Study on Prediction Method of Mechanical Properties of Casting Al-9Si-2Cu-0.4Mg Alloy

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Abstract: In this paper, we designed stepped samples with different solidification times to investigate the effect of solidification time on the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy. Based on the mechanical properties of alloys with different solidification times, we used linear fitting to process the data and obtained a predictive model for the relationship between solidification time and mechanical properties, which can be used to predict the mechanical properties of different parts of cast Al-9Si-2Cu-0.4Mg alloy components. The results indicate that with increasing solidification time, the strength and impact of the cast Al-9Si-2Cu-0.4Mg alloy decrease linearly. The predictive model obtained through linear fitting can effectively predict the mechanical properties of alloys with different solidification times. The accuracy of the prediction method for components was verified, and the results show that this method can accurately predict the strength and hardness of Al-9Si-2Cu-0.4Mg alloy with small prediction errors.

Keywords: cast Al-9Si-2Cu-0.4Mg alloy, solidification time, mechanical properties prediction

1 Introduction

The casting of Al-9Si-2Cu-0.4Mg alloy has promising mechanical properties and castability, with wide application prospects in high-tech fields such as aerospace, aviation, and automotive industries [1]. In the early stages of material development, it was found that the mechanical properties of this alloy are sensitive to solidification time. However, most castings have variations in wall thickness, and when the alloy is applied to castings, there may be issues of localized mechanical properties not meeting the required standards due to excessively long solidification times [2]. Therefore, in this study, stepped samples with different solidification times were designed. The solidification times were calculated using Procast simulation, and the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times were obtained. A predictive model for the relationship between solidification time and mechanical properties was developed using linear fitting. This model was then utilized to predict the mechanical properties of Al-9Si-2Cu-0.4Mg alloy castings.

2 Experimental procedure

In order to study the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times, a combination of two variables, wall thickness, and chill was used to design stepped samples with different solidification times. The wall thicknesses were set at 7, 10, 13, and 16mm. Using Procast simulation, the solidification times at the ends and in the middle of the tensile test bars were calculated, resulting in a solidification time range of 8 to 356 seconds for the stepped samples. At room temperature, according to the requirements of the GBT 228.1 standard, tensile tests were conducted using a DDL-300 universal testing machine at a speed of 1mm/min. Additionally, hardness was tested using an HB-3000 Brinell hardness tester, with an experimental load (F) set at 0.2kg and a load application time of 10 seconds, following the GB/T 231.1 standard. Based on the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times, data was processed using linear fitting to obtain a model for the mechanical properties of the alloy with different solidification times. This model was then used to predict the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy components.

3 Result and discussion

Mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times

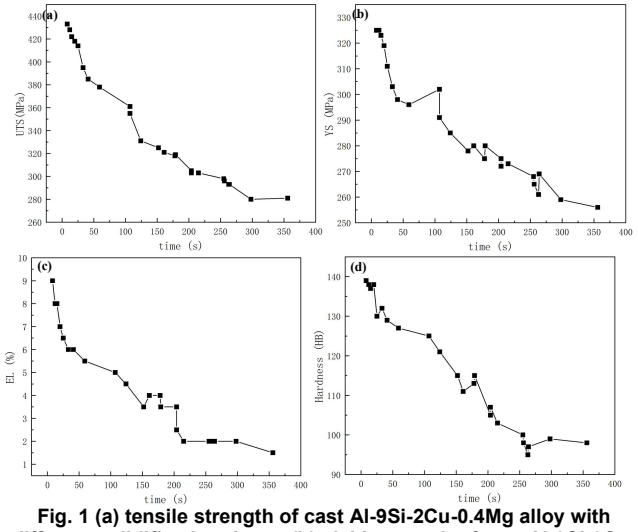

Fig. 1 (a) tensile strength of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times; (b) yield strength of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times; (c) elongation of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times; (d) hardness of cast Al-9Si-2Cu-0.4Mg alloy with different solidification times

Figure 1 illustrates the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy at different solidification times. It can be observed from the figure that with an increase in solidification time, the tensile strength, yield strength, elongation, and hardness of the alloy linearly decrease. As the solidification time increases from 8 seconds to 356 seconds, the tensile strength of the cast Al-9Si-2Cu-0.4Mg alloy decreases by 35.1%, the yield strength decreases by 21.2%, the elongation decreases by 83.3%, and the hardness decreases by 29.5%.

4 The linear regression model of the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy as a function of solidification time

Using statistical analysis tools, the mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy at different solidification times were processed to obtain the following predictive models for the mechanical properties: UTS=414.2-0.4766× time; YS=316.3-0.1989 × time; EL=7.36-0.02026 × time; Hardness=137.2-0.1402×time.

The coefficient of determination for all models is greater than 0.7, indicating that the linear models can effectively express the relationship between mechanical performance indicators and solidification time. Specifically, the coefficient of determination for tensile strength is 92.1%, for yield strength is 91%, for elongation is 90.3%, and for hardness is 94.2%.

5 Prediction of the mechanical properties of Al-9Si-2Cu-0.4Mg alloy castings

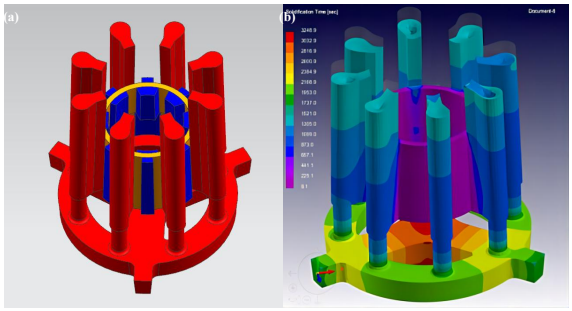

Fig. 2 (a)Casting process for cylindrical castings; (b) Simulation results of the temperature field in Procast

Figure 2 depicts the casting process and Procast temperature field simulation for the cylindrical castings, with a solidification time range of 11 to 209 seconds. Table 1 presents the measured mechanical property values of the cylindrical castings, compared with the predicted performance. The average predicted percentage errors for tensile strength, yield strength, elongation, and hardness are 1.9%, 2.8%, 7.9%, and 1.9% respectively. The predictive models can be effectively utilized for strength and hardness prediction of Al-9Si-2Cu-0.4Mg castings.

Table 1. Measured mechanical properties of cylindrical castings

Time/s	Measured values			
	UTS /MPa	YS /MPa	EL /%	Hardness/ HB
11	401	314	7.0	136
15	402	313	8.0	138
20	395	312	7.0	135
24	399	311	6.5	133
36	383	309	6.0	132
45	385	307	6.0	132
60	382	304	6.0	129
68	373	302	6.0	131
77	375	300	5.5	124
83	367	299	5.5	128
92	361	298	5.0	129
136	355	289	4.5	123
148	351	286	4.0	118
174	341	281	3.5	115
188	321	279	3.0	112
209	321	275	2.5	104

Conclusion

The mechanical properties of cast Al-9Si-2Cu-0.4Mg alloy are sensitive to solidification time. Based on the data of solidification time and mechanical properties, a linear fitting model can be used to predict the strength and hardness of the alloy castings.

Acknowledgments

This project was supported by the National Key Laboratory of Advanced Casting Technology

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