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Influence of Chemical Composition on Porosity in Aluminium Alloys

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Abstract

Porosity is one of the major defects in aluminum castings, which results is a decrease of a mechanical properties. Porosity in aluminum alloys is caused by solidification shrinkage and gas segregation. The final amount of porosity in aluminium castings is mostly influenced by several factors, as amount of hydrogen in molten aluminium alloy, cooling rate, melt temperature, mold material, or solidification interval. This article deals with effect of chemical composition on porosity in Al-Si aluminum alloys. For experiment was used Pure aluminum and four alloys: AlSi6Cu4, AlSi7Mg0, 3, AlSi9Cu1, AlSi10MgCu1.

Keywords: Aluminium, Porosity, Chemical composition

1. Introduction

The final integrity of casting, properties and surface finish, is greatly influenced by the presence of porosity. Gas porosity in aluminum alloys is due to the segregation of hydrogen dissolved in the molten metal as it has almost no solubility in the solid phase. Therefore, porosity is the result of the combination of solidification shrinkage and segregation of gases. The liquid permeability is reduced in the solid dendritic area hindering efficient metal feeding and decreasing the pressure in the liquid. Simultaneously, gas concentration is locally increased due to segregation. Consequently, if the gas exceeds the effective solubility limit, nucleation and growth of pores has to be considered.

2. Influence of Solidification Interval

The amount of porosity in final casting is mostly influenced by amount of hydrogen in molten aluminium alloy, cooling rate, melt temperature, mold material, or solidification interval. This article is focused on studying the effect of solidification interval on final porosity in aluminium castings via APM modul in simulation software ProCAST. Wide solidification interval produces more microporosity at the expense of macroporosity. Conversely, in case of narrow solidification interval (pure aluminium, eutectic aluminium alloy) prevails macroporosity, and presence of microporosity is low in the casting (fig. 1).

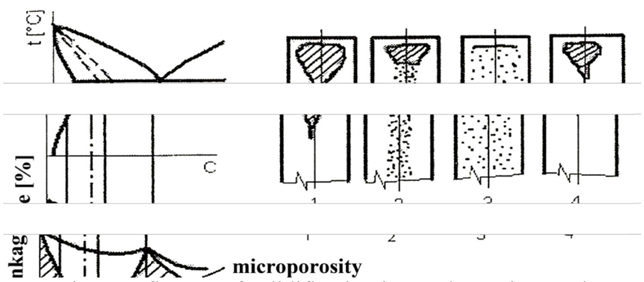

Fig. 1. Influence of solidification interval on micro and macroporosity

3. Experiment

Casting of experimental samples was carried out in cooperation with company NEMAK Ltd. Nemak is focused on production of the cylinder heads for the automotive industry. Cooperating with the real casting company was a great advantage because alloys used in experiments were in fact alloys commonly used in practice.

Alloy was poured into experimental mold called Sanduhr Probe, which is used by the company Nemak to evaluate porosity. Experimental casting consists of three parts - riser, interconnection and a section which was analysed. The shape of the mold - casting was designed on the basis of theoretical knowledge about the formation of porosity. Inside the reduced area of the casting (interconnection part) metal solidifies first, which prevents further feeding of the melt into the bottom - analysed part of the cast. This causes nucleation of porosity and possibility of its further evaluation. At the figure 2 can be seen the shape and dimensions of the experimenal casting and mold Sanduhr probe .

a)

b)

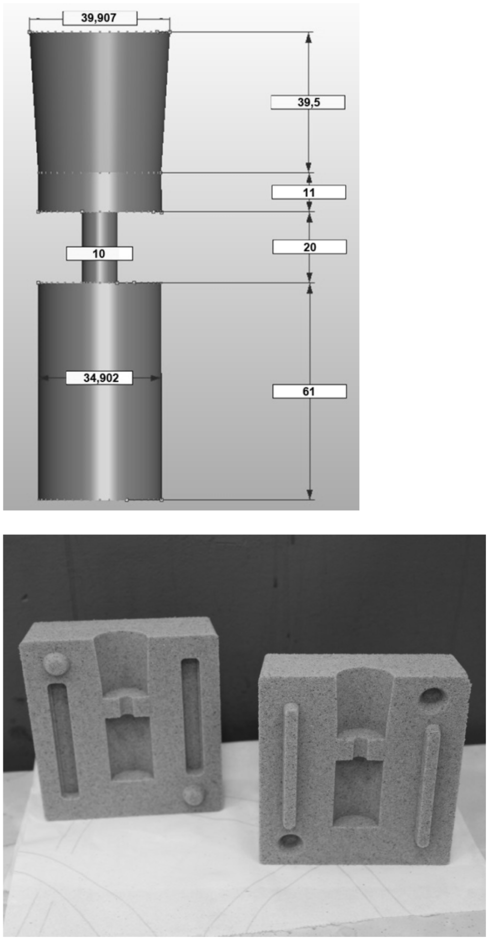

Fig. 2. The shape and dimensions of the experimental casting (a) and Sanuhr probe mold (b)

After casting and cooling, the test samples were cutted vertically and polished for the purpose of surface porosity evaluation.

For evaluation was necessary to convert samples surface into digital form. Individual samples were captured by scanning at high resolution - 4800dpi. Scanned sample can be seen at the figure 3.

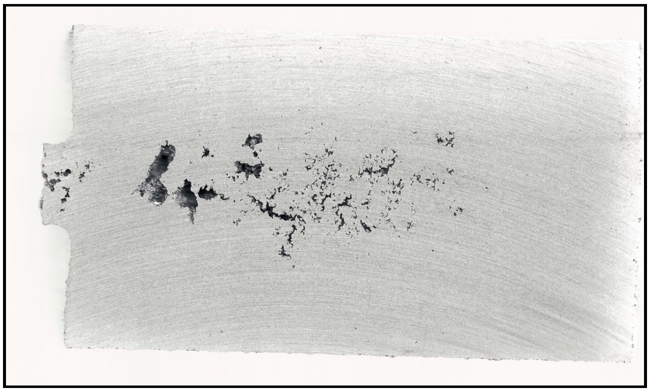

Fig. 3. Sample after scanning

Scanned samples were consequently processed using a graphics program Adobe Lightroom. By using this software has been enhanced contrast, brightness and microcontrast. This setting is the most appropriate in order to eliminate traces of the grounding, while the pores are preserved. Also evaluated area was displayed by using only two colors - black and white, which was important for the evaluation of the percentage using the histogram method. At the image 4 can be seen sample surface after the contrasting ready for evaluation.

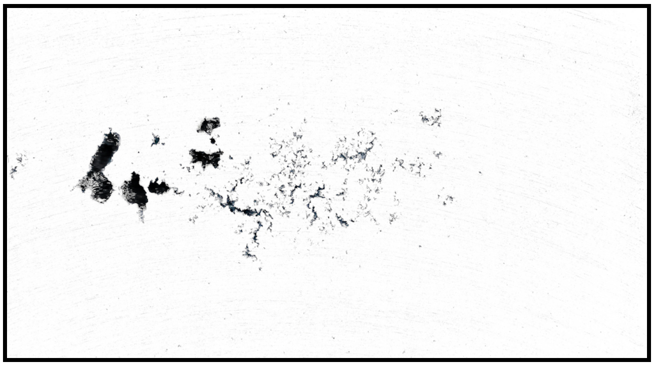

Fig. 4. Sample after contrasting

Evaluation of samples was performed using graphic software Adobe Photoshop CS5 by using a histogram method. In used software was selected whole evaluated area and consequently, the number of all pixels was identified. In the next step was marked only places with black points (pores) and again, the counting of the pixels were executed. From these two data it was possible to evaluate percentage of pores in the samples. Evaluation with help of the software Adobe Photoshop can be seen at the figure 5.

For this experiment were selected following alloys:
- Pure aluminum,
- AlSi6Cu4,
- AlSi7Mg0.3,
- AlSi9Cu1,
- AlSi10MgCu1.

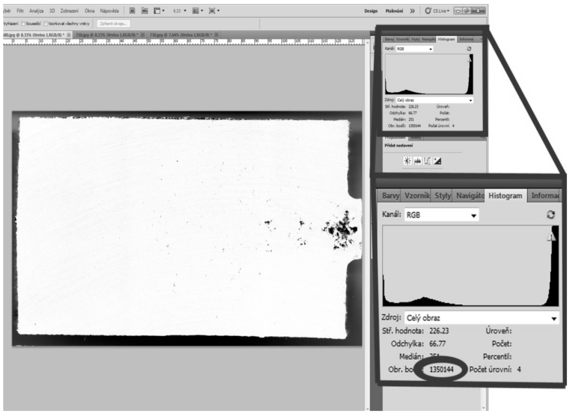

Fig. 5. Sectional evaluation of porosity with Adobe Photoshop

These alloys were chosen because of the gradual growth of silicon in the alloy Al-Si to pure aluminum towards eutectic point in order to be able to observe the solidification interval width effect on nucleation of porosity. All alloys were cast at a temperature of 720 ° C ± 5 ° C into a experimental mold. Except the pure aluminium samples all samples were casted after the degassing process, which was carried out by blowing nitrogen and subsequent inoculation and modification. At the figure 6 is shown diagram with marked alloys used in experiment.

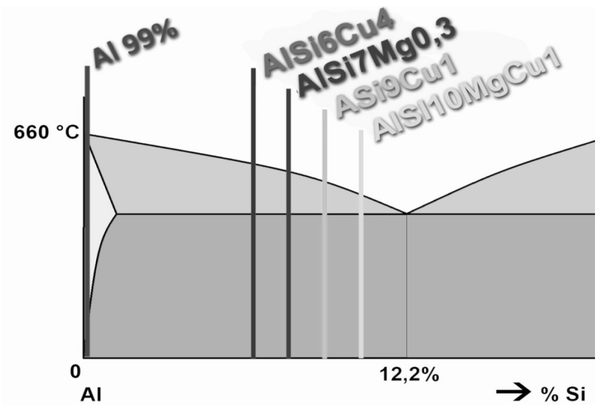

Fig. 6. Used alloys marked in Al-Si diagram

After casting and cooling, test samples were cutted and polished for the purposes of surface porosity evaluation. The lowest value of porosity was observed in aluminum alloy AlSi6Cu4 (0.28%) with the widest interval of solidification. When the alloy AlSi7Mg0, 3 value was 0.48% and the 2.29% alloy AlSi9Cu1. Significant increase in porosity was assumed at alloy AlSi10MgCu1 (4.74%) and the largest amount of surface porosity of the variant with pure aluminum, where can be observed one big shrinkage pore.

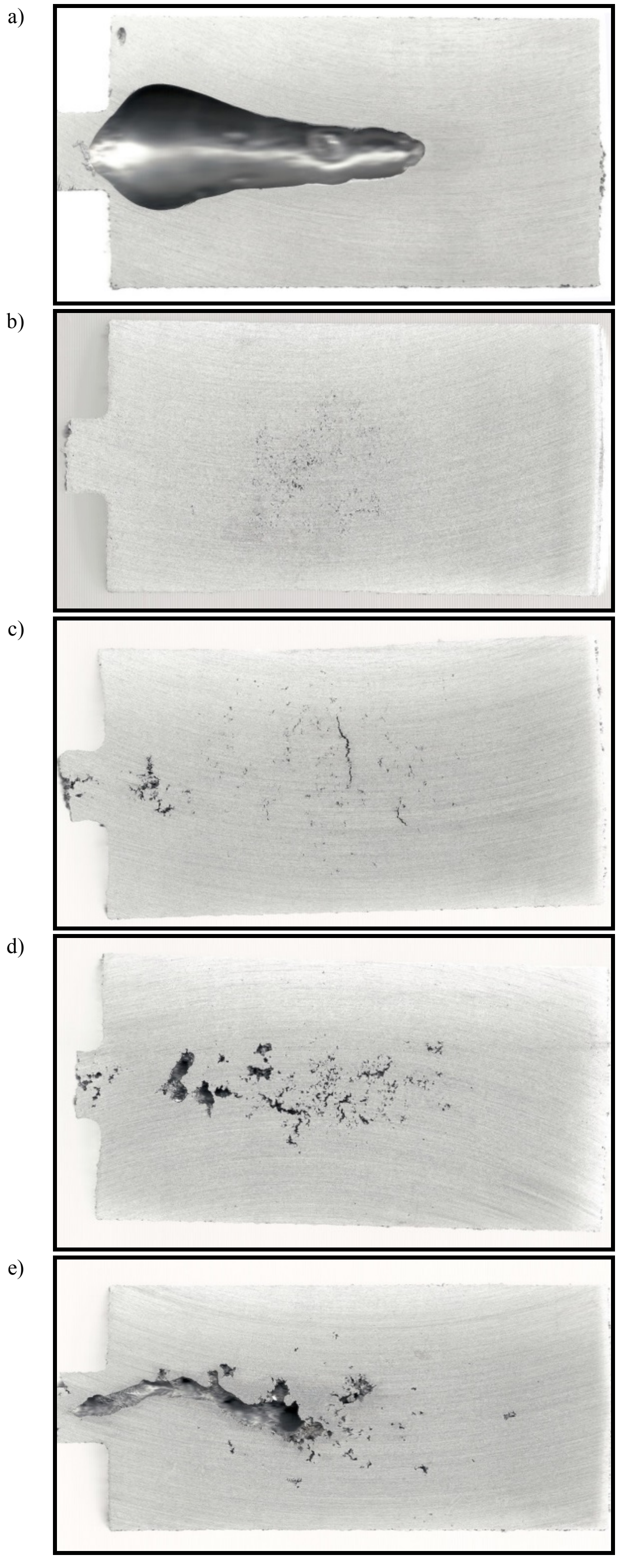

Fig. 7. Test samples after cutting and grinding. a) Pure aluminum b) AlSi6Cu4, c) AlSi7Mg0,3, d) AlSi9Cu1, e) AlSi10MgCu1

Comparison of individual samples can be seen at the figure 7. The results can be seen in the table below and their comparison at the figure 8.

Table 1.
The measured values of porosity during analysis of the chemical composition effect on porosity

Alloy	Porosity [%]
Pure aluminium	19,32
AlSi6Cu4	0,28
AlSi7Mg0.3	0,48
AlSi9Cu1	2,29
AlSi10MgCu1	4,74

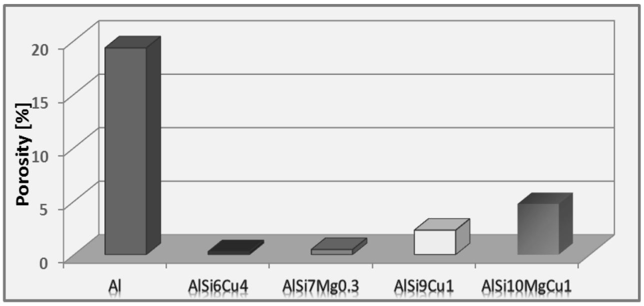

Fig. 8. Comparing of the measured values of surface porosity

4. Conclusions

Based on a comparison of individual results can be concluded that alloys with wider solidification interval (AlSi6Cu4 , AlSi7Mg0,3) have less tendency to porosity formation as an alloy with a narrow interval of solidification (AlSi9Cu1, AlSi10MgCu1), respectively, alloys approaching with their chemical composition to the eutectic point or pure metals. It is also possible to observe samples of the pure metals and eutectic alloys have a high tendency to the formation of large pores and bubbles concentrated in the places with big mass of the melt, while other parts of the casting is almost free from pores. On the other side, samples with a wide solidification have a tendency to the formation of microporosity, which is evenly distributed throughout the casting. It can be therefore concluded, that from perspective of porosity occurence, the alloys with a wide solidification interval are more suitable for stressed castings than alloys approaching with their chemical composition to the eutectic point.

Acknowledgements

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