Casting Process Simulation of Engine Tappet and Checking the Various Features of the Casting Process

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Received: 22 June 2024 - Accepted: 28 October 2024

Abstract

Simulation is one of the methods of interest in various industries, including automobile manufacturing, to reduce the costs, material wastage, and increase the productivity. Simulation has an effective role in reducing process costs and as a result can lead to an increase in productivity in part manufacturing processes. Also, the simulation reduces the environmental pollution caused by the prototypes. In the meantime, it is important to pay attention to the simulation of casting processes, and in the current research, a car engine tappet part is made using analysis simulation and a real sample. The results show that the simulation has played an effective role in identifying possible defects and making a healthy part, and also in the real sample, the presence of carbide and ledeburite structures has been a factor in increasing the hardness of the part. Finally, the increase in hardness may increase the wear resistance of this part, which plays an effective role in the performance of the car engine.

Keywords: Software Simulation, Cast Iron, Casting, Engine Tappet.

1. Introduction

Today, simulation is considered one of the main methods in the development and manufacturing of various parts, which leads to cost reduction and increased productivity [1-3]. Among the different parts, it is very important to pay attention to the simulation of the car parts [4]. In this regard, in research, Jelenschi et al investigated valve simulation. The results showed that simulation is a suitable method for choosing a suitable design [5]. Also, the importance of simulation has been observed in the research of Wenjiang et al [6].
One of the most important parts of a car engine is the engine tappet part [7]. This part is usually made of cast iron, and the surface of the tappet must have higher tribological characteristics due to contact with other surfaces, therefore the outer part becomes white cast iron. Simulation is also important in analyzing the structure of white cast iron. In research, Karel et al mentioned the numerical simulation optimization of ductile iron casting [8].Also, in another research, the effect of adding rare earth elements to cast iron has been investigated in simulation and reality [9].

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Also, the simulation of solidification of cast iron and aluminum has been investigated in another research by Mihai et al [10], and all these cases are proof of the importance of the simulation process.
According to this introduction, the importance of simulating and manufacturing the tappet part of the engine is still important. In the current research, necessary research has been carried out to develop a simulation and compare it with reality.

2. Materials and Methods

To simulate and manufacture a sample, in reality, a tappet piece was designed first using CATIA software. Fig. 1. shows the final CAD design of the piece.
The simulation was done in the Click 2Cast software environment. For simulation, meshing of the part was done in the software environment and then white cast iron was selected for the material of the part. The type of cast iron was selected according to the ASTM A532 standard. Sand casting was also chosen for the process. Then the results of mold filling and freezing were examined. Melting temperature and mold temperature were determined as 1380 and 21 degrees Celsius, respectively.

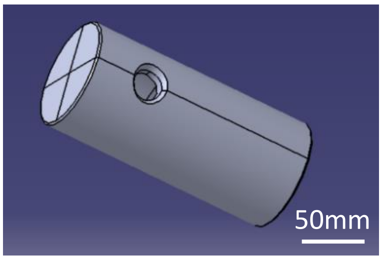

Fig. 1. Designed Tappet in CATIA software Scale 50mm.

After examining the simulation results, a sample of the tappet was made using the melting process in a sand mold. To examine the microstructure, an optical microscope was used. Sanding was done on the surface of the sample from 100 to 2000 and Al-2O3 suspension was used for polishing. Chemical etching was also carried out by Nital Solution.
To check hardness, a Vickers hardness tester was used. The applied force was 10 kgf and the time of applying the force was 12 seconds.

3. Results and Discussion

Fig. 2. shows the state of the cold shuts in the part. Tracing the cold shuts in the casting part is one of the important results of the simulation. As it observed, it has appeared around the holes created in the cold shuts piece. In general, cold shuts are considered a defect and are created when two metal streams melt before they collide. Due to this issue, it is necessary to increase the melting temperature to fix this defect.

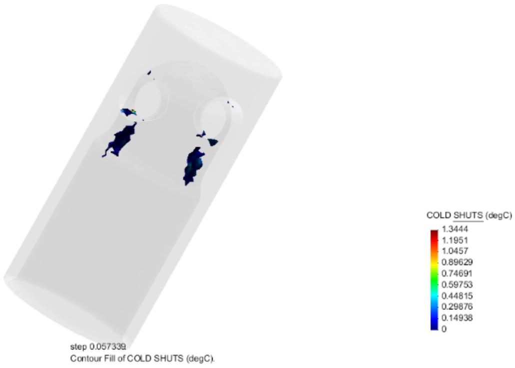

Fig. 2. Cold Shut results after simulation.

Fig. 3. shows the results of filling the mold. As it is known, due to less thickness at the end of the part, there is a possibility of damage of the mold and, also, the part not being fully formed. In the current situation, it is necessary to revise the design and increase the thickness. Also, the use of pressurized casting can be useful.
Fig. 4. shows the temperature distribution in the piece during the melting process. As it is known, the end of the sample has a higher temperature and the surface of the part that is subjected to wear must be cooled faster. This is also true in the manufactured parts, and increasing the cooling rate leads to an increase in carbide on the surface of this cast iron and, as a result, an increase in the hardness is expected.

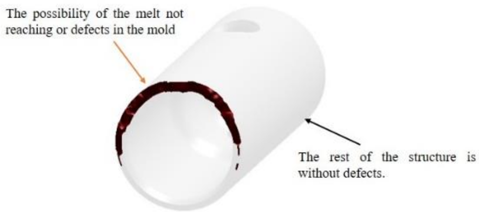

Fig. 3. filling results after simulation, According to the definition of the process parameters, minimum defects are created in the part.

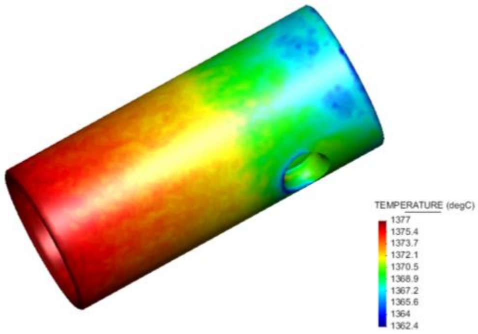

Fig. 4. temperature distribution in the piece during the melting process.

Finally, Fig. 5. shows the remaining gas holes in the part. As it is known, on the surface of the piece and parts of the body, the remaining gas in the mold has led to the creation of holes that may affect the quality of the piece. To solve this issue, gas discharge or the use of vacuum processes may increase the quality of the part.

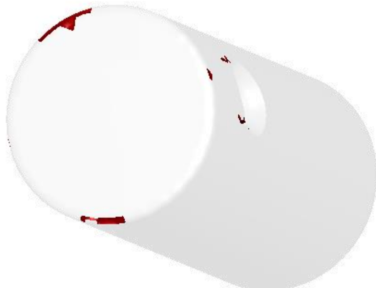

Fig. 5. Air entrapment results after filling the mold.

4. Manufacturing the Tappet

Fig. 6. shows a representation of the manufactured part after the casting process (an additional machining process has been done on this part, and for this reason, it looks different from the first 3D model). The construction of the part is done according to the simulation results in Fig. 2. To Fig. 5., and as the appearance of the part shows, no defects such as air entrapment or cold shuts are observed, and this shows the importance of simulation.

It is worth mentioning that two different areas of the surface of the piece have been investigated for microstructure.The microstructure confirms the formation of carbides and ledeburite structures on the surface of the piece. An increase in surface carbide leads to an increase in surface hardness, and according to classical theories and some results, hardness leads to an increase in the wear resistance of the part [11], which is the main application of the part.Fig.6.The final shape of the part and parts this part is displayed in the body after the machining operation of the surface microstructure does not affect the surface structure.

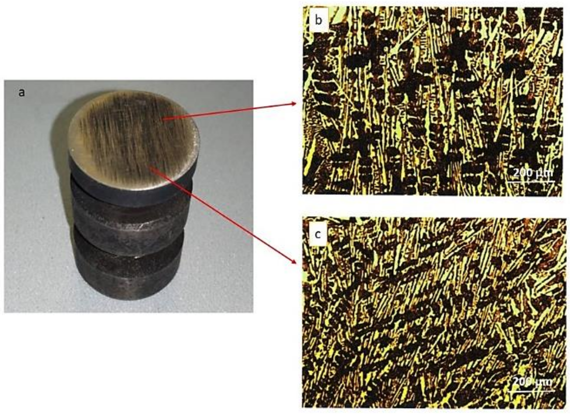

Fig. 6. The final shape of the part and parts of the surface microstructure (this part is displayed in the body after the machining operation, and for this reason, it is different in appearance from the simulation, and the machining operation does not affect the surface structure).

Finally, Fig. 7. shows the comparison between the hardness in the simulation mode and the manufactured sample.
The first point is that the simulation results are largely consistent with the real results, and the second point is that due to the formation of surface carbide on the part, the hardness of the part has increased significantly, which leads to the improvement of its performance. It should be noted that copper coolant was used in this process and the surface cooling rate was extremely high in making the real sample.

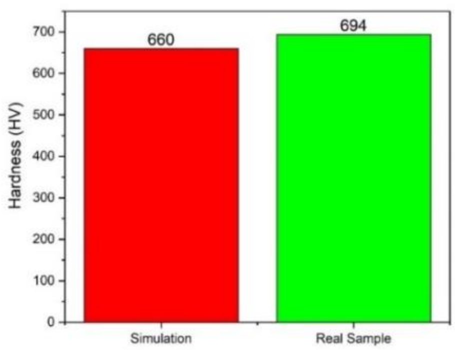

Fig. 7. Hardness results in both simulation and manufactured samples.

5. Conclusion

As mentioned before, simulation has an effective role in identifying defects, improving performance in manufacturing costs, and reducing material wastage. In the present research, it was shown that some casting defects such as cold shuts can be identified by simulation, and as a result, methods to fix them before mass production are possible.
Also, the results showed that the use of simulation can be effective in analyzing hardness results. About the real sample, the presence of carbide has led to an increase in the hardness of the sample, which has an effective role in the performance of the engine tappet part and an increase in wear resistance.

Author’s Contribution

O. Ashkani With M. R. Tavighi: Designing the 3D model, choosing materials, Simulation with Click 2Cast software, writing the original text, supervising the manufacturing of the samples, Project manager, Z.Arzaqi: Manufacturing and casting the sample, Information review, writing the original text, proposal of the test, F. Badretalei: proposal of the test, software simulation, Checking microstructure, revising the original text, S.Chizari: Manufacturing the final part, Hardness test, revising the text, S. Mahboubizadeh With M. R. Tavighi: writing the original text, Software simulation, revising the original check, Final text approval.

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