SELECTION OF PARAMETERS OF THE MANUFACTURING PROCESS OF COMPOSITES ALMMC / C_F BY GPI ï COMPOSITION OF MATRIX ALLOY

M. Dyzia[1*], A. J. Dolata[1], J. ś leziona[1]

[1] *Silesian University of Technology, Faculty of Materials Science and Metallurgy, KrasiŒkiego Str. no 8, 40-019 Katowice, Poland*
**corresponding author: maciej.dyzia@polsl.pl*

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Abstract

Obtaining a strong bonding on the carbon fiber and aluminium matrix interface, require a favorable wetting conditions and limitations reactivity between the aluminium matrix and carbon fibres. In the processes of infiltration, one of the factors conducive to such a connection is the chemical composition of the alloy matrix. The composition of the alloy also decides on technological properties such as castability and shrinkage. The paper presents the results of comparative fluidity tests of AlSi9Cu(Fe) and AlSi9Mn alloy with addition of magnesium and strontium. It was compared the metal flow path in the beam with a width of 20 mm and different thicknesses in the graphite mould. In case of modified alloy AlSi9Cu(Fe) + 1% Mg +0.03%Sr was observed a slight decrease of fluidity. While in the case of alloy AlSi9Mn+ 1% Mg +0.03%Sr length of filled increased comparing to similar beams on base alloy.

1 Introduction

Aluminium matrix composites reinforcement with carbon fibres (AlMMC/CF) are perspective engineering materials. Main advantages of those materials are: high stiffness, specific strength as well as low coefficient of thermal expansion and high coefficient of thermal and electric conductivity. Potential area of application them could be aerospace, automotive, and also electronic industry [1]. The aluminium alloys used for composites must have appropriate strength. Carbon fibres are characterized by a high elasticity modulus (from 250 to 400GPa) with deformation until failure of 1-3%. To take advantage of the strength, the matrix must show deformation higher than that of the fibres. Wide range of researches concern problem of reactivity and wettability into Al/C system in process of composites production [2-6]. Achieve the strong bonding at the interfaces fiber-alloy requires obtain of the interlayer. However, during the producing of carbon-reinforced aluminium metal matrix composites there is possibility the Al_4C_3 formation. The experimental works presented by many authors confirmed reaction (1), [4,6].

$$4Al(1) + 3C(s) \rightarrow Al4C3(s) \qquad \Delta F933K= - 172\ kJmol^{-1} \qquad (1)$$

The aluminium carbide promotes wetting, but it is brittle and hydrophilic phase, decreases corrosion resistance and strength of composite materials. Limitation of this phenomena is possible by modifying the alloy matrix, the suitable fiber surface preparation (technological coating) and selection of technological parameters [6-10]. In the case of liquid technologies such factors are: preheating of the metal and contact time liquid phase with the fibers.

From the point of view of the liquid-phase technology, the aluminium alloy matrix should be characterized by low viscosity, low surface tension and low reactivity with carbon fibres. Al-Si alloys fulfill this condition. Selection of chemical composition of the alloy matrix has been taking into account the conditions of applied preform infiltration process and the properties of carbon fibers. The paper presents selection of matrix alloy for two different methods: high pressure die casting (HPDC) and gas pressure infiltration (GPI). Limitation of reactivity in the system Al/CF is possible when the alloy contains a minimum of 7% silicon and manganese and titanium additions. Decrease of the surface tension and thereby reduce the contact angle provides of magnesium and strontium presents. The article presents the possibility of modifying the matrix alloys applied for infiltration processes of carbon textile perform. Influences of modifying additives was assessed by the technological tests: fluidity and mold filling.

2 Experimental researches

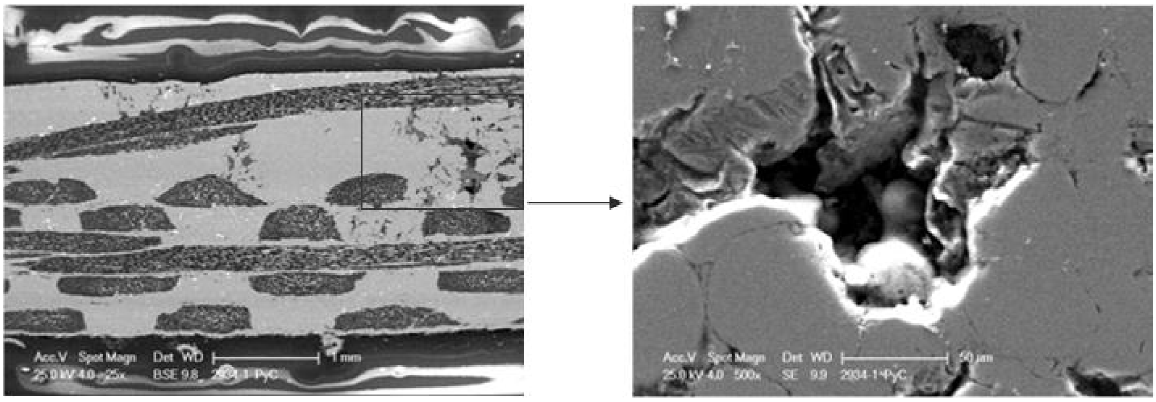
The research was carried out with aluminum alloys applied in the pressure casting processes AlSi9Cu(Fe) and AlSi9Mn. The chemical composition of alloys applied in the study are presented in Table 1. Modifying the chemical composition of the matrix alloy was made on the basis of previous studies described in the works [7-10].

	Element (wt %)								
alloy	Si	Fe	Cu	Mn	Mg	Ni	Ti	Sr	Al
AlSi9Cu(Fe) 226D	9.9	0.9	2.2	0.21	0.44	-	0.03	-	Bal.
AlSi9Mn TR37	9.57	0.07	0.14	0.5	0.04	0.006	0.033	0.01	Bal.

Table 1. The chemical composition of aluminium alloys

The selection of components is important not only for point of view proper wettability in carbon metal system, but also for technological requirements. Different thermodynamically conditions of infiltration process demand individual preparing of matrix alloy for composite fabrication method. For instance addition of an iron, indispensable in a die-cast process, in gas-infiltration process (GPI) leads to forming the brittle phases of Al-Fe system which contribute to increase in general embitterment of the composite. In long-term GPI process conditions proceed disadvantageous phenomena connected with growth of silicon phase and interaction between liquid aluminium alloy and nickel coating.

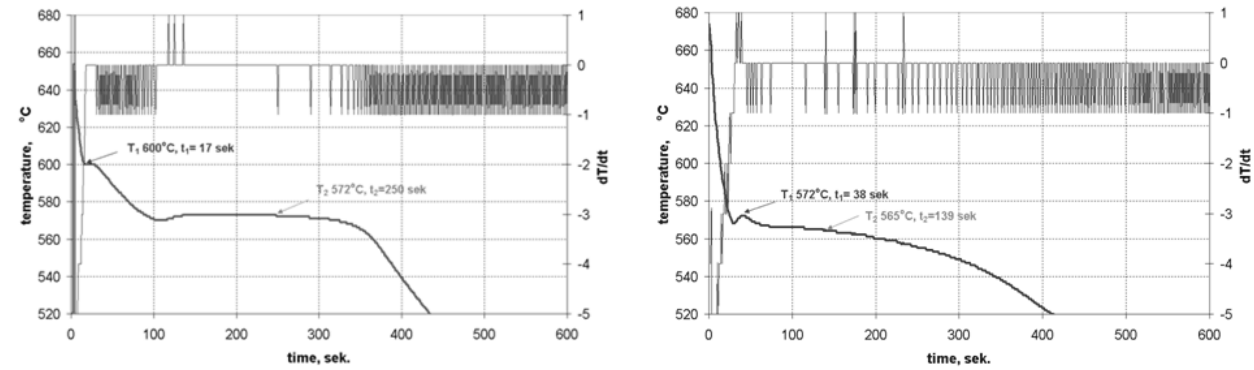
The Figure 1 shows the effect of matrix shrinkage, which is accompanied by a growth of phase Si-lamella in the non reinforced area of composite. The aim of the study was determine the effect of modifying additives on the filling mould and the possibility to reduce the influence of shrinkage during the solidification.



(a) (b)

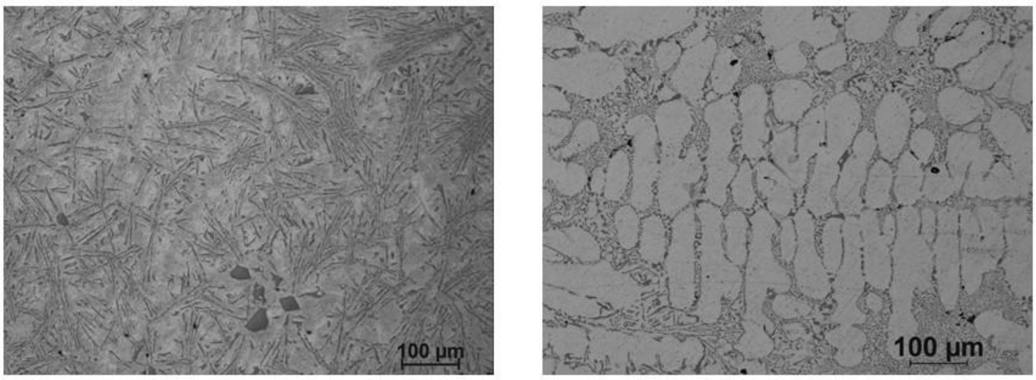
Figure 1. a) Al MMC/Cf composite obtained with GPI process, b) shrinkage effect

In the first phase of the study the time and temperature of solidification selected alloys was determined. Cooling curves (Fig. 2) were recorded by the use of Quick-Cups (thermal analysis cups) with K thermocouple. The use of the cups with identical thermal conductivity, known and standardized dimensions, provided the same conditions and the rate of heat removal during cooling of castings. This allowed to assume the preheating level of alloy during mold filling. The AlSi9Cu(Fe) ï 226D alloy solidification temperature was recorded in the range of 572-565 °C, while the AlSi9Mn ï TR37 alloy solidified in the temperature range of 600-572 °C. Therefore, for the assumed casting temperature 720 °C in the overheating the alloys difference was 28 °C. The microstructure of alloys casted in Quick-Cups mould was presented in Figure 3.



(a) (b)

Figure 2. Solidification curves of matrix base alloy: a) AlSi9Cu(Fe), b) AlSi9Mn



(a) (b)

Figure 3. Microstructure of alloy: a) AlSi9Cu(Fe), b) AlSi9Mn

For the evaluation ability to fill the mold a graphite casting mould was applied. Based on studies presented by J. Campbell R.A. Harding [11] the mould allowed the simultaneous casting of eight beams with different cross-section was designed (Fig. 4). Inlet in the mould was built by graphite crucible with bottom a 6mm diameter hole that provides a constant flow of liquid metal.

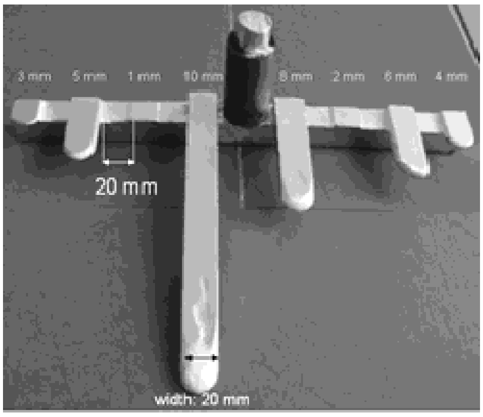


Figure 3. View a sample of fluidity casting

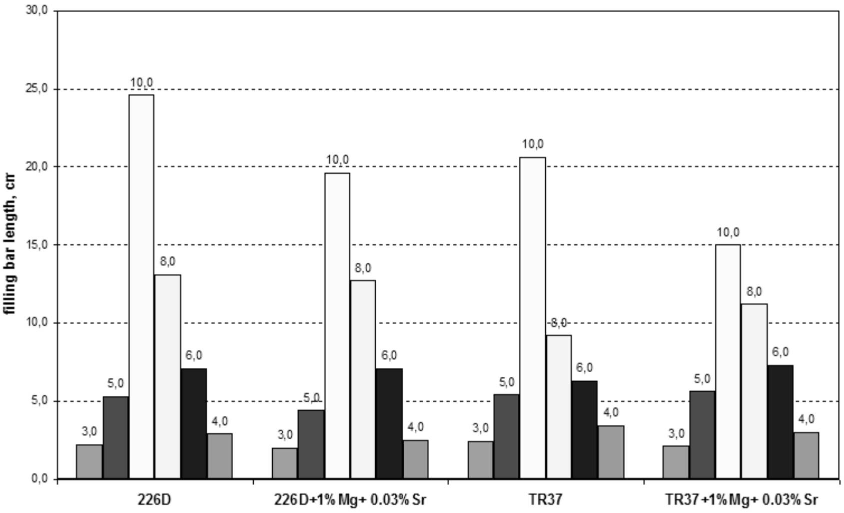


Figure 4. Comparison of filled beams length ig graphite mould

In cooperative studies assessed the influence of addition 1%Mg and 0.03% Sr to the base alloys AlSi9Cu(Fe) and AlSi9Mn. It was compared the metal flow path in the beam with a width of 20 mm and thicknesses: 3 mm, 5mm 1 mm, 10mm, 8 mm, 2 mm, 6 mm, 4 mm, respectively (Fig. 4). Clear differences in the filling are visible only in the channel cross section 20 x 10 mm. Beams of height 1 and 2 mm have not been practically filled, and were not taken in comparing the results. For the alloy 226D+1%Mg+0.03%Sr, there was no effect modification and 10 mm thickness beam was 20% shorter then base 226D. However for TR37+1%Mg+0.03%Sr increase in length of 5 mm, 6 mm and 8 mm thickness beam was observed (20%, 15%, 3% respectively). Therefore, although the lesser degree of overheating modified TR37 an increase of fluidity of alloy was observed. In the macroscopic scale also compared the shape of the metal stream during the solidification. Surface shrinkage effects were the most visible on 10 mm thickness beam in TR37 alloy (Fig. 5).

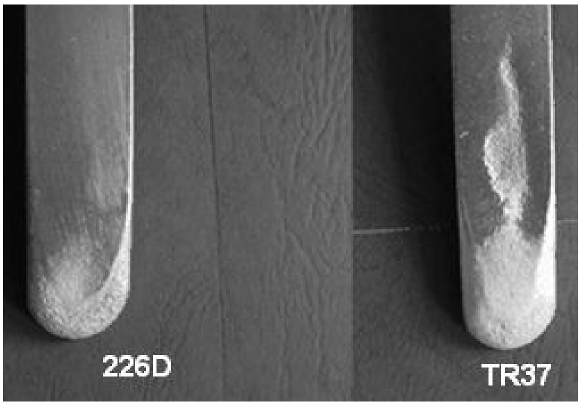


Figure 4. Surface shrinkage effects on 10 mm thickness beam

Further researches for a full description of the phenomena connected with the metal chemical composition and flow in the channel are needed. In next step studies will be analyzed the microstructure of the alloy in the area of the end the flowing streams

3. Conclusion

The proposed method for evaluating the casting properties of alloys has comparative purposes only. The main role of additives such as Mg and Sr is to improve the conditions of wetting in the system Al/CF. In the case of an alloy AlSi9Cu(Fe) intended for use in the HPDC process small change of fluidity has no significant meaning. While for AlSi9Mn the effect of improving the melt fluidity is beneficial from the standpoint of technology GPI. For explanations of phenomena associated with filling the mould during the infiltration process and impact of the liquid alloy with reinforcing phase will be carried out a complete study of the microstructure. Further studies will concern the influence of the chemical composition of the alloy to interface boundary between carbon fibres and the aluminum matrix.

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