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Corrosion resistance studies of SS316L surface generated by Magnetic Field Assisted Abrasive Finishing

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Abstract

In this paper, an attempt has been made to investigate the corrosion resistance of SS316L surface generated by Magnetic Field Assisted Abrasive Finishing (MFAAF) process. The characterization on the finished surface of SS316L was studied by electro chemical studies like potentiodynamic polarization and impedance studies. These studies indicated that the MFAAF process could enhance the corrosion resistance of the surface in sea water medium. The polarization studies had shown that MFAAF process could be adopted to improve the corrosion resistance of the machined SS316L surfaces. To examine the microscopic changes in the surface texture resulting from corrosion, the Scanning Electron Microscopy images have been carried out to gain insight of corroded surfaces.

Keywords: Corrosion resistance; Magnetic field assisted abrasive finishing; SS316L; Potentiodynamic polarization.

Introduction

Surface finish is an important quality characteristic of machined components in terms of corrosion resistance, aesthetics, tribological considerations and fatigue life improvement as well as precision fit of critical mating surfaces. To obtain high level finishing of surfaces, from the last two decades many newer methods are identified by the researchers. Magnetic Field Assisted Abrasive Finishing (MFAAF) is one of the fine finishing methods to achieve smoother surfaces. Salient feature of MFAAF process is the use of controllable magnetic field in the finishing zone to produce mirror like nano level finishing without making any micro cracks and simple in operation [1]. Many researchers [2-5] conducted the experimental investigations to identify the significant process parameters to improve the surface obtained by the MFAAF process. Researchers made attempts to optimize the process parameters to improve the surface finish in MFAAF process. The obtained finished surfaces were studied using surface roughness profiles, Atomic Force Micrographs,

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Scanning Electron micrographs [6-8]. It was reported that to reduce the gradual degradation of material by electro chemical attack the surface corrosion resistance of the parts are need much care. This corrosion resistance could be increased by careful finishing technique to reduce surface scratching. From the literature, it is identified that limited work has been carried out on the corrosion studies for the surface generated by the MFAAF process. Hence, this paper investigates the study of corrosion resistance of MFAAF machined surfaces of SS316L material using electrochemical techniques. The obtained results were reported and discussed on the electrochemical behaviour and corrosion resistance of SS316L surface produced by MFAAF process in a 3% NaCl solution. Potentiodynamic studies like polarization measurements and impedance studies were made before and after MAAF process for comparative purposes. From the obtained results, it was observed that the MFAAF finished surface is offering better corrosion resistance comparing the surface obtained by grinding process. To study the enhancement of corrosion resistance, SEM micrographs of corroded samples obtained before and after MFAAF were also studied and reported.

Experimental Details

Workpiece material

Austenitic stainless steel grade 316L (SS316L) non-magnetic material was selected for this study. The chemical composition of selected SS316L material is shown the Table1.

MFAAF experimental setup

An electromagnet assembly was fitted to the spindle of precision vertical milling machine to conduct the MFAAF experiments. The experimental setup consists of electro magnet, mandrel, sleeve, lock-nut, contact brushes and power supply for electromagnet. The photographic view of MFAAF spindle assembly is shown in figure 1.

The MFAAF experiment was conducted as per the following process parameters for the present study which are as follows: voltage supplied to the electromagnet at 22 V; machining gap at 1.5mm; rotational speed of electromagnet at 540 rpm; abrasive size at 1200 mesh; and Feed rate at 35 mm/min. The other parameters like finishing time (15min), grain size of iron particle (300 mesh), total amount of magnetic abrasive particle (10g) and mixing ratio (80% Fe, 20% SiC abrasive) were kept constant for the experiment. The MFAAF experiment before and after samples were utilized for the electrochemical studies. Before starting the electrochemical experiments, the surface roughness of the samples before and after MFAAF process were obtain (by Mitutoyo surftest SJ301) to understand the surface irregularities. The obtained surface roughness profiles are shown in figure 2.

Experimental setup for corrosion studies:

An experimental setup was developed to study corrosion behaviour of SS316L material via potentiodynamic polarization and impedance measurements using the electrochemical analyzer, 3% of NaCl solution, platinum electrode for working electrode and a PC with data acquisition system. The developed experimental arrangement was shown in Figure 3. For the electrochemical studies of SS316L surface with 1 cm^2 exposed area, Hg/Hg_2cl_2/3.5%NaCl and 4 cm^2 area of platinum surface were used as working electrode, reference and counter electrodes respectively. The corrosion studies were carried out in 3.5% NaCl. During Potentiodynamic polarization studies, ±200mV were shifted from open circuit potential with scan rate of 1mV/sec.

Results and Discussion

Corrosion studies

Potentiodynamic polarization measurements

This potentiodynamic polarization measurement was carried out on the machined surface obtained by MFAAF process and the results were presented in Fig 4. It is evident from the figure 3 that E_{corr} (0.0197mV/sec) value is shifted to positive potential with simultaneous shifting of I_{corr} [9]. Hence the machined surface is offering better corrosion resistance in sea water medium than the machined surface obtained by grinding. The above observation clearly indicated that MFAAF process increases the homogeneity of surface atoms at their lattice planes with high degree of alignment of atomic structures by MFAAF. This could not be achieved through other conventional finishing processes. Also it was visualised that the corrosion potential values for MFAAF surface was 10 decades in mV/sec higher than the surface finishes resulted from grinding process.

Impedance studies

The Nyquist diagram for the corrosion resistance of metallic layer produced from MFAAF processes are presented in Figure 5. The real resistance was potted against imaginary resistance and the charge transfer resistance along with double layer capacitance values were calculated from the frequency maximum. These studies indicated that the corrosion resistance process is not following diffusion control as the perfect semi circles have not been encountered. The resistance was noted by best fitting the curve through alteration of electrochemical Randles circuits (Fig 6) as this seems to be peculiar for highly corrosion resistance surfaces [10].

The charge transfer resistance value for surface produced by MFAAF process 5.5KΩ/cm^2 which is higher than (R_t = 2.3KΩ) the finishing achieved through grinding process.

SEM Micrographs

SEM micro graphs of corroded surfaces of SS316L in 3.5% NaCl is presented in figure 7. It is seen that the appearance of laminated structures with voids and streak lines indicating that the attack of chloride ion is more than the surface finishing of SS316L prepared by MFAAF process. The appearance of uniform and layered structure along with absence of non-uniformity in the surface confirming that MFAAF process could enhance the corrosion resistance of the said alloy in sea water medium. These results are found to be in good agreement with the results of electrochemical studies reported in this work.

Conclusions

Based on the above investigations, the following conclusions are drawn:

i) The corrosion kinetic parameters indicated that the surface finish of MFAAF Process is superior than the other conventional finishing techniques

ii) There is no heterogeneity on the surface of SS316L prepared from MFAAF technique which is further evidence from its enhanced charged transfer resistance

iii) SEM images showed the presence of the layered structure along with decreased voids and pits on MFAAF patterned SS316L confirming its high corrosion resistance characteristics.

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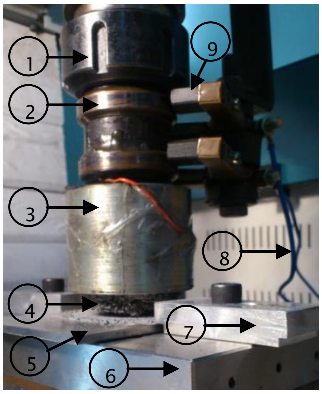
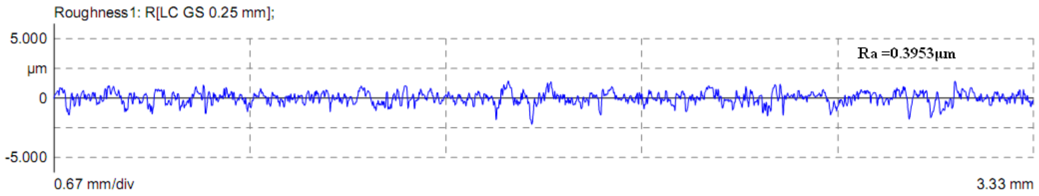
Figures

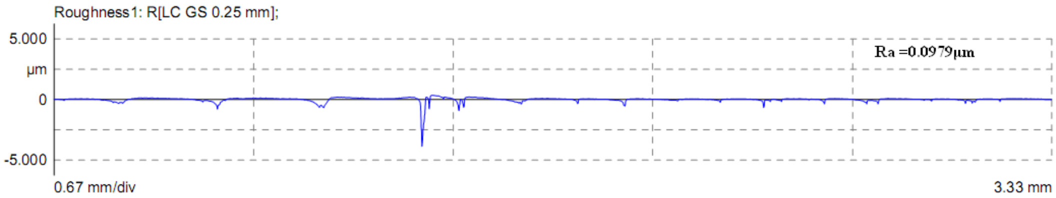


1. CNC machine spindle
2. Slip ring
3. Electromagnet
4. Magnetic Abrasive Flexible Brush (MAFB)
5. SS316L Workpiece
6. Dynamometer

Figure 1 Photographic view of MFAAF spindle assembly



b) Before MFAAF process



b) After MFAAF process

Figure 2 Surface roughness profiles

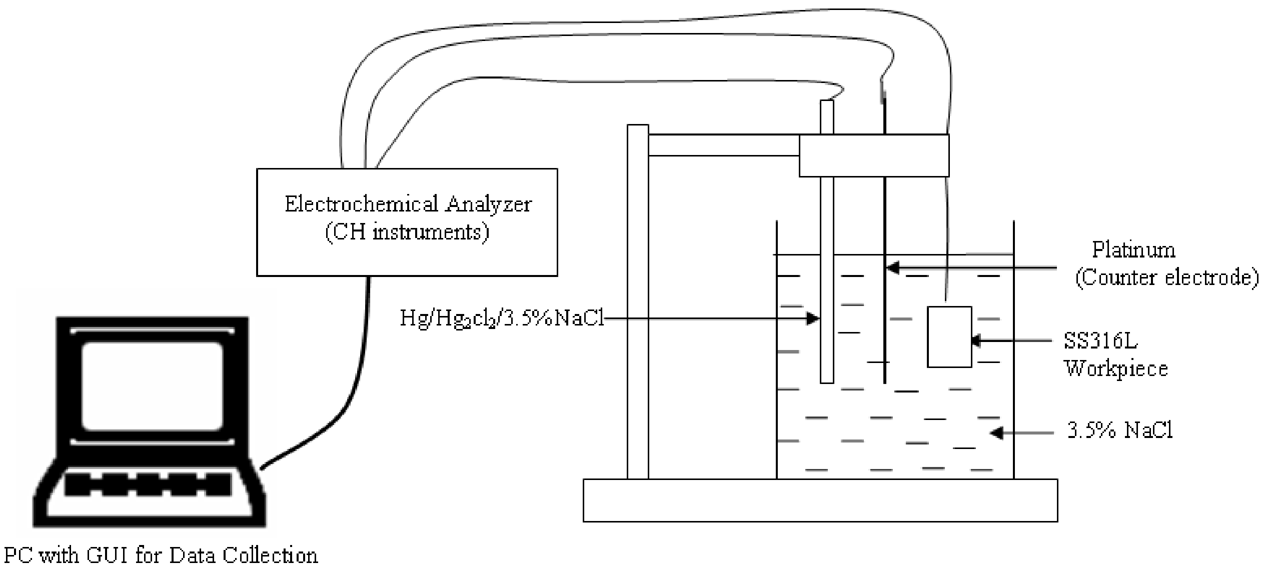
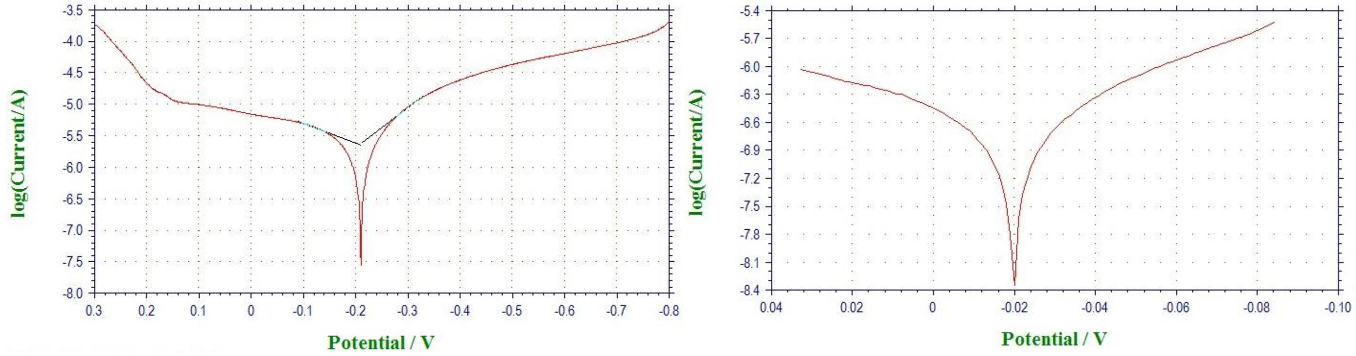
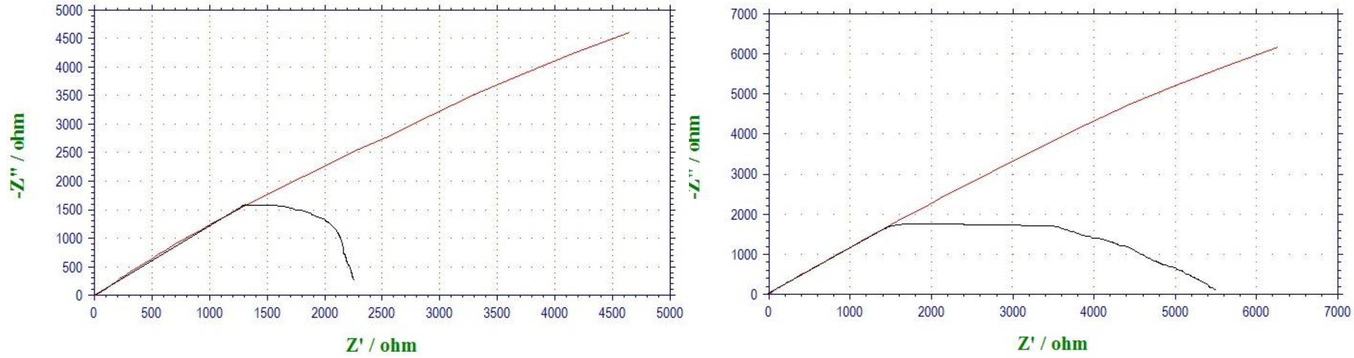


Figure 3 Schematic view of experimental setup for electrochemical corrosion studies



a) Before MFAAF process b) After MFAAF process

Figure 4 Potentiodynamic plots for Corrosion behaviour



a) Before MFAAF process b) After MFAAF process

Figure 5 Nyquist diagram for Corrosion behaviour of SS316L

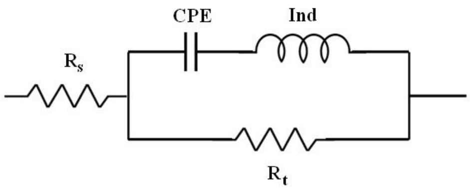


Figure 6 Electrical equivalent circuit

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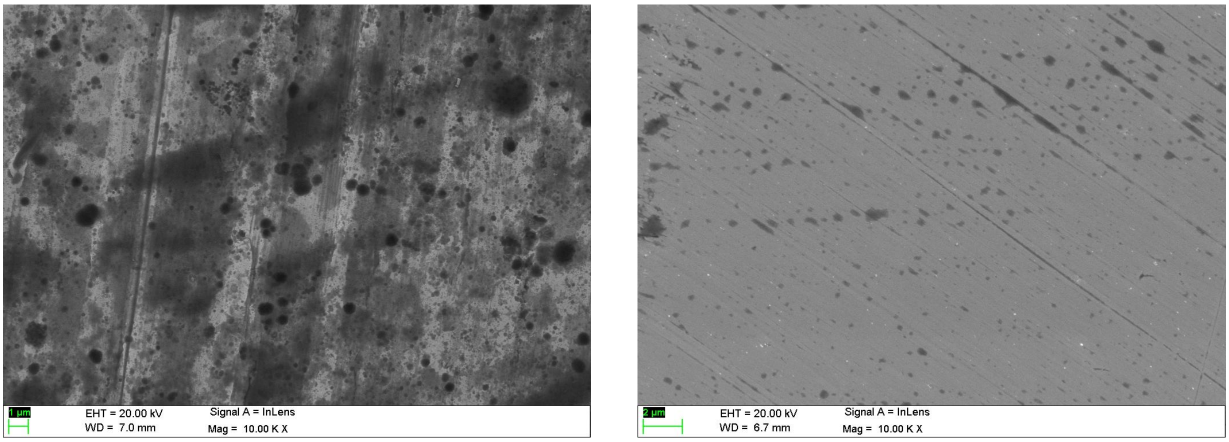

Before MFAAF process b) After MFAAF process

Figure 7 SEM images

Tables

Table 1 Chemical composition of SS316L work material (Wt.%)

Alloying Elements	Cr	Ni	Mo	Mn	Si	P	S	C
Observed weight ratio (%)	16.1	10.0	2.0	1.8	0.5	0.03	0.003	0.021