TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 07/20 pp152-156
Volume 13, Number 2, April 2008

Optimization of Casting Process for Heat and Abrasion Resistant Large Gray Iron Castings

S. M. Yoo [1,**], Y. S. Cho[2], C. C. Lee [2], J. H. Kim [3], C. H. Kim[3], J. K. Choi[1]

1. Center for E-Design, Korea Institute of Industrial Technology, Yeonsugu Sondodong 7-47,
Incheon 406-800, Korea;
2. Kwanghee Casting Mfg. Co., Seogu Kyungseodong 381-75, Incheon 404-170, Korea;
3. R&D Center, Doosan Engine Co., Ltd., Sinchondong 69-3, Changwon 641-370, Korea

Abstract: Numerical simulations were used to optimize the casting design and conditions for large cast iron castings for marine engines. Simulations of the mold filling and solidification sequences were used to analyze the problems of previous casting conditions with marked improvements for large cylinder liner parts. The amount and positions of chills were optimized to improve the mechanical properties and to minimize the shrinkage and micro porosity in the castings. Ultra sonic testing, penetration testing, and mechanical property testing show no defects in the castings with the productivity significantly increased.

Key words: gray cast iron; numerical simulation; marine engine; cylinder liner; chill; casting design optimization

Introduction

Cast iron is still an essential engineering material which has high cost efficiency, outstanding castability and machinability, good thermal conductivity, and damping capacity[1,2]. Pressure tightness is one of the important factors for gray iron castings like cylinder liners, cylinder blocks, and exhaust valve housings used in pressure applications. Defects like shrinkage and porosity occur mostly at the joints between thin and thick wall thicknesses. The use of uniform wall sections prevents most leaks in castings, but in foundry shops it is hard to realize this. In practice chill blocks are applied to prevent formation of internal defects and for directional solidification.

Because the production of large ships such as the 5000-10 000 TEU container ships has increased dramatically in Korea, low speed two-stroke marine diesel engines are in great demand. Accordingly, the demand for marine engine components such as cylinder liners and crankshafts has increased rapidly. It has become more and more important not only to improve the quality of products but also to deliver the parts on schedule. The main product of the Kwanghee Casting Mfg. Co. is gray iron cylinder liners for low speed diesel engines with bore sizes from 50 mm to 980 mm for propelling oceangoing ships. The pouring weights of the various liners are from about 4 tons to 16 tons. As production has increased the ratio of casting defects caused by microporosities or shrinkage found during the final machining increased between 2003 and the middle of 2004, even though the mechanical properties still met the specifications. The casting defects increased the production costs and delayed delivery.

Numerical simulations are widely applied in the cast iron foundry industry to analyze the heat and fluid flow during the casting process and to predict casting defects[3-11]. In this study the casting conditions of cylinder liners for large diesel marine engines were optimized using simulations and the results were compared with experimental data.

Received: 2007-10-07

** To whom correspondence should be addressed.
E-mail: yoosm@kitech.re.kr

1 Numerical Analysis

The commercial software Z-Cast™ was used to simulate the fluid flow in a sand mold with a shower gate and the solidification sequence for a L70MC cylinder liner with an inner diameter of 700 mm. The solidification behavior and temperature distribution in the mold, core, and casting were evaluated using a transient heat flow analysis. The optimal processing parameters for the cooling were obtained from the analysis of fluid flow and solidification. The process parameters for sound castings without shrinkage defects were determined by analyzing the temperature distributions in the mold and casting, the variation of temperature gradients, and the solidification time.

Figure 1 shows the mesh and the calculated filling patterns in the casting. The filling behavior was stable without extreme turbulence during the filling stage. The temperature distribution after the filling was mostly uniform, with the temperatures of some areas where the chill blocks were installed, cooling rapidly.

Figure 2 shows the solidification times and temperature distribution for the original casting conditions. The predicted defects areas, where liquid regions become entrapped in the casting during solidification are very close to those observed in the real cast parts.

2 Experimental Procedures

A gray iron cylinder liner was successfully cast using the modified casting conditions in a furan mold with the mechanical properties then evaluated as shown in Fig. 3. The pouring temperature was 1355℃. All the experimental results met the qualifications. The chemical composition of the L70MC cylinder liner is listed in Table 1. Table 2 shows the microstructure analysis results and the mechanical properties of the L70MC. The minimum tensile strength was 256 N/mm^2 with about 0.4% elongation. The Brinell hardness ranged from 202 to 225. The graphite and microstructure of the cylinder liner at the center of the casting are shown in Fig. 4. Modifications of the core and use of the optimal amount and positioning of chill blocks improved the shape and size of the graphite and the fractions of different phases compared to previous conditions.

3 Results and Discussion

The initial results were used to optimize the casting conditions. The temperature distribution in the casting after solidification with the modified casting design is shown in Fig. 5. The size of the core was changed to optimize the cooling and venting so that fewer chill blocks were needed. All the indirect chill blocks were removed, which greatly reduced the man hours required for positioning the chill blocks. The solidification front moves more gradually towards the riser with the final solidification zone in the riser. Consequently, the shrinkage defects were predicted to occur only in the riser.

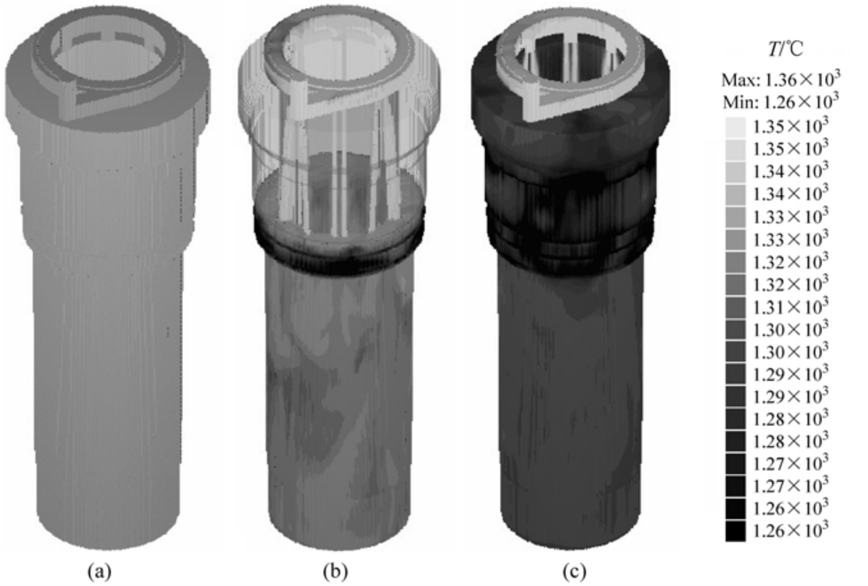

Fig. 1 (a) Meshed model and temperature distributions after (b) 50% filled and (c) full filled of a cylinder liner for original casting conditions