THE CORROSION OF HIGH SPEED STEEL IN AQUEOUS MEDIA

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ABSTRACT

Th corrosion of M2 high speed steel in aqueous media containing chloride, bromide, iodide, nitrate, sulphate and perchlorate salts of sodium and potassium of varying concentration has been studied using corrosion potential measurements, voltammetric and electrochemical impedance techniques. The influence of the cation was found to be small and an order of anion aggressivity was established as: sulphate > chloride > bromide > perchlorate > iodide > nitrate.

INTRODUCTION

High speed steels have important applications in tools and drills, and are often used as substrates for wear-resistant hard thin film coatings. These coatings need to exhibit good corrosion resistance as well as good wear resistance. A study of the corrosion of the high speed steel in diverse environments is important in developing a diagnostic for the breakdown of the coatings in these media.

For this purpose M2 high speed steel was employed, which is an austenitic steel obtained using powder metallurgy technology. Manufacture is followed by annealing, quenching and tempering processes, which alters the microstructure and leads to high hardness and high toughness [1,2].

The electrochemical characteristics and corrosion resistance of samples of high speed steel in aqueous environments containing different inorganic salts of sodium and potassium were evaluated using corrosion potential measurements and their variation with time, voltammetric techniques and electrochemical impedance spectroscopy. The reproducibility of corrosion phenomena was tested and localised corrosion and pitting investigated.

EXPERIMENTAL

Discs of heat-treated M2 high speed steel (6.4% W, 5.0% Mo, 4.2% Cr, 1.9% V, 0.9% C) of area 0.8cm2 were mounted as electrodes, attaching a wire to the rear, and covering with epoxy resin, leaving just one face exposed. This was polished down to 1µm particle size with diamond lapping compound. Solutions containing chloride, bromide, iodide, nitrate, sulphate and perchlorate salts of sodium and potassium of varying concentration were prepared using Millipore Milli-Q water. A 3-electrode cell containing a Pt foil auxiliary electrode and saturated calomel reference electrode was employed, and controlled by a PAR273 potentiostat or a Solartron 1250/1286 frequency response analyser with electrochemical interface combination for impedance experiments.

RESULTS AND DISCUSSION

Corrosion potential measurements showed initially sharp variations towards negative values, stabilising after about one to two hours, see Fig.1 and Table 1. Measurements of polarisation resistance are shown in Table 1, as are corrosion currents from Tafel analysis, see also Fig.2.
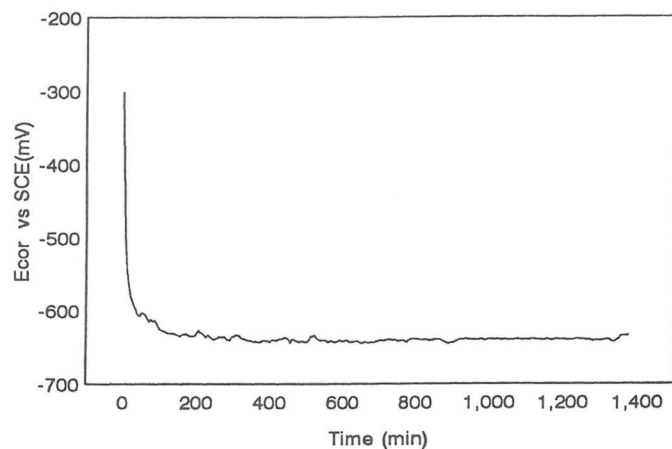

Fig.1 Variation of corrosion potential, E_{cor}, of M2 steel in 0.1M K_2SO_4 with time.

It can be seen that the data from the several types of experiment follow the same trend, in terms of effect of anion and cation influence. In particular, a less negative corrosion potential implies a higher polarisation resistance and lower corrosion current. There was evidence of significant pitting: pitting and protection potentials in cyclic

Table 1 Data from experiments with M2 steel

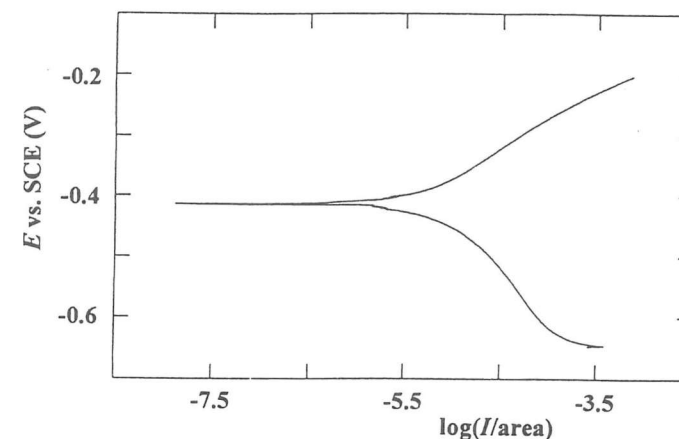| Solution	t_i/min.	E_{cor}/mV (1300 min.)	R_p/kΩ cm^2	I_{cor}/µA cm^{-2}
K_2SO_4	45	-640	1.1	15.9
KCl	90	-595	1.9	7.4
KBr	85	-595	2.1	6.5
KI	140	-540	4.6	3.6
KNO_3	180	-475	5.7	2.9
NaCl	70	-575	1.5	7.6
NaBr	85	-583	2.1	6.4
$NaClO_4$	95	-605	2.3	5.1

Fig.2 Linear sweep voltammetry of M2 steel in 0.1M KCl; scan rate 2mV s^{-1}.

voltammetry gave results in the range -0.5 - -0.25V and -0.60 - -0.35V vs. SCE respectively, the more positive values corresponding to the less aggressive media.

Impedance spectra showed evidence of charge separation and diffusion processes. Modelling of the interface was possible with two parallel pathways containing one or (in the case of sulphate anion - the most aggressive) two constant phase elements. This was reasonable given the existance of pits and large areas of the surafce which were either not visually corroded or corroded in a uniform fashion. The

microscopic roughness of the electrode surface led to the necessity of using constant phase elements.

Visual observations were made using optical and scanning electron microscopy with chemical microanalysis of the corrosion products. This showed that iron was preferentially oxidised within the pits, there being debris around the edge of the pit on top of the polished surface which was rich in iron - presumably iron oxide. Pit density was greatest for sulphate-containing solutions followed by chloride.

General analysis of the experimental data shows that there is a marked influence of the anion present on the corrosion rate and corrosion mechanism. In the presence of sulphate, chloride, bromide and perchlorate there is significant pitting corrosion, observed electrochemically and through visual observation. With respect to iodide ion, the corrosion rate is much lower but experimental evidence obtained from current-voltage profiles and impedance plots points to the mechanism being the same. For nitrate anion there are clear inhibition effects and the pitting potential is significantly more positive than for the other anions. The effect of the cation being sodium or potassium is very small, observed differences being attributable to differences in solution conductivity.

We conclude with a general order of anion aggressivity in these type of media towards M2 steel:

sulphate > chloride > bromide > perchlorate > iodide > nitrate

with little influence arising from the presence of sodium or potassium cation.

ACKNOWLEDGEMENTS

REFERENCES

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CHEMICAL AND ELECTROCHEMICAL BEHAVIOR OF URANYL COMPOUNDS IN OXIDE SALT MELTS

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Influence of the composition of molten mixtures Me_2RO_4- $Me_2R_2O_7$- UO_2RO_4 (Me = Li, Na, K, Cs; R = S, Mo, W) and of the main potentiostatic electrolysis parameters on the chemical, phase composition of cathode deposits and on their current efficiencies have been studied. Experiments were carried out at temperatures of up to 900°C in the air. It has been showed that uranyl-containing oxide salt melts with various cationic and anionic composition can be used for electrochemical obtaining of granular uranium oxides with the O / U atomic ratio ranging from 2.014 to 2.667.

Key words: salt melt, electrolysis, cathode deposit, uranium oxides, current efficiency, uranyl salts, sulphates, molybdates, tungstates.

The poured nuclear reactor fuel elements manufactured from UO_2- PuO_2 or UO_2 electrolytic granules by the vibro-compaction method went through the prolonged reactor tests and demonstrated the high performance characteristics. At the same time it is well known that the gaseous chlorine used at the stage of the irradiated fuel dissolution in