Optimization of casting conditions for heat and abrasion resistant large grey iron castings


Abstract: Numerical simulation technology was applied for optimizing the casting design and conditions in large cast iron castings for marine engine. By the simulation of mold filling and solidification sequences the problems of the previous casting conditions were analyzed and marked improvements for large cylinder liner parts were derived from these results. Especially the amount and positions of chills were optimized to increase the mechanical properties and to minimize the shrinkage and microporosity in the castings. Ultrasonic testing, penetration testing and mechanical property testing were carried out for the parts with the modified casting conditions. It showed that no defects in the castings were found and the productivity could be distinctly increased. The mechanical properties satisfied also the specification demanded.

Keywords: grey cast iron; numerical simulation; marine engine; cylinder liner; chill; casting design optimization

CLC number: TG143.2/TP391.9
Document Code: A
Article ID: 1672-6421(2007)02-124-04

C ast iron is still an essential engineering material which has high cost efficiency and outstanding castability, machinability and properties like good thermal conductivity and damping capacity [1]. Pressure tightness is one of the important factors for grey iron castings like cylinder liners, cylinder blocks and exhaust valve housings which are used in pressure applications. Defects like shrinkage and porosity occur mostly at the joints between thin and thick wall. By the design of uniform wall section most leaking trouble in castings could be prevented, but in foundry shops it is hard to realize this idea. In practices chill blocks can be applied to prevent forming of internal defects and to keep directional solidification.

Because the production of large ships like 5 000-10 000 TEU containerships increases dramatically in Korea, low speed two-stroke marine diesel engines are in great demand in the market. Accordingly the needs of marine engine components like cylinder liners and crankshafts have increased rapidly. It becomes more and more important not only to improve and keep the quality of products but also to deliver the parts on schedule. The main product of Kwanghee Casting Mfg. Co. is grey iron cylinder liners for low speed diesel engines with bore sizes from 500 mm to 980 mm for propelling oceangoing ships. The pouring weights of different liners are from about 4 tons to 16 tons. As the production has increased the ratio of casting defects caused by microporosities or shrinkage which were found during the final machining has increased from 2003 to middle of 2004, even though the mechanical properties has met the specification. Because of the casting defects the production cost kept increasing and delivery schedules are often delayed.

Numerical simulation is widely applied in the foundry industry for the analysis of heat and fluid flow during the casting process and the prediction of casting defects [2-4]. In this study the optimized casting conditions of cylinder liners for large diesel marine engines were obtained by the simulation and compared with the experimental results.

1 Numerical analysis

The commercial software Z-Cast™ was used for the simulation of fluid flow in a sand mold with a shower gate and solidification sequence for the cylinder type of L70MC with the inner diameter of 700 mm. The solidification behavior and temperature distribution of mold, core and casting part were evaluated by transient heat flow analysis. Optimal process parameters of cooling condition can be obtained by the above fluid flow and solidification analysis. The process parameters for sound castings particularly without shrinkage defects are determined using simulation results such as temperature distribution of mold and casting, the variation of temperature gradient and solidification time.

Figure 1 shows the enmeshed model 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 uniform in general, but the temperature of some areas where the chill blocks were installed, cooled down rapidly.

Figure 2 shows the solidification time and temperature distribution in previous casting conditions. The predicted defects area which indicated the entrapped liquid zone during the solidification was very close to those in real casting parts.

2 Experimental procedures

The grey iron cylinder liner with modified casting conditions was successfully cast in a furan resin bonded sand mold and the mechanical properties were evaluated (Fig. 3). The pouring temperature was 1355°C. All the experimental results met the qualifications. The chemical composition of the cylinder liner L70MC is listed in Table 1. Table 2 shows the microstructure analysis results and mechanical properties of L70MC. The minimum tensile strength was 256 N/mm² with about 0.4% elongation. The Brinell hardness was in the range of 202 to 225 HB. The graphite and microstructure of the cylinder liner at the center of the casting are shown in Fig.4. Through the modification of core and adoption of optimal amount and positioning of chill blocks the shape and size of graphite and the fractions of different phases were improved than those of previous conditions.

3 Results and discussion

Based on these results some casting conditions were optimized and new conditions were derived. The temperature distribution of castings after solidification of modified casting design is shown in Fig.5. The size of core was changed for optimum cooling and venting. The used number of chill blocks could be many reduced.
All the indirect chill blocks were removed. Thereby much man hour for the positioning work of chill blocks could be saved. The solidification front moves toward riser gradually and the final solidification zone was induced in the riser. Consequently, the shrinkage defects were predicted in the riser.

Two nondestructive tests - ultrasonic testing and penetration testing were carried out to control the soundness of the casting parts (Fig. 6). It showed that all the casting parts were defect free. During the final machining of the cylinder liners of L70MC type no defects are found up to now. The optimization and modification can be successfully applied to other 12 different types of cylinder liners and the productivity can be distinctly increased.

4 Conclusions

Numerical simulation of the mold filling and solidification sequences for large cylinder liners was carried out for the
optimization of casting process. Based on the simulation results of the temperature distribution and solidification sequence of the casting, modified casting design and conditions were acquired.

With less chill blocks especially without indirect chill blocks in the core the cooling effect was effectively improved through the optimization. The marked improvements can be achieved both in mechanical properties and productivity. These simulation results can be applied to other types of cylinder liners.

![Fig. 5 Calculated results of improved casting design and process parameters](image)

![Fig. 6 Nondestructive test of cylinder liner](image)

**References**


