SIMULATION AND EXPERIMENTAL STUDY ON THE FENOTEC CASTING METHOD OF THE ENGINE BLOCK RV95

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Abstract

The new designs or new materials used in foundries for sand casting products in Vietnam now often rely on experience and adopt the try-to-fix method to gradually find the best implementation. This method is very time-consuming, and the product is often unsatisfactory in the first many castings. This study developed a casting simulation model to compare experimental and simulated results using the Fenotec molding technology for the RV95 engine body. The 3D simulation model that was used to simulate the casting process with the same boundary conditions as the experiment also gave similar results. The results show that when making new castings for the first time from experience, there are many casting defects such as cracking, metal deficiency, porosity, etc. In order to improve the casting results, the pouring gate, the arrangement of additional risers and the size of the runner were studied on the simulation to improve the defect results on the casting. After that, the parameters in the simulation model used in the experiment reveal that the molded product meets the required quality and no longer has defects. This molded product, after checking the mechanical and geometric parameters, can be put into mass production.

Keywords: FENOTEC casting, engine block RV95, casting defects, simulation, mass production.

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1. Introduction

Fenotec casting technology, with the curing of Alkaline Phenolic resin via ester catalyst to improve the disadvantages of sand casting method, has many environmental benefits [1, 2]. Fenotec plastic-sand [2, 3], derived from Alkaline Phenolic resin, is a special binder used in casting industry thanks to its low viscosity. Due to its toughness like plastic, it is easy to remove the sample without breaking the mold, especially in difficult and complex details [2, 4]. One of the biggest advantage of Fenotec technology is that it can be applied for all types of materials from nonferrous alloys, to cast iron, steel, and high alloy steel [3, 4]. Fenotec technology is used to cast objects with large, medium, and small sizes [4]. The advantage of Fenotec technology is that it helps to utilize the advantages of alkaline phenolic resin binder such as an increase in sand recovery efficiency, high-quality steel casting, no hot tears defection with steel casting, excellent casting surface, and surface machining cost reduction; therefore, it is suitable for fresh sand mold technology to make cores without affecting the quality of fresh sand mix. Besides employing simple sand mixing and recycling equipment, the technology is user-friendly, cost-saving, energy-saving, and environmentally friendly [1, 5]. Fenotec resin sand casting process requires a lot of strict conditions when switching from using Furan resin [5].

RV95 engine (9.5 HP) is a widely used diesel engine in life. This engine has features such as compactness, fuel economy, better stability, high efficiency, easy starting and operating, smoothness and durability in operation. This motor is applied in water pump, generator, air compressor, river/marine boat, tiller tractor, agricultural machinery, industrial machinery, etc. The engine block RV95 (also known as the body) is the place to store and install the engine's structure and systems. These parts can be installed inside or outside the engine body. There are holes in the body, lubricating oil paths, and cooling water. In addition, the body also contains many other parts of the engine, results in it regularly complicated structure. Owing to that fact, the body is usually fabricated by the casting method, with the materials being cast iron or aluminum alloy.

Currently, the casting of engine blocks with new designs in foundries in Vietnam often relies on experience and uses the try-to-fix method to gradually find the best implementation. Therefore, in the initial experiments, there are many defects in the product. This study presents the defects commonly found when casting engine block products in the early stages; then a simulation model is built to find the casting defects on simulation software; and finally, the casting method is improved on simulation to get the best results and conduct casting experiments.

2. Materials and methods

If the casting object is aligned vertically, it is very difficult to isolate the mold when casting because the height of the mold must be high enough to contain details, leading to too high mold. Therefore, the horizontal position was chosen for the mold. As to the mold cavity and parting plane, the bisect method was used to meet the requirements of the complex details, allowing easy sample removal when making molds. For the mold cavity of the engine block, it is advisable to choose the face that makes it easy to extract the sample and locate the mold assembly core and to avoid curved or stepped surfaces [6, 7]. With the RV95 body, the parting line that coincides with the sample face was chosen.

To design the core box, ASTM 1020 billet was selected for box fabrication. The size of the core box is designed based on the size of the core, while the material of the core box depends on the material of the core [7, 8]. For core materials, the steel ASTM 1020 was chosen to ensure high temperature resistance while there were not high requirements for mechanical properties. The gating system must ensure that no slag and impurities are added to the casting, adjust heat phenomena and condensation in castings, with small weight, and the most of the box's volume. The gating system consists of a pouring basin, sprue, choke, and runner [7, 8].

The main component of mold-making sand is SiO2 (quartz), which also includes clay and impurities in it such as Al_2O_3, $CaCO_3$, Fe_2O_3, etc. The process of making mold is based on the steps of inspecting the sample, cleaning and coating the sample, checking the sand mixing system. In the study, first, the automatic mixing system was initiated, followed by the starting of the sand discharge machine. The sand was then discharged into the mold. After that, the sample was separated, and the mold was coated before being dried and assembled along with the core. The process of making cores is to check and prepare the core box, install the core box on the core making machine, start the core making machine, proceed to select the automatic core making machine, clean and assemble the core [7, 8].

Smelting iron is an important process that is crucial to all the requirements of castings [9]. The smelting iron must satisfy mechanical properties, composition, size accuracy and is closely related to defects occurring on casted parts. To meet the requirements, the smelting process must strictly adhere to the principles of smelting, element composition and smelting temperature [9]. The process of smelting gray iron used in VEAM foundry factory with the requirements and procedures for a smelting operator is easy to understand, that is to prepare materials, inspect the smelter before smelting, refill the smelter, check the C and Si components by the CE meter. For the engine block in this study, the required material was grey cast-iron FC250. After casting, the sample was cut to observe its micro-organization. **Fig. 1** shows the micro-structure of the casting product. The parts were tested for tensile strength and hardness.

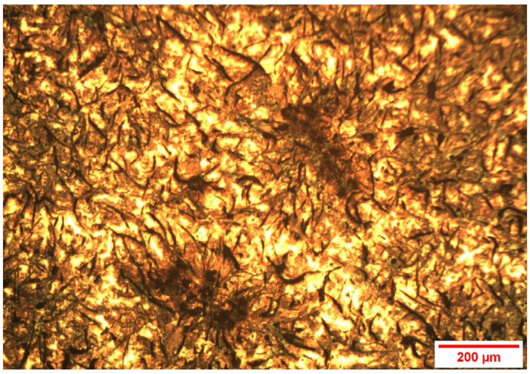

Fig. 1. Micro-structure of FC250 cast-iron in RV95 engine block after etching

The results show that the tensile strength and surface hardness of engine block RV95 are measured at 273 MPa and 254 HB. The chemical composition of the casting product is presented in **Table 1**. The results of the microstructure in **Fig. 1**, tensile strength, hardness, and chemical composition of the material of the molded product in **Table 1** reveal that the product met the requirements of the required material, FC250.

Table 1
Chemical composition FC250 cast-iron used for RV95 engine block (weight %)

C	Si	Mn	P	S	Cr
3.21	2.0	0.76	0.036	0.0321	0.035

3. Results and Discussion

3. 1. Initial experimental results

In the first experiment, the arrangement of pouring beans, cooling positions, and channels were made according to the experience of casting similar products by engineers of VEAM factory. The results show that there are many casting defects shown on the product. **Fig. 2–4** display the defects of castings, such as porosity at the water tank position (**Fig. 2**), broken sand mold (**Fig. 3**) and lack of material (**Fig. 4**).

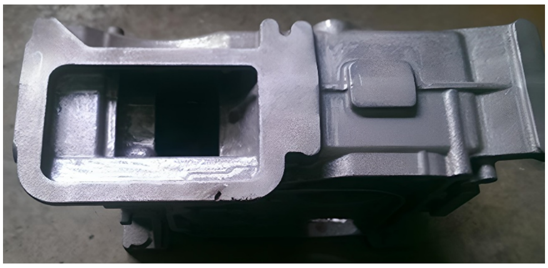

Fig. 2. The casting product with a porosity at the position of water tank

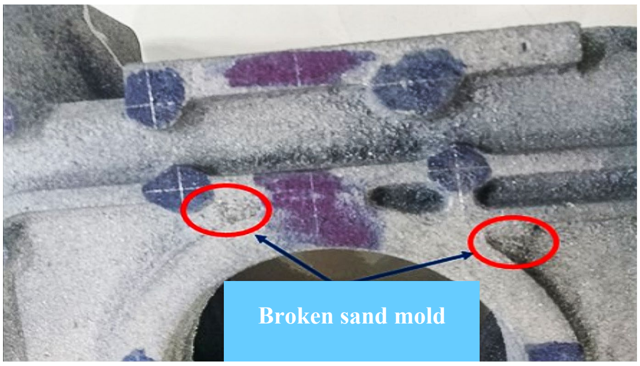

Fig. 3. The casting product with a broken sand mold occurring near the bearing assembly surface

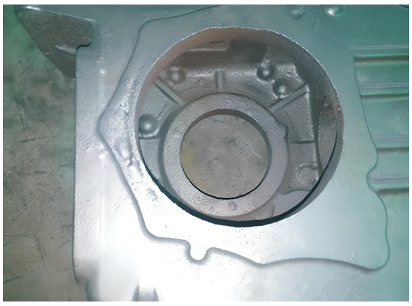

Fig. 4. The casting product with shortage of fill material

3. 2. Simulation process

To simulate the metal pouring process in the Fenotec mold, a detailed 3D model was developed and employed into Click 2 cast software for simulation. The Click 2 cast software is made by the Altair Software Company, used for the simulation of casting process, filling speed, shrinkage position and casting defects, etc. [10, 11]. In this simulation model, the positions of the pouring cup and the metal pouring temperature were taken from the initial experimental parameters.

Fig. 5 presents a 3D model built to use in the simulation research. The results show that for the layout at the initial experiment, the simulation model gives the same casting defect results (**Fig. 6**).

Fig. 7 shows the time it takes for liquid metal to fill the cavity. In which the results illustrate that after 11.50 s, the entire molten metal has filled the cavity of the mold, and it also indicated the last position in the filled mold.

After the simulation results coincided with the initial experiment, the pouring position, size and position of the steam and the channel were rearranged to overcome the casting defects in the simulation study. Once the simulation results had eliminated all these defects, the next step was to conduct a casting experiment to check the results.

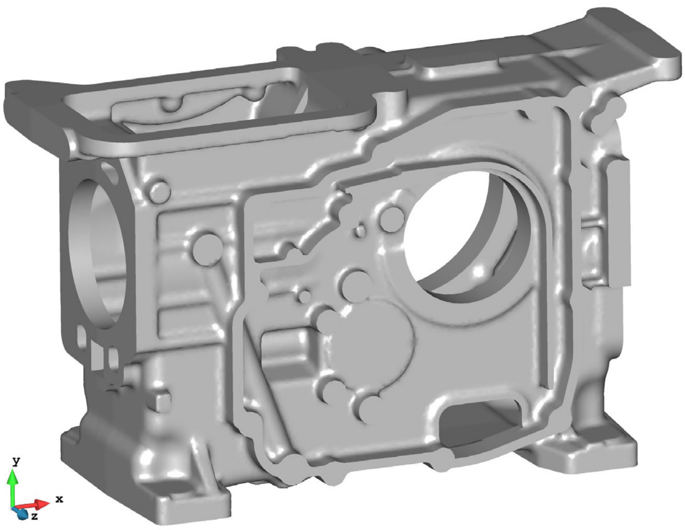

Fig. 5. The 3D model in the simulation study

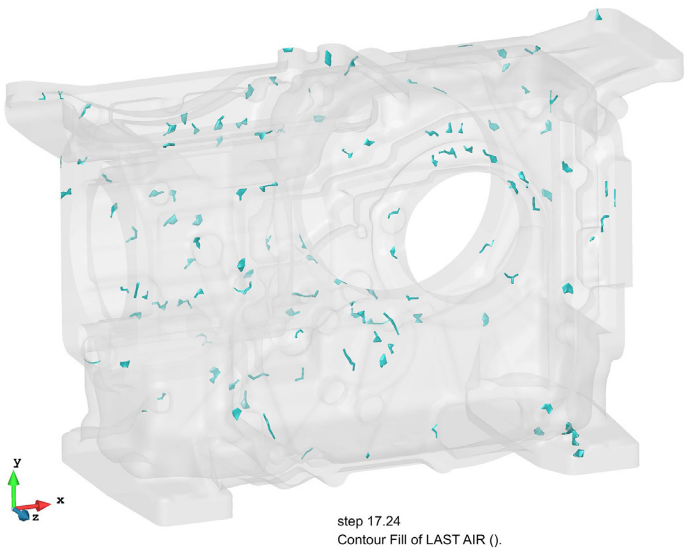

Fig. 6. The last air entrapment on the casting product

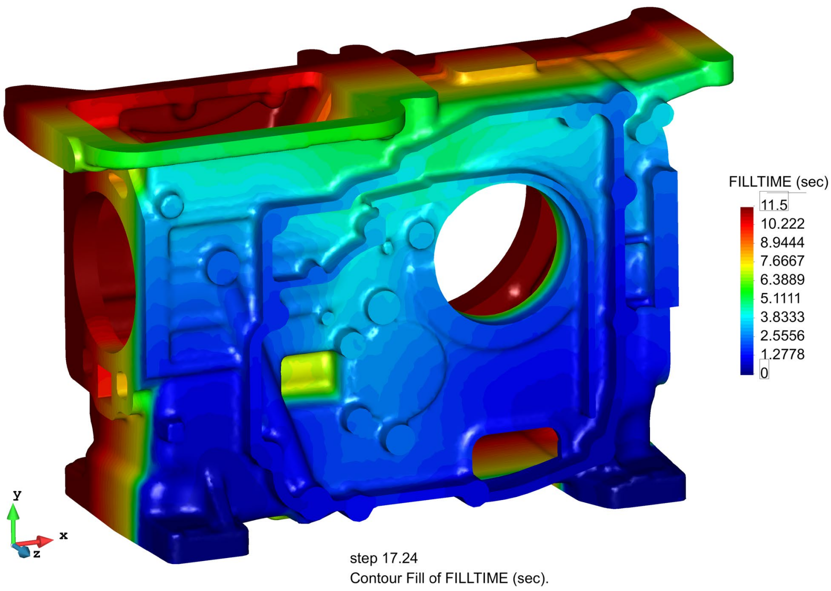

Fig. 7. Mold filling time

3. 3. Improvement experimental results

The casting product is shown in **Fig. 8.** The body of the detail is not defective outside, while the surface of the cast meets the product requirements of the customer. The dimensions and center of the hole are no longer deviate. The size satisfies the requirements of the casting drawings. The RV95 body has met the requirements of chemical composition, mechanical properties, and micro-organization. The product has no external defects and has the right size according to the drawings. The sample is manufactured accurately, and precisely, so it is ready for mass production.

Fig. 8. The improvement experiment of the casting product

3. 4. Discussion

The results of this study reveal that the try-to-fix approach currently used in foundries in Vietnam for parts with new designs or new materials is not effective. The process of establishing a technique to implement is quite time-consuming, and results are frequently poor at first attempts with this method, which calls for workers to have many years of expertise.

The majority of the simulation researches on casting in sand molds, however, are in favor of flow process studies or studies of mold materials. There is a gap in the inability to employ the simulation model directly in the creation and manufacturing of molded products in Fenotec molds.

Therefore, the steps taken to solve the problem in this study are proposed as follows:

– Step 1: Use the Fenotec technique to do the experimental casting;

– Step 2: Develop the simulation model using the initialized boundary conditions from Step 1;

– Step 3: Evaluate and validate the simulation model against the experimental findings;

– Step 4: Modify the simulation model's parameters to get rid of casting flaws;

– Step 5: Use the simulation model's parameters to verify and examine the mold's requirements. When the product satisfies the requirements, move to Step 6;

– Step 6: Products are mass-produced.

4. Conclusions

In this study, the Fenotec casting technology for the RV95 body was investigated comprehensively. The results show that in the first experiment conducted based on experience, there are many casting defects shown on the product, i.e. porosity at the water tank position, broken sand mold and lack of material, etc. The boundary conditions for the simulation setup, which were based on the experiment data, were successfully included into the 3D model. The results from simulation and experiment are congruent with one another, as shown through comparison. In other words, the same defect location and type are present on the simulated product as they are on the experimental casting.

The simulation findings also demonstrate that casting defects were eradicated with changes to the pouring gate arrangement, the placement of additional risers, and the runner size. The outcomes of the following experimental confirmation further demonstrate that the molded product now satisfies the specified quality standards and is defect-free after the experimental model's parameters have been changed. With the success of this project, the simulation process can be applied to production, which will help save time and production costs, thereby speeding up the production process, and meeting the time requirements of customers. The simulation application process is used to produce other details right away at the factory.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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The study was performed without financial support.

Data availability

Manuscript has associated data in a data repository.

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