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Measurement of Process Parameters in Magneto-Rheological Fluid Assisted Cylindrical Surface Nano Finishing Process using Grey Relational Methods

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Abstract*: Techniques for the analysis of machining parameters on cylindrical surface finish of 304L stainless steel with multiple response. It depends on quadratic pattern - (GRG) Grey Relational Grade is proposed in this paper. In this work, optimized the machining parameters such as working gap, Work-Piece Speed (WPS), and wheel speed rate and flew value are concluded the various responses such as Material Removal Rate (MRR), Normal Force (F-N), and surface roughness (Ra). Optimal process parameter is determined by Taguchi concept utilizing the GRG the performance index. And value of GRG used to recognize parameters optimum level. A antecedent of Variance (ANOVA) is used to resolve the augmentation of aspect r.

Keywords: *Cylindrical surface finish, magneto rheological fluid, AISI 304L austenitic stainless steel, genetic algorithm, ANOVA, microstructure study.*

I. INTRODUCTION

In the precise parts manufacturing process, the ultimate operation to finalize is concerning their workers intensive, consumption of time as well as the controllable least nature. The final finishing process in traditional has no capability to provide characteristics of surface which is needed but in some cases , this kind of processes are economically incompetent due to taking long time to process and the requirement of equipment that in high expensive one. Based on their certain purpose, it requires the lubrication wearing and them playing useful in component service life.

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The surface finish and treatment are influenced in the low energy by strongly. Due to rough surfaces and irregular surfaces is revealing exhaustion properties, the environment of surface is an essential cause for component strength influence and the efficiency is decreased because of increment of surface roughness and increasing in optimal losses. AISI 304L stainless steel have the extensive properties like better corrosion resistance, high ductility, good spinning and excellent drawing. Low carbon content means during solder and lower sensitivity to intergranular corrosion. It is used in following application are cryogenic vessels, beer barrels, chemical equipment's, paper industry, coal and oil well filter screens, cooling coils, , flexible metal hose, food processing tools, nuclear vessels, refrigeration equipment, valves, shipping drums, textile dyeing equipment, tubing spinning. Magneto rheological finishing process is an advanced precision finishing process technology used for finishing material surfaces up to nano level. **[1]** Lohitaksha M Mayar investigated the Inconel 718 super alloy parameter optimization with several answers, which relate to the Taguchi orthogonal array with GRA**. [2]**P. Jayaraman and Maheshkumar explained the AA 6063 T6 aluminium admixture of turning based on optimization machining parameters. [3] Zahid A. Khan et al consider the chattels of Raw mean and kerf width on steel (SS 304). [4] J.B. Saiden et al studied during varied responses the effects of process parameters gets variations in their shear rate and MRR(Material Removal Rate) in wire electrode discharge machine (WEDM) operations**. [5]**Sunil Jhaet al studied in the (MRAFF) magneto rheological abrasive flow finishing process, the effect on pressure and roughness in amount of last cycles. **[6]**Ajay Sidpara, V.K. Jain says a model in theoretical that improves the in depth mechanism of understanding about the material removal by acting forces over the work piece while the finishing process of MR fluid.**[7]**Ajay Sidpara and V.K. Jain conducted a prediction study of process parameter effects. [8] Shai N et al. With the help of Magnetic Geology (MRF), we studied the precise micro-turf surfaces of tungsten carbides and found that the micro-hardening of the valley (B-V) from the surface of the micro-grinding surface with hard or medium abrasive size instruments indicates the depth of the layer.

Factual depth of the distorted surface layer induced by milling is defined by MRF spots. **[9]** Kyung proposed a latest deferring process utilizing a magnet or heological fluid. They used more than one material removal mechanisms induced by magnetic heat flux. [10] H.B. Cheng investigated the fictional implementation of RB-SiC materials. It arises the question of magnetic resonance (MRF) of RB-SiC glass. Aspects of various glazing liquids, limitations in analysis of physical techniques, effects on the properties of some processing parameters, and accuracy of surface relative removal rates. [11] H.B. Cheng conducted an experimental investigation of optical aspheric components and showed that after 10 minutes of refinement the roughness on the top of the an be reduced from 3 to 1nanometer.**[12]** VK Jain et al developed a method, Chemo-Mechanical Magnetic-Chemical accomplish (CMMRF) for silicon brighten, and it is used for magnetic-chemical finishing (MRF) and chemical mechanical polishing (CMF). B) combines both features and has no effect on the process involved. [13] F.C. Sai et al

drifting out an experimental analysis to obtain optimal processing conditions for SKD 61 axle steel abrasive jet polishing. **[14]**J ae-SeobKwakinc by using permanent magnet on the opposite site of work piece is done by experimental verification and the simulation is run by magnetic flux density and non ferrous materials[15] Ajay Chidbara and V.K. During the MR fluid-based finishing process, Jain performed a test trial, which is used for brittle materials ranging from optical glasses to hard crystals**. [16]**N. Senthilkumaret al verified the shape of cutting, angle of relief and nose radius of machining parameters using Taguchi based GRA. [17] a. Sadiq and M.S. Shanmugam proposed a new method to improve the coating on non-magnetic surfaces in the process of magnetic-chemical abrasion. **[**18] Mamila Ravi Shankar and others performed an experimental analyze and mechanism for the removal of material in the nanoparticles of MMCs using the Abrasive Flow Termination (AFF) procedure. [19] Ajay Chitbara, V.K. Jain examined the effect of process parameters on the filling and dispersion of empty single crystalline silicon material in MRF. In this current study, work has been proposed to study the effect of varying process parameters on the cylindrical surface termination process with the help of magnetic-rheological fluid (MRF).

II. PROPOSED SYSTEM WITH PROCEDURE

A. Material

Austenite stainless steel (AISI 304L) cylindrical pipe of 160 mm outer diameter; 8 mm thickness and 265 mm length workpiece material was used for this nano level cylindrical surface finishing study. Composition of chemical content in the workpiece material is representing in Table. 1.

Table 1. Chemical architecture of work piece material (SS 304L)

Material	C	Mn	P	S	Si	Cr	Ni	Al	Fe
SS 304L	0.03	2	0.045	0.03	0.75	20	12	0.1	balance

Table 2. Selected levels and Parameters

Parameters	Levels 1	Levels 2	Levels
Working gap (mm)	5	10	15
Workpiece rotation (rpm)	275	300	350
Wheel speed (rpm)	200	250	300
Deliver rate (mm/rev)	0.1	0.15	0.2

B. Cylindrical surface machining

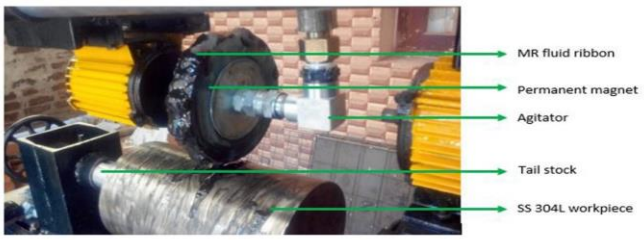


Figure 1. MR fluid cylindrical surface machining of AISI 304L stainless steel

The cylindrical surface accomplish experiments is lugged out to finish the final surface of the object up to nano level with the aid of Magneto- rheological (MR) fluid. The cylindrical finishing machine experimental setup is shown in Fig. [1]. Magneto rheological fluid composed of silicon oil with grease, CIPs (carbonyl iron particles) and Sic (silicon carbide).

Table 3. Design of experiments and output value

Ex. no	Working gap (mm)	Workpiece speed (rpm)	Wheel speed (rpm)	Feed rate (mm/rev)	Normal force (N)	Ra (nm)	MRR (mg/min)
1	5	275	200	0.1	23.37	26	0.267
2	5	275	200	0.15	23.41	18	0.314
3	5	275	200	0.20	24.62	24	0.343
4	5	300	250	0.1	19.28	30.5	0.195
5	5	300	250	0.15	20.74	42	0.357
6	5	300	250	0.20	21.69	24	0.200
7	5	350	300	0.1	18.96	27	0.238
8	5	350	300	0.15	20.24	33	0.305
9	5	350	300	0.20	22.35	40.5	0.333
10	10	275	250	0.1	16.75	38	0.248
11	10	275	250	0.15	17.24	22.5	0.205
12	10	275	250	0.20	19.52	21	0.290
13	10	300	300	0.1	18.27	37.5	0.219
14	10	300	300	0.15	18.92	39	0.267
15	10	300	300	0.20	19.68	25.5	0.248
16	10	350	200	0.1	19.05	30.5	0.186
17	10	350	200	0.15	20.59	29	0.224
18	10	350	200	0.20	22.16	26.5	0.262
19	15	275	300	0.1	19.57	36	0.219
20	15	275	300	0.15	22.42	28.5	0.245
21	15	275	300	0.20	21.75	19	0.268
22	15	300	200	0.1	20.68	22.5	0.257
23	15	300	200	0.15	21.75	35	0.239
24	15	300	200	0.20	23.15	31.5	0.305
25	15	350	250	0.1	20.47	23.5	0.285
26	15	350	250	0.15	19.84	34.5	0.291
27	15	350	250	0.20	21.43	28	0.246

Wheel type rotating magnetic tool of 25mm thickness consist of number of tiny holes of 3-5mm diameter on the outer surface of the circular to for MR fluid passage. The MR fluent is accumulate the circular surface of a accumulate magnetic device by a hydraulic pumping system, which carries the fluid to the work zone surface. Stainless steel (SS 304L) work specimen issued for this surface finishing study. AISI 304L austenitic steel, having size of 200 mm diameter and 350 mm length is chosen as a work piece. Table. 3. Shows the chemical composition of (SS 304L) stainless steel. Initially, the work sample is completed by regular grinding. Tests were conducted at different levels of feed rate, wheel speed rotation, work piece rotation, and measurement of the natural and tangential emission response tool operating in the workplace.. Each experimental trail was performed for 12-15 minutes to obtain the better finish.

III. RESULT & DISCUSSION

A. Grey relational analysis

Taguchi method is explains the optimal method parameter values for nano level finishing of austenite material of stainless steel. The parameters which are important is involved in this finishing operation are working gap (WG), workpiece speed (WS), wheel speed (WHS) and feed rate (FR). The parameters classified into three levels are presented in **Table. 2.**The experiment were investigate for the cylindrical finishing parameters by using approach of L_{27} orthogonal array as in **Table. 3.** Following steps wereto be followed to find the optimal process parameters value.

Step 1: S/N ratios data transformation

The output data is to be converted to S / N rate. Calculating the S / N rate formulas is below,

Better larger

$$\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{{y_{ij}}^{2}}\right)$$

Better smaller

$$\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}{y_{ij}}^{2}\right)$$

Step 2: For further analysis, a single input a transformation performed is Normalization to apportion data and scale it for adequate range.

$$Z_{ij} = \frac{Y_{ij}-\min\left(Y_{ij}, i=1,2,\ldots,n\right)}{\max\left(Y_{ij}, i=1,2,\ldots,n\right)-\min\left(Y_{ij}, i=1,2,\ldots,n\right)}$$ (Rate with larger-better case)

$$Z_{ij} = \frac{\max\left(Y_{ij}, i=1,2,\ldots,n\right)-Y_{ij}}{\max\left(Y_{ij}, i=1,2,\ldots,n\right)-\min\left(Y_{ij}, i=1,2,\ldots,n\right)}$$ (Rate with smaller-better case)

Step 3: Distribute S / N ratio values in Gray co-efficient (GC) calculation

$$GC_{ij} = \frac{\Delta_{min} + \lambda\Delta_{max}}{\Delta_{ij} + \lambda\Delta_{max}}\begin{cases} i = 1,2,\ldots,n - \text{experiments} \\ j = 1,2,\ldots,m - \text{responses}\end{cases}$$

GC_{ij}- Grey relational co-efficient

Δ- difference b/w inY_{0j} and Y_{ij}

Y_{0j}- optimum performance value

Y_{ij}- jth response of ith normalized value

Δ_{min}- high value of Δ

Δ_{max}- high value of Δ

λ- distinctive co-efficient that range is $0 \le \lambda \le 1$

Step 4: Gauge grey relational grade (G_i)

$$G_i = \frac{1}{m}\sum GC_{ij}$$ m - Number of responses

Step 5: choose excellent level for the factors depends on higher average G_i through ANOVA method.

Table 4. Normalized values of S/N ratio and grey grade.

Normal force (N)	Ra (nm)	MRR (mg/min)	S/N rate Fn (N)	S/N rate Ra (nm)	S/N rate MRR (mg/min)	Normalized S/N ratio Fn	Normalized S/N ratio Ra	Normalized S/N ratio MRR	(G_i)
23.37	26	0.267	27.37317	28.29946	-11.46977	0.135074	-2.193983	8.87156	0.62912
23.41	18	0.314	27.38802	25.10545	-10.06140	0.130634	-1.63753	8.44113	0.65460
24.62	24	0.343	27.82576	27.60422	-9.29411	-0.00022	-2.07286	8.20663	0.58434
19.28	30.5	0.195	25.70214	29.68599	-14.19930	0.63463	-2.43553	9.70577	0.82808
20.74	42	0.357	26.33617	32.46498	-8.94663	0.44508	-2.91968	8.10043	0.68245
21.69	24	0.2	26.72519	27.60422	-13.97940	0.32879	-2.07286	9.63856	0.71299
18.96	27	0.238	25.55676	28.62727	-12.46846	0.67809	-2.25109	9.17679	0.85237
20.24	33	0.305	26.12421	30.37027	-10.31400	0.50845	-2.55475	8.51833	0.73657
22.35	40.5	0.333	26.98555	32.14910	-9.55111	0.25095	-2.86465	8.28518	0.61819
16.75	38	0.248	24.48029	31.59567	-12.11096	0.99991	-2.76823	9.06753	0.66817
17.24	22.5	0.205	24.73074	27.04365	-13.76492	0.92503	-1.97520	9.57302	0.94974
19.52	21	0.29	25.80959	26.44438	-10.75204	0.60251	-1.87079	8.65221	0.82358
18.27	37.5	0.219	25.23477	31.48062	-13.19111	0.77435	-2.74819	9.39765	0.89131
18.92	39	0.267	25.53842	31.82129	-11.46977	0.68358	-2.80754	8.87156	0.82210
19.68	25.5	0.248	25.88050	28.13080	-12.11096	0.58131	-2.16459	9.06753	0.96336
19.05	30.5	0.186	25.59789	29.68599	-14.60974	0.66579	-2.43553	9.83121	0.84726
20.59	29	0.224	26.27312	29.24795	-12.99503	0.46393	-2.35922	9.33772	0.74413
22.16	26.5	0.262	26.91139	28.46491	-11.63397	0.27312	-2.22280	8.92175	0.67142
19.57	36	0.219	25.83181	31.12605	-13.19111	0.59586	-2.68641	9.39765	0.79038
22.42	28.5	0.245	27.01271	29.09689	-12.21667	0.24283	-2.33290	9.09984	0.65904
21.75	19	0.268	26.74918	25.57507	-11.43730	0.32161	-1.71935	8.86164	0.71894
20.68	22.5	0.257	26.31101	27.04365	-11.80133	0.45261	-1.97520	8.97290	0.75439
21.75	35	0.239	26.74918	30.88136	-12.43204	0.32161	-2.64379	9.16566	0.67160
23.15	31.5	0.305	27.29101	29.96621	-10.31400	0.15963	-2.48435	8.51833	0.61295
20.47	23.5	0.285	26.22235	27.42135	-10.90310	0.47911	-2.04100	8.69838	0.75568
19.84	34.5	0.291	25.95083	30.75638	-10.72214	0.56028	-2.62201	8.64307	0.76039
21.43	28	0.246	26.62044	28.94316	-12.18129	0.36010	-2.30612	9.08902	0.70096

The experiment calculation is done about S/N ratio and the values of the grey grade (G) and tabulated in Table 5. S / N ratio for friction welding at each stage is summarized in Table 6, which summarizes the effect of the assigned S / N ratio at each stage of the erosion fusing method**.** These tables evaluated from orthogonal array S/N ratio values.

Table 5. Results for ANOVA for cylindrical finishing parameters

Cylinder finishing parameters	DF	SS	MS	F	P-value	% contribution
WG	2	0.33365	0.16683	5.50	0.044	33.54
WS	2	0.04171	0.02085	0.69	0.538	4.19
WLS	2	0.13852	0.06926	2.28	0.183	13.93
FR	2	0.02311	0.01155	0.38	0.699	2.32
WG*FR	4	0.04914	0.01228	0.41	0.799	4.94
WS*FR	4	0.12090	0.03022	1.00	0.477	12.15
WLS*FR	4	0.10580	0.02645	0.87	0.532	10.64
Error	6	0.18192	0.03032			18.29
Total	26	0.99475				100

Table 6. The S/N table for cylindrical surface finishing parameters

Parameters	Level 1	Level 2	Level 3
Working gap(A)	**0.6999**	0.9423	0.7138
Workpiece speed(B)	0.7753	0.8377	**0.7430**
Wheel speed(C)	**0.6855**	0.8202	0.8503
Feed rate(D)	0.8241	**0.7534**	0.7785
Optimal setting parameters: $A_1B_3C_1D_2$			

B. Analysis of Variance (ANOVA)

Audit the causes of Categorical Factors (CF) on response using ANOVA technique and it is used to get important values of tensile strength, and impact strength. It decays the unpredictability in the response variable along with the various factors. It depends on the analysis type which may be necessary to check the suitable factors and a large amount of response variability is allocated to each factor. To establish the important factor that give additional nearer to the output performance of ANOVA. It is responsible for dividing the absolute variable measured into the dependent variable into its resources. A total measured variance value is completely variation of total which attained from participants. A dependent measure reveals the output of the study as output variables and makes valuable way to conceive/envision it.

Factors that influence the dependent variable are input factors, effects of treatment and conditions of treatment and these are reflected by independent variable because of these two variables are closely related with each of them. For investigation the ANOVA is carried out for which cylindrical surface finishing parameters like wheel speed, WPS, feed rate and working gap. Results of ANOVA for these parameters are evaluated using S/N response tables. Effects of Individual and interactive factors importance is evaluated. It is suitable for all types which reveal the high contribution nearer to the rough surface of the material.

C. Optimal parameters for better surface roughness

S/N ratio of the finishing parameter is high and it is considered as best for the parameters. The higher values consequent is representing in boldface for every factor. From S/N table, three cases of weightage is considered and it is observe that the level of the forecast cylindrical finishing parameters is $A_1B_3C_1D_2$that is working gap (WG) = 5 mm, workpiece speed (WS) = 350 rpm; wheel speed (WHS) = 200 rpm; feed rate (FR)=0.15mm/rev.

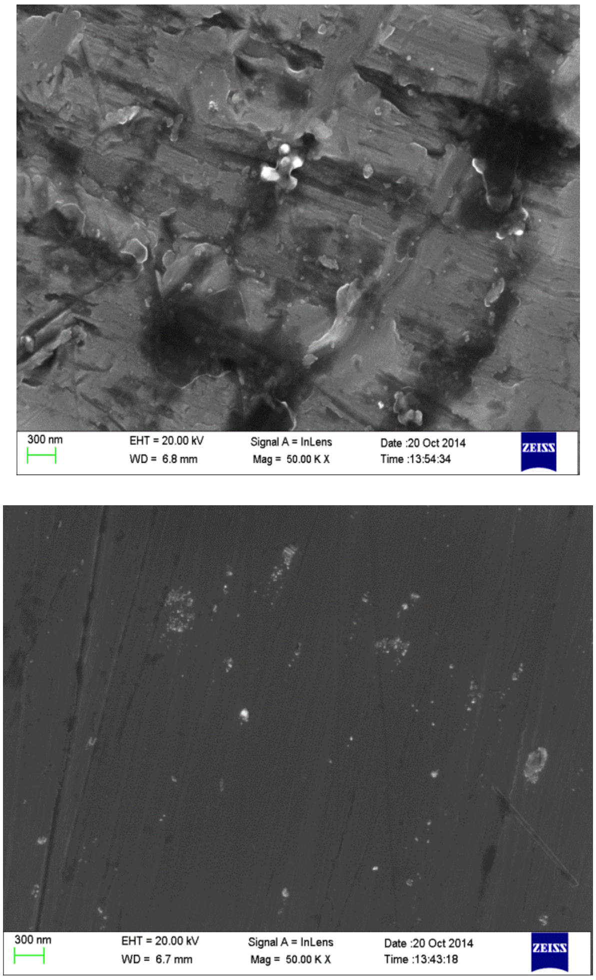


Figure. 2. Scanning electron microscope image (SEM) (a) without MR fluid finished workpiece at 300 nm level. (b) MR fluid finihsed workpiece at 300 nm level.

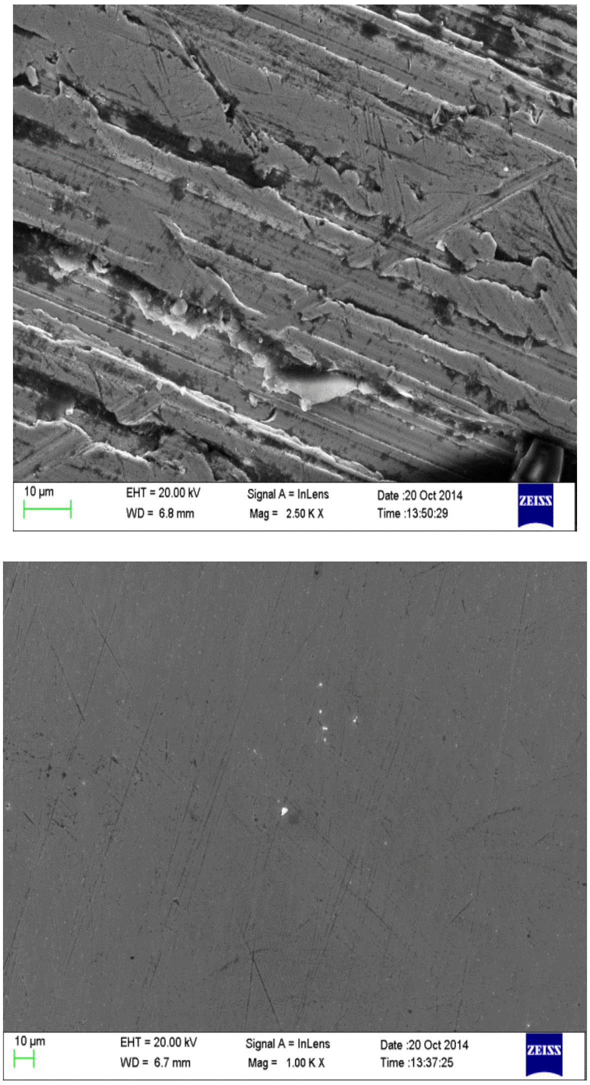
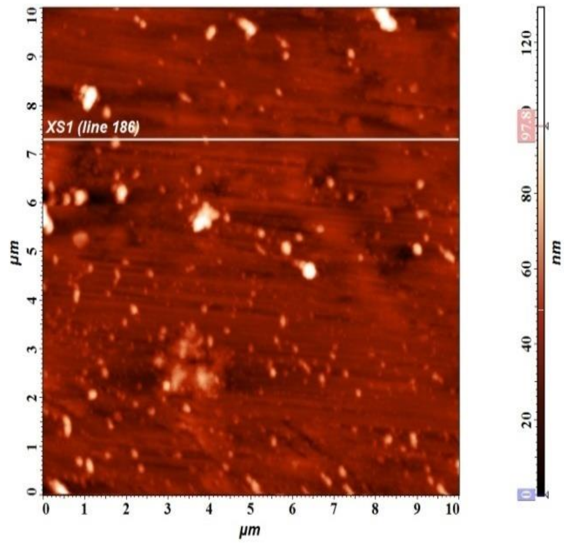


Figure.3 scanning electron microscope (SEM) image (a). without MR fluid finished workpiece at 10 µm level. (b). MR fluid finihsed workpiece at 10 µm level.



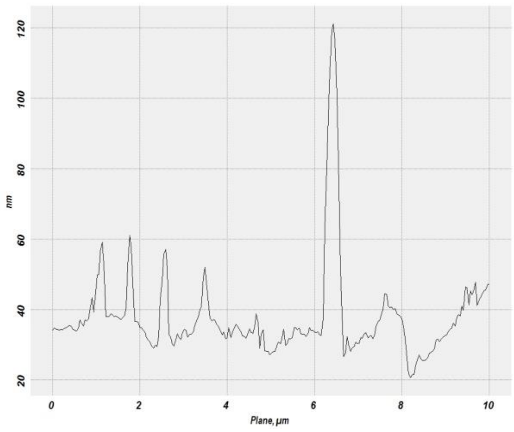


Figure. 4 Atomic force microscopic image of (a) 304L stainless steel without MR fluid finished surface (b) Cross sectional view.

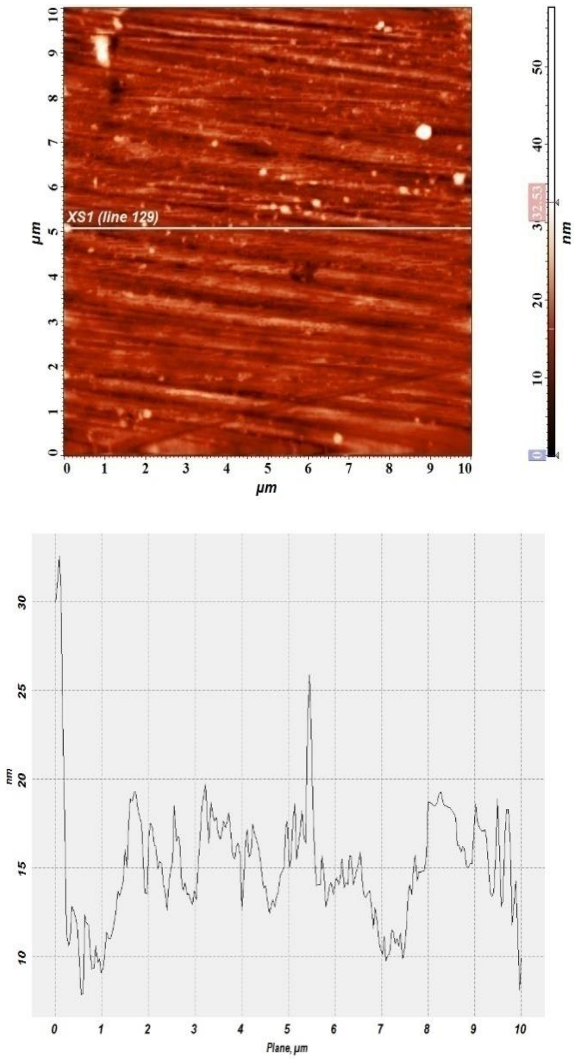


Figure. 5.Atomic force microscopic image of (a) 304L stainless steel with MR fluid finished surface. (b) Cross sectional view.

D. FESEM and AFM micro structural study.

MR fluid assisted cylindrical surface finishing of 304L stainless steel material is evaluated and micro structural examination done under the standard metallographic procedure is shown in Figures. 2, 3,4,5 and 6.

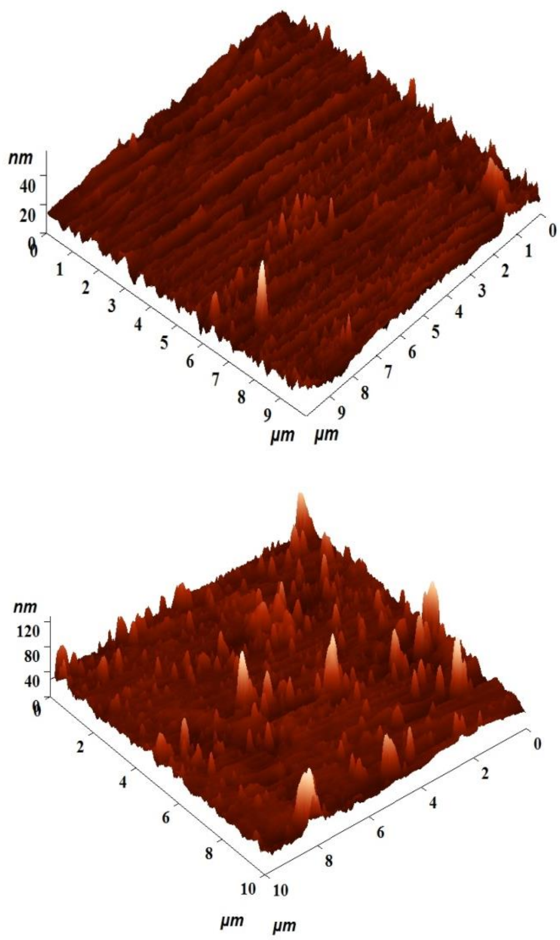


Figure 6. Topography of (A) MR fluid finished surface (B) without MR fluid finished surface.

The cylindrical finishing topography in 3D of final surfaces are appeared in figure (A) and figure (B). The exp.no.3 shows that the surface roughness value about 18mm which is obatained as minimum and it reveals that finishing of MRF process AISI 304L stainless steel done by the parameters with proper combination and the 304L SS without MR fluid is around 100nm to 50–120 nm. Therefore, surface roughness of significant reduction is achieved. Thus, in this study the roughness reduction of surface is achieved.

IV. CONCLUSION

This experimental verification is reveals the process parameter effects through carrier wheel speed, workpiece speed, working gap and feed rate for finishing 304L stainless steel by cylindrical MR fluid finishing method. The Ra is suffered by feed rate as well as work piece speed.

MRR increases with increasing the concentration of CIPs and the also carrier wheel speed is increased while MRR decrease and in an optimum level the abrasive concentration past is also increased. In the instant study the low coarseness of surface about 4nm is achieved. The selection study is done with the independent parameters which are in the particular range. The carrier wheel speed, working gap, WPS and the feed rate used to minimize and maximize the final Ra and maximize MRR respectively.

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