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Utilizing ANSYS, CFD Simulation of Magneto-Rheological Abrasive Flow Nano varnishing of Stainless Steel

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Abstract: For the present analysis, magnetorheological abrasive flow finishing (MRAFF), of combined cross-breed type of abrasive flow machining process and magnetorheological finishing (MRF), has been considered. It is used for the smaller parts and also for complex geometry for a wide range of modern applications. Present study, a model for forecasting material evacuation and surface discomfort was assessed. CFD modelling in ANSYS 18.1 FLUENT was used to investigate the flow through the stainless-steel workpiece. Different parameters impacting surface roughness have been determined by accepting the medium as Bingham plastic.

Advanced estimation of information parameters has been established by the S to N Ratio plot and Means plot to achieve improved surface completion.

The following are the results of the optimization: The best process parameters for minimum axial stress are: 0.3T (magnetic density), 45 bar (inlet pressure) , and 0.01 m/sec (inlet velocity).

0.3T (magnetic density), 45 bar (intake pressure), and 0.03 m/sec (inlet velocity) parameters for maximum value of radial stress. For a minimum value of indentation depth, process parameters are 0.3T (magnetic density), 37.5 bar (inlet pressure), and 0.01 m/sec (inlet velocity).

Key Words: Magneto rheological (MR), Abrasive Finishing, Magneto-Rheological Finishing (MRF), Optimization

1. INTRODUCTION

"Magneto rheology" describes a fluid in which the viscous velocity imposes a magnetic force to the extent that it transforms into a viscoelastic solid. The study of material flow in the presence of external volume is known as rheology. Technologies for magnetorheological (MR) spraying, including as seat dampers and shock absorbers, have been employed successfully in many different applications. However, MR fluids can only show a yield pressure of 50–100 kPa at a magnetic flux of 150–280 kA/m. To build a high pressure yield system, it is essential to choose the various MR fluid components, including the carrier fluid, magnetic particles, and additives, correctly.

1. Liquid carrier

60 to 80 % of the volume of MR fluid is made up of carrier liquid. The viscosity of liquid carrier should be minimum and temperature-independent at the maximum magnetorheological effect.

2. Silicone oil

Silicone oil has excellent heat transfer characteristics, exceptional flexibility, a very low melting point, oxidation resistance, and high flash points. It's quite tough to sign silicone oil. In addition to the vast temperature range, the physical characteristics, usability, and shell temperature slope remain largely unchanged between 40 and 204 °C.

3. Magnetic Particles

The thickness of particles having energy between 1 and 10 m. The proportion of soluble particles in the solution can reach 50%. The available energy does not increase with the active particle's size, even when the MR fluid's viscosity does. High power satellite magnetization, low coercive, high permeability, low hysteresis loop, and low recovery are only a few of the features of magnetic fields that are used in the creation of MR fluid.

4. Additives

Grease and other additions with obvious ingredients are used to boost stability. Magnetic particles are combined with materials like guar gum, polystyrene (PS), and other goods to reduce the concentration of CI particles, strengthen the stability of the fibres, and prevent CI particles from coming into touch.

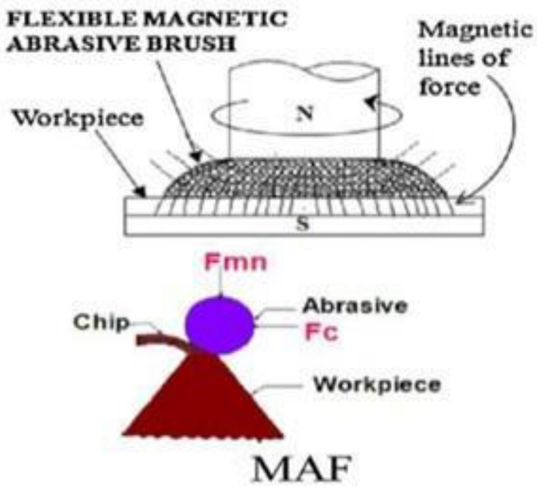

Fig. 1. Magnetic abrasive flow machining [6]

2. LITERATURE REVIEW

A structure for the CIP chain and surface roughness test model was put up by Jha and Jain (2004). The investigation was conducted on a piece of stainless steel work using various combinations of SiC and CIP particles in magneto-rheological polishing fluid to achieve a specific amount. The CIP and SiC size combinations have been computerized to remove the inherent complexity of the original profile data and the model offered by the external hardness.

The function of counterfeit behavior and the impact of magnetic fields and cycles on the evils of robustness are discussed by Jain et al. (2007). The hydraulically enabled test setup is intended to comprehend the performance and performance's parts. All studies were carried out on stainless steel in various magnetic fields to determine their impact on the surface.

Through FEM, Das et al. (2008) carried out their work on the plastic Bingham flow. It has been approximated what makes up the mixture of big, ferromagnetic particles suspended in MR polishing fluid. The model is also suggested to calculate the outer material hardness removal.

Shah et al. (2015) carried out and stated the impact of modifying the maximum number of finishing cycles and pressure on the work surface on the stiffness of stainless steel. A new appearance labeled "illegal entertainment" is proposed due to an increase in the number of cycles completed in the research on hydraulically completed power outages.

A thorough literature analysis of the MRF process in the case of experimental and experimental science characters, of MR fluid, is provided by Topuz et al. (2012). A model created by Kordonski and Jacobs predicts the distribution of surface deformation over an agreement and is a reliable test.

According to Ginder et al. (2002), the operational region above the wall can be made strong by using the energy needed to move the items offered hydrodynamic movement of Magneto-rheological fluid when transposing the gap. It is also discovered that this finishing method lowers the optical optical components' stiffness to 10A0.

Zhang et al. (2010) examine factors that have an impact on the process of completing the magnetorheological, such as a portion of the power aspects of the magnetic field distribution. It has been created and tested to remove material at a pace that is comparable to the K9 glass screen.

Jayswal et al. (2005) considered how artificially checking a small silicon-based area with the aid of iMR. The most crucial element will manifest as a side effect. The line item approach (EFP) was used to look into how the magnetic field affected the boundary of the tool cluster in finite element profiles.

In order to reproduce the characteristics of dating equipment, Hai-Ning et al. (2012) suggested a mathematical model in the magnetorheological finishing process, which is validly valid. Additionally, it describes the evaluation and distribution of emissions within the impact work as well as the composition and size of the controlling activity.

The magnetic force and medium near the work surface were measured using 2D computational fluid dynamics (CFD) in the current investigation using ANSYS.

to comprehend the stainless steel nano-finishing process supported by a magnetic field and to determine the rotational depth, axial pressure, and radial pressure in order to determine the rate of material removal.

2.1. Various Steps Used for CFD Analysis

In Figure 2, the various steps are used to develop the model. For the creation of geometry, we select the design as given in Figure 4.2 and we create with the help of CAD software i.e., CREO, and then the geometry is to be imported in ANSYS Software by using the CFX tool.

After importing geometry, now we generate the model by using CFX geometry generation.

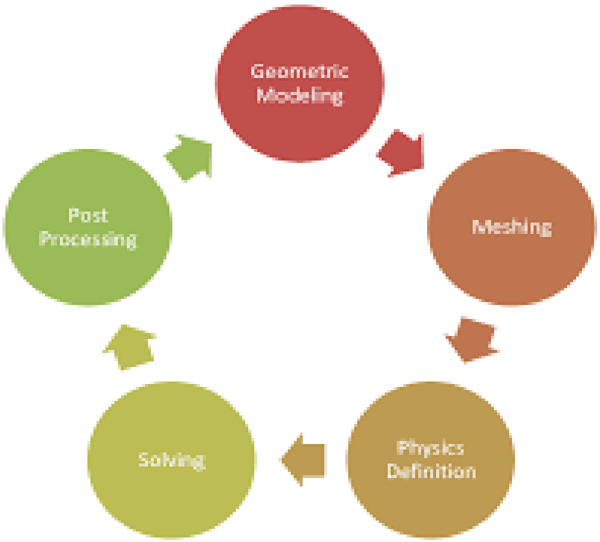

Figure 2. Steps Used in CFD Simulation

3. CALCULATION

Here in section we follow the below procedure step by step

(a) CFD calculations determine the radial stress (σrad) on the material of the workpiece to be

(b) The total Indentation Force (F_N) is evaluated

(c) Now indentation diameter (Di) is evaluated

(d) The depth of indentation (t) is evaluated

(e) The projected area (A') is evaluated

(f) Now, F_{shear} and F_R are evaluated

(g) Now, finally, we have obtained F_{shear} and FR values

From the calculation, we have obtained F_{shear} is greater than the F_R, so therefore material removal should occur on the work piece surface.

Surface roughness was also calculated for 200 cycles (i = 200) and found as = 0.43µm.

4. RESULT AND DISCUSSION

Fig. 3 shows the velocity distribution of work piece

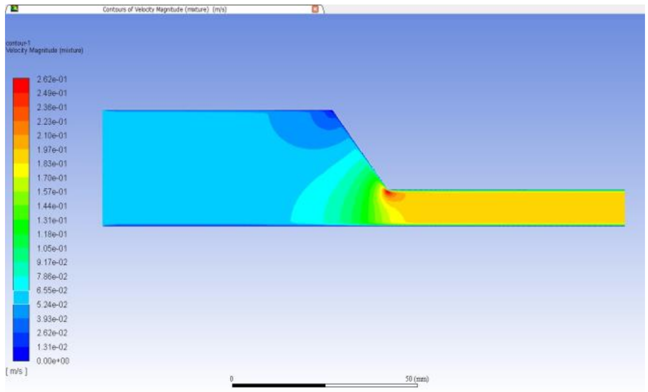

Fig 3. Velocity distribution lengthwise the work piece fixture

Fig. 4 shows the pressure distribution along the work piece.

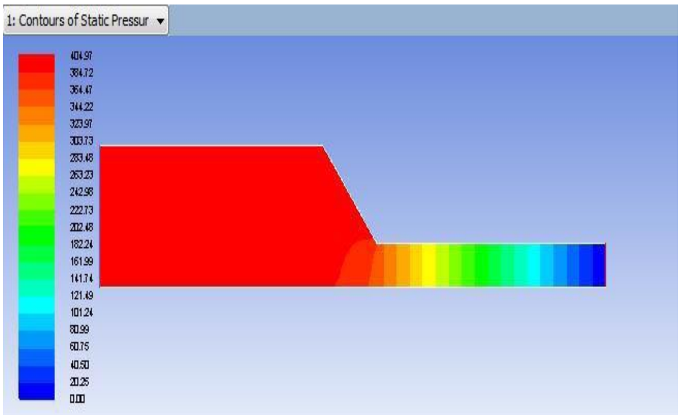

Fig. 4. Pressure distribution lengthwise the workpiece fixture

Table 1 shows the input parameters for the present analysis.

Table 1. For analysis Input parameters

S.NO	Parameter	Value
1	Workpiece Material	Stainless steel
2	BHN No	277 BHN
3	tensile strength (Ultimate)	860 MPa
4	Yield strength	540.30 MPa
5	Type of Polishing Fluid	20% by vol. of CIP and 20% by volume of SiC
6	abrasives mesh size	800
7	viscoplastics base medium	20 wt. % of AP3 type greases and 80 wt. % of Paraffins liquid

Table. 2. For analysis Input Experimental s Parameters

Process parameters & Unit	**Code**	**Low (1)**	**Medium (2)**	**High (3)**
Magnetic Field Density (T)	A	0.3	0.4	0.5
Pressure (bar)	B	30	37.5	45
Velocity (m/sec)	C	0.01	0.02	0.03

4.1. Axial Stress

Fig.5 shows the SN-ratio for the axial stress for smaller is better condition.

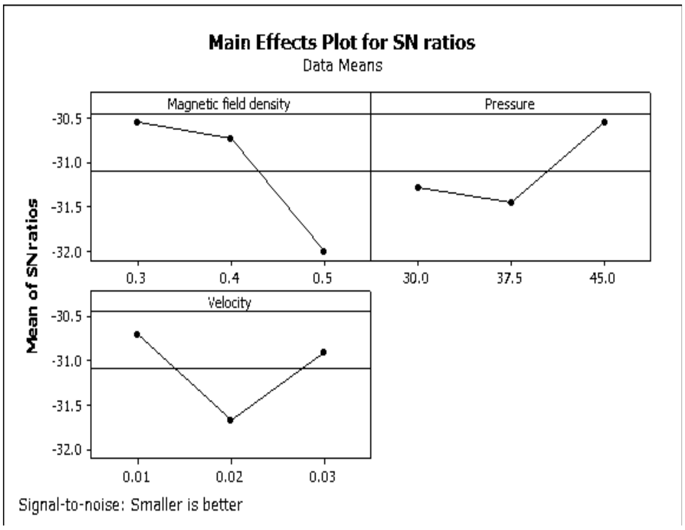

Fig 5. Main Effects of plot for axial stress (SN ratios)

4.2 Radial Stress

Fig.6 shows the SN-ratio for the radial stress for higher is better condition.

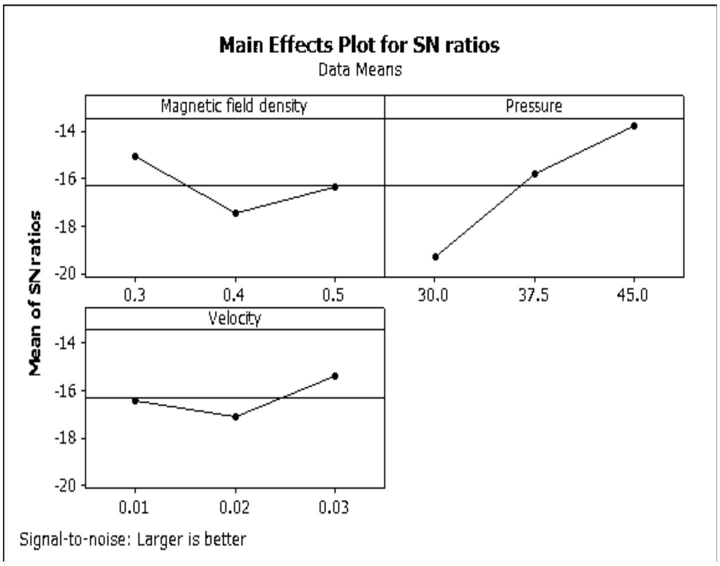

Fig 6. Main Effects of plot for radial stress (SN ratios)

4.3. Indentation Depth

Fig.7 shows the SN-ratio for the Indentation Depth for smaller is better condition.

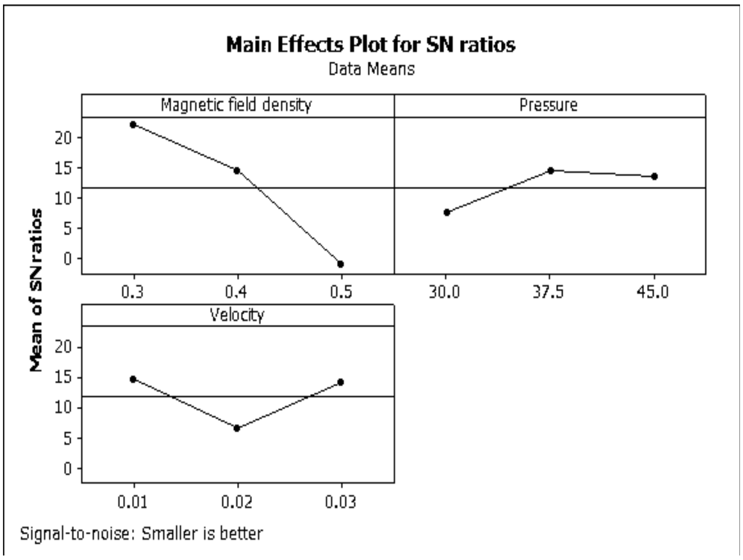

Fig 7. Main effect of plot for Indentation Depth (SN ratios)

5. CONCLUSIONS

The following key findings have been reached based on the current inquiry and analysis.

1. It is determined from the current CFD analysis that the leading cause of material expulsion occurs when the shear force are applied on abrasive particle, which is higher as compared to the opposing force generated by the workpiece material

material expulsion occurs due to the material's strength. This conclusion is validated the present theoretical model.

2. Based on the present CFD results, this can be stated that presnt model is able to calculate the nano-level finishing.

3.CIPs do not require a tie force equal to normal force, which is fewer necessary to indent into the abrasive particle, when no magnetic effect is applied.

Therefore, a smoother surface was formed, but material removal still took place since the shear force was more significant than the reaction force.

4. It is determined that in order to optimize the finishing process, low axial stress and indentation depth, as well as high radial stress, are necessary.

5. The following conclusions were drawn from the optimization:

The process parameter for minimum axial stress are: 0.3T (magnetic density), 45 bar (inlet pressure), and 0.01 m/sec of (inlet velocity).

For maximum value of radial stress, the process parameters are 0.3T (value of magnetic density), 45 bar (value of intake pressure) , and 0.03 m/sec (value of inlet velocity).

For minimum indentation depth, the process parameters should be 0.3T (value of magnetic density), 37.5 bar (value of intake pressure) , and 0.01 m/sec (value of inlet velocity).

5.1. Scope of further work

1. Dynamic analysis to explore the effect of the magnetic field- assisted Nano-finishing process can be analyzed in future.
2. Different experimental and operational variables from the present analysis can be considered for the future studies.

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