# Effect of Different Pressures on Microstructure and Properties of Squeeze Casting $Al_5Mg_2SiMn$ Alloy

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**Abstract:** In this paper, the mechanical properties and microstructure of $Al_5Mg_2SiMn$ alloys formed under different pressures are investigated. It is found that the yield strength and elongation of the alloys show an increasing trend with the increase of pressure, but the increase gradually decreases. Meanwhile, the $Mg_2Si$ interlamellar space (ILS) decreases with increasing pressure, and the magnitude of the decrease decreases with increasing pressure. The pressure of squeeze casting increases the melting point of the alloy, and the solidification of the alloy provides the subcooling degree, which increases with the increase of pressure. And the subcooling degree provides the interfacial free energy for the formation of $Mg_2Si$, so the interlamellar space of $Mg_2Si$ decreases with the increase of subcooling degree. The mechanical properties of $Al_5Mg_2SiMn$ alloys are mainly affected by the interlamellar space of $Mg_2Si$. The smaller the $Mg_2Si$ interlamellar space is, the better the tensile strength and plasticity of the alloy is.

**Keywords:** $Al_5Mg_2SiMn$ alloys; pressures; $Mg_2Si$; subcooling degree; interlamellar space

## 1 Introduction

Under the general trend of automotive lightweighting, aluminum alloys with low density and high specific strength can reduce carbon emissions under the premise of ensuring automotive performance and safety [1]. Heat-treatment-free aluminum alloys can further reduce the cost and energy consumption in the production process. $Al_5Mg_2SiMn$ alloy relies on the Mg element to form the second phase, possessing heat-treatment-free characteristics, and having better stress corrosion resistance, which is used in the inner door panels, vibration-damping towers, and other automotive components [2]. In this paper, the heat treatment-free $Al_5Mg_2SiMn$ alloy is taken as the object. The most suitable production process of heat treatment-free aluminum alloy $Al_5Mg_2SiMn$ is determined by regulating the extrusion casting pressure, which reveals the mechanism of the pressure's influence on the microstructure and mechanical properties of the alloy.

## 2 Experimental procedure

The alloy used in the experiment was Al-5Mg-2Si-0.6Mn-0.3Fe-0.3Cu. It was solidified under a pressure of 0,30,40,50,60,80,100,125,150,200 MPa and then cooled in air. The microstructure and composition of the samples were characterized and analyzed using OM, SEM, and EDS. Mechanical properties are determined by averaging the results of at least three valid measurements.

## 3 Result and discussion

### Microstructure

Fig. 1 shows the microstructure of the alloys. In the figure, the white phase is detected as $Al_{15}(Fe,Mn)_3Si_2$ phase by composition, the black phase is $Mg_2Si$, and the gray phase is Al matrix. From the Fig.1, it can be seen that with the increase of extrusion pressure, the ILS of $Mg_2Si$ is decreases gradually, and the ILS of $Mg_2Si$ with pressure is shown in Fig. 2（b）.

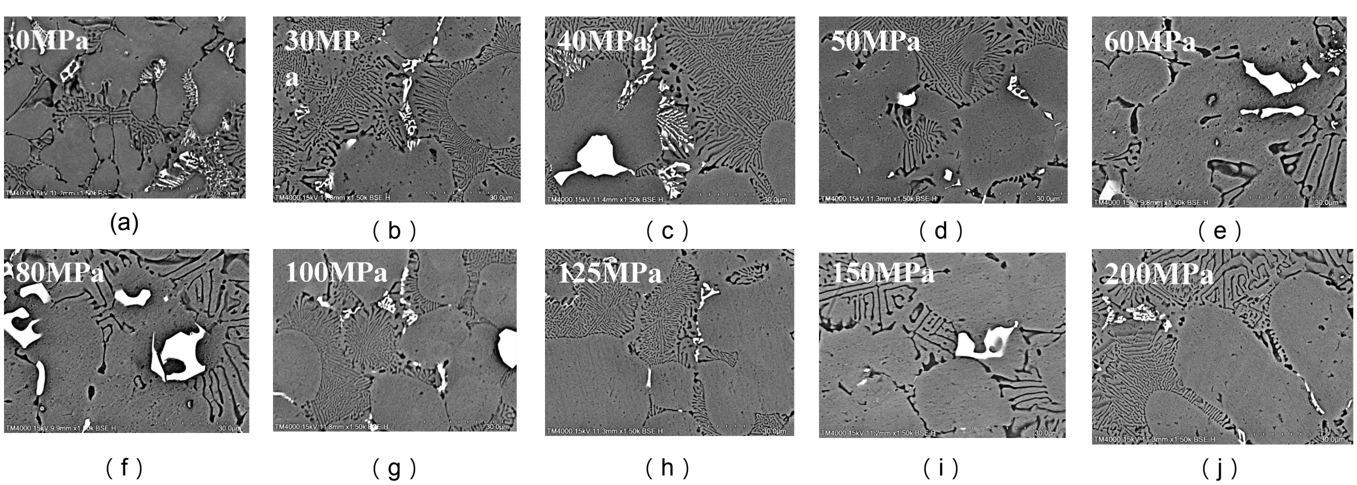



**Fig. 1 SEM images of of alloys with different Fe pressures**

**Mechanical properties**

The mechanical properties of the alloy at different pressures are shown in Fig. With the increase oh pressure, the tensile strength of the alloy increases from a minimum of 194 MPa to a maximum of 263 MPa, the yield strength increases from a minimum of 131 MPa to a maximum of 154 MPa, and the elongation increases from a minimum of 1.6% to a maximum of 5.1%.

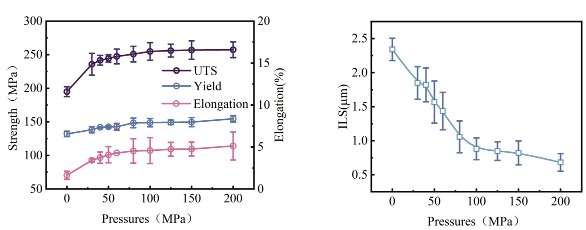
The ILS of the eutectic organization has a significant effect on the properties of the alloy. The smaller the ILS of the eutectic organization, the higher the strength of the alloy, which can be described by the Hall-Petch (Hall-Petch) formula [3]. Let be the yield strength and $\sigma^*$, m is constant related to the material, then we have

$$\sigma = \sigma^* + m\lambda^{-\frac{1}{2}} \quad (1)$$

**Effect of pressure on $Mg_2Si$**

Al-$Mg_2Si$ eutectic belongs to lamellar eutectic. the growth rate of eutectic R determines the speed of diffusion. Diffusion rate depends on the two-phase laminar sheet spacing $\lambda$ [3]. Minimum spacing of the eutectic lamellar sheet is determined by the thermodynamic conditions. The change of Gibbs free energy in the formation of eutectic consists of two parts, one is the bulk Gibbs free energy and the other is the change of interfacial Gibbs free energy, which is related to the eutectic lamellae spacing λ.

$$\lambda* = -\frac{2\gamma_{\alpha\beta} \cdot T_E}{\Delta H \cdot \Delta T_0} \quad (2)$$




（a）Mechanical property （b）ILS of $Mg_2Si$

**Figure 2 Mechanical properties of alloys at different pressures with $Mg_2Si$ lamella spacing**

$\gamma_{\alpha\beta}$ is the interfacial energy, $\Delta T_0$ is the subcooling degree, $T_E$ is the eutectic temperature.

**4 Conclusion**

The pressure of squeeze casting raises the melting point of the alloy, and the solidification of the alloy provides subcooling, which increases with the increase of pressure. The subcooling provides interfacial free energy for the formation of $Mg_2Si$, therefore the ILS of $Mg_2Si$ decreases with the increase of subcooling. The mechanical properties of $Al_5Mg_2SiMn$ alloys are mainly affected by the ILS of $Mg_2Si$, and the smaller the ILS of $Mg_2Si$ is, the better the tensile strength and plasticity of the alloy.

**Acknowledgments**

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