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Influence of Silicon on Temperature Dependence of Thermal Conductivity of Al–Si–Fe Alloys

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Abstract

Temperature dependence analysis of thermal conductivity was carried out for series of aluminum alloys with 1% Fe (mass%) and different content of silicon starting from 0% to 6% (mass%). It is shown that the best alloy for heat exchange applications is alloy with 4% of silicon (mass%). Temperature dependence of thermal conductivity shows the strong decreasing character for silicon-alloyed samples in comparison to pure aluminum.

Keywords: aluminum–silicon alloys, thermal conductivity, heat exchange, iron, cast alloys, structure, temperature

1. Introduction

Thermal conductivity is a physical property, which is crucial characteristic for heat exchange application [1]. Aluminum alloys are widely used as heat exchangers of electronic components in vehicles and aircrafts. [2]. Pure aluminum has one of the best thermal conductivity parameter compared to other metals, however, its plasticity does not allow using pure aluminum as constructive material, for example, for production of radiators and similar applications [3]. New electronic equipment in vehicles and aircrafts demands from industry new heat exchange solutions. One of the requirements is always a reduced cost of manufacturing technology. Aluminum–silicon alloys are the cast alloys, which have production cost cheaper than the cost of pressure metal treatment technologies [3]. However, low cost of manufacturing technology faces with facts that alloying by different decreases the thermal conductivity [4]. That is why improving of thermal conductivity of aluminum–silicon alloys is a research task of the present work.

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2. Results and Discussions

The main idea of work is to study the influence of iron and silicon addition to aluminum–silicon cast alloys on temperature dependence of thermal conductivity. All alloys presented in the work contains up to 1% of iron (mass%). Iron is added for improving of technical properties of the analyzed alloys. At industry small additions of iron has a big impact on fulfilling the mold during die casting process. Table 1 contains information on compositions of alloys obtained in laboratory furnaces and the parameters of thermal conductivity measured at four different temperatures.

All experimental alloys are obtained in laboratory furnaces. Initial materials for melting is pure aluminum (99.98% Al mass%) and Al–Si alloy with 12%Si (mass%) at the same level of purity.

The analysis of densities is made by two different methods: hydrostatic weightings and geometrical measurements. The analysis of thermal conductivity is carried out on equipment for measurements of thermal diffusivity and thermal conductivity by laser flash 'NETZSCH LFA 457 MicroFlash'.

Table 1: Thermal conductivity of analyzed alloys at room, 50°C, 100°C and 150°C temperatures.

Alloy	0%Si	2%Si	4%Si	6%Si
W/k·m (room temperature)	246.9	198.9	191.1	161.2
W/k·m (50°C)	239.8	188.0	177.2	166.8
W/k·m (100°C)	232.5	183.2	172.9	166.4
W/k·m (150°C)	227.1	178.9	168.5	163.4

Dependence of thermal conductivity on temperature for pure aluminum is shown in Figure 1. It is seen that thermal conductivity decreases from 246.9 W/K·m at room temperature to 222.2 W/K·m during heating from 25°C to 150°C. It is shown that only alloys with a content of silicon from 2% to 6% (mass%) should be observed, investigated and discussed because higher amount of silicon significantly leads to decrease thermal conductivity. Figure 2 contains experimental results at room, 50°C, 100°C and 150°C for series of experimentally made alloys with chemical compositions according to the Table 1.

For application of heat exchangers, it is necessary to show the highest possible values of thermal conductivity. The value of thermal conductivity of pure aluminum is the goal, however, which cannot be reached making alloying with elements which have lower parameters of thermal conductivity. As shown in Figure 2, there is observed

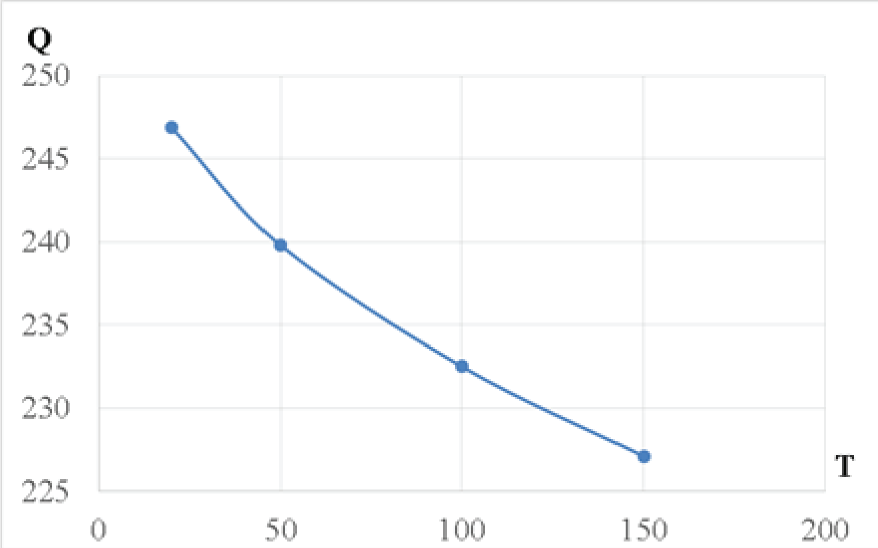

Figure 1: Temperature dependence of thermal conductivity of pure aluminum.

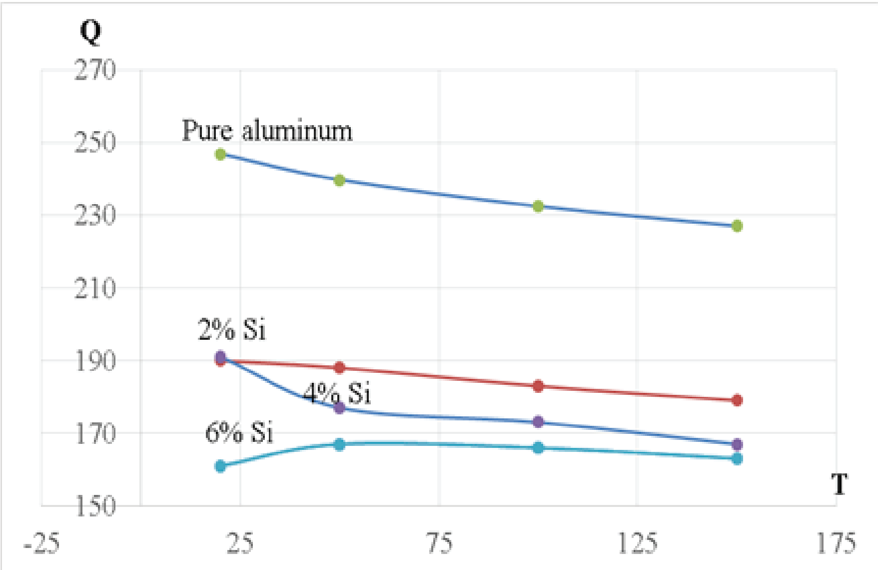

Figure 2: Temperature dependence of thermal conductivity of pure aluminum and alloys with 2%, 4% and 6% Si (mass%).

a significant decrease of thermal conductivity for the alloy with the highest amount of silicon. Temperature dependence of thermal conductivity also shows that alloying of the alloy with more silicon decreases parameters of thermal conductivity at 50 °C, 100 °C and 150 °C temperatures. It is obvious, that a composition of alloy has big impact, however, it is shown in Table 1 and Figure 2 the thermal conductivity of the alloys influenced by both iron and silicon elements addition. In our opinion, alloy with 4% of silicon is the most prospective for using in construction of heat exchange materials. This alloy has higher thermal conductivity parameter and better properties for die casting process. The tendency of reducing the values of thermal conductivity by adding more silicon to the alloy does not allow to discuss any possibilities of using the alloys with higher contents of silicon.

Moreover, big impact on thermal conductivity has the technology of production. Casting alloys have various defects. Experimental alloys in the present work are obtained by casting technologies. Different densities of analyzed alloys also influence on thermal conductivity. The structure formation processes should be discussed and investigated in the ongoing work.

3. Conclusion

As a result of the work it is shown how thermal conductivity is reduced in aluminum–silicon alloys with 1% of iron and different content of silicon. Significant influence of iron and silicon on thermal conductivity at four temperatures are also shown. Alloy with 4% of silicon (mass) is proposed to be used as a prospective material with higher heat exchange properties and casting properties.

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