses chemical abrasion and automatic material removal [1]. Additionally, elastic emission machining (EEM) is gaining popularity due to its high surface quality and atomic material removal. Each abrasive particle utilised in this procedure eliminates an atomic peak and polishes the surface under Pressure and underflow created by a blower and a roller, respectively. However, another problem is finishing force control, so AFM, CMP, and EEM are not well suited for finishing complex geometries such as porous additively manufactured parts [2]. Instead, one should precisely control the machining force and bonding strength made by applying an external magnetic field to achieve a perfect method for finishing complex internal geometries. So, some new techniques appeared such as magnetic abrasive finishing (MAF), and magnetic float polishing. To achieve a perfect method for finishing complicated internal geometries, one must precisely control the machining force and bonding strength created by applying an external magnetic field. So, some new techniques appeared, such as Magnetic Abrasive Finishing (MAF), magnetic float polishing (MFP) and Magnetorheological finishing (MRF) [3]. These processes can indeed control magnetic adhesion and are not applicable to any geometry. To achieve the perfect finishing goal, their advantages should be combined. According to earlier research on this technique, it can finish intricate internal surfaces [4]. One of the method' best uses could be the polishing of biomedical equipment like stainless-steel coronary stents. It is possible to apply protective strategies, such as alternative coating processes, than those included in this study [5]. However, continuum mechanics and artificial intelligence approaches could be used to look into the modelling and optimisation of these processes to boost the effectiveness of this process. When extrusion pressure from the hydraulic actuators is applied to the abrasive medium, standard or radial force and axial force are produced. Normal force (Fn) causes abrasive grain indentation on the workpiece surface, whereas axial force (Fa) causes material removal. They are translating the abrasive grain of dia(dg) with velocity (V_f) from the indented depth of (t) from the workpiece surface in the form of a microchip. As demonstrated in the mathematical model consists of certain assumptions such as the medium is homogenous, flow is quasistatic, incompressible, laminar, and axisymmetric and there is no swirling motion of the fluid [6].AFF is a surface polishing method that uses viscoelastic soft abrasive media that flows back and forth on the surface of the manufactured surface while under Pressure. Potential applications for alloys based on aluminium include the transportation, automotive, and aerospace sectors. 7075 aluminium is well suited to producing highly stressed parts and structural components. The alloy offers good fatigue strength and average machinability. 7075 is also popular in motorsport for gears and shafts due to its good strength and excellent stable corrosion property. 7075 is a high-strength structural material.

DESIGN OF HYDRAULIC CYLINDER

Hydraulic cylinders derive their power from hydraulic fluid under Pressure, which is commonly oil. In the cylinder barrel of the hydraulic cylinder, a piston attached to a piston rod swings back and forth. The cylinder bottom (also called the cap) closes one end of the barrel, and the cylinder head (also called the gland) closes the other end, which is where the piston rod comes out of the cylinder. There are rings and seals that move on the piston. The piston separates the cylinder's bottom chamber (cap end) from the piston rod side chamber.

Mechanical self-locking systems at one or both ends. Different terminations, position indication in the piston rod, and an indicator that shows lock engagement are all possible. Spherical bearings at each lot are the most typical termination, but other designs, including flanges, trunnion mountings, and sheaves houses for wire operation (jigger winch cylinders), will also be acceptable. In addition, the cylinder wall may be used to mount the tube termination. On multiple portions of a cylinder, there should be parallel threads that are enclosed against leaks to the outside by O-ring seals or something related. The O-ring material shall be specified and suitable for the intended purpose. Its works under pressures above 250 bar. The material used in seals shall be specified and suitable for its intended purpose, with good sealing properties and proper resistance against the hydraulic fluid. A manufacturer's remark or a test report may be necessary. Sealing between the stuffing box and the cylinder tube must be at least 2 mm from the threaded portion of the tube and comprise an O-ring with support ring (s). Sheave housing and wheel bolts are subject to design approval and must be submitted with the hydraulic cylinder's blueprints. The way and force with which the wire enters and leaves the wheels must be specified. All of the welds on a sheave house must be done from one side and go all the way through.

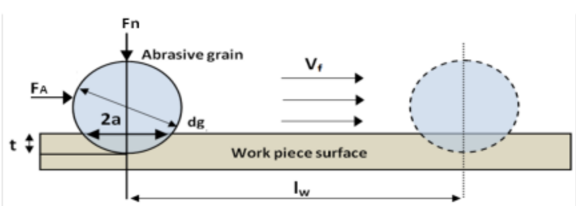

Figure 1 Forces acting on the abrasive particle in the AFF process

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Table 1 Chemical compositions

Al	Cr	Cu	Mg	Mn	Si	Ti	Zn
87.1	0.28	2	2.1	<0.3	<0.4	<0.2	5.1

Table 2 Mechanical Properties

Mechanical Properties	Value
density of material	2.7
Poisson's ratio	0.30
Modulus of Elastic	75 Gpa
Tensile Strength	220 Mpa
Yield Strength	95 Mpa
Hardness	87 HB
Shear Strength	150 Mpa

EXPERIMENTAL METHODOLOGIES

It comprises a specially made fixture that holds the Spur gear to be finished. The Spur gear is sandwiched between two medium-filled cylinders that are placed opposite each other. An AFF medium that is isoelastic and self-deforming is pushed back and forth through the obstruction between the fixture and the workpiece spur gear by one hydraulic cylinder that is controlled by the hydraulic power pack unit. The effectiveness of finishing in the AFF process depends on the fixture's design, which supports and holds the workpiece during it is made up of two Nylon discs, each of which has 12 circumferential holes drilled to match the outside and inside pitch circle diameters of the spur gear. This lets the AFF medium flow in and push it out over the flank surfaces of the spur gear. The fixture's upper and lower discs have 8 mm drills for this. To properly mount the spur gear and avoid relative movement during AFF media motion under high extrusion pressure, a hub with a protrusion at the center of the lower disc and equal depression in an upper disc of the fixture was developed. Four locating pins were also put around on both discs to prevent relative motion during finishing.

Finishing time, AFF media viscosity, extrusion pressure, abrasive particle type, size, and concentration, Spur gear geometry, material hardness and chemical composition, fixture, and clamping method are significant parameters of the AFF process, which affect the surface finish and deviations in pitch and runout of the spur gear finished by AFF process. The two most crucial AFF process parameters, the viscosity of the AFF medium and finishing time 't,' are expected to be crucial in fulfilling the stated goals of the current work. The two most crucial AFF process parameters, the viscosity of the AFF medium and finishing time 't,' are expected to be crucial in fulfilling the stated goals of the current work. The abrasive particles, putty, and oil were combined to create the AFF medium. Abrasive silicon carbide was chosen to finish AL 7075, which has a hardness of 87 HRB. Silicon oil was selected as blending oil which helps in easy control over the viscosity of the AFF medium. The viscosity of the AFF medium and the finishing time 't' are the two most important AFF process parameters that are likely to be very important in reaching the goals of this work. A redwood viscometer measured the viscosity of the prepared AFF medium. The mesh size of the abrasives particle 'M_a' used in the gear grinding depends on the module of the gear, and the recommended ranges of mesh size are 120 to 150 for modules less than 1.5; 90 to 100 for the module in the field from 1.5 to 5; and 80 for module more than.

Table 3 Machining Parameters

S.No.	CONTROL PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
1	Fluid Pressure (bar)	100	125	150
2	Abrasive Mesh Size	80	100	120
3	Number of cycles	2	4	6

Table 4 Weight of specimen

Specimen No.	Before Weight (g)	After Weight (g)
1	95	92.9
2	94.4	91.8
3	95.8	92.9
4	96.2	93.8
5	95.2	90.4
6	94.8	91.5
7	96.5	92.1
8	94.2	90.4
9	96.2	93.5

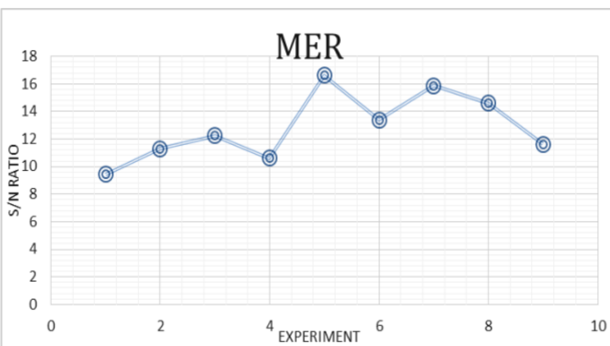
MER Analysis

The material removed from the surface and Surface quality depends on the following: (1) No. of cycle (2) Extrusion Pressure(3) Abrasive mass Flow rate (4) Viscosity (5) Abrasive particle size. As per the first experiment, observation reveals that the MER was lower range (2.1 g) with 100 bar pressure, 80# and 2 cycles. It was attained with the low kinetic energy of jet penetration and a lower cycle level. The second experiment reveals that the MER was slightly larger (2.6 g) than the previous trial with 100 bar pressure, 100# and 4 cycles because of insufficient kinetic energy of jet penetration and moderate cycle level. The third trial discloses the MER behaviour as previous with 100 bar pressure, 120# and 6 cycles because of the sufficient kinetic energy of jet penetration and higher range of cycle level. Finally, the fifth trail displays that the maximum level was attained at 125 bar

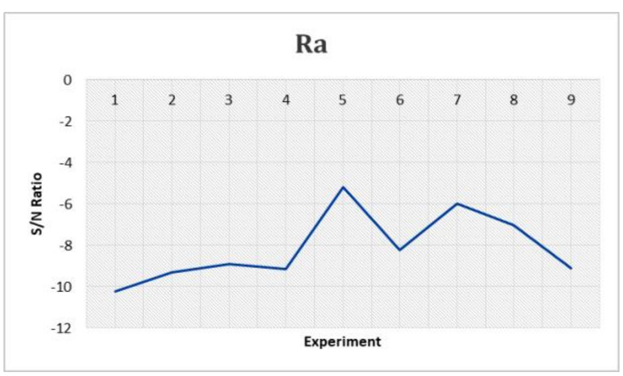
Table 5 Experimental results

SI.No.	Fluid Pressure (bar)	Abrasive Mesh Size(#)	No of cycles	MER (g)	Ra (μm)	S/N ratio (MRR)	S/N ratio (Ra)
1	100	80	2	2.1	4.58	9.454	-10.207
2	100	100	4	2.6	4.12	11.309	-9.288
3	100	120	6	2.9	3.94	12.258	-8.900
4	125	80	4	2.4	4.06	10.614	-9.160
5	125	100	6	4.8	2.57	16.635	-5.188
6	125	120	2	3.3	3.65	13.380	-8.236
7	150	80	6	4.4	2.82	15.879	-5.995
8	150	100	2	3.8	3.17	14.605	-7.011
9	150	120	4	2.7	4.04	11.637	-9.117

pressure, 100# and 6 cycles due to sufficient kinetic energy for jet penetration and a higher range of cycle level for a higher erosion rate.Researchers have found that first cycles increase surface quality and material removal, then stabilise. After 20 starts, material removal diminishes with increasing cycles. Increased cycles lower surface roughness, according to experiments.



6.1 S/N ratio plot for MER



6.2 S/N ratio plot for Ra

CONCLUSION

This study focuses on the effects of several AFF process factors on machining and accuracy, including Fluid Pressure, Abrasive Mesh Size, and Cycles. MER and Ra were also examined. With a Taguchi analysis of three parameters, we find that the abrasive mesh size has the most impact on MRR and that fluid pressure has the greatest impact on Ra. It is possible to improve the Micro Electro Mechanical System by optimising the AFF parameters of Spur gears (MEMS). The maximum level of material erosion rate was attained at 125 bar pressure, 100# and 6 cycles due to sufficient kinetic energy for jet penetration and a higher range of cycle levels for a higher erosion rate. It can be seen that with an increase in the number of cycles, Surface Roughness decreases. As the force exerted on a surface rises, the roughness of that surface first grows. In contrast, the rate of transformation grows with increasing pressure, cycle count, and material. Removal increases.

Ethical Approval

No ethical approval was necessary for this study.

Author Contribution

All authors made substantial contributions to the conception, design, acquisition, analysis, or interpretation of data for the work. They were involved in drafting the manuscript or revising it critically for important intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work, ensuring its accuracy and integrity.

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