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Front Cover Weight Optimization and Redesign

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Abstract – In today's global era design and development of any product is very crucial work. Development process begins from origin of product to the end of its use. Hence in the development of any product it should be optimized and well planned. In this paper, weight optimization of front cover is done by using 3D scanning and reverse engineering method. Before doing the 3D scanning and reverse engineering conducting a fit and function study is very important. Also the study includes the whole development process of front cover with finite element analysis. In whole development process, development of pattern is vital. The finite element analysis is done for checking quality in regards to stress analysis and sealing analysis. The process of optimization discussed in this paper can also be used in designing and developing of any other parts.

Keywords: Optimization, FEA analysis, Fit and function, 3D scanning, sealing analysis

INTRODUCTION

Engineering is a profession whereby principles of nature are applied to build useful objects. Optimization is one of them, which is used to reduce the excess parameters and foolproof the part. In the study, the front cover weight optimization is done by using 3D scanning and reverse engineering process. The front cover is used as a cover, which is fits on engine and covers crankshaft gear, camshaft gear and intermediate gear. One can say its saves the engine parts from contamination. Also the oil is circulated throughout the mating gears that the front cover utilizes a cover for it and there is no any oil leakage problem. Weight optimization of front cover is done because due to the extra allowances, along with extra material the development cost of the front cover increases, also it may be heavier so that the handling of it is very difficult. Increase in weight indirectly affects on the overall weight of engine, hence it's necessary to reduce or optimize the weight of front cover. Study gives the information about the software's used for 3D scanning and modeling. Along with study involves the development process of front cover that includes pattern and core making, casting, machining and testing. Finally the force and sealing analysis is done to get the equivalent stress and total deformation of front cover during loading condition and hence prove that the optimized front cover is safe to use.

FIT AND FUNCTION STUDY

In the front cover development process it's very important to study the fit and function of it. As discussed that the front cover is used to cover the internal gears of the engine that becomes its function. Study also used to define the needful parameters of the front cover during foundry and machining processes. Number of front covers used according to the particular engine codes, so that there is necessary to study the fit and function. The figure shows the various parts assembled with front cover. It contain fan and fan pulley, oil filling body, belt tension and belt tension pulley, pointer, Fuel injection pump (F.I.P.) and F.I.P. pulley, window plate. Crank shaft and crank pulley. During the fitment of front cover at the mating face, if the surface roughness and tolerances are not given properly then there is chances of oil leakage. Hence the tolerances, surface finish, material standard, fouling are the parameters analyzed during fit and function study.

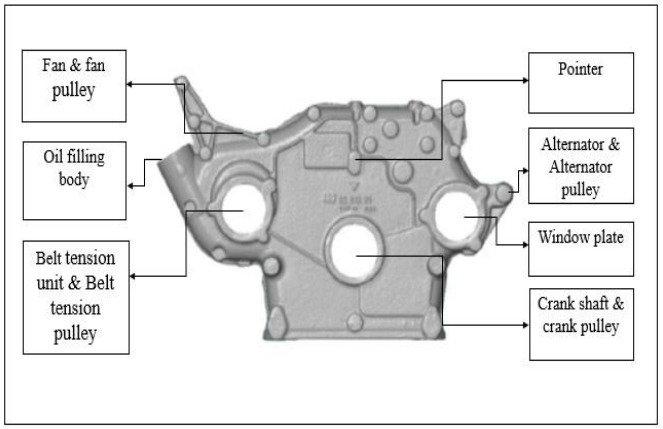

Fig. 1 Front cover and engine parts

REVERSE ENGINEERING AND 3D SCANNING

The development process may be started from the 3D scanning of the part. 3D scanning process is

carried out to identify the extra allowances are given on the part. For performing such operation the input parameters that needed are casting 2D drawing, machining 2D drawing, casting 3D model, machining 3D model. After giving the input parameters the processes are done like casting scanned and getting 2D layout report, machining scanning and getting machining 2D layout report, casting and machining supper impose report, casting and machining layout summery. Mainly the reverse engineering involves following steps,

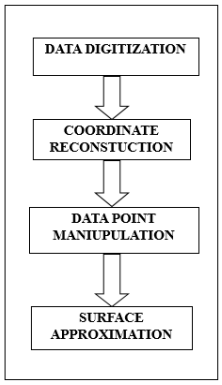

Fig. 2 Reverse engineering steps

In that, reverse engineering team of KOEL uses POLYworks software for data point manipulation, coordinate reconstruction and surface reconstruction. Also for 3D scanning of front cover ROMER LASER ABSOLUT scanner is used.

From the analysis obtained outputs are casting mark-up drawing, machining mark-up drawing, modified casting model, modified machining model, draft copies of modified casting and machining drawing. The extra allowances are obtained by overlapping the models and allowances identification is done by Geomagic qualify software.

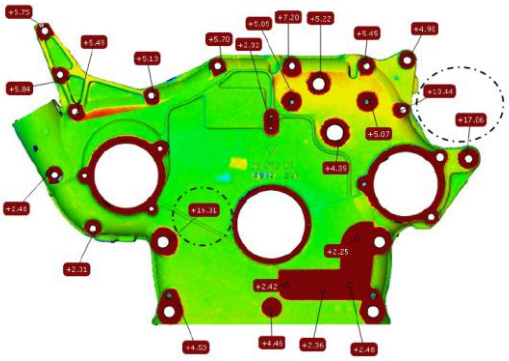

Fig. 3 Geomagic analysis of outer side

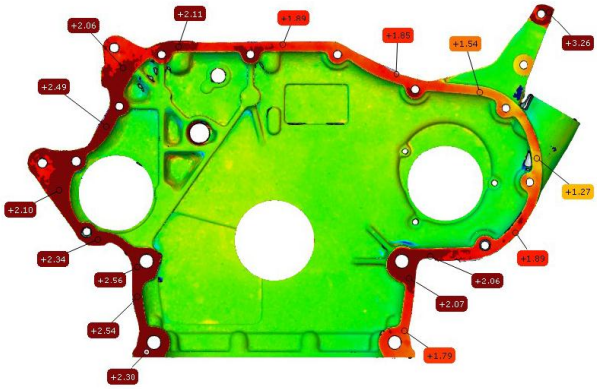

Fig. 4 Geomagic analysis of mounting side

Pattern and core making

After obtaining the results from 3D scanning and allowance analysis pattern making is done. The data obtained is used to give the allowances during pattern design. In pattern design process some of the points need to consider that the casting drawing supplied to the pattern shop, the pattern shop and machine shop co-operation, pattern materials, standards, type of pattern, match plate size etc. In design process, 3D model of cope and drag pattern with match plate and gating system arrangement is obtained with proper allowances. Also core box is designed as per the shape of core used. Before doing casting operation it is very important to select exact size of match plate or proper selection of match plate must be necessary.

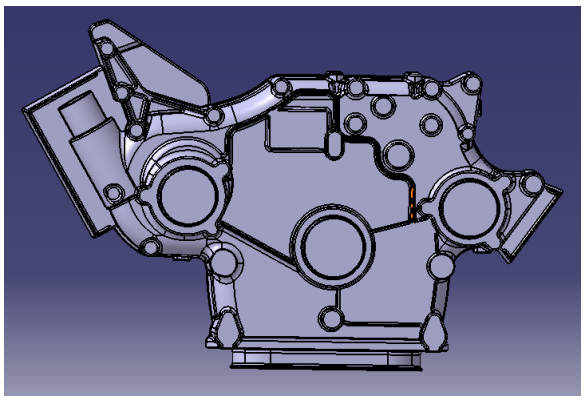

Fig. 5 3D model pattern

After completing the design process cutting or making a master pattern is done as per the design. The material basically used for master pattern is thermocol. It need much time because proper cutting is necessary. Then by using this master pattern with proper material selection and additives casting of this pattern for front cover is obtained. Now this casting pattern is machined and is given proper finish. While finishing precaution must be taken that the base must be positioned so as to avoid any oblongs. Also proper clamping is vital during machining to restrict any movements.

Fig. 6 Drag pattern of front cover

Fig. 7 Cope pattern of front cover

Along with pattern making process, cores are also prepared as per design. Split core box is used to get the cores. After which the two portions of the split core box are temporarily joined together with the help of dowel.

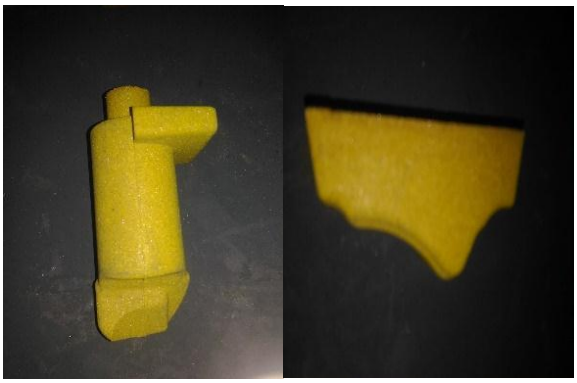

Fig. 8 Sand cores

Casting process

Casting is a base for foundry industry. It is one of the most vital tool for shaping of metals and alloys. It is one of the most versatile process and allows one to design freely in terms of shape, size and product. By utilizing the above patterns, the casting for front cover is prepared. The material used for casting is grey cast iron. The chemical composition of grey cast iron contains 2.5 – 4.0% carbon, 1.0-3.0% silicon and the rest is iron. The specifications of the material used is tensile strength of up to 200 N/mm^2 and Brinell hardness ranging between 160 -220 BHN. Base sand is utilized to prepare the mold and core which is without a binder. Performing the sand test is very important from quality point of view as it indicates working quality of molding sand and helps foundry men to control its properties. The various tests on molding sand are moisture content test, grain fineness test, permeability test, etc. and for core sand are hot strength test, green strength test, etc. After completion of these test and processes one can begin the casting. The casting process follows as first by preparing mold box and furnace, then pouring the molten metal in prepared mold box, after which the casting is solidified, then fettling and shot blasting is carried out. After heat treatment and painting one can obtain the main casting part. To check the composition of material at various stages, material composition reports tests are carried out. These tests are tensile test bar and spectrometer and microstructure analysis. In tensile test, a bar of composition is prepared and is test for deformation and failure in its cross section, parallelly in microstructure analysis, a coin of the composition is prepared which is observed under the microscopic machine and structure analysis is done.

Fig. 9 Prepared casting

Machining process

After preparing casting, machining process is done. In this process casting part is finish to get desired final shape and size. To obtain quality in product, proper finishing is important for which use of proper machines and tooling is important. The various machines are Lathe, VMC and HMC machines with proper tooling. The most economical means to produce a repetitive jobs with special work holding and tool guiding devices is through jigs and fixtures. As per the operations performed various fixtures that are operated on front cover are

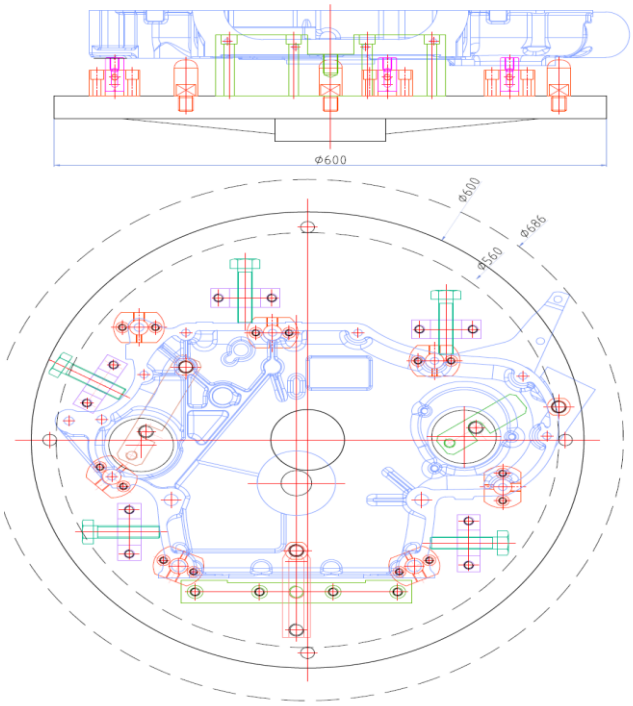

Fig. 10 Facing fixture

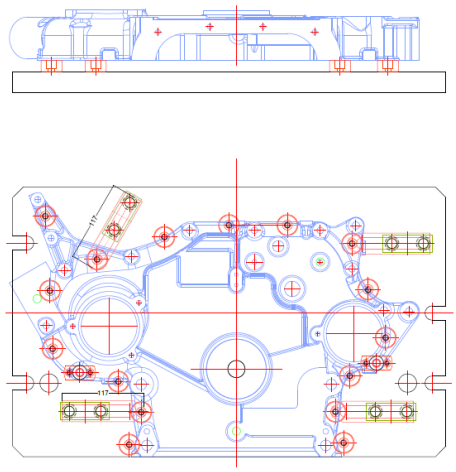

Fig. 11 VMC holding fixture

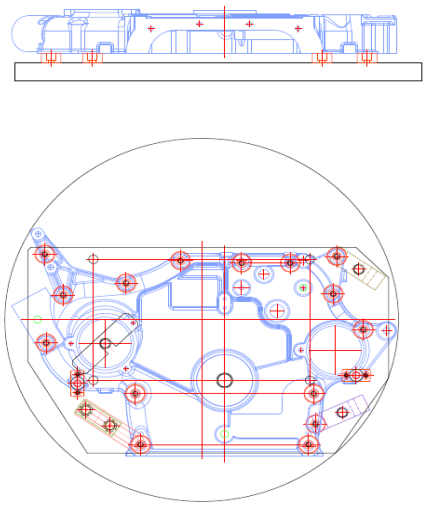

Fig. 12 HMC holding fixture

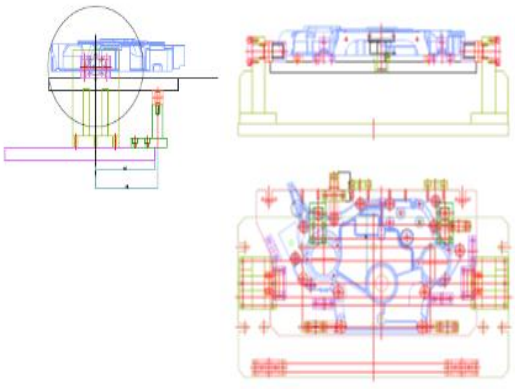

Fig. 13 Index able VMC holding fixture

In the first facing operation roughing of mounting face is done by using lathe machine. On the VMC front cover is machined in two steps first the outer side of front cover drilling operation is carried out for bolting purpose and then mounting face side machining is done. Dowel holes are crucial as they mark the reference for other holes. Along with milling operation, machining of crankshaft bore, FIP bore and work plate bore is done after drilling operation. Milling operation is also carried out for the mounting face and the fouling cut is given in the same. The holes at the bottom face where the oil pan is mounted is drilled by employing HMC machine.

Fig. 14 Machined component

Testing and measuring of the machined component is very crucial from quality point of view. For this purpose various gauges are employed like Vernier caliper, Vernier height gauge, Dial indicator, Coordinate measuring machine (CMM), Plug and thread plug gauges and surface roughness tester. The CMM machine is employed to measure displacement in three dimensional Cartesian coordinate system of physical objects by sensing discrete points. The roughness tester is employed to check the roughness value of mating faces in terms of R_z value (the value must be 12.5 for front cover).

Force analysis

Force analysis is done to analyze the forces and moments acting on the part. The two main factors of this analysis are the amount of stresses acting at different point and deformation caused by it. For this analysis ANSYS 16 software package is utilized. Fixed support is taken by bolting the front cover to the crank case.

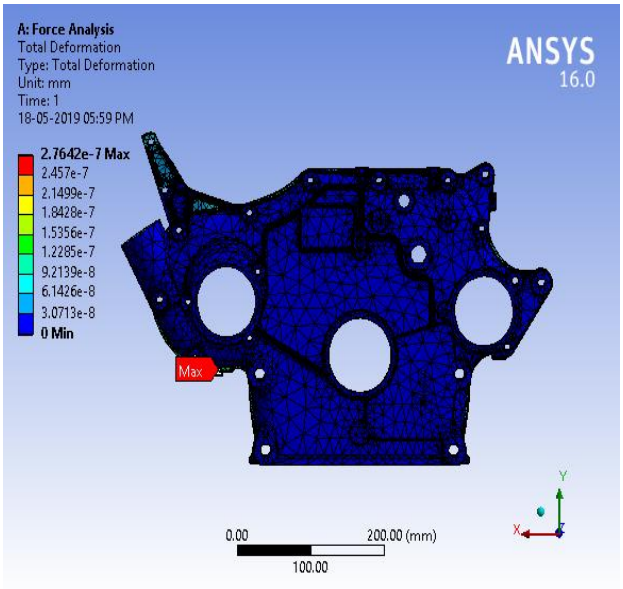

Fig. 15 Total deformation of front cover

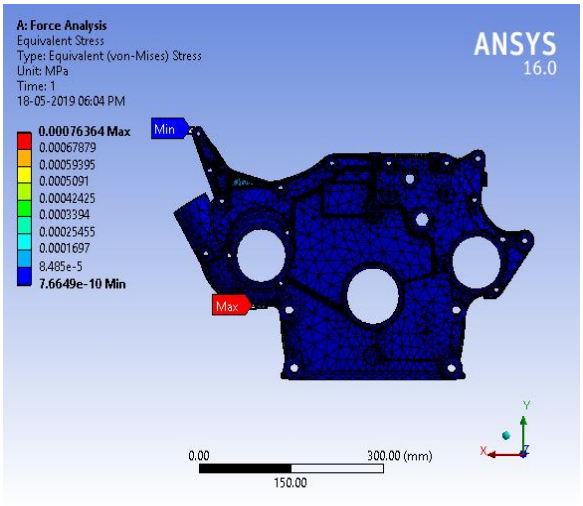

Fig. 16 Equivalent stress of front cover

After performing the analysis through the software it was determined that the maximum stress that was acting on the front cover was 2.7642e^{-7} MPa. The tensile strength of the front cover was found to be 200 MPa. After application of these forces it was found that the maximum deformation in the front cover was 0.00076364 mm which is negligible.

Sealing analysis

The front cover is used to protect the parts like intermediate gear, camshaft and crankshaft gear. It is also connected to the oil pan of engine. The gear oil is circulated through the gears of engine for their smother functioning. Therefore, the front cover also comes in contact of oil and it should not leak through or in between mating faces. So, to ensure this sealing analysis is carried out. The sealing analysis is carried out at bolting holes as there is major possibility of leakage at this place. The sealing analysis is done at the mounting face. For this analysis torque is converted to preload, for 10 mm and 8 mm hole diameter which is 2.5N and 3.125N respectively.

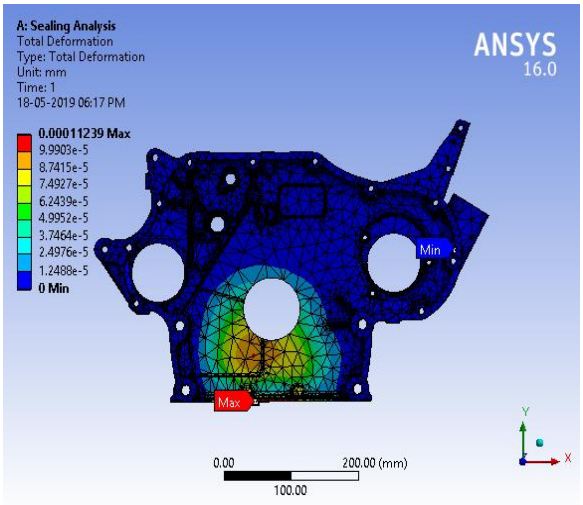

Fig. 17 Total deformation for sealing analysis

After doing the analysis it was found that the total deformation at bolting holes of the front cover is 0.00011239 mm which is negligible and therefore it meets the acceptability criteria and is safe for use.

CONCLUSION

The goal of this research work was to optimize weight of the front cover that is used in engine to cover the parts, by reducing excess amount of material. The method utilized for this purpose is 3D scanning and reverse engineering. In this technique, scan of the object was obtained. After which model generation was done using POLYworks software and to get extra allowances Geomagic qualify software was used. By using obtained results the extra allowances were reduced and an optimized pattern and then casting was obtained. Along with weight optimization, cost is also optimized. The total reduction in weight was 950 grams and reduction in cost per component was found to be about 63.65Rs. Finite element analysis is done which helped in force and sealing analysis. These testing reports proved that the optimized front cover sample that was prepared is valid and safe for its use. From the above obtained results, optimization is the best possible way to reduce excess of material used and therefore reducing the cost.

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