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Theme: Physical metallurgy and material behavior at high temperatures

CREEP PROPERTIES AT 650ºC OF MARAGING 300 STEEL SOLUTION ANNEALED*

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Abstract

In the development of the structural materials for the advanced applications, as in the aerospace industry, there is a constant strive to increase both strength and toughness. Maraging steels are iron-nickel alloys designed to combine both properties that are achieved through the age-hardening of low carbon martensite. This alloy have a metastable martensitic structure that can revert to austenite when heated in temperatures close to the aging temperature, and this effect can be enhanced with the temperature increasing and time of treatment. Therefore, the study of creep behavior in elevated temperatures has technological importance to the development of this material. In this work the creep behavior of a maraging 300 steel solution annealed is evaluated by carrying out creep tests at 650ºC and in a stress of 200, 300 and 500 MPa. Creep parameters, such as steady state creep rate ($\dot{\varepsilon}_s$), final creep time (t_f), and stress exponent from secondary creep (*n*) are determined, considering that they are important to evaluate the creep resistance of the material.

Keywords: Creep; Maraging; High Temperature

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1 INTRODUCTION

Maraging steels are a special class of ultrahigh strength steels that differ from other steels in that they are not hardened by carbon. Carbon, in fact, is an impurity element in these steels and is kept as low as is commercially practicable. Instead of relying on carbide precipitation, these steels are hardened by the precipitation of intermetallic compounds. The absence of carbon in the steels confers significantly better hardenability, formability, and a combination of strength and toughness [1,3]. These steels are based on the Fe-Ni binary alloy with additions of various alloying elements such as cobalt, molybdenum, titanium and aluminum for precipitation hardening [1-3]. Maraging refers to the ageing of martensite, that is easily obtained in these steels owing to the high nickel content. The martensite without carbon is quite soft, but heavily dislocated [1,3]. Maraging 18%Ni grades are denoted by numbers such as 200, 250, 300 or 350, the number specifying the level of the yield strength in ksi that can be obtained in the steel with appropriate heat treatments [1-4]. Maraging steels have good machining properties and are widely used in many military and commercial industries, mainly for aircraft, aerospace and tooling applications, for example as a rocket motor case and in the important parts of airplanes [1,3].
Data available on the mechanical properties of Maraging steels at elevated temperature are scarce and most of the studies on the low grades were confined to tensile properties or stress-rupture studies up to 540ºC [2,5]. Specialized applications of the steel occasionally demand short-time exposures at unusually high temperatures and it is desirable to have data on the creep behavior of the material during such service conditions.
In this work the creep behavior of a maraging 300 steel solution annealed at 820ºC is evaluated by carrying out creep tests according to ASTM E-139-06 [6], at temperature of 650ºC and stress of 200, 300 and 500 MPa. The parameters as the primary creep time (t_p), steady state creep rate ($\dot{\varepsilon}_s$), final creep time (t_f), final strain (ε_f) and reduction of area (RA) are determined, considering that are important to evaluate the creep resistance of the material.

2 EXPERIMENTAL PROCEDURES

Material was provided in bars by a cooperation work of Villares Metals SA and DCTA/IAE (Departamento de Ciência e Tecnologia Aeroespacial / Instituto de Aeronáutica e Espaço). Chemical composition of the Maraging 300 Steel was in accordance with AMS 6521 A [6]. The material was submitted to thermal treatment at temperature of 820 ºC for 1 hour to be solution annealed. The heat treatment was conducted at IAE/DCTA, using a Brasimet Koe 40/25/65 furnace. After the solution annealing, the specimens have been hot-forged with dimensions according to ASTM E139 standard. Constant load creep tests were conducted at 650ºC on a standard creep machine at stress of 200, 300 and 500 MPa. Samples with a gauge length of 18.5 mm and a diameter of 3 mm were used for all tests. Creep tests were performed according to ASTM E139 standard [7].

3 RESULTS AND DISCUSSION

Representative creep curves at 550ºC are shown in Figure 1.

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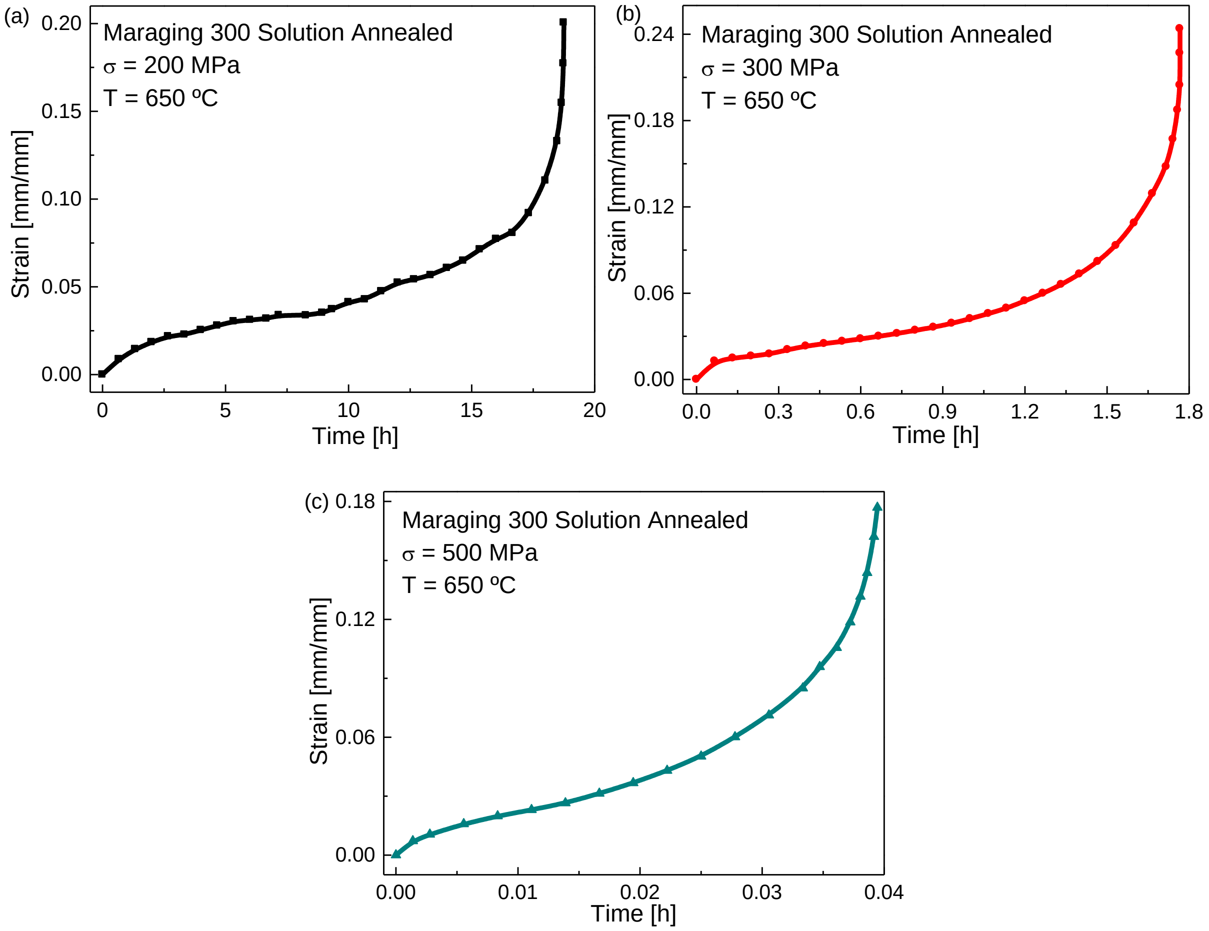

Figure 1. Creep curves of the solution annealed maraging 300 alloy at 650 ºC and (a) 200 MPa, (b) 300 MPa and (c) 500 MPa.

Figure 2 shows the stress dependence of the steady-state creep rate (*n*) for the test conditions. By standard regression techniques, the values of n can be described in terms of a power-law creep equations [8], according Equation 1:

$$\dot{\varepsilon}_s = B\sigma^n \qquad (1)$$

where B is the structure-dependent constant and σ is the applied stress.

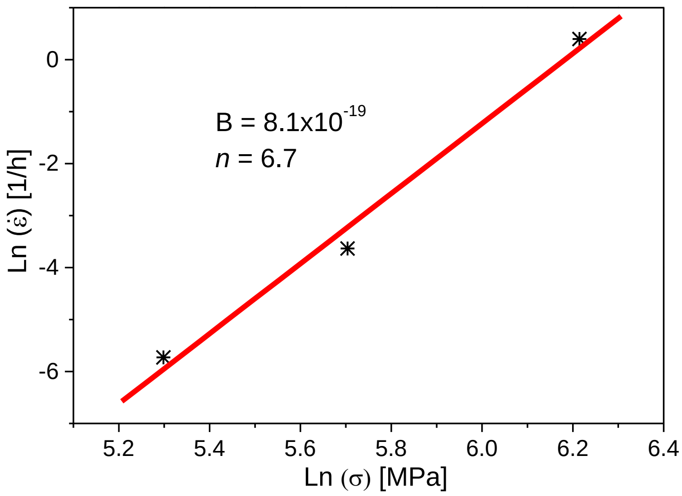

Figure 2. Stress dependence of the steady-state creep rate (*n*) at 650ºC of the solution annealed maraging 300 alloy.

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Table 1 summarizes the results obtained from the creep tests at 650ºC, which shows the values of stress (σ), primary creep time (t_p), secondary creep rate ($\dot{\varepsilon}_s$), final creep time (t_f), final strain (ε_f), reduction of area (RA) and stress exponent from secondary creep (*n*).

Table 1. Creep data at 650 ºC of maraging 300 solution annealed

Stress [MPa]	t_p [h]	$\dot{\varepsilon}_s$ [1/h]	t_f [h]	ε_f [mm/mm]	RA [%]	*n*
200	1.330	3.25×10^{-3}	18.75	0,2005	46.22	6.7
300	0.133	2.64×10^{-2}	1.77	0.2439	58.44	
500	0.003	1.49	0.04	0.1769	38.11	

Figure 1 shows that the material showed clearly the three stages of creep – primary, secondary and tertiary – and most of the creep life of this alloy is dominated by a constant creep rate (secondary). This phenomenon is thought to be associated with a stable dislocation configuration due to recovery and hardening process [8]. The material shows good resistance to creep at 200 MPa and 300 MPa, as can be inferred from the near horizontal shape of the curves from Figure 1 (a) and (b) and the lower steady-state creep rate and final creep time (t_f) from Table 1. However, at 500 MPa, the material exhibited a lower creep resistance, with fracture after 0.04 h. Secondary creep rate ($\dot{\varepsilon}_s$) increases and the final creep time (t_f) decreases with increasing stress since the stress dependence of creep rate is normally well represented by a power law equation [8]. Secondary creep exponent (*n*) of 6.7 suggests that the dominant creep mechanism is dislocation creep.

4 CONCLUSION

Constant load creep tests are conducted with a solution annealed Maraging 300 alloy at 650ºC and a stress of 200, 300 and 500 MPa. The alloy has showed a typical creep behavior with the three stages. Most of the creep life of this alloy is dominated by a constant creep rate that is thought to be associated with a stable dislocation configuration due to recovery and hardening process. Results show that the estimated value of stress exponent from secondary creep (*n*) is 6.7 at 650ºC, that suggests dislocation creep as dominant mechanism, and the secondary creep rate has increased with increasing test stress, following the power law equation.

Acknowledgments

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