

CREEP RUPTURE PROPERTIES OF Cr-Mo STEEL

S. AHILA and S. RAMAKRISHNA IYER

*Department of Metallurgical Engineering,
Indian Institute of Technology, Madras 600 036, India*

ABSTRACT

This paper describes the creep rupture properties of 2.25Cr-1Mo steel in salt mixture containing sodium sulphate and potassium pyrosulphate. To begin with, fusion point determination of various compositions of this mixture was carried out. Lowest melting mixture was selected as a corrodent for creep studies. The creep results of coated specimens was compared with that of uncoated specimens. It was observed that the coated specimens showed higher rupture life and lower creep rate. The coating acted as a protective layer for oxidation reactions.

KEYWORDS

2.25Cr-1Mo steel, Creep, high temperature, rupture life, hot corrosion, sulphate-pyrosulphate mixture.

INTRODUCTION

Creep resistant low alloy 2.25Cr-1Mo steel is widely used in power generating stations for superheater tubes. The main advantage of this steel is the improved creep strength from chromium and molybdenum additions and enhanced corrosion resistance from chromium. This steel which has substantial documentation of its elevated properties is discussed in more detail elsewhere (Smith, 1971; Cane, 1979, 1983; Viswanathan, 1974; Klueh and Oakes, 1976).

Superheaters are exposed to fuel impurities containing sulphates and chlorides of sodium and potassium. These salts form deposits on the surface of the alloy which at the operating temperatures may form liquid phase. The formation of eutectic liquid phase results in accelerated attack of the material due to enhanced diffusion of reacting gases through it (Alexander, 1963; Stringer, 1985).

This paper presents the effect of salt mixture on the creep rupture properties of 2.25Cr-1Mo steel.

EXPERIMENTAL PROCEDURE

Deposits from boiler tubes showed the presence of pyrosulphates and sulphates of sodium and potassium. Initial study was undertaken to find out the possibility of formation of low melting mixture of these salts.

Determination of eutectic point of the mixture. Various compositions of sodium sulphate and potassium pyrosulphate were taken in an alumina crucible. These were heated in a well insulated pot furnace whose heating and cooling rates were adjusted to be 3°C per minute. The fusion of the mixture and the appearance of liquid phase were observed visually during heating. The mixture was cooled from above its melting point and the cooling rate of each salt mixture was recorded. Near the region of the melting point, the cooling rate (rate of change of temperature, T with time, t that is dT/dt) was the lowest. The temperature at which dT/dt was minimum was taken as the melting point of the mixture. The lowest melting mixture was used as a coating for hot corrosion studies.

Effect of hot corrosion on creep. To understand the mechanism of hot corrosion and creep, 2.25Cr-1Mo steel specimens were coated with a mixture of 30% Na_2SO_4 and 70% $K_2S_2O_7$ and subjected to creep tests in single lever constant load creep machines. The specimens were of 40mm gauge length, 4mm width and 2mm thick. Creep tests were done at temperatures of 550°C and 600°C and stress levels of 170 MPa and 180 MPa. The results were compared with that of uncoated specimens.

RESULTS AND DISCUSSION

Fig.1 shows the variation of melting point with weight percentage composition of sodium sulphate in the mixture containing sodium sulphate and potassium pyrosulphate.

The minimum melting point of the mixture was found to be 170°C which corresponds to the composition of 30% of sodium sulphate and 70% potassium pyrosulphate by weight.

Fig. 2 and Fig. 3 show the creep rupture characteristics of 2.25Cr-1Mo steel. Increase of stress or temperature decreased the rupture life and increased the creep rate. It was interesting to observe that the coated specimens

showed lower creep rate and higher rupture life compared to that of pure specimens.

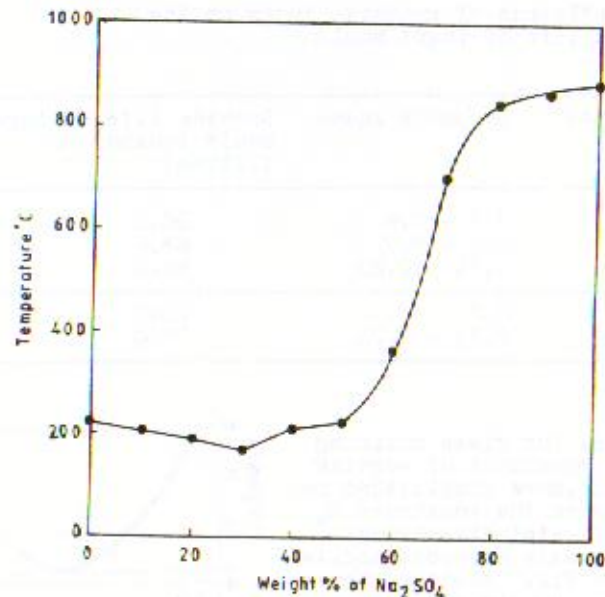


Fig. 1. Binary Phase Diagram of $Na_2SO_4 - K_2S_2O_7$ System

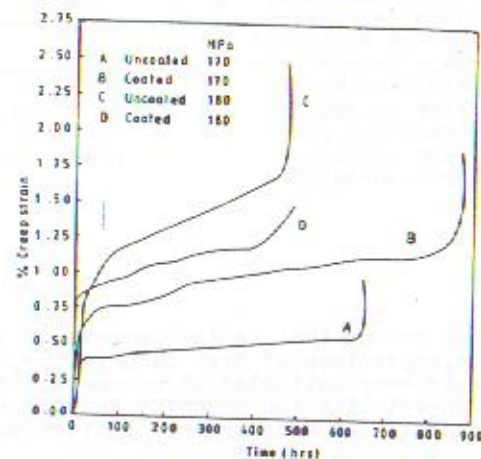


Fig. 2. Creep Curve of 2.25Cr-1Mo steel at 550°C

To understand the mechanism of this reverse trend, the weight gain studies were carried out on pure and coated coupons. The coated specimens showed lower weight gain compared to uncoated ones. The surface of both specimens showed loosely bound oxide layers. But the depth of attack was found to be less on coated specimens. This showed that the coating could protect the base material from attack to some extent though not prevent it from attack completely, since ultimate failure resulted in both cases.

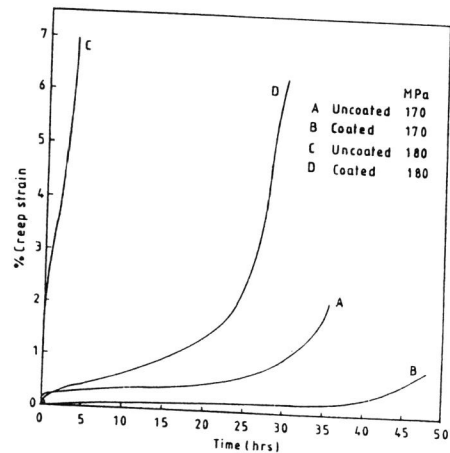


Fig. 3. Creep Curve of 2.25Cr-1Mo steel at 600°C

Fig. 4 and Fig. 5 are the Scanning Electron Micrographs (SEM) of uncoated and coated specimens respectively subjected to creep at 600°C.

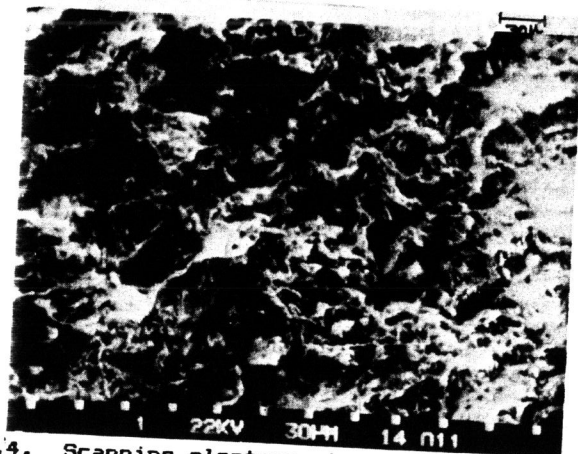


Fig.4. Scanning electron micrograph of uncoated 2.25Cr-1Mo steel subjected to creep at 600°C

Scanning electron micrograph was taken near the region of failure. The white region in the micrograph represents the oxidised products which are less on the coated specimens. Localised oxidation attack was observed in both the cases.

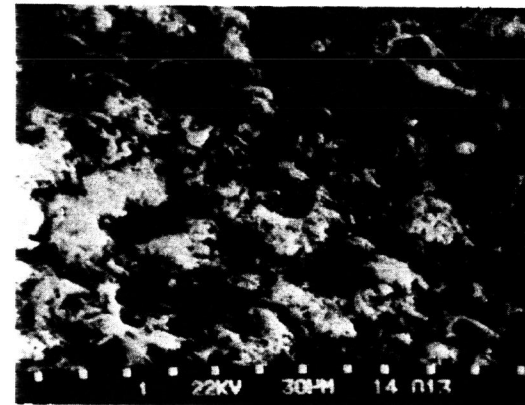
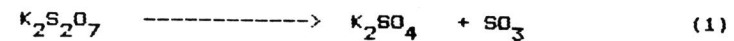


Fig. 5. Scanning Electron Micrograph picture of 2.25Cr-1Mo steel coated with 30% Na₂SO₄ - 70% K₂S₂O₇ and crept at 600°C

It is known that pyrosulphates are unstable and they decompose to corresponding sulphates. In this case, potassium pyrosulphate decomposes to potassium sulphate according to the equation :



K₂SO₄, being the product of decomposition, has melting point of 1071°C. Due to this reaction, coated salt mixture actually contains potassium sulphate and sodium sulphate. The minimum melting point of this mixture is reported to be 823°C. This is above the test temperature in the present study. So, liquid phase is not possible and the mixture exists as solid coating on the surface at 550°C and 600°C.

This proves that the coating has decomposed to a compound (K₂SO₄) of higher melting point and only solid phase reactions were possible. As the oxygen could have relatively free access to the interior of the uncoated specimen, it showed higher oxidation rates.

CONCLUSIONS

It was concluded that the coating of 2.25Cr-1Mo steel by $\text{Na}_2\text{SO}_4 - \text{K}_2\text{S}_2\text{O}_7$ increased the life of the material. The reason is attributed to the fact that the salt mixture, instead of forming a liquid phase at test temperatures, decomposed to a solid mixture of higher melting point. Diffusion of reacting gases like oxygen through solid phase is less than that in liquid phase. This resulted in enhanced creep life of the material.

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