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Spray Forming of Mg_2Si Rich Aluminum Alloys

N. Ellendt[1,a], V. Uhlenwinkel[1], O. Stelling[2], A. Irretier[2] and O. Kessler[2]

[1]Universität Bremen, Fachbereich Produktionstechnik, Fachgebiet Verfahrenstechnik, Badgasteiner Str. 3, 28359 Bremen, Germany
[2]Stiftung Institut für Werkstofftechnik, Badgasteiner Str. 3, 28359 Bremen, Germany
[a]ellendt@iwt.uni-bremen.de

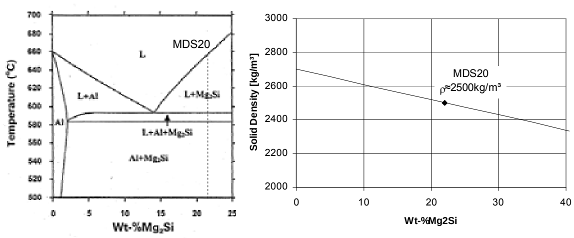
Abstract

Aluminum Alloys with a content of 22 wt.-% Mg_2Si were spray formed. This alloy features by a low density and is therefore a superior material for leightweight applications. The main problem in spray forming of this type of alloy was the occurance of high porosities. First process optimizations have been performed to decrease porosity under a certain level, so that it can be closed by an extrusion process

Keywords: aluminum alloy, mg_2si, spray forming

1. Introduction

Aluminum alloys with a high content of Mg2Si can be characterized by their reduced density and higher high-temperature strength compared to other aluminium alloys and therefore are a superior material for lightweight automotive applications. Decreasing the mass of a piston leads to an increased power density which makes it possible to reduce the fuel consumption of an engine. The companies Mahle and PEAK have developed and patented a manufacturing process for this class of alloys [1], which can not be cast with acceptable mechanical properties for high contents of Mg_2Si. Compared to conventional casting techniques, the Mg_2Si-content can be dramatically increased in Spray Forming which leads to new lightweight alloy systems. The alloy used in this work, MDS20, contains 22 wt.-% Mg_2Si and is shown in the quasi-binary phase diagram in Fig. 1a (dotted line). As can be seen in Fig. 1b, the density of the MDS20 alloy is roughly 2500kg/m³, further increase of the Mg2Si content can decrease the density to 2400kg/m³ and below.

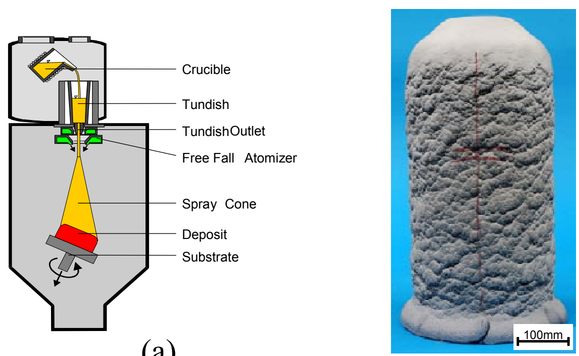


(a) (b)

Fig 1. (a) quasi-binary system Al-Mg_2Si [2], (b) Density of Al-Mg_2Si-Alloys

2. Spray Forming Experiments

The used spray forming setup is shown in Fig 2a. The alloy elements are molten in a crucible. Once the melt is superheated to 75K-170K, it is poured into a tundish in a way that a constant melt level is held. The melt exits the crucible through an outlet nozzle with a constant mass flow. This melt stream is then atomized using a free fall atomizer to a spray cone. A scanning atomizer is used to distribute the melt on the deposit surface. During their flight, the particles cool down rapidly until they impinge on the substrate in a semi-solid state to form the deposit. The substrate is rotating and withdrawn, so that a cylindrical deposit can grow up. Billets with a diameter of approx. 215mm have been spray formed with the MDS20 alloy (Fig 2b).



(a) (b)

Fig. 2. (a) Spray Forming Setup (b) Spray Formed Billet

3. Spray Forming Experiments

Table 1 shows the range of the varied process paramete rs. Experiments were conducted with an allow with a Mg_2 Si content of 21.8%. Besides the melt superheat above liq uidus, the gas and melt flow was varied to give gas-to-met al ratios (GMR) of 1.82 up to 2.62.

Table 1. Process parameters varied

Mg_2Si content of melt [weight-%]	21.8
Melt superheat [K]	75-170
Melt flow [kg/s]	0.09-0.15
Atomization gas flow [kg/s]	0.19-0.30
Gas-to-melt ratio (GMR) [-]	1.82-2.62

The radial porosity distribution of billet slices was deter mined using the buoyancy method. In the initial experime nts, porosity occurred to too hot spray conditions. Hence, the melt superheat was decreased. Fig. 3a shows the effect of melt superheat on the radial distribution of porosity. It can be seen that there is a global influence on the level of porosity. The spherical shape of the pores (Fig. 3b) indicat es that the porosity is due to too hot spray conditions.

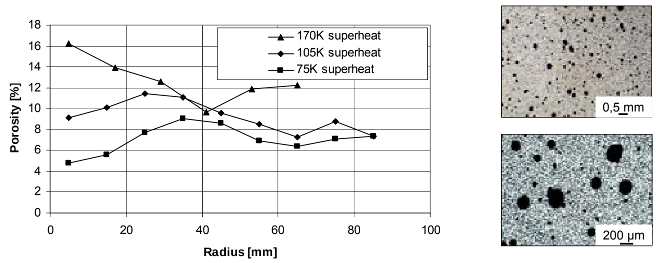


Fig. 3. **(a) radial distribution of porosity for different melt superheats, GMR=1.82**
(b) shape of pores

From the radial distribution of porosity, an average valu e weighted by volume fraction can be calculated. Fig. 4 sh ows the dependency between the average porosity and the melt superheat: A decrease of the melt superheat from 17 0K to 75K decreases the average porosity from 11.8 down to 7.2%. The radial variation of porosity also decreases.

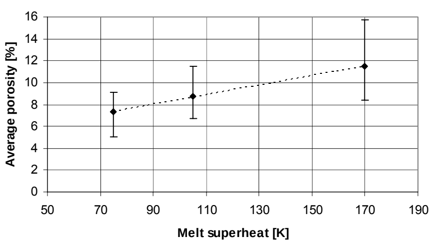


Fig. 4. **Effect of melt superheat on the average porosity of the deposit, 21.8% Mg_2Si, GMR=1.82**
Bars indicate the radial variation of porosity

As a further decrease of melt superheat was not possibl e as this would have increased the possibility of a freezing of the melt, the gas-to-metal-ration (GMR) was increased in order to obtain colder spray conditions. Again, solder s pray conditions lead to lower porosity and a reduced radia l variation of the porosity (Fig.5). Finally, an average poro sity of 5.1% was achieved for the highest GMR used.

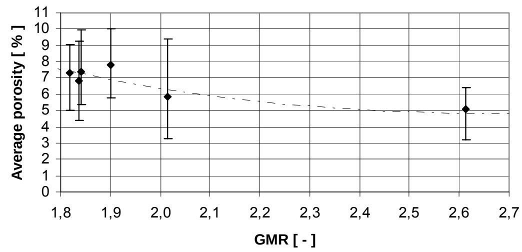


Fig. 5. **Effect of GMR on the average porosity of the deposit, 21.8% Mg_2Si, melt superheat: 75K Bars indicate the radial variation of porosity**

4. Summary

Billets with a content of 22 wt-% Mg2Si have been sprayformed and analyzed regarding porosity. It was shown that decreasing the melt superheat helps to reduce the porosity in the center part of the billet, whereas changes in the GMR especially affect the (radially) outer half of the billet. Due to the low thermal conductivity of the material, the heat stays long in the center of the billet which leads to hot porosity and is more complicated to eliminate. Average porosities could be reduced from 11.5% to 5.1%. Future work also includes the increase of the Mg_2Si content to reduce the density even more.

5. Ackknowledgement

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