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Observations on the Influence of Hydrogen on the Sintering of an Al-2Mg Alloy

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Abstract

Hydrogen, in even small quantities, is extremely deleterious to the sintering of aluminium. Understanding the cause of this effect is complicated by the multiple interactions that occur in multi-component systems. In this work, we examine the sintering rsponse of Al-2Mg (a simplified system) in pure nitrogen and nitrogen-hydrogen using dilatometry, differential scanning calorimetery, thermogravimetry and metallography.

Keywords: sintering, aluminium, atmosphere, nitrogen and hydrogen.

1. Introduction

Two practices that are critically important for the sintering of aluminium are the use of magnesium and a dry nitrogen atmosphere. Magnesium has been shown to partially reduce the Al_2O_3 on the aluminium particle surfaces through the formation of spinel, which facilitates interparticle diffusion and improves the wetting characteristics of the particles with the liquid phases that are present during sintering in some systems.[1] Magnesium is also used as a getter to reduce the oxygen level in the sintering atmosphere to a level low enough for AlN to form.[2] It is for this reason that nitrogen is the most efficious atmosphere for sintering aluminium. The formation of AlN is thought to improve the sintering response by reducing the internal pore pressure relative to the furnace pressure and facilates pore filling during the late stages of liquid state sintering.[3] It has been shown that the beneficial effect of nitrogen can be dramatically affected by the presence of hydrogen and/or moisture in the nitrogen atmosphere.[3,4] However, the mechanism by which hydrogen poisons the sintering of aluminium remains elusive.

In this work, experimental investigations have been conducted to examine the sintering properties of Al-2Mg in atmospheres of N_2 and N_2+5%H_2. This simplified alloy system is selected in order for the role of the sintering atmosphere in solid state or transient liquid state sintering to be determined.

2. Experiment

Aluminium powder grade AM650PM from Ampal Inc. was mixed with 2 wt% Mg powder (< 45 μm) and 1 wt% Acrawax in a Turbula mixer and pressed at 200 MPa into cylinders 10 mm in diameter and ~10 mm in height. The wax was burnt off in nitrogen at 350°C for 1 hour. The sintering properties were examined by dilatometry using a Netzsch Dil 402C dilatometer, and by thermogravimetry (TG) and differential scanning calorimetery (DSC) using a Netzsch 409CD STA instrument. The sintering temperature was 590°C. Three sintering atmospheres were used: N_2, N_2+5%H_2, and N_2 which was changed to N_2+5%H_2 after 80 minutes. The dew point of the nitrogen was <-60°C. The solidus temperature of Al-2Mg is 628°C, while there are Al-Mg eutectic reactions at 437°C and 450°C.

3. Results and Discussion

The results of the investigations are shown in Fig. 1: (a) dilatometry, (b) TG, and (c) DSC. The following general observations can be made:

- The sintering environment has no influence on the expansion which occurs at about 440 - 490°C. This is associated with the formation of liquid at Al and Mg interfaces.
- There was an exothermic reaction and a weight gain associated with the shrinkage in N_2. This is probably due to the formation of AlN, as observed previously. (Note that the stepwise change in the heat flux at ~ 50 minutes of sintering is an artefact of the sintering profile.)
- After the initial expansion, shrinkage occurred in N_2 but not in N_2+5%H_2, and it stopped shortly after N_2 was changed to N_2+5%H_2 at 80 minutes.

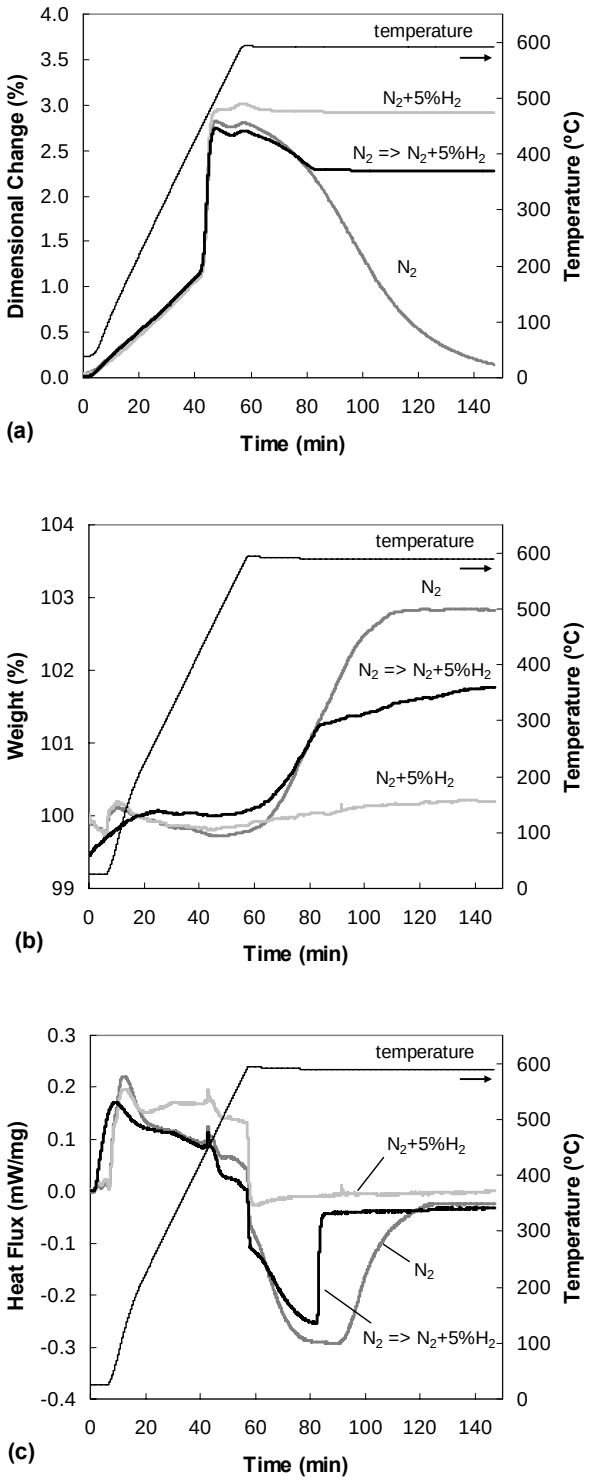

Fig. 1. Results of (a) dilatometry, (b) TG, and (c) DSC study of the sintering of Al-2Mg at 590°C.

After 80 minutes, the sample had been at 590°C for ~24 minutes. Thus the liquid formed from the eutectic reactions is expected to have been completely absorbed by the surrounding solid. At this time, the system would consist of a single phase (Al-Mg) solid solution. The arrest of shrinkage when the sintering atmosphere is changed from N_2 to N_2+5%H_2 indicates that, as in the case of liquid state sintering, N_2 is necessary for and H_2 is poisonous to solid state sintering in aluminium.

4. Summary

Experimental investigations have been carried out to study the effect of hydrogen on the sintering of Al-2Mg. It was found that the sintering shrinkage of the sample in N_2 was associated with a weight gain, presumably due to the formation of AlN. No shrinkage occurs in N_2+5%H_2 and shrinkage stops when N_2 is changed to N_2+5%H_2 at a stage where the transient liquid would have been completely absorbed by the surrounding solid.

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6. References

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