

## Conference Paper

# Influence of Silicon on Thermal Conductivity at Room Temperature of Al-Si-Fe Alloys

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## Abstract

The analysis of densities and thermal conductivities has been performed for cast experimentally made aluminum alloys containing different content of silicon starting from 0% to 12% (mass%). All alloys have been additionally supplemented by iron up to 1% mass for better casting properties. Results have shown a strong tendency of decrease in the thermal conductivity with increasing silicon content. The same character is found for densities behavior.

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## 1. Introduction

Aluminum industry is rapidly developing industry that is becoming more widespread from decade to decade [1]. Aluminum alloys are well-known materials not only because of their low-density, which gives the possibility to reduce mass of equipment and details produced by engineering industry at all; these alloys are widely used for heat exchange [2]. Pure aluminum has perfect thermal conductivity; however, it is impossible to make any detail from it because of its plasticity [3]. Humanity started to develop industry of aluminum–silicon alloys with the main goal to make production process less expensive and more effective. One of that evolution's way was to develop cast aluminum materials. It is well known fact that silicon strongly increases cast properties, which allows aluminum parts easy to be obtained [4]. However, thermal conductivity of alloyed aluminum reduces up to 2 times in comparison to pure metal, which make not applicable to use cast aluminum alloys for high efficiency motors and electronic components [2]. That is why improving of thermal conductivity is great task

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for generations; however, our goal of present work is to find the compositions with the best thermal conductivity at room temperature.

## 2. Results and Discussions

This work is aimed at studying the influence of iron addition to aluminum–silicon cast alloys on thermal conductivity of alloys. Iron is an element, which is proposed for improving of technical properties of alloys. For example, it is used as addition to cast aluminum alloys for better fulfilling the form under the die casting process.

All experimental alloys are obtained in laboratory furnaces. Initial materials for melting were 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 contains information on compositions of alloys obtained in laboratory furnaces and the parameters of thermal conductivity measured at room temperature.

TABLE 1: Results of thermal conductivity analysis at room temperature.

Alloy	0%Si	2%Si	4%Si	6%Si	8%Si	10%Si	12%Si
W/k·m	244.4	198.9	191.1	161.2	167.3	162.9	141.4

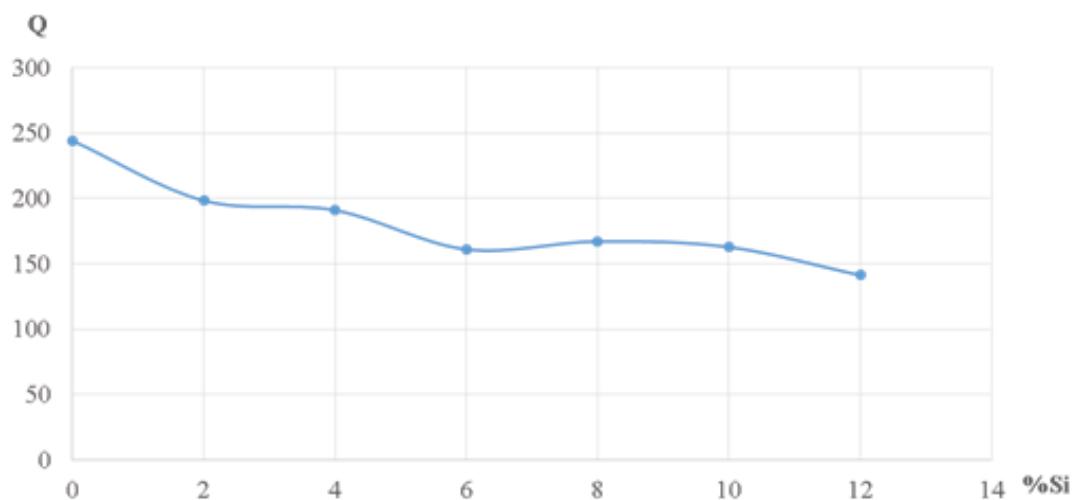
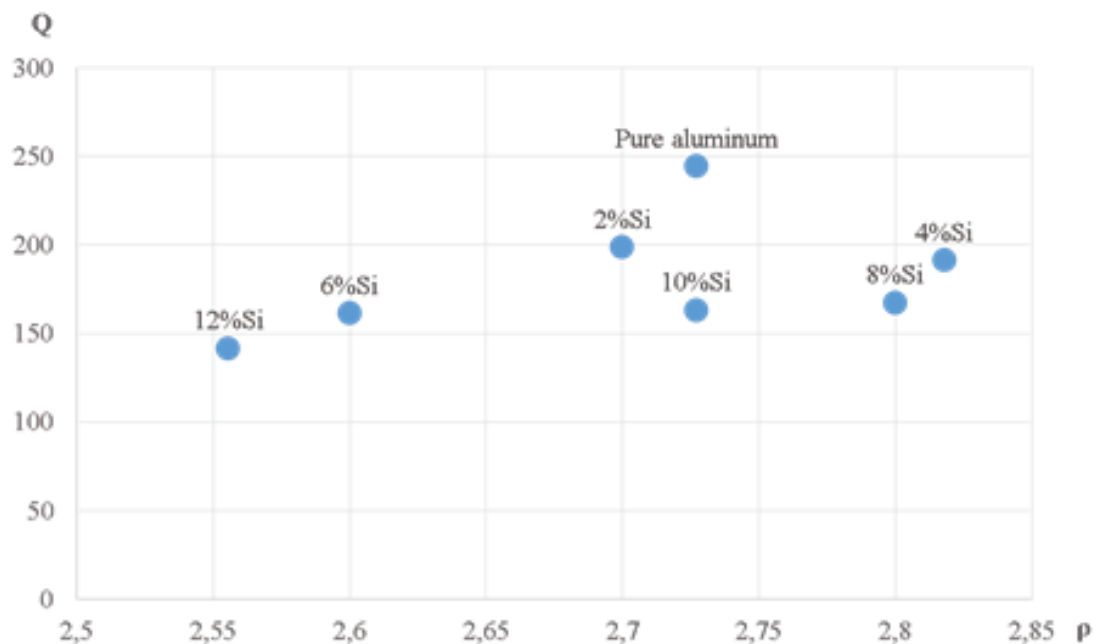


Figure 1: Dependence of thermal conductivity on content of silicon.

Dependence of thermal conductivity on a content of silicon as shown in Figure 1 presents expected behavior. Physical nature of density states that any amount of alloying element in aluminum matrix will decrease the property of density. However, the main interest was to analyze what is the impact of iron content. Alloying by iron in amount of not more than 1% leads also to decrease the thermal conductivity. In comparison, pure aluminum has 244.4 W/K·m, any other alloy with 1% of iron has thermal conductivity lower than 200 W/K·m.



**Figure 2:** Thermal conductivity and density correlation.

Abnormal densities are seen in Figure 2 for the alloys with 4% and 8% silicon (mass%). The explanation might be the following: all melting procedures are made strictly under the same conditions. Alloys with 4% and 8% silicon (mass%) might have impact of structural aspects of formation the crystalline material. Alloy with 10% of silicon (mass%) has also higher value of density. In our opinion, intermetallic interactions may lead this effect because of reducing amount of pores in casting during alloy is being crystallized. Finally, this let fixing high density values.

Alloys produced by casting contains different casting defects, and experimentally made alloys in the present work are not the exception. Using one conditions of obtaining the alloys doesn't guarantee that alloys of different compositions will mix equally and form crystalline structure equally. Porosity might be different also for different compositions like in our experiment. Iron and aluminum form intermetallic phases, these phases influence on structure formation process under cooling. Less pores is

better for mechanical properties and thermal conductivity, however, casting technologies will not let to make material completely without any percentage of porosity. The investigation of porosity formation in analyzed alloys is a purpose for further investigations.

### 3. Conclusion

It is shown how thermal conductivity decreases in aluminum–silicon alloys with 1% of iron and with different content of silicon. The highest values of thermal conductivity have been observed on alloys with 2% Si and 4% Si (mass%): 198.9 W/K·m and 191.1 W/K·m. Significant influence of iron on thermal conductivity at room temperature is also discussed. However, alloy with 4% of silicon (mass) might be applicable for production of thermal conductive materials like radiators, which are possible to be obtained by a cheap technology of manufacturing – die casting.

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### References

- [1] Haizhi, Ye. (2003). An overview of the development of Al-Si-alloy based material for engine applications. *JMEPEG*, vol. 12, pp. 288–297.
- [2] Jablonski, M., Knych, T., Mamala, A., et al. (2017). Influence of Fe and Si addition on the properties and structure conductivity aluminum. *Archives of Metallurgy and Materials*, vol. 62, no. 3, pp. 1541–1547.
- [3] Tanski, T., Labisz, K., Krupinska, B., et al. (2016). Analysis of crystallization kinetics of cast aluminum–silicon alloy. *Journal of Thermal Analysis and Calorimetry*, vol. 123, pp. 63–74.
- [4] Kim, Y.-M., Kang, D.-S., Hong, S.-K., et al. (2016). Influence of variation in the silicon content on the silicon precipitation in the Al-Si binary system. *Journal of Thermal Analysis and Calorimetry*, vol. 123, pp. 63–74.