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TECHNOLOGICAL DEVELOPMENT OF THE CASTING PROCESS FOR THE THIN-WALLED GRAY CAST IRON

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Abstract

The research was performed to optimize the casting process and geometry of the fireplace door frame casting to increase productivity and prevent the appearance of the surface casting defects. The ProCAST software support was used to optimize the vents and casting temperature. Although, the proposed optimization reduced casting time and the mass of the casting, the increase in the hot spot had a negative impact on the appearance of the burn-on. The simulation results indicated that the appearance of the surface defect could be avoided by lowering the casting temperature of the optimized version.

Keywords*: gray cast iron, optimization, numerical simulation, technical development, solidification, microstructure*

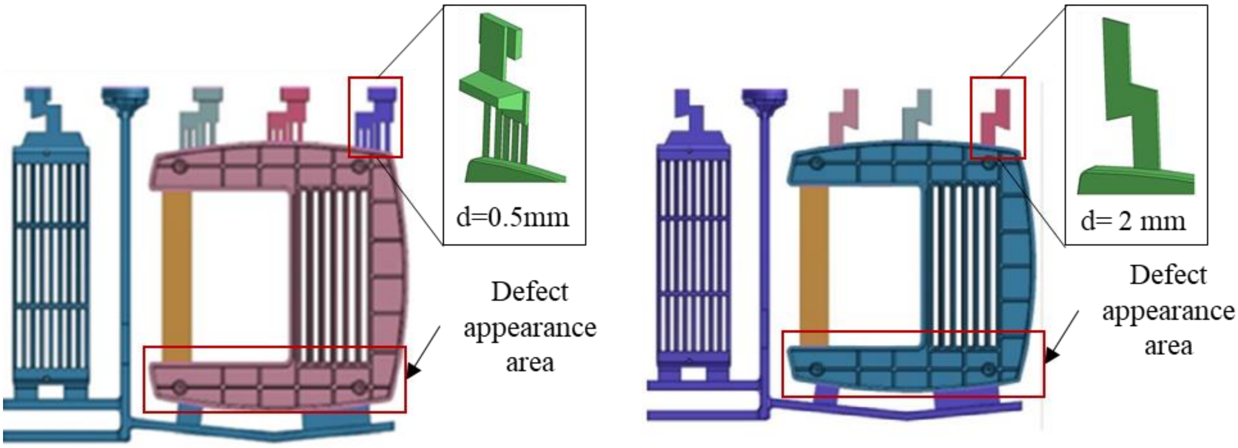
1. INTRODUCTION

The gray cast iron is frequently used in mechanical engineering, process and automotive industry, production of fittings for the plumbing systems and in the domain of radiators and heating elements [1]. Optimization of the process parameters, technological elaboration of the casting process as well as the melt processing affect solidification sequence and microstructure development enabling realization of desired product properties and overall quality. Casting conditions, mainly chemical composition and cooling rate, affect the nucleation process and the appearance of the irregular graphite lamellae morphology impacting the product properties [2, 3].

The aim of the paper is to optimize the casting process and geometry of the fireplace door frame casting in order to increase productivity and prevent the appearance of casting defects in the form of surface burn-on. The achievement of the optimal casting geometry was related to the optimization of the vents whose role is to dissipate heat from hot spot. The optimization was based on the numerical simulation, since it provides an insight in various casting processes including solidification, heating, and cooling conditions [4, 5]. The impact of the optimization on microstructure development, mainly graphite size, shape, and distribution, was evaluated using metallographic analysis.

2. EXPERIMENTAL

The increase in productivity and prevention of the burn-on of the thin-walled gray iron casting was the imperative of this work. Data acquired from the original geometry indicated that vent design is inconvenient due to the premature solidification prior to the end of filling. This way vents prevent the heat dissipation and do not serv their purpose (Figure 1 a). Technological development led to the design of optimized geometry of the casting (Figure 1 b) and numerical simulations were performed for both cases using ESI GROUP ProCAST software support.



a) b)

Figure 1. The fireplace door frame casting: a) Original casting geometry, b) Optimized casting geometry

As indicated by Figure 1, the changes were made in the design of the vents while clamp (yellow area) and inlets were not changed. This type of casting geometry optimization should increase the dissipation of the heat to prevent the occurrence of the burn-on in the hot spot. Although, the clamp is not a part of the casting, it serves to minimize the deformation of the final product.

Table 1 shows the casting parameters for two technological developments of the casting.

Table 1. Casting parameters for two technological models of casting geometry

Geometry of the casting	**Original**	**Optimized**
Inlet (mm)	1.5x50 and 2x140	1.5x50 and 2x140
Casting time (s)	8.37-8.88	7.2
Temperature (°C)	1385	1410
Vents (mm)	d=0.5	d=2
Mass (kg)	24.9	23.9

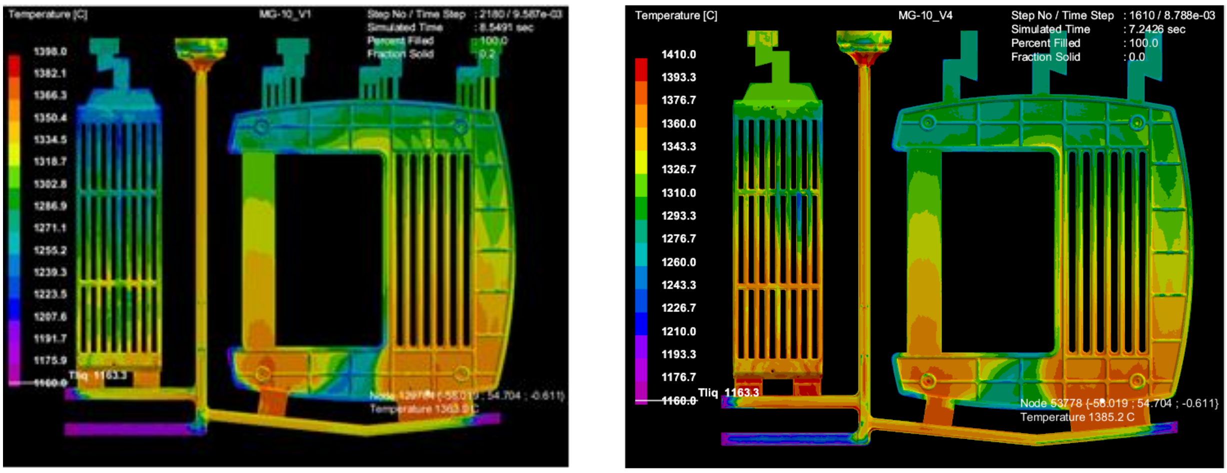
Distinctly, the casting time and the mass of the product were reduced for the optimized model (Table 1). Temperature of the casting process was higher for the optimized casting geometry which prevented the vent solidification before the mold cavity was completely filled. This means that the optimization was effective in the productivity improvement.

Chemical analysis of the castings was performed using optical spectrometer Leco GDS500A to track potential difference in chemical composition of the melt used in original and optimized casting. To evaluate optimization success, microstructure was examined using inverted metallographic microscope Olympus with DP 27 digital camera and Stream Motion software support. The graphite shape, size and distribution were determined according to EN ISO 945-1:2018.

3. RESULTS AND DISCUSSION

Comparison of the simulation results for the original and optimized casting geometries is given in Figure 2, while Table 2 indicates the appearance of burn-on defect in the heat zone. A targeted reduction in casting time and mass was achieved. The mass of optimized casting geometry is 1 kg lower when compared to the original version. The casting time is reduced by 1.3 s (Table 1).

In order to prevent the underfilling of the vents, the pouring temperature of the optimized version was increased by 25 °C when compared to the original casting procedure.

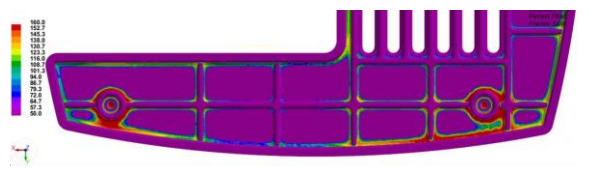
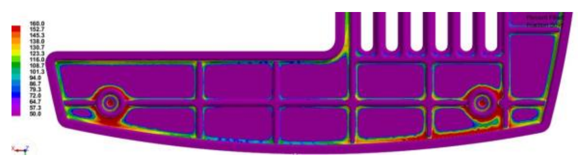
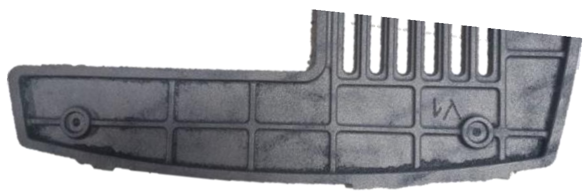


a) b)

Figure 2. The comparison of the temperature field for the: a) Original casting geometry, b) Optimized casting geometry

Although, the increase in pouring temperature to 1410 °C of the optimized version prevented the underfilling of the vents, it also increased the size of the hot zone (Figure 2). causing the formation of burn-on defect on the casting surface (Table 2).

Table 2. The temperature field and casting surface in the heat zone

	Original casting geometry	**Optimized casting geometry**
Temperature field		
Casting surface		

Results of chemical composition analysis are shown in Table 3.

Table 3. The results of chemical composition analysis

Casting geometry	**Chemical component, wt. %**								
	C	Si	Mn	P	S	Cu	Cr	Sc	CE
Original	3.63	2.04	0.49	0.33	0.103	0.142	0.106	1.046	4.42
Optimized	3.58	2.08	0.55	0.40	0.106	0.152	0.105	1.043	4.41

Despite increased content of silicone (Si) and phosphorus (P), the lower level of carbon (C) resulted in higher carbon equivalent (CE) of the second melt. Since CE is above 4.3, both melts are hypereutectic (Table 2).

The results of the metallographic analysis of the size, shape and distribution of graphite lamellae are indicated in Table 4.

Table 4. Results of metallographic analysis of size, shape, and distribution of graphite lamellae

Model geometry	**Graphite lamellae size**	**Graphite lamellae shape (mean value)**					**Distribution of graphite lamellae**
		I (%)	II (%)	III (%)	IV (%)	V (%)	
Version 1	5	59.33	28.33	30	0.33	2	B
Version 2	5	55.33	36.66	7.33	0.66	2	B

Lamellar form of type I graphite has the largest share in the microstructure for both original and optimized versions with a slightly increased amount in the original version due to the higher carbon content. Degenerated types of graphite (type II and type III) often form in hypereutectic alloys. The presence of spiky graphite (type II) increases proportionally with the increase in phosphorus content, while the amount of vermicular graphite (type III) decreases, respectively. In both versions, the graphite lamellae are distributed as rosettes (type B) with a random orientation. This type of graphite distribution most often occurs in near-eutectic alloys that are improperly inoculated. The pouring temperature elevation and optimization of the model did not have a significant impact on the graphite shape and distribution.

4. CONCLUSION

The research was performed in order to optimize the casting process and geometry of the fireplace door frame casting to increase productivity and prevent the appearance of the surface casting defects. Optimization of the vents and casting temperature enabled increase in productivity in a form of reduced casting time and mass of the casting. Although, the increase in pouring temperature of optimized version prevented the underfilling of the vents, it has also increased the size of the hot spot. The increase in pouring temperature did not have a significant impact on the size, shape, and distribution of graphite lamellae. However, it had a negative impact on the occurrence of surface defects, mainly burn-on. The simulation results indicated that the appearance of the surface defect could be avoided by lowering the casting temperature of the optimized version to 1385 °C.

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