

## Changes in Eutectic Silumin Structure Depending on Gate Geometry and Its Effect on Mechanical Properties of Casting

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The gate geometry has a direct influence on casting properties. It was proven that changes in gate dimension (height) influence the permanent deformation values and die cast porosity. The present paper discusses the issue whether changes in gate dimension may affect the structural composition of eutectic silumin. It presents results of the microsection analysis of samples taken from castings made with different gate dimensions to compare the phase  $\alpha$  and phase  $\beta$  proportion forming eutecticum. Consequently, conclusions are drawn to examine the influence of gate dimensions on the cast eutectic structure as well as the structure correlation and the selected mechanical properties.

**Keywords:** high pressure die casting, mechanical properties, eutectic structure, gate

### 1 Introduction

In the die casting technology, the structure and process parameters of the gating system correlate with direct influence on the resulting quality of die cast. The gate geometry has the most significant impact on quality of die cast. It was proven by authors of the following publications: Influence of Structure Adjustment of Gating System of Casting Mold upon the Quality of Die Cast (Gašpár, 2017, Lüdenscheid: RAM - Verlag), Analysis of Influence Dimensions of the Gate on the Homogeneity of the Low Weight Castings Made of Silumin (Majerník, 2017, in: Manufacturing Technology) and Analysis of the Impact of the Construction of a Gate on the Macroscopic

Structure of a Casting and Its Influence on the Mechanical Properties of Castings (Majerník, 2017, in: Manufacturing Technology) that gate dimensions (height) have a direct influence on permanent deformation and porosity of a casting. As explained in the publications above, changes in mechanical (qualitative) properties of castings result from changes in the mold cavity filling mode. Surface hardness of castings was amongst the selected parameters in the above publications. While the identified average value of surface hardness was 106 – 107 HB, no marked influence of the gate dimension on die cast hardness was proved. Tab. 1 below shows results of the study of gate dimension influence on mechanical properties of castings as presented in the above publications.

**Tab. 1** Values of selected parameters depending on gate dimension

Sample No.	Ingate height [mm]	Ingate weight [mm]	Permanent deformation $S$ [mm]	Surface harness $HB$	Porosity $f$ [%]
1	1.25	60.968	0.068	107	0.89
2	1.03		0.053	107	0.87
3	0.92		0.044	107	0.85
4	0.82		0.033	106	0.18
5	0.75		0.058	106	1.27

To ensure that relevant results are obtained for gate height correlation, batches of castings with constant process parameters were prepared. Process parameter settings are illustrated in Tab. 2.

**Tab. 2** Die casting process parameters

Die Casting Process Parameters	
Parameter	Value
Melt temperature [°C]	708
Mold temperature [°C]	220
Injection plunger speed [m.s <sup>-1</sup> ]	2.9
Creep [MPa]	25
Mold cavity filling time [s]	0.019

This paper analyses the structural composition of eutecticum and dependencies of structure formation on changes in height of gate and its influence on the selected mechanical properties of castings.

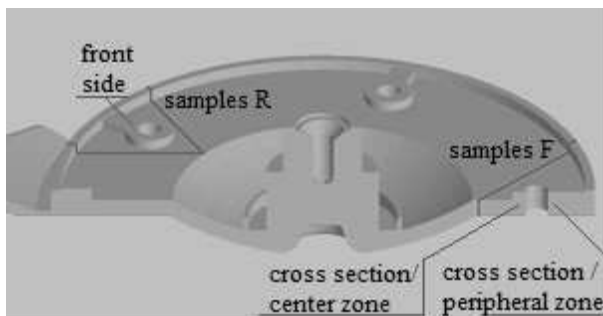
### 2 Test Sample Characteristics

Die castings were made from EN AC 47 1000 (AlSi12Cu(Fe)) alloy. The die cast chemical composition was tested in the laboratory using a Q4 TASMAN spectrometer under the ambient temperature of 22°C and relative humidity 50%. Test samples were measured and the average of three sparking cycles were examined. The measurement of chemical composition values is illustrated in Tab. 3.

**Tab. 3** Chemical composition of cast alloy

Chemical composition of experimental cast alloy [%]											
Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti
85.27	12.02	0.71	1.19	0.21	0.13	0.02	0.02	0.35	0.02	0.03	0.03

The eutectic structure was tested at critical places of castings. Critical places were defined to be construction holes in the casting. It is where cores are placed in the die casting process. Based on hydrodynamics examination and liquid flow around cores, a high probability of casting faults was concluded in those places. Fig. 1 shows the sampling points for examination of the metallographic structure. The selected mechanical properties of castings were also measured in those places.

**Fig. 1** Eutecticum structure measurement points

Casting quality can be influenced by the method of filling the mold cavity, that is the melt flow course in the mold cavity. For this reason, F samples were taken places opposite to the ingate where the melt flow hits the mold

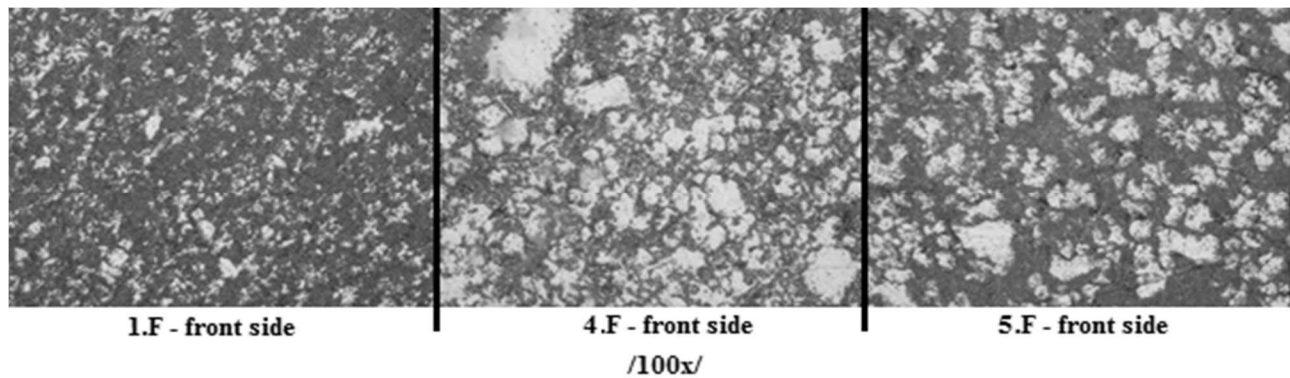
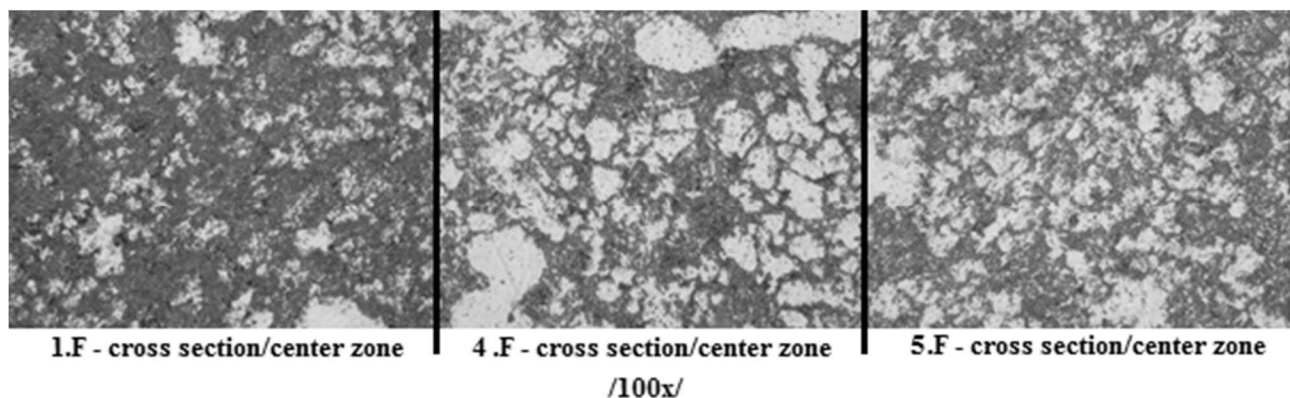
face and splits into two streams advancing along the mold wall towards the ingate. R samples were taken from places where the melt bounced off the front side of the cavity is merged with the melt flowing through the ingate. Microsections were made on the face below the surface as well as in the casting blank according to zones in the direction of thermal gradient in the cooling process.

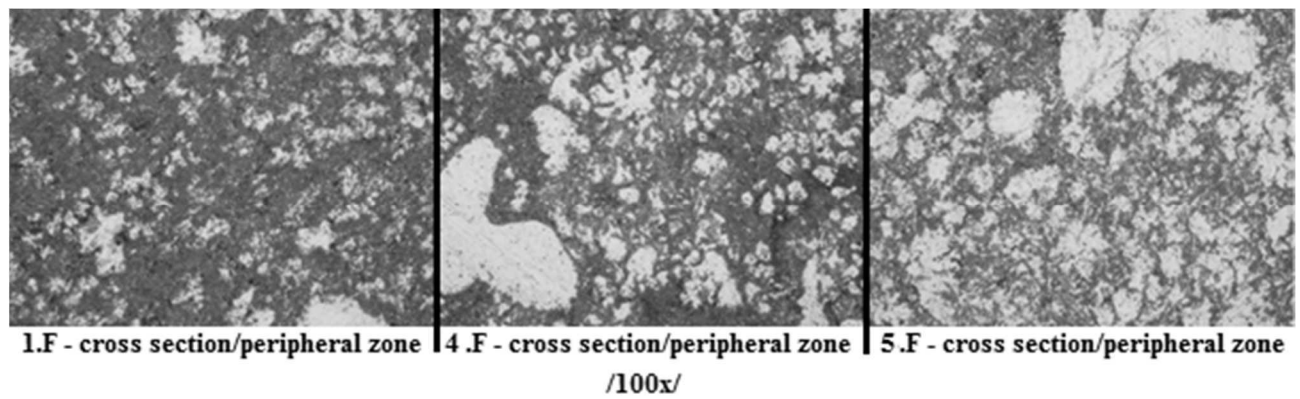
Microsections were made on samples taken from sets of die casts marked as Sample 1, Sample 4 and Sample 5. Linear changes of the selected properties were observed in Sample 1 to Sample 4. Samples exhibiting the minimum and maximum values of the examined properties were selected. Sample 5 was selected because of the local linearity extremes of the selected parameters.

### 3 Metallographic Structure Examination

Microsections were made in accordance with the Czech standard CSN 42 0491. To reveal the structure, samples were etched with 0.5% water solution of hydrofluoric acid at the temperature of 22°C. The metallographic structure of selected samples was examined in Olympus GX51 microscope and 100x magnification.

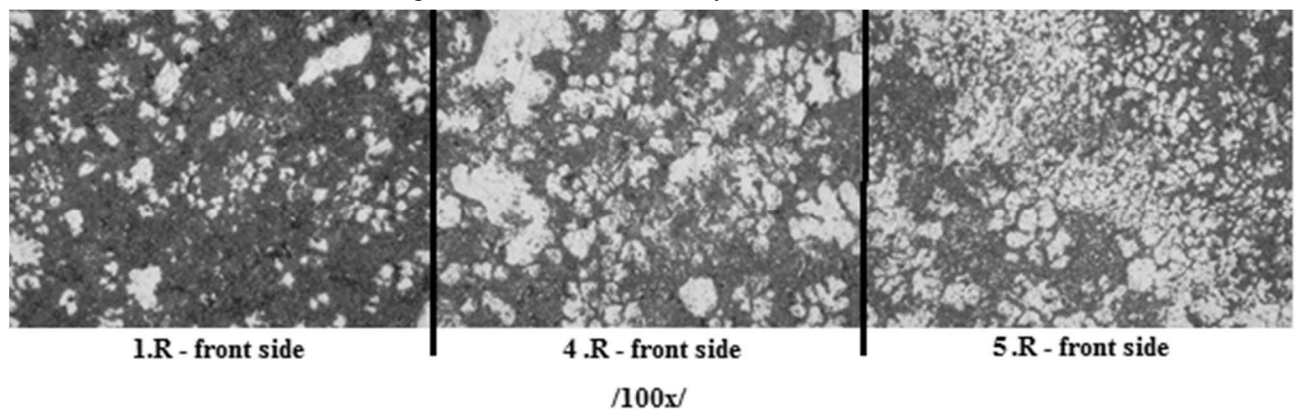
Fig. 2, Fig. 3 and Fig. 4 show the comparison of microsections and the structure of samples taken from the area opposite to the gate.

**Fig. 2** Samples x.F - front side microsection structure**Fig. 3** Samples x.F - cross section/center zone microsection structure

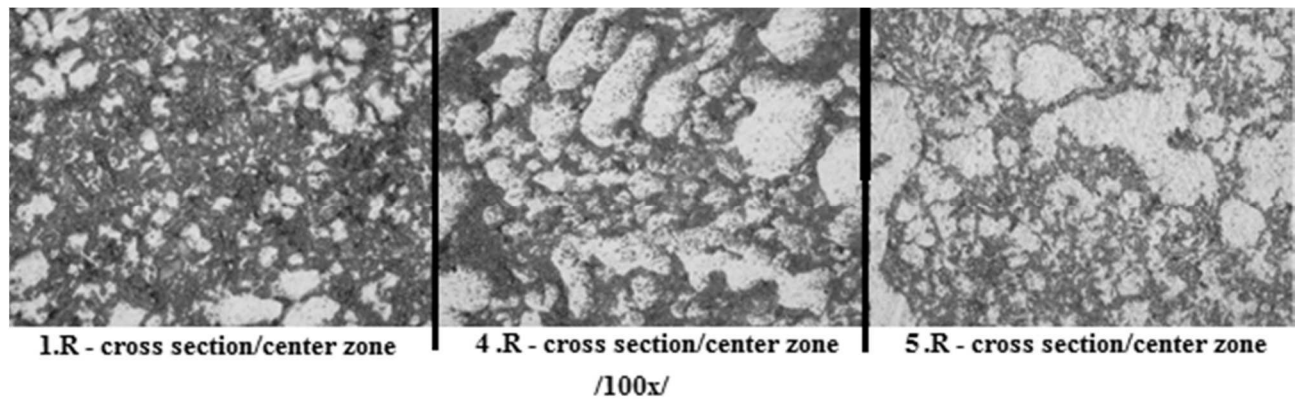


**Fig. 4** Samples x.F - cross section/peripheral zone microsection structure

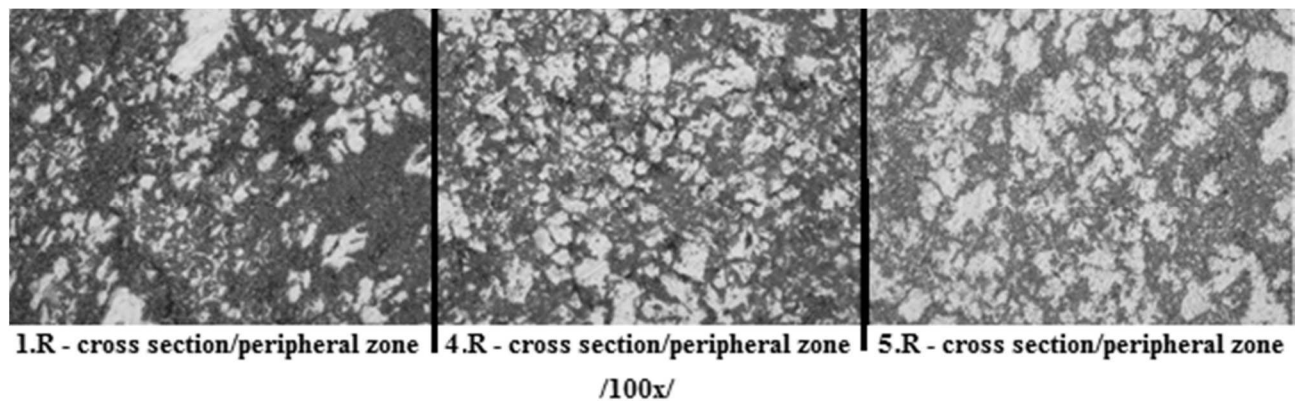
Fig. 5, Fig. 6 and Fig. 7 show the comparison of microsections and the structure of samples taken from the melt merging area nearby the gate outlet to the mold cavity.



**Fig. 5** Samples x.R - front side microsection structure



**Fig. 6** Samples x.R - cross section/center zone microsection structure



**Fig. 7** Samples x.R - cross section/peripheral zone microsection structure

The conclusion based on comparison of the structures of samples taken at different height of the ingate is that the proportion of  $\beta$  phase in the microsection decreases in all the examined places with the decreasing height of the ingate. Therefore, we can conclude that changes in height of gate as well as the method of filling the mold cavity have an influence on the structural composition of eutecticum.

#### 4 Evaluation of Structural Influence on Mechanical Properties of Castings

Eutecticum represents a mixture of solid solution of the  $\alpha$  phase and the  $\beta$  phase crystals formed by eutectic transformation. Eutectic silumin is characterized by the silicon concentration of 11.7 to 12.5 %. The  $\alpha$  phase is a solid solution of aluminum with different content of other elements forming white precipitates. The  $\beta$  phase is a solid solution of almost pure silicon (content above 98% Si) forming grey precipitates. Silicon improves the strength of a solid solution and its corrosion resistance. In case of a higher content, pure silicon is present which improves the hardness, but the values of deformation characteristics and ductility are decreasing. It correlates with the values of permanent deformation.

It was established by comparing the structures of microsections from castings made at different height of the ingate that the proportion of the  $\beta$  phase in the microsection decreases with the decreasing height of the ingate. Considering the fact that microsection samples were taken from different places of the casting, we can conclude the  $\beta$  phase is decreasing in the whole casting.

Based on the average values of mechanical properties of each batch of castings illustrated in Table 1, the conclusions can be expressed as follows:

a) Decreasing proportion of the  $\beta$  phase has a positive influence on permanent deformation

While the  $\beta$  phase has silicon content above 98%, its higher content will decrease ductility, namely also the level of resistance against deformation caused by permanent strain. Table 1 shows that permanent deformation reduction has a linear course in Sample 1 to Sample 4. Sample 5 shows a certain local extreme. This phenomenon can be explained by the porosity of samples where Sample 5 exhibited high porosity values. The extreme porosity is caused by the mold cavity filling mode. The height of gate being the lowest in those castings accelerates the melt flow causing dispersion behaviour of the mold cavity filling mode. Dispersion filling allows enclosed gas in melt, thus resulting in higher porosity.

b) Decreasing proportion of the  $\beta$  phase has an influence on surface hardness of castings

It was proved that values of surface hardness of castings are not dependent on the gate dimension (height), but on the subcooled melt in the contact area of the mold face. The minimum hardness difference  $\Delta HB = 1$  was identified between Sample 1 and Sample 4 casting batches. It is obvious from the comparison of microsections that Sample 4 and Sample 5 have a proportion of the  $\beta$  phase lower than Sample 1. Silicon improves hardness of castings, namely its higher content in the casting can influence surface hardness of castings.

#### 5 Conclusion

The identification of dependencies of the gating system construction and mechanical properties is a significant aspect in technical practice for influence on the casting properties, and production efficiency increase, and positive direction in the economic sphere. It is concluded that a pertinently designed gating system together with the adequate settings of process parameters is important to achieve good quality indicators of production and reduce scrap in the casting production which has a positive influence on the economic aspects of production.

This paper presented results of the study of the gate geometry influence on the eutectic silumin structure and examined the influence of eutectic elements on mechanical properties of castings. It was established that the gate dimension (height) can influence the  $\alpha/\beta$  phase proportion in eutecticum over the whole casting. The selected mechanical properties were confronted with changes in the  $\beta$  phase proportion. The mechanical properties of the casting continuously changed similar to changes in the  $\beta$  phase proportion in the casting. Therefore, it is well founded that the  $\beta$  phase proportion has an influence on changes in mechanical properties, namely the values of permanent deformation and to some extent, on the values of surface hardness of castings.

The paper established the influence of the gate dimension (height) on formation of the eutectic alloy structure and the influence on casting properties. The aim of future research in this field is to define and describe the causes of influence on the structure.

#### Acknowledgement

*This paper has been prepared within the project VEGA 1/0041/16.*

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10.21062/ujep/118.2018/a/1213-2489/MT/18/3/439

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