Surface Integrity, Surface Finish and Corrosion Characteristics of Stainless Steels in Saline Water Medium

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Abstract
The surface roughness of austenitic (304), martensitic (410) and ferritic (430) grades of stainless steels have been measured after fine emery paper grinding. The surface integrity of the ground samples were further examined in SEM. Metal removal during emery paper grinding occurred by rubbing, ploughing, micro cracking and gouging out of metal grains. The rate of corrosion/year, as determined through potentiostat test in 0.9 N NaCl solution, increased with surface roughness but it was insignificant in case of the metallographically polished samples of all the stainless steels. Corrosion progressed fast from the grinding pits on the stainless steel sample surfaces.

1. Introduction

Stainless steels are often used in corrosive environments. Although stainless steels are resistant to attack of oxidizing acids, most of the stainless steel grades are amenable to corrosion in saline medium [1], surface finish of the steels influence resistant to corrosion [2]. The austenitic stainless steel 304L is widely used as a structural material for which surface finish has signification effect on the service performance. A reference for choosing appropriate grinding parameters for machining 304L stainless steel has been provided by Nian Zhou, et al [3]. Another study also indicated that the surface roughness of the workpiece material is largely affected by the machining method and the parameters used [4]. The potentiostat technique has been used in the past to examine the overall corrosion behaviour of 316SS [5]. Similarly corrosion resistance behaviour of S43903 ferritic stainless steel was evaluated in different hydrochloric acid solution and the acid chloride concentration [6]. Surface integrity has a significant effect on service condition and residual stress may influence failure of duplex stainless steels in service [7]. In this study the specific effect of emery paper polishing on the surface integrity and surface finish of austenitic (304), martensitic (410) and ferritic (430) stainless steels and its ultimate effect on corrosion characteristics in 0.9N NaCl solution has been examined.

Table 1: Chemical composition of stainless steels samples.

Table: 1(a) Austenetic(304)

Carbon	0.08
Manganese	1.36
Phosphorus	0.03
Sulphur	0.03
Silicon	0.6
Aluminium	trace
Chromium	19.05
Nickel	9.73
Iron	balance

Table: 1(b) Martensitic (410)

Carbon	0.15
Manganese	1.36
Phosphorus	0.04
Sulphur	0.04
Silicon	0.5
Aluminium	trace
Chromium	12.72
Nickel	trace
Iron	balance

Table: 1(c) Ferritic(430)

Carbon	0.11
Manganese	1.31
Phosphorus	0.04
Sulphur	0.04
Silicon	0.65
Aluminium	trace
Chromium	18.19
Nickel	trace
Iron	balance

Table 2: Electrochemical data extracted from polarization curves for three different grades of stainless steels in 0.9N NaCl solution at room temperature.

Steel Type	E_{Corr} (mV)	I_{Corr} (μA/ cm^2)	Corrosion Rate (μm/year)
304SS Emery paper grinding	-604.1	5.3424	61.894
304SS Polished Sample	-266.6	0.0176	0.20384
410SS Emery paper grinding	-479.2	3.9988	46.327
410SS Polished Sample	-369.6	2.5595	29.658
430SS Emery paper grinding	-651.3	12.6131	146.12
430SS Polished Sample	-177.2	0.2536	2.9383

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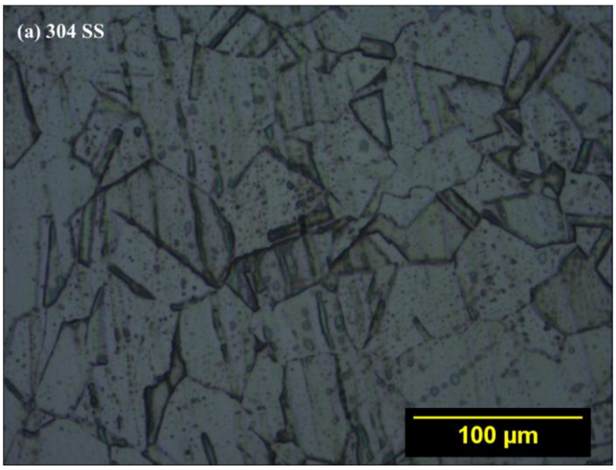
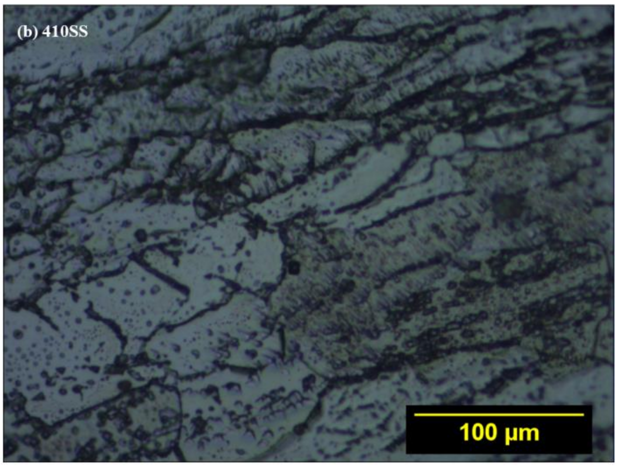
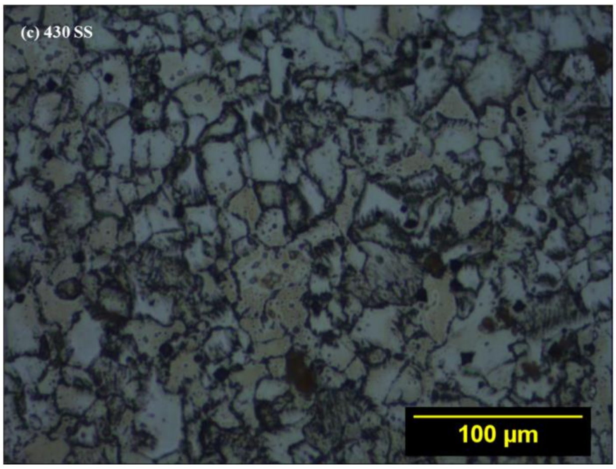


(a) Austenitic 304



(b) Martensitic 410



(c) Ferritic 430

Fig: 1. Microstructure of as received stainless steel samples

2. Experimental procedure

The composition of the as received 5mm thick stainless steels plates are given in table 1.The microstructures of steels are shown in fig.1 (a, b & c). The plates were polished by emery paper grinding. The emery papers were coated with silicon carbide (SiC) abrasive particles of grit size 240#.The surface roughness of the emery paper ground samples were measured by a Bruker Contour Elite K 3D optical surface profilometer. From each area (1.26mm × 0.9mm) of measurement, roughness values and Ra were calculated. The Ra value is the arithmetic average value of the roughness profile determined from deviations about the mean line over the evaluation length. In the current work, three area of each ground samples were measured and the reported roughness is the average of these three measurements. For the purpose of comparison, the surface roughness of metallographically polished samples of the three steels was also measured. The surface characteristics of the ground samples were examined by scanning electron microscopy (Hitachi S-3400M). Corrosion characteristics of both the ground and metallographically polished samples of the three stainless steels were determined by potentiostat test. Each square shape test sample had a surface area of 1cm×1.5cm. Each experiment was conducted in 100ml of 0.9N NaCl solution.

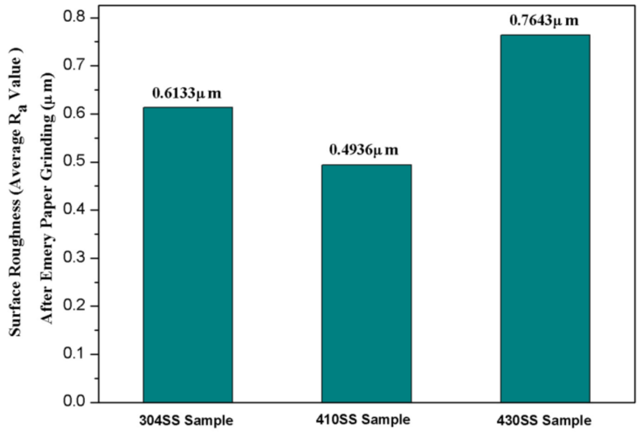


Fig: 2. Surface finish data are presented in bar diagram form

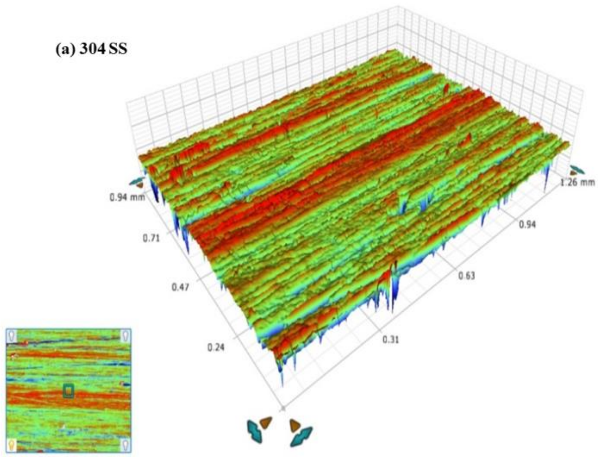


Fig: 3(a).3D pictures of the surface topographyand surface roughness of 304 stainless steel sampleobtained after emery paper grinding by 3D optical surface profilometer

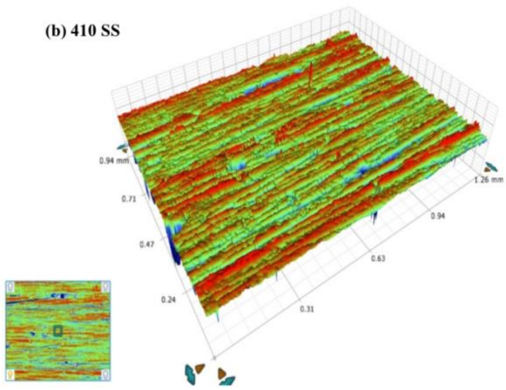


Fig: 3(b).3D pictures of the surface topographyand surface roughness of 410 stainless steel sampleobtained after emery paper grinding by 3D optical surface profilometer

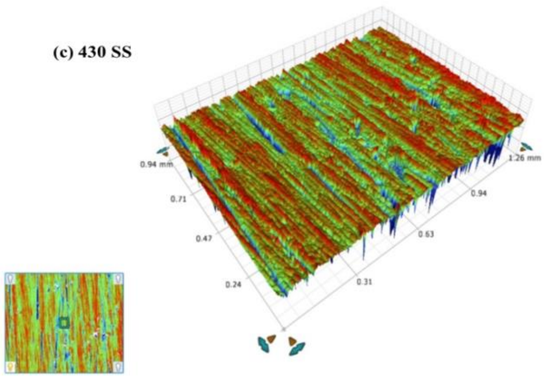


Fig: 3(c).3D pictures of the surface topographyand surface roughness of 430 stainless steel sampleobtained after emery paper grinding by 3D optical surface profile meter

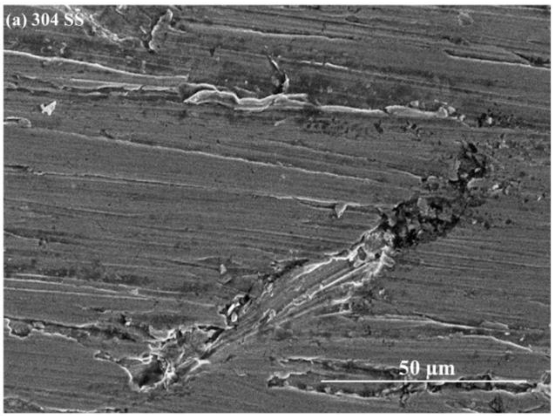


Fig: 4(a). 304 stainless steel sampleSEM photographs ofemery paper grinding

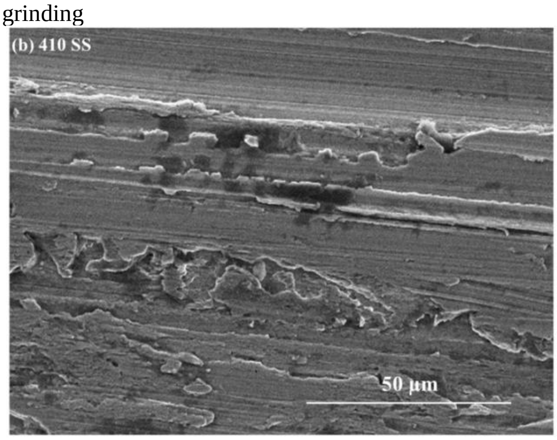


Fig: 4(b).410 stainless steel sample SEM photographs ofemery paper grinding

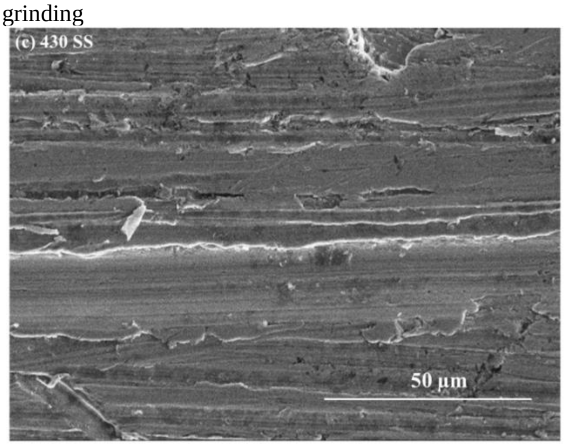


Fig: 4(c). 430 stainless steel sample SEM photographs ofemery paper grinding

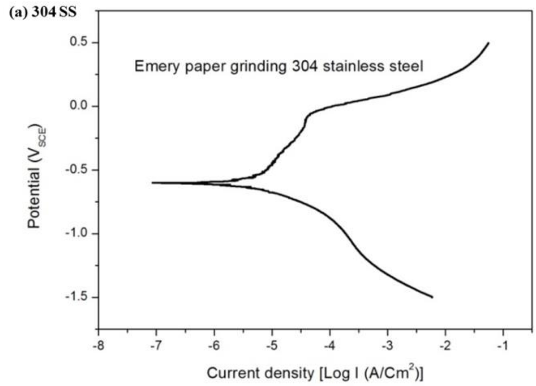


Fig: 5(a). The experimental polarisation curve of 304 stainless steel sample

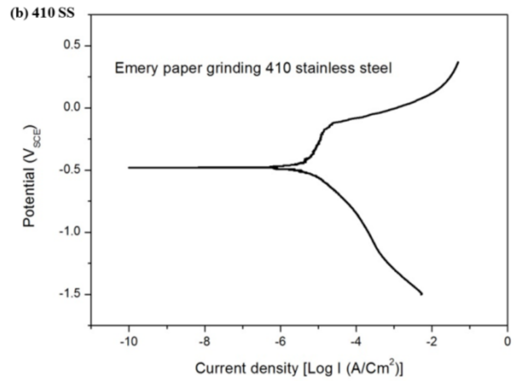


Fig: 5(b). The experimental polarisation curve of 410 stainless steel sample

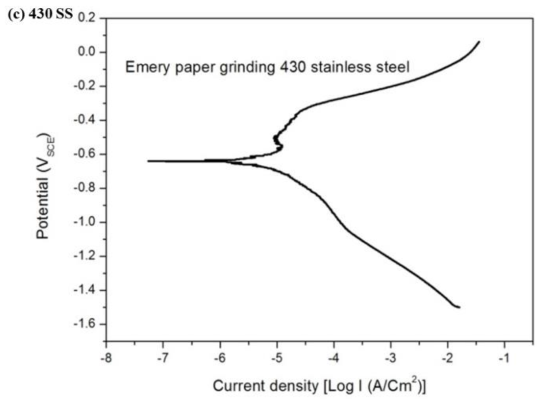


Fig: 5(c). The experimental polarisation curve of 430 stainless steel sample

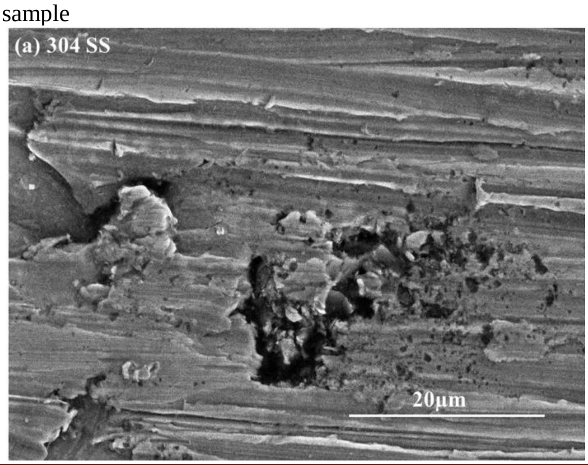


Fig: 6(a). Emery paper grinding corroded sample of 304 stainless steel sample

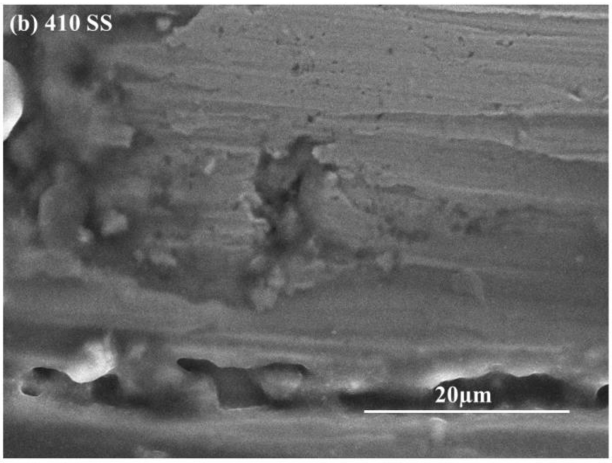


Fig: 6(b). Emery paper grinding corroded sample of 410 stainless steel sample

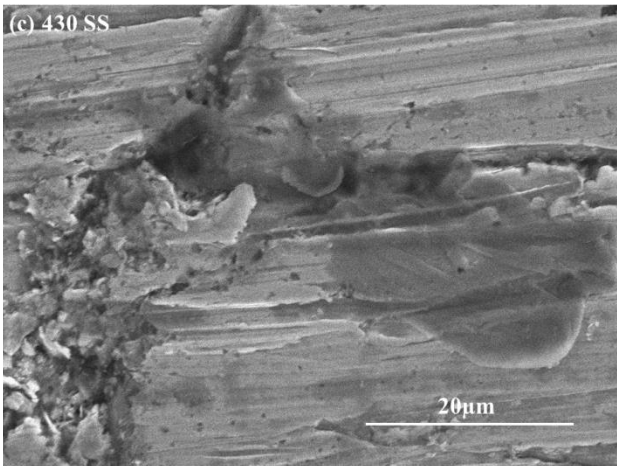


Fig: 6(c). Emery paper grinding corroded sample of 430 stainless steel sample

3. Result and Discussion

The surface finish data are presented in bar diagram form in fig.2. The 410 martensitic stainless steel developed the smoothest surface, obviously because of its higher hardness.The ferritic 430 stainless steel had developed the roughest surface. Of course, the variation of roughness of all the steels was in the range of 0.5 to 0.75 µm only. Comparatively, the roughness of the metallographically polished samples was insignificant. The mode of metal removal and the extent of surface damage could be better appreciated from the 3D pictures and SEM photographs of the surfaces presented in fig.3 (a, b & c) and fig.4 (a, b & c). Emery paper grinding progressed mainly by rubbing and ploughing. But it is apparent from the SEM photographs in fig.4 (a, b & c) that microcracking and gouging out of grains also occurred.The gouging effect was most prominent in case of 304 stainless steel, which was the softest steel among the three.

The electrochemical data collected from the potentiostat test are presented in table 2. The potentiostat curves are presented in fig.5 (a, b & c). The tabular data clearly illustrate the effect of surface finish. The metallographically polished samples of the three steels suffered insignificant corrosion compared to that of the emery paper ground samples.

The corrosion rate/year was highest for the 410 stainless steel, and lowest for the 430 stainless steel, which recorded maximum and minimum roughness respectively after emery paper grinding. The SEM photographs of the corroded samples of the three stainless steels shows corrosion pits in fig.6 (a, b & c). Figure 6 (a) shows corrosion pits are most prominently formed in region of grains pull outs. The ploughing marks are still present. In addition to the formation of corrosion pits, the cracks on the surface have also suffered further corrosion in case of 410 stainless steel sample shown in figure 6 (b). The corrosion pattern on 430 stainless steel surface shown in figure 6 (c) is more or same as in figure 6 (b). Surface finish is known to have marked effect on pitting corrosion. The present results are in conformity with the existing epicene that pitting corrosion is less likely to occur on a polished than on the ground surfaces.

4. Conclusions

- Metal removals from surfaces of different grades of stainless steels occur by rubbing, ploughing and gouging out of grains. Surface roughness of all types of stainless steels after the emery paper grinding is still significantly high.
- Surface roughness has direct influence on the corrosion rate of stainless steels in 0.9N NaCl solution.
- Corrosion progresses prominently from the pits generated during emery paper grinding.

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iii. Prof. Ajit K. Chakrabarti is the principal supervisor for Mr. Abhimanyu Chaudhari.
iv. Prof. Tushar K. Roy is co-supervisor for Abhimanyu Chaudhari.

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Nomenclature

SEM	Scanning Electron Microscope
SS	Stainless Steel
Ra	Arithmetic average roughness
µm	micrometer
E_{Corr}	Potential corrosponding to active to passive zone
I_{Corr}	Current density for passive layer formation