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STRESS RELIEVING AS A TECHNIQUE FOR IMPROVING THE CORROSION RESISTANCE OF LOW ALLOY STEELS

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ABSTRACT

The corrosion behaviour of a low alloy steel in 18% H_2SO_4 solution, containing 1000 ppm chloride ion, after annealing and stress relieving is reported in this study. Annealing, followed by stress relieving at 400°C, appears to improve the corrosion resistance properties of this alloy.

Key Words: Stress relief, corrosion resistance, alloysteels.

INTRODUCTION

Low alloy steels, fall under the carbon-steel group and have carbon content in the range of 0.15–0.20% with alloying elements like, Ni, Cr, Cu, W, Si, Al, etc. in lower concentrations. Such an alloy reveals high strength to weight ratio and finds applications in mining industries and ropeways.

They have also been reported to reveal higher corrosion-resistance than mild steels, in some applications. However, the reason behind the lower corrosion rates, is not clearly known. Reports regarding the corrosion behaviour of low alloy steels, in presence and absence of chloride ions, after stress relieving treatment are very few, although extensive work [1 – 9] have been reported, correlating microstructure with corrosion rates and film thickness for different compositions.

This investigation analyses the corrosion behaviour of a low alloy steel as a function of annealing and stress-relieving process, using potentiodynamic and potential vs time data and corrosion-rates based on weight-loss technique. Rockwell hardness values and S.E.M. photomicrographs are also presented.

EXPERIMENTS

a) Materials

Low alloy steel specimens having the following percentage compositions were used; C=0.15%, Mn=0.44%, Ni=0.74%, Cr=0.57%, Cu=0.09%, Pb and Sb traces. Rectangular specimens of identical surface area, are employed for the electrochemical studies. Material composition is determined by atomic absorption spectro photometric method.

(b) Procedure

(i) *Corrosion-rate:* Rectangular specimens of identical surface area of 1 cm^2, polished with extra fine emery paper and degreased with trichloroethylene, are immersed in 100 ml. of 18% H_2SO_4 solution, for a period of 1 hour. The corroded specimens are cleaned in clark's solution and the weight loss values are determined.

(ii) *Heat treatment:* The specimens of low alloy steels are annealed at 910 ± 50°C, in an inert atmosphere. The soaking period, employed in the annealing process is at the rate of 1 hr/sq. inch cross-sectional area. Annealed specimens are stress relieved at 400°C, for different periods in a horizontal muffle-furnace, under controlled environment.

(iii) *Micro-examination and hardness:* Microstructure is studied in both metallurgical and scanning electron microscope. Hardness values are determined in Rockwell hardness testing machine.

(iv) *Electrochemical tests:* The specimens are anodically polarized, using the potential sweep cyclic voltammetric-technique at a scan-rate of 50 mV/sec and the potential-current values are recorded. Potentials are recorded, using micro voltmeter with respect to Hg/$HgSO_4$ in 18% H_2SO_4 solution, as a function of time.

RESULTS AND DISCUSSION

Table I reveals the effect of annealing and stress relieving heat treatment on the physical and chemical properties of the low alloy steel. Stress relieving at 400°C for 15 hours, decreases the weight-loss corrosion-rate values in 18% H_2SO_4 solution. The potentials become more positive, after annealing, followed by stress relieving in 18% H_2SO_4 solution, both in presence and absence of 1000 ppm chloride ion. The corresponding corrosion currents have been reduced considerably, which

Table I: Effect of heat treatment on the physical and chemical properties of the low alloy steel

sl. No.	Treatment	Hardness (Rc)	Corrosion rate x 10^{-4} (g/sq. cm^2/hr.)	Potential at passive transpassive transition (mV)		Current at passive transpassive transition (mA)	
				18% H_2SO_4	18% H_2SO_4 + 1000 ppm chloride	18% H_2SO_4	18% H_2SO_4 + 1000 ppm chloride
1.	Annealed at 910 ± 50°C	57 ± 1	5.15 ± 0.05	1200	1210	100	227
2.	Annealed at 910 ± 50 °C and stress relieved at 400°C for 15 hrs	51 ± 1	4.08 ± 0.05	1300	1310	50	102

indicate the improvement in corrosion-resistance properties. Stress relieving results in the decrease of hardness values from 57 Rc to 51 Rc.

Table II, shows the effect of stress-relieving time on the potential values in 18% H_2SO_4 with 1000 ppm chloride ion as well as the microstructure and hardness of the low alloy steel. It is observed that the potential values, tend to become more positive, as the stress relieving time is increased from 5 hours to 15 hours. Microstructure examined under microscope, reveals that coagulation at the grain-boundaries, increases with stress relieving time. Stress relieving for a period of 15 hours reveals ordered black lines at higher magnification. Average hardness values, also reveal a decreasing trend with stress relieving time.

Therefore the mechanism behind stress relieving of the annealed specimens, appears to be analogous to a process, where the micro stresses are relieved progressively, resulting in the ordering of the matrix. Such microstructural modification appears to improve the corrosion-resistance characteristics, by the formation of a stable passive film.

Table II: Effect of time on potential vs time, microstructure and hardness of the annealed and stress-relieved specimens (18% H_2SO_4 + 1000 ppm chloride)

Stress relieving time (hour)					
5		10		15	
Min.	mV	Min.	mV	Min.	mV
0	−450	0	−300	0	−420
10	−430	10	−365	10	−420
25	−425	25	−360	25	−437
35	−423	35	−300	35	−220
45	−405	45	−235	45	−150
60	−490	60	−220	60	−60
Microstructure					
Grains and grain boundaries (Fig. 1)		Grains with coagulation within grain boundaries (Fig. 2)		Grains with coagulated grain boundaries (Fig. 3) and an ordered pattern of dark bands (Fig. 4)	
Average Hardness (Rockwell – c)					
55 ± 1		53± 1		51 ± 1	

53 ± 1

S.E.M Photographs

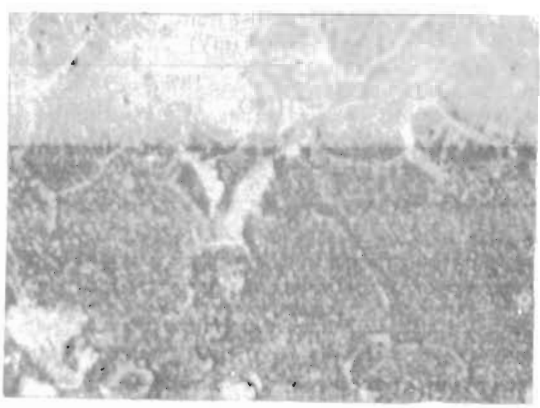


Fig. 1

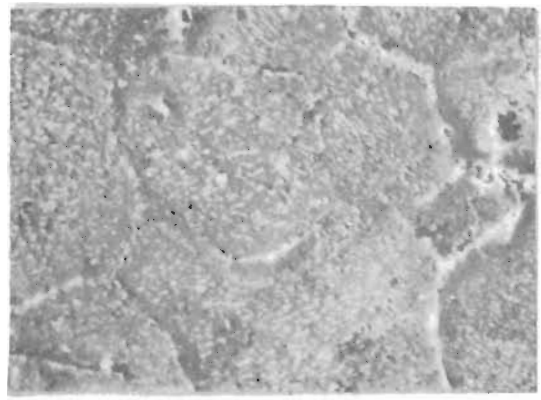


Fig. 2

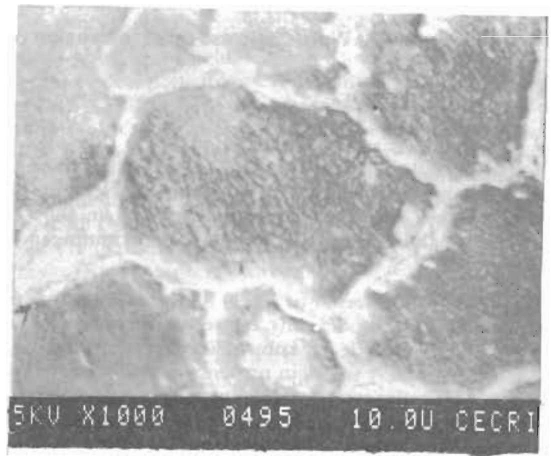
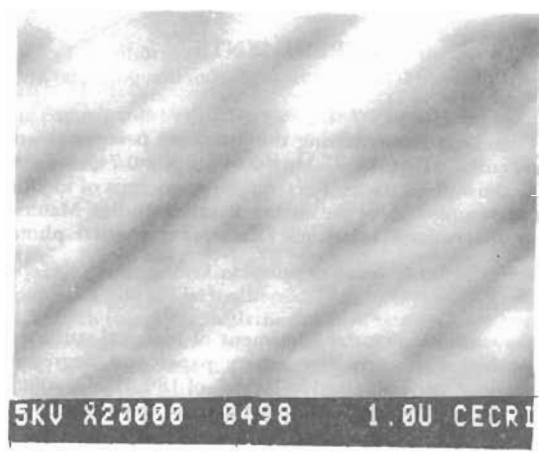


Fig. 3



CONCLUSION

In conclusion, stress relieving of annealed specimens of low alloy steel, appears to improve the corrosion resistance, at the cost of marginal reduction in hardness.

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