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Magnetorheological Finishing Process of External Cylindrical Surface

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***Abstract*— Magnetorheological finishing process is developed for finishing of external surfaces of non ferromagnetic cylindrical object.The process make use of smart fluid called Magnetorheological Fluid for finishing which has the property to become stiff in the existence of magnetic field. the smart MR polishing fluid is made of carbonyl iron particles , abrasive particles, base fluid. magnetic force acts on magnetic CI particles which further exert a repulsive force on non magnetic silicon carbide particles perfom finishing as tool rotate as well as reciprocateon rotating cylindrical object .**

***Index Terms*— Ansoft maxwell, cylindrical copper workpiece,magnetorheological fluid,mathematical modelling.**

I. INTRODUCTION

final surface roughness play an important role in product quality, particularly in situations such as precision fitsand high strength application . Traditional process used for super finishing are not capable to super finish the workpiece surface without any defect .due to the limitation of traditional finishing processes , various magnetorheological (MR) fluid based finishing process have been developed .These MR fluid based finishing process have precise control over the finishing forces and are used for fine finishing of workpiece surface . due to magnetic field , the carbonyl iron particles present in MR polishing fluidallign to form chains in direction of magnetic field lines and grip the non magnetic abrasive onto the workpiece surface.CIparticles present in particles present in MR polishing fluid are acted by magnetic normal force due to the magnetic field. Intensity of magnetic normal force acting on CI particles depends on the gradient magnetic field in the working gap.CI particles exert repulsive force on non magnetic silicon carbide abrasive particles and make them to indent into the workpiece surface .due to relative motion between tool and workpiece surface,gripped indented SiC particlesalso move and remove the peaks of rougness from the workpiece surface , Therefore,it is very important to understand the distribution of magnetic flux density and magnitue of indentation force acting on an SiC abrasive to study the in-depth mechanism of material removal in MR fluid- based finishing processes.

MR tool is constituted of solid cylindrical core mounted permanent magnet drived by motor running with speed of 1400rpm core is running at 750rpm . In the existence of magnetic field produced by permanent magnet,magnetic CI particle form chain in the working gap and grip non magnetic SiC particles on the outer surface of workpiece.The CI particles present in MRpolishing fluid experience magnetic force due to magnetic field which is liable for penetration of abrasives into the workpiece surface. Due to produced magnetic force,the CI particles stick over tool surface and pushes active abrasive particles with repulsive force toward workpiece surface due to rotation and reciprocation of MR tool , abrasives are acted by centrifugal force ,tangential force, and axial force . The sum of the magnetic force and centrifugal force is liable for penetration of abrasive into the workpiece surface while the sum of the tangential force and axial forceacting on abrasives particles is responsible for material removal in form of tiny micro chips While the sum of the tangential force (F_t) and the axial force (F_a) acting on an active abrasive particle is responsible for material removal in the form of tiny micro chips .abrasive particles have cutting edges and due to abrasion action by them, the peaks of roughness cut down and surface get finished.

II. VARIATION OF SURFACE ROUGHNESS WITH LINEAR MOMENT OF TOOL

MATHEMATICAL MODELING

A. *Variation with rpm of tool*

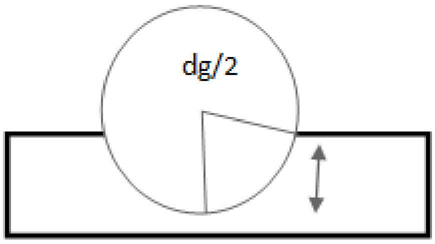

Fig 1. Variation with rpm of tool

d_g = Average grain diameter

d = depth of penetration

$$d=\frac{d_g}{2}-\frac{1}{2}\sqrt{D_g^2-D_i^2}$$

by knowing the initial roughness value Y_i and after finding forces is over we have to calculate the final roughness value and by taking the mean over all the roughness value. We can get actual roughness value.

Y_i = initial depth(initial roughness)

$Y_i' = Y_i - N_g d$

N_g= no. of grains in one stroke for N no. of particle

$$R_a=\frac{\sum|Y_i'|}{N}$$

B. *Variation with linear movement of tool*

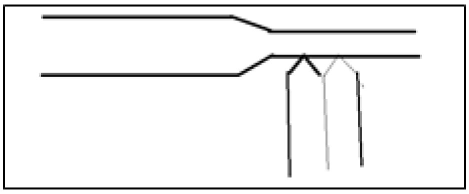

Fig 2. variation with linear movement of tool

Feed-position of cutting tool in two different position during one revolution of workpiece. Therefore the maximum roughness will be the distance between the finished surface and point R.

Enlarge view

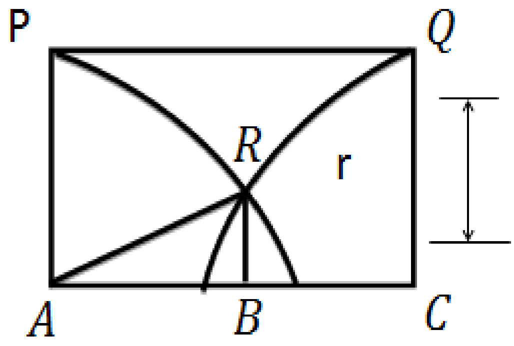

Fig 3 Enlarge view of cip particle

r = radius of cip particles

In ΔARB

$$AR^2 = RB^2 + AB^2$$

$$r^2 = (r - h_{max})^2 + \left(\frac{f}{2}\right)^2$$

$$h_{max} = \frac{f^2}{8r}$$

h_{max} = maximum surface finish

III. Simulation

The MR process magnetostatically analyzed for magnetic flux density distribution in MR polishing fluid region using Maxwell Ansoft software. magnetorheological tool (with flat permanent magnet cylinder) are modeled of size of dia 22 mm and height of 25 mm. For magnetic finite element analysis, material assigned to the body MR tools is non-ferromagnetic stainless steel while permanent magnet are assigned with NdFeB. MR polishing fluid with thickness of 1 mm and relative permeability of 5 is modeled over the permanent magnet . Cylindrical nonferromagneticworkpiece of copper is modeled over the outer surface of MR polishing fluid. relative permeability of CI particles is taken 4000and of SiC is 1The size of SiC particle of 57 µm diameter and CI particles of 54 µm diameter has been taken in analysis. The modeled MR process is magnetostatically simulated with 10 numbers of passes in Maxwell Ansoft software, and magnetic flux density distribution in the MR polishing fluid region is evalu-ated. Magnitude of magnetic flux density in MR polishing fluid region is evaluated magnetostatically from the tools' outer surface of permanent magnet to the surface of cylindrical nonferromagneticworkpiece.

The rotating shaft of magnetorheological tool is passed through the bearings of C-shaped bracket. The C-shaped bracket is clamped on lathe. The belt and pulleys are used to rotate the magnetorheological tools onto the cylindrical workpieces with the help of motor.

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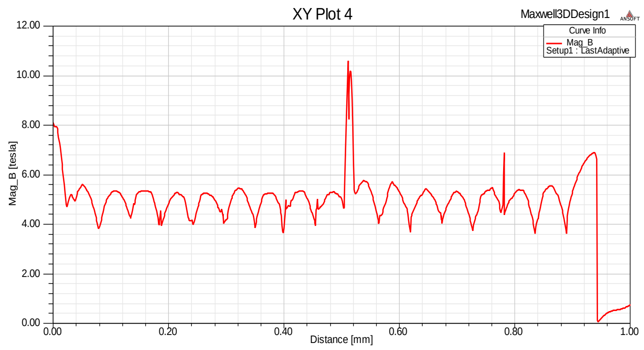

Fig 4. Graph between Magnetic field and distance

Magnitude of normalized magnetic flux density through chain Within the working gap from outer surface of finishing tool to the inner surface of copper cylindrical workpiece , the magnitude of magnetic flux density varies over a line as moving from one CI particles to another in chain. graph of magnitude of normalized magnetic flux density throughcenter of CI particles and SiC particle in the modeled chain is obtained from FE analysis as shown in figure

From the coordinates of the graph and modeled particles size,it has been observed that peaks in the graph show the edge of CI particals and troughs represent the centre of particles as shown in fig.

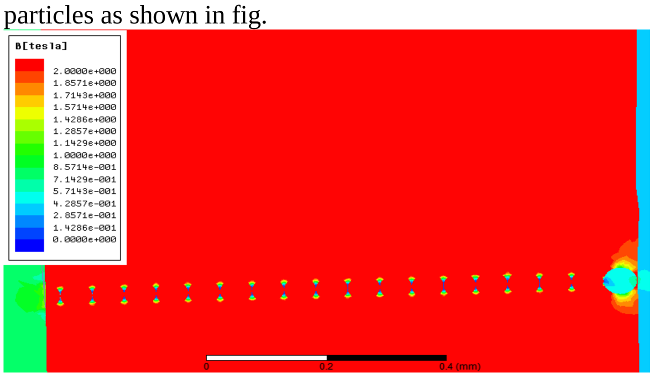

Fig 5 simulation results

Magnetic flux density distribution in MR polishing fluid in working gap obtained from finite element analysis.

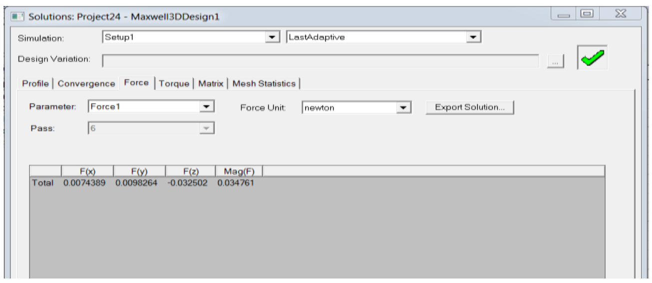

Fig 6. Simulation result

IV. Results and Discussions

The high gradient of magnetic flux density over the outer-end surface of finishing tool attracts the carbonyl iron particles (CIPs) toward it and gives repulsive back force to the abrasives that indent them into the roughness peaks over the surface of cylindrical nonferromagneticworkpiece.The surface roughness parameters of surface of ground cylindrical non ferromagnetic workpieces before MR process are found as R_a = 0.295µm, and R_z = 2.767 µm whose roughness profile is shown in fig

Fig 7. initial surface roughness

The experiments are performed on Copper Sheet for measuring the outcome of finishing time on final surface roughness value. The experimental result of consequence of finishing time on surface roughness for nonferromagnetic work material is shown in Fgure. The experiments are performed on magnetic field 0.6 T at MRF tool tip on which stiffened ball end is formed. The surface roughness profiles are obtained by SURFCOM FLEX for all the experiments and to understand the finished surface morphology and quality.The surface roughness is checked after every 30 minutes. After 90 minutes surface roughness reduces to 187 nm. Therefore, it is confirmed that a newly developed low cost ball end MR finishing process is able of nanofinishing.

Fig 8. Final surface roughness

The decrease in average surface roughness value describes the finishing capability of a new low cost ball end MR finishing method. The quantity of material which is sheared from the workpiece depends on the bonding strength of silicon carbide particle and carbonyl iron particles.

V. CONCLUSIONS

- low cost ball end MR finishing tool has been developed for nanofinishing of workpiecesurfaces.
- The magnetostatic simulation of the present developed MRF tool with copper work piece clearly shows that the almost uniform magnetic flux density in the working gap of 1mmwhichresultsinnearlyuniformfinishedsurfaceevenwithoutanyfeedtothe workpiece.
- Uniform finishing can be obtained on the surface of workpiece at 750 rpm of tool.
- The property of MR polishing fluid is utilized to accurately control the abrading forces for getting the precise surfacefinish.
- The overall results concluded that the value of average surface roughness of copper sheet decreased from 295 nm to187 nm almost uniformly over the surfaceswith finishing time of 90 minutes in case of without giving feed.

Comparatively the present developed finishing process was found likely more efficient to finish the surfaces with less time and more uniformity over the surfaces even without any feed to theworkpiece.

- Better surface finishing will be obtained in comparision to other traditional processes on the external surface of the cylindrical workpiece.

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