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Mechanism of stress corrosion behaviour of prestressing steel in phosphate medium

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SCC behaviour of cold drawn and stress-relieved prestressing steel has been studied at room temperature in 1N Na_2HPO_4 at pH 3. Effect of stress on anodic polarisation behaviour was studied. Time-to-failure was studied under unpolarised and polarised conditions. Susceptibility increased under constant cathodic overpotentials and decreased under constant anodic potentials. This study confirms the hydrogen embrittlement mechanism.

Key words: Stress corrosion cracking, prestressing steel, hydrogen embrittlement

INTRODUCTION

Stress corrosion cracking (SCC) behaviour of pure iron, mild steel and C-Mn steels has been widely studied and a variety of environments have been identified. Cold drawn prestressing steel has been shown to exhibit SCC in sulphide and nitrate media [1]. SCC of prestressing steel in sodium phosphate medium was studied and a mechanism involving hydrogen embrittlement was proposed [2]. Susceptibility was found to decrease under cathodic or anodic polarised conditions whereas it was maximum under unpolarised conditions. To understand the phenomenon better, further studies were carried out in extra pure 1N dibasic sodium phosphate at pH 3 and the results are presented in this paper.

EXPERIMENTAL

Material: Cold drawn and stress relieved prestressing steel of nominal diameter of 7mm was machined to a reduced diameter of 3mm and gauge length of 21mm. Prior to testing, the specimens were mechanically polished and degreased with trichloroethylene.

Test medium: 1N dibasic sodium phosphate (analytical grade) at pH 3.0.

Test equipment: Mayes Unisteel constant load SCC testing machine was used for time-to-failure studies. For electrochemical studies a Wenking model potentiostat was used. The stress corrosion cell consisted of a platinum gauze auxiliary electrode and saturated calomel reference electrode.

Fractography: Fractography of the failed samples was studied using scanning electron microscope.

RESULTS AND DISCUSSION

Time-to-failure studies were carried out under a constant stress of 90% proof stress (a) under unpolarised conditions (b) under constant anodic potentials and (c) under constant cathodic potentials. In addition, the dynamic anodic polarisation behaviour of prestressing steel under stressed and unstressed conditions was studied at a sweep rate of 10 $mV.sec^{-1}$.

The anodic polarisation behaviour is of an active-passive type and there is no significant difference between stressed and unstressed conditions.

The time-to-failure under unpolarised and polarised conditions is given in Table I. It is seen that cracking occurs at room temperature even under unpolarised conditions within 9 hrs.

The steel is not found susceptible to cracking under constant anodic overpotential over a wide range of 100-1700 mV. This covers active zone, active to passive zone, passive zone and transpassive zone. This is to be expected since stress has no influence on the anodic polarisation behaviour. It has been reported that in the case of nitrate medium, application of stress significantly alters the dynamic anodic polarisation behaviour and a region of unstable passivity is obtained under stressed conditions [3]. Cracking could be obtained under different anodic overpotentials in such systems.

Under cathodic polarised potentials it is observed that time-to-failure significantly decreases at the overpotentials in the range 500-1200 mV. It may be inferred that hydrogen embrittlement may be the predominant mechanism because of cathodic charging. However, it is significant to note that no failure occurs for a reasonable period of 10 hrs under a cathodic overpotential of 250 mV.

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TABLE–I: Effect of polarisation on time-to-failure

Time to failure at rest potential: 9 hrs

	Overpotential (mV)	Time-to-failure (minutes)
Anodic		
	100	NF
	350	NF
	500	NF
	1000	NF
	1500	NF
	1700	NF
Cathodic		
	250	NF
	500	81
	750	55
	1000	35
	1200	65

NF —No failure for a period of 10 hrs

Typical fractograph of the failed specimen is shown in Fig. 1. Fracture mode appears to be predominantly transgranular.

CONCLUSION

Cold drawn and stress relieved prestressing steel is susceptible to cracking in 1N sodium phosphate (dibasic) at pH 3.0. The susceptibility decreases under constant anodic overpotentials and increases under constant cathodic overpotentials.

Fig. 1: SEM of the fractured surface of the specimen failed at a constant cathodic overpotential of 500 mV

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