Effect Of Surface Patterning On Corrosion Behavior Of SS304 Stainless Steel

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Abstract:

SS304 stainless steel is used as a structural/component material in aircrafts and ground vehicles. Corrosion degrades the performance of mechanical structures/components as it drastically reduces their operating lifetime by causing early failures. Traditionally, coatings and inhibitors are used to mitigate corrosion. In recent years, surface patterning is being explored as an alternative route to alleviate corrosion. In this work, the wetting characteristics and corrosion behavior of microgroove patterned SS304 stainless steel surfaces are investigated in order to understand the relationship between these two properties. Groove shaped patterns were created at micro-scale on the steel surface with varying ridge and channel widths by photolithographic technique. Structural features of the patterned surfaces were characterized using 3D optical profilometry. The wetting behavior of the test samples was characterized by the sessile drop method. The corrosion behavior of the test samples was studied using an electrochemical test setup with saline water as the corrosive media. Parameters such as corrosion potential, current density and polarization resistance were obtained from TAFEL plot to quantify the corrosion rate. Results showed that the microgroove patterned surfaces were hydrophobic and had anisotropic wetting characteristics. The corrosion rates of the patterned surfaces were significantly lower when compared to that of the flat steel surface. A direct relationship was observed between the wetting characteristics and corrosion behavior of the test samples. The improvement in corrosion resistance shown by the patterned surfaces is explained in terms of their wetting characteristics.

Keywords: micro patterned surface, hydrophobicity, current density, corrosion potential, corrosion rate

1. Introduction

Corrosion is one of the major issues in affecting the structur alintegrity of the air craft. Globally researchers are working on the ways to decrease the severity of the corrosion as much as possible. Coating is one of the commonly accepted solutions to eradicate corrosion. While the structure is undergoing stress either it may be mechanical or thermal, paint will lead to peel off which kind le sus to go for al ternative means to control corrosion. The nature it self gives the possible solution to eradicate corrosion. Hydrophobic surface which repel sthe contact of water from the surface like water rolling on the lotus leaf. The surfaces with contact angle (0) $90^0<0>150^0$ and lower contact angle hysteresis known as hydrophobic surface. The contact angle hysteresis is the difference between advancing (0_A) and receding (0_R) contact angle which helps the water droplet to bounce and roll on the surface leads to self cleaning property. The hydrophobic surface has wide application such as

wetting, corrosion, anti icing etc.,[1]

The hydrophobic surface can be achieved either by coatings or micropatterning the surface. For long run coating is not suitable hence micropatterning is preferred in our work. Most of the machined component surfaces were compiled of micropillars / posts, micropits, microgrooves as the roughness asperities. The variation of the surface roughness R_a is directly linked with wetting behavior of the material which determines the contact angle of the surface [2-3]. By roughening the surface air is trapped on the rough surface between solid and liquid interface. The contact angle for air is more than 180^0which makes the surface hydrophobic.

Bychoosingsuitableroughnessonecanablereduce the penetration of liquid in to the solid surfaces and in turn, the corrosion can be controlled through the augmented Laplace Pressure offered by the micropatterns [4-7]. In this paper, micro groove patterned rough surfaces likewise in paddy leaf will be created on the stainless steel S304 surface which is majorly used in the mechanical components and structures and the corrosion behavior was studied with respect to itswettability.

2. Experimental

2.1 Surface Preparation andCharacterization

The surface of the SS304 samples was polished initially by emery sheet to remove the bur and impurities on the surface followed by cleaning using acetone and distilled water. Photolithographic technique was preferred to impinge micro groove pattern on the surface with different ridge width to channel ratio. The morphology of the microgroove patterns was measured using 3D optical profilometer with the help of Veeco software and it was listed in Table1. For better understanding SEM image was taken which was shownin Fig.1.

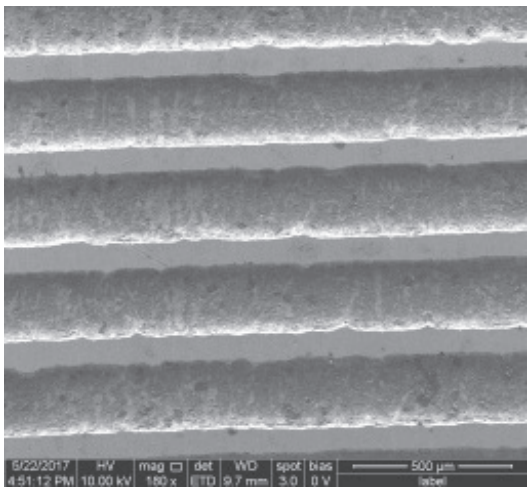


Figure 1: Micro Groove Patterns Captured using SEM

2.2 Static Contact Angle and Contact DiameterMeasurement

Wetting study was conducted on both plain and micropatterned surface by capturing the morphology of the liquid droplet placed on the surface using high speed camera. The sample was thoroughly cleaned before starting the experiment to remove the impurities and substrates on the surface. Microgroove patterned surface follows heterogeneous wetting [3]. Hence image was taken both perpendicular and parallel to the grooves. For each case 10 sets of experiment was conducted at different places on the surface of the specimen and the average value was taken with standard deviation. The static contact angle and static contact diameter of the liquid droplet was measured using Image J software and the results were shown in Table 2.

Table 1: Geometrical Dimension of Microgroove Patterned Surface

S.No	Sample	Ridge Width (µm)	Channel Width (µm)	Channel Depth (µm)	Solid Fraction
1	MP 1	58.27	182.18	43.9	0.24234
2	MP 2	97.24	261.14	42.7	0.27133
3	MP 3	112.5	188.53	40.14	0.37372

2.2 Measurement of Corrosion Characteristics

The corrosion characteristics of plain and microgroove patterned surface was quantified by means of conducting electrochemicale xperimentins aline water environment with pHvalue8. The sample was immersed in saline water for 1hr dwell time to stabilize before starting the experiment. The surface area of the specimen exposed to the corrosive

Table 2: Wetting Characteristics of Plain and Microgroove Patterned Surface

S.No	Sample	Contact Angle0_T (degree)	Contact Angle0_N (degree)	Contact Diameter D_T(mm)	Contact Diameter D_N(mm)
1	Plain	77.719		3.275	
2	MP 1	127.77	88.37	1.815	2.84
3	MP 2	138.98	103.25	1.563	2.16
4	MP 3	124.32	82.32	1.956	2.97

environment is 1cm^2. By using NOVA software TAFEL plot was generated for both plain and micropatterned surface. The fitting parameters like corrosion potential, polarization resistance, corrosion current and corrosion rate were obtained from TAFEL plot and it was listed in Table3.

Table 3: Corrosion Characteristics of Plain and Microgroove Patterned Surface

S.No	Sample	Corrosion Potential(V)	Icorr (A)	Corrosion rate (mm/year)	Polarization Resistance (fi)
1	Plain	-0.557	1.116e-005	0.121	3240
2	MP 1	-0.492	3.415e-006	0.037	9523
3	MP 2	-0.347	2.745e-006	0.029	9782
4	MP 3	-0.509	4.360e-006	0.047	6045

3. Results andDiscussion

3.1 WettingStudy

Static contact angle measured on micro patterned shows better wetting property when compare to plain surface. The contact angle measured on plain sample is below 90^0 which are not showing hydrophobic behaviour. Microgroove pattern surface shows heterogeneous wetting behaviour, the morphology of the liquid drop let varies from along the groove stoper pendi culartо the grooves. Static contact angle measured perpendicular to the groove shows more than 124^0 because the spreading of waterdrop let was arrested with presence of ridges. Mean while for parallel to the groove case exhibits contact angle more than 82^0 which is lower than perpendicular to the groove case because the water droplet caneasilys preadalong the channels. The variation in contact angleand contact diameter with respect to the solid fraction was shown in Fig. 2. The contact angle increases upto solid fraction 0.3 then drop occurs this may bedue to the capil larity effect induced by the entr appedair molecule in the channels. This phenomenon totally depends upon the morphology of the surface and roughness. For the geometrical dimension considered in our study the capil larity effect supports solid fraction upto 0.3 then drop occurs. The contact diameter also follows the same trend as contact angle. The contact diameter of the liquid droplet on the surface of the sample is more for plain surface when compare to the micropatterned surface.

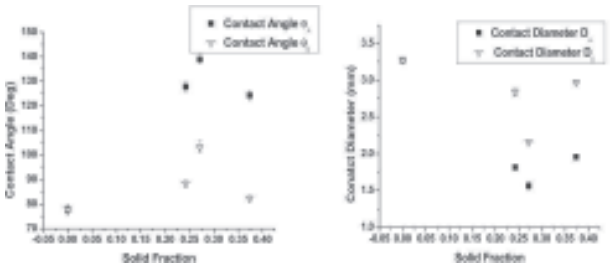


Figure 2: Variation of Wetting Characteristics with respect to Variation in Solid Fraction

3.2 Corrosion Study

The overall fitting parameters obtained from TAFEL

plot shows microgroove pattern have better corrosion resistant property when compare to the plain surface. The fitting parameters obtained from the TAFEL plot are compared with solid fraction and the results were shown in Fig. 3.

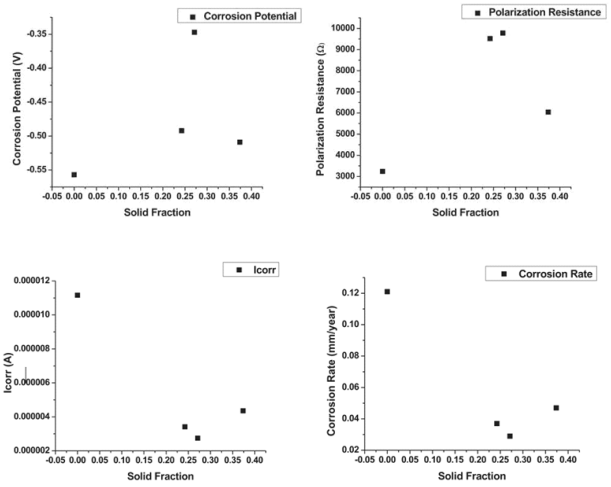


Figure 2: Variation of Fitting Parameter with respect to Variation in Solid Fraction

Corrosion potentialtries to shift from negative to positive valuedue to the implementation of micropatterns. However it increases upto solid fraction 0.3 then drop occurs due to the loss of capillarity effect. Meanwhile all other fitting parameters are also follows the same trend. Within the geometrical dimension taken in our study microgroove patterned sample MP2 with solid fraction 0.27133 shows better resistance to corrosion with corrosion rate 0.029mm/year which is drastically less when compare to the plain surface whose corrosion rate is 0.121mm/year.

Form the above results it is clearly understood surface morphology, wetting behavior and corrosion behavior are interlinked with each other. Wetting and corrosion resistance are inversely related with each other, if wetting decreases corrosion resistance leads to increase. The reason is according to Cassie Baxter air pockets are formed in the gap between the channels which provides the cushion effect and opposes the penetration of chloride ions within the channel. Literally the liquid drop let is floating over the channel and it reduces the contact area of the environment with the parent material. Corrosion resistance property of any material can be maximized by inducing micro groove patterns on the surface. Yet there are several other techniques like coatings are available but they failed to do their role in the presence of stress and it will peel off after acertain period of time. Microgroove patterns may stand as a possible solution to eradicate corrosion even in the presence of stress.

4. Conclusions

From our research work the following conclusions are arrived,

- Microgroove pattern surface acts as hydrophobic surface and its contact angle is more than $124^0$for SS304 steelsurface.
- Microgroove patterns surface shows composite wetting i.e., heterogeneous wetting nature.
- Microgroove pattern surface have better corrosion resistance property and less wetting character is tics when compare to the plain surface.Within the geometrical dimension taken in our study, wetting decreases up to solid fraction 0.3 then increases meanwhile corrosion resistance shows opposite trend because both are inversely related with eachother.

Microgroove patterning the surface is the innovative way to reduce corrosion even in the presence of stress and suitable for prolong application

5. References

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