Creep behaviour of Ca and Bi individually added AZ91 magnesium alloy

Jichil Majhi, Sourav Ganguly, A.K.S. Bankoti, and A.K. Mondal

Department of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela 769008, India.

Email: jichil.kamesh@gmail.com

Abstract

The combination of high specific strength and low density makes magnesium alloys a potential in engineering application. However, it suffers from poor tensile and creep properties at elevated temperatures. The present investigation studies the effect of the Ca and Bi on the creep behaviour of the AZ91 magnesium alloy. To determine the creep behaviour Impression creep testing setup was employed in which a flat ended cylindrical indenter having diameter of 1.5 mm was impressed on the specimens. All creep tests were carried out under constant punching stresses in the range of 300-480 MPa and in the temperature range of 423-523 K. The study showed that the impression creep behaviour of AZ91 alloy is significantly improved by the individual addition of Ca and Bi. It is shown that the individual Ca added alloy exhibits a superior creep resistance than the individual Bi added alloy because of the higher thermal stability of the Al_2Ca phase in the former alloy compared with that of the Mg_3Bi_2 phase in the later one. The stress exponents values are in the range of 4.0 to 6.3 and activation energies are in the range of 105.8 ± 4.1 kJ/mol to 108.2 ± 8.3 kJ/mol, have been estimated from the alloys. Accordingly, from the stress exponent value and activation energies, dislocation climb controlled by pipe diffusion is the dominant creep mechanism for all the alloys in the temperature and stress level employed.

Keywords: AZ91 alloy, squeeze casting, impression creep, dislocation climb.

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Jichil Majhi

Research Scholar

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

National Institute of Technology Rourkela

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The Indian Institute of Metals
Metallurgy Materials Engineering

BITS Pilani
K K Birla Goa Campus

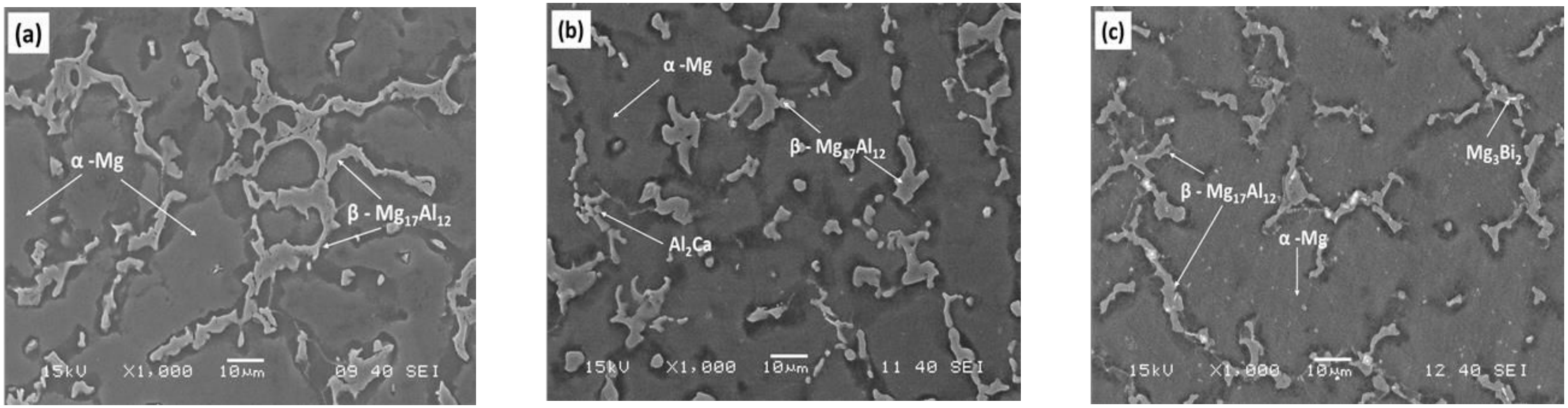
Introduction

- The application of Mg alloys in automotive industry has increased significantly due to their high specific strength.
- Among the Mg alloys, the AZ91 alloy exhibits a good combination of room temperature properties.
- However, the alloy exhibits poor creep resistance beyond 130 °C due to the softening of the β-$Mg_{17}Al_{12}$ phase present along grain boundaries.
- In this work Ca and Bi are individually added to the AZ91 alloy to enhance its creep resistance by the formation of thermally stable intermetallic compounds.

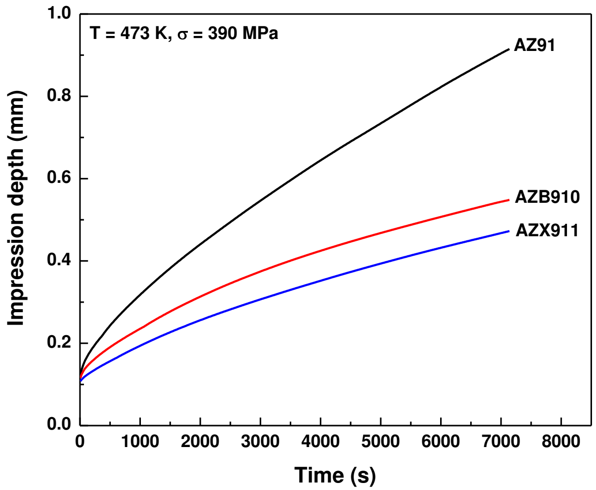
Experimental procedure

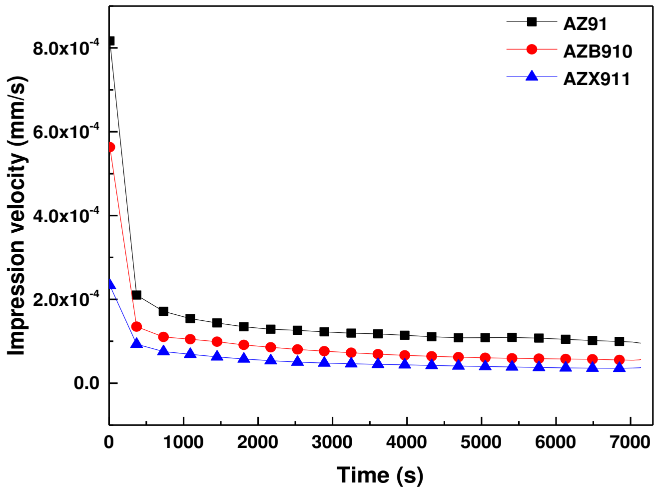
- Impression creep was used to carry out creep tests on the alloys.
- The depth of penetration (h) was recorded as a function of time (t).
- The impression creep tests were conducted in the stress range of 300–480 MPa and temperature range of 423–523 K for a dwell time of 7200 s.

Results and discussion



SEM micrographs of the (a) AZ91, (b) AZX911 (AZ91-1.0Ca) and (c) AZB910 (AZ91-0.5Bi) alloys

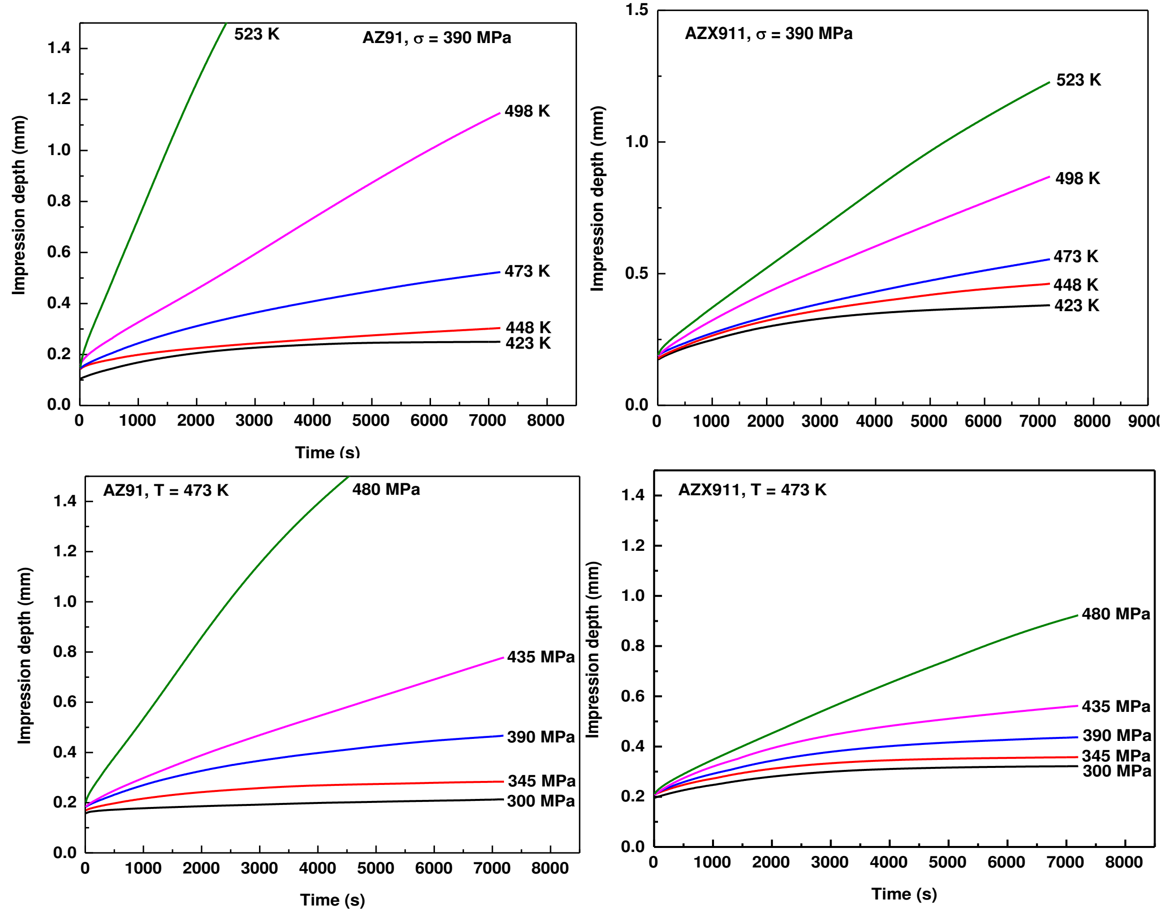




- The additions of both Ca and Bi are effective in improving creep resistance
- The AZ91-1.0Ca alloy exhibited the best creep resistance

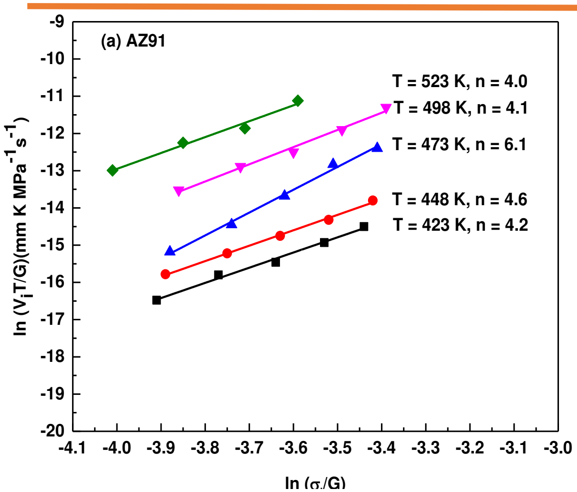
Effect of temperature and stress on impression creep behaviour

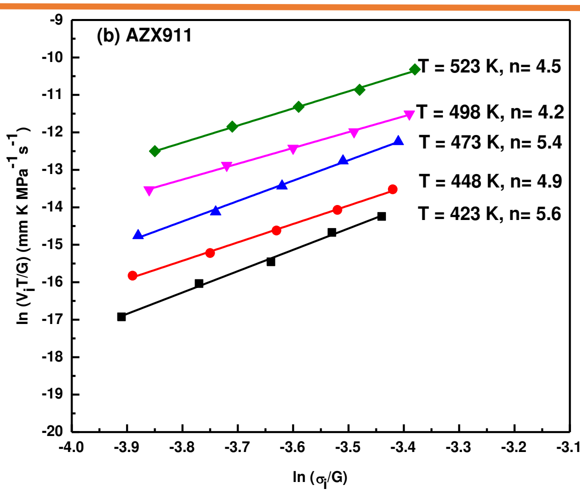
- With increase in both temperature and stress, creep rate increases
- The effect was more pronounced with increase in temperature, as creep rate depends exponentially on it.
- The creep rates of the AZX911 (AZ91-1.0Ca) alloy is far better than that of the AZ91 alloy.

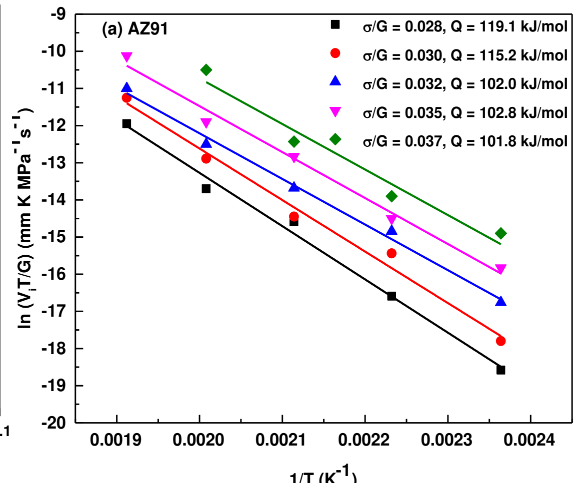


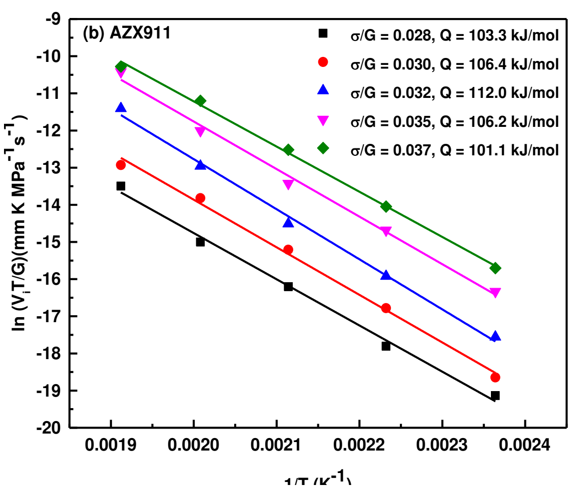
Effect of temperature and stress on impression creep behaviour of AZ91 and AZX911 alloys

Stress exponent (n) and activation energy (Q) values of the alloys









- The values of stress exponents (n) in the present study were in the range of 4.0–6.1, and activation energies were in the range of 105.8 ± 4.1 kJ/mol to 108.2 ± 8.3 kJ/mol.
- These values suggested dislocation climb controlled by pipe-diffusion is the dominant creep mechanism.

Stress exponent (n) and activation energy (Q) values of (a) AZ91 and (b) AZX911 alloy

Conclusions

➢ The base AZ91 alloy consists of primary Mg (α-Mg) and β–$Mg_{17}Al_{12}$ phases. The addition of Ca and Bi additionally resulted in the formation of Al_2Ca and Mg_3Bi_2 phases, respectively.

➢ The additions of both Ca and Bi are effective in improving creep resistance of the AZ91 alloy. The AZX911 (AZ91-1.0Ca) alloy exhibited the best creep resistance among the alloys employed.

➢The stress exponent values lie in the range from 4 to 7, and the activation energies are in the range from 105.8 ± 4.1 kJ/mol. to 108.2 ± 8.3 kJ/mol. It indicate the dislocation climb controlled by pipe diffusion is the dominant creep mechanism.

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