Application of Non-mold Casting in New Process Verification of Cylinder Head

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Abstract: To solve the problem of long period in the process of new technology verification, this paper studied the new cylinder head process verification of triethylamine cold box core-making. Through using non-mold casting technique, the cylinder head verification process has been verified quickly. The results showed that, compared with the traditional method of verification, some effects have been found in the application of non-mold casting technique. Period was reduced by more than 45%, cost was reduced by more than 90%, and the risk of mold obsolete, due to process modifications, was eliminated.

1 Introduction
With the high speed development of modern manufacturing, the development direction of the casting industry are high efficiency, low energy, green and environmental protection. Especially with the implementation of the national environmental protection policy, the technology of renewable recycling of casting materials has matured, then energy saving and emission reduction of cold core box core modeling process has been pay more attention of casting enterprises at home and abroad [1,2]. Under the circumstances, the hot core box core technology of cylinder head has not kept pace with the development of casting technology, so it is necessary to carry out research and verification on the cold core box core technology of cylinder head. The rapid verification of new technology will greatly improve the development speed of new technology and provide strong support for technology upgrading.

Non-mold casting technology can directly develop and manufacture mold or casting prototype without mold. This technology can directly save the development and manufacturing process of the mold, thus greatly reducing the manufacturing cycle and manufacturing cost. Currently, there are mainly laser selective sintering (SLS), micro - drop sputtering and core - forming methods for mold - free casting [3,4]. The core processing and forming method can retain the characteristics of the original process, so it has high accuracy and credibility to verify the new process. In this paper, to study the application of CAD/CAE technology, virtual reality technology and non-mold casting technology in the process of new process verification. The cold core box core making process uses the cold core box core ejector to accurately produce the outer mold sand mold and inner cavity sand core of the casting, and then carries out the precise core setting, core setting, mold closing and casting. This process can produce sand cores with stable dimension precision and better quality, so the final casting surface reach the good quality, the high casting dimension precision, the small casting machining allowance and the small casting weight deviation.

2 Rapid validation of the new process
This paper plans to use CAD/CAE technology, virtual reality technology and non-mold casting
technology to quickly verify the core forming process of a cylinder head triethylamine cold core box. The verification process is as follows:

2.1 3D modeling and feature analysis of simulation casting CAD

UG software was used to build a 3d model of the cylinder head and to analyze the structural characteristics. The 3d model of cylinder head parts is shown in FIG 2: the product is a four-cylinder head product, which belongs to the complex engine parts. The contour size is 600mm*210mm*100mm, the material is HT250, the total weight of the casting is 40.5Kg, the thinnest wall thickness is 5mm, and the internal structure is complex. In order to satisfy the requirements of product size and quality, complex core design and exhaust system design need to be carried out for product casting with cold core box core making process.

After the establishment of the 3d model of cylinder head parts, the hole structure and other features that need to be processed later will be filled in. The machining surface will be offset to retain the processing allowance of 4-6mm and with 1% scale according to gray iron material. The casting 3d model is obtained by the above operations.

![Figure 2. 3D drawing of a cylinder head part](image)

2.2 Design of casting process, CAE simulation and virtual reality design

On the basis of 3d model casting, CAD technology, CAE casting simulation system and virtual reality technology are adopted to design and optimize the casting process of cylinder head.

2.2.1 Casting process design

According to the analysis of product structure characteristics, to design the casting process of bottom injection vertical casting, which can ensure the steady rise of metal liquid, avoid the damage of complex and weak water sleeve core and other thin-walled structures in the process of metal liquid filling, and reduce the defects of oxide slag and porosity. Then design 5 exhaust vents, the size is 45 x 10mm. The casting process of the designed cylinder head is shown in FIG. 3.
2.2.2 Optimization of casting process

The feasibility of CAE casting simulation system was verified. Through the simulation of casting stress, mold filling and solidification, to predict the casting defects such as deformation, porosity and shrinkage porosity. FIG. 4 shows partial solidification results of cylinder head and shrinkage cavity defects. The CAE simulation results were visualized with 3D in the virtual reality laboratory, and the process was evaluated and optimized by casting process, smelting and molding technicians. CAE simulation and process review results show that there is no shrinkage defect in the uneven wall thickness of cylinder head, only a small number of shrinkage cavity defects occur in the upper part of the top, and the parts are concentrated. According to the above simulation and analysis results, the improvement measures of adding a small number of riser to the corresponding defect position of the original process are adopted. CAE simulation and simulation were carried out for the improved measures, and the shrinkage defects in the casting were eliminated. Therefore, the optimized final pouring process was determined.

2.3 Casting parting design and virtual assembly technology

After determining the final pouring process of cylinder head, the fractal design was carried out on the basis of the original 3d model by using UG software and combining the characteristics of complex core digital processing and forming. The classification plan is shown in FIG 5. According to the plan, the cylinder head core is mainly divided into six sand cores, including upper and lower water jacket core, inlet and outlet channel core and upper and lower board core.
Figure 5. Mold design scheme of cylinder head casting

Under the virtual assembly environment of UG, or through the human-computer interaction and virtual scene technology of virtual reality system, the virtual assembly and visualization of cylinder head core parts can be realized. Through virtual verification, the assembly sequence of cylinder head is bottom core, bottom core, inlet and outlet core, top core and top core. When the two sand cores of the inlet and outlet core are assembled to the bottom structure, they should be assembled from the hole of the launching core at an oblique angle. In the actual assembly, the assembly personnel should be instructed in the assembly action to avoid damaging the launching core of the thin wall.

In the 3D visualization process of mold filling, it is found that the water sleeve core inside the cylinder head is difficult to exhaust, and there is a risk of forming stomata inside the casting. Therefore, the exhaust passage is designed inside the water jacket core as process 1, as shown in FIG. 6. The scheme of no exhaust passage is designed inside the water jacket core as process 2. After the two process plans are determined, the following two processes are quickly verified using the non-mold casting technology.

Figure 6. Design scheme of air duct inside water jacket core (process 1)

2.4 Digital mould-free forming of the cold core box core of cylinder head

2.4.1 Design of machining tool path

Based on the fractal design scheme, the process is completed by using UG software. Blank blanks and machining tool paths are respectively designed on water jacket core, air channel core and upper and lower type plate core. The processing method is to select the Cavity Milling process. The generally processing order is M16 Cavity Milling→M8 Rest-Milling→B6 Zlevel-Profile. After the completion of the tool path design of each part, use the processing method is M16 Cavity-Milling→M8 Rest-Milling. The PTP file is processed respectively, and the corresponding name is given, and the confidential molding machine without die is imported. FIG. 7 is the design of machining tool path for part of cylinder head sand core.
2.4.2 Production of cold core box sand billet

In order to improve the production efficiency, the artificial triethylamine solidification forming method is adopted for the production of the sand billet, that is, the simple sand block core box of aluminum alloy is made first, then the mixed triethylamine cold core resin sand is manually filled into the core box, and the resin sand is solidified with triethylamine after compacting, and finally moulded. Because the size of each part after the cylinder head casting is not different, all the sand blanks are designed to be the same size. All sand billets can be made by using a simple core box.

2.4.3 Processing and forming of cylinder head cold core box sand core

After the completion of the production of the sand blank, the magnetic blocks are clamped and fixed at 4 sides in the digital non-mold precision forming machine, and the milling, decoding, downloading and nc processing are carried out. The sand core of cylinder head is processed and shaped by triaxial machining. The water sleeve core and the air core of the internal designed air duct need to be processed on both sides, that is, after the single-side processing is completed, the sand blank should be turned over and positioned and then processed on the second side. FIG. 8 shows the process of the inlet and outlet core with a border. In the process of processing, it is necessary to use compressed air to blow out the broken sand in time, so as to avoid the movement or damage of the sand billet caused by sand accumulation and even break the cutting tool fracture.

2.4.4 Repair and size test

After the completion of core processing, repair and size testing. The main repair is to remove the border and support. For example, in FIG. 8, the cylinder head air sleeve core needs to be processed on both sides during the processing, so there is a virtual border around it for the positioning of the second processing. The border is also left after the processing is completed, and it needs to be removed by tools such as grinding wheel pieces. The dimension accuracy of the core of the cold core box was detected by using the three-coordinate measuring instrument. The precision of the core of the cold core box of the cylinder head was about 0.3mm plus or minus. And the manufacture of the core is not due to take out the
mold leaving the draft.

2.5 Assembly, whole dip coating and casting forming

The processed base core, upper water sleeve core, launching core, inlet core and exhaust core are locked into one body through the core locking sand column on the sand core, so as to realize the stability of each core when the base core group is immersed and coated. After the combination of all the sand cores of the cylinder head casting mold, the overall dip coating was carried out. After drying, the casting process was conducted. The core assembly and casting process were shown in FIG 9. It turns out: ① the performance testing and anatomic verification of the castings indicate that the dimensions and precision of the castings produced by using the cold core box technology meet the quality requirements, and no defects such as eccentric core breaking may occur due to the change of the core making process have been found. ② If the cooling water sleeve core does not design the exhaust passage, more stomatal defects are found after the cylinder cover is dissected, which can be solved by designing the exhaust passage.

Figure 9. Core forming, casting and forming after box closing

Figure 10. Blank parts of formed cylinder head

3 Conclusion

The research results show that the rapid verification of cylinder head cold core box technology by non-mold casting technology and other methods has the following advantages:

① With high speed, the method of no-die digital machining and forming is adopted to replace the method of cold core box mold forming, and the cycle is shortened by more than 45%. Non-mold casting, wood mould and metal mould are used to complete the single manufacturing of cylinder head, and the expected cycle is 16 days, 30 days and 90 days respectively.

② Vacuum chamber mold is low in cost and adopts the method of non-mold digital processing and forming to replace the method of cold core box mold forming, with the cost reduced by more than 90%. The cost of single cylinder head manufacturing is estimated to be 0.58 million yuan, 64,000 yuan and 60.23 million yuan respectively.

③ Greening, lightweight and non-mold casting saves 6-7 sets of molds and saves the use of wood and molds. Because the casting process does not need to consider the slope of drawing die, it can reduce the amount of processing and provide technical support for the lightweight design of cylinder head.
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