Efficient Wall Thickness Analysis Methods for Optimal Design of Casting Parts

Bhaskar Sinha
Bhaskar.sinha@geometricglobal.com
Geometric Limited

Abstract

Wall thickness is an important parameter for casting design. Thin wall sections cause breakage of parts during manufacturing or during usage of the part. Thick wall sections cause problems in castings and increase weight, needs more material thus increasing the cost. Optimal wall thickness is also important for adequate and sufficient strength of parts.

The current process of wall thickness measurement involves taking sections of the design along standard axis and then measuring those sections using tools available in Computer Aided Design (CAD) Software. Designers use these methods to measure wall thickness. It takes couple of weeks time to analyze a complete casting for power train parts. Moreover, the process is not accurate and error prone. Most of these errors may be detected during simulation and analysis phase. This phase is a complex and time consuming process. Also it requires specialized knowledge to use these softwares.

In this paper, we describe an easy and efficient process related to wall thickness check for power train design, where design checks are performed in an automated fashion by the designer. This helps to correct many of the defects arising out of the wall thickness of the model. By providing this process right at the design stage, valuable time and effort is saved. Also high quality of the part guaranteed right at the design stage.

1 Introduction

Quick time to market product has been key element for success. In case of manufacturing, there is an immense pressure to manufacture defect free parts at lowest cost, at shortest time and with highest quality. The industry constantly looks for processes and tools to optimize the three components.

In case of power train application, where parts are mostly manufactured by the die casting process, parameters in designs like draft, wall thickness, fillets and corner radii are important requirements. Optimal wall thickness is required for proper design. Thick areas in the design cause problems like increased weight, more material usage, reduced efficiency, shrinks and warps in casting process. All these lead to increase in cost. Thin areas will cause breakage of the part.

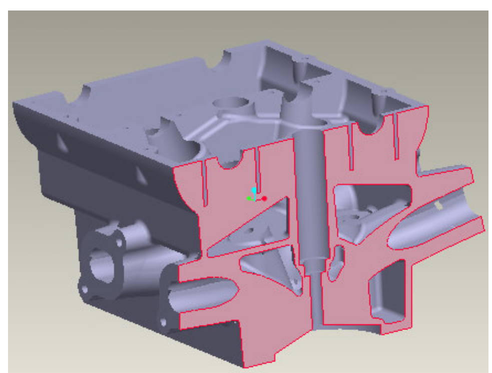
This paper focuses on the wall thickness of designs and shows how using advanced tools on existing CAD system can produce designs with optimal wall thickness. The paper talks in detail the current processes in the casting design in relation to wall thickness analysis, particularly, in the automotive sector and shows the benefits of using advanced tools to improve the design of model at the early stage.

2 Current process in industry

Die cast designs are checked for wall thickness, sharp corners, fillets, draft angle and other parameters for design for manufacturability. The current process of checking wall thickness is to cut sections of the design along the standard axis, X, Y and Z. Sections are cut at every 5 mm interval. Each section is measured for proper thickness using measurement tools available in the CAD system. Areas with lower thickness or higher thickness are considered as defects and the design is modified to remove those defects. The process is repeated till optimal design is achieved.

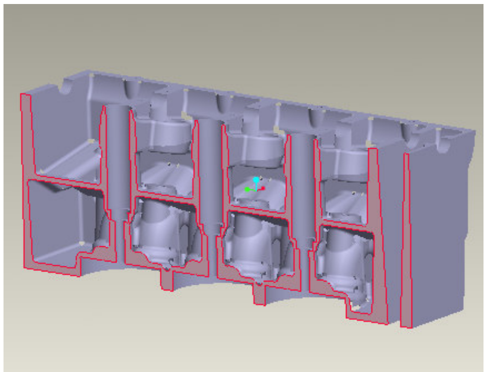
The existing process is time consuming and lot of human interaction is required. It is error prone since critical areas may be missed. Sometimes these critical areas go undetected and parts are manufactured with non-optimal wall thickness. It has been observed that parts have been manufactured with thick sections which increases the weight and reduce the efficiency, increase cost by requiring more material to fill the part.

Figure below shows the wall thickness measurement process.

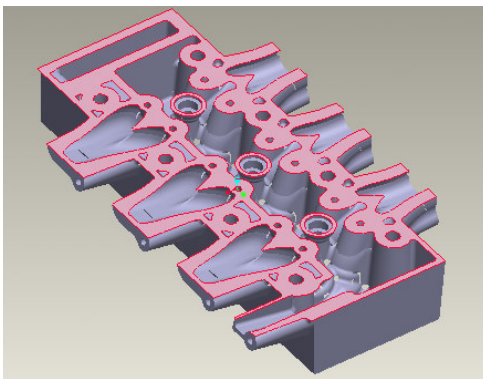


Cross Section of Engine block along XY Plane

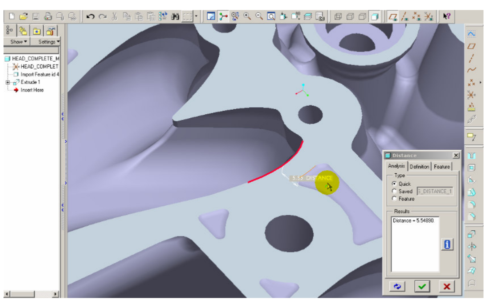
Presented in Engineering Design 2007



Cross Section of Engine block along YX Plane



Cross section of Engine block along ZX Plane



Inspect each cross section for critical wall thickness [1]

Figure 1: Traditional Method of measuring wall thickness

3 New Approach

Using the automated tools over the manual approach has the advantage of achieving optimal wall thickness quickly and in an accurate fashion. Here one of the tools called GeomCaliper [2] is described and how this automated tool is used to achieve better design is highlighted.

3.1. Definition of Thickness

A definition of wall thickness needs to be established before going further. In this paper, two methods of wall thickness are defined. First method is called Ray Method and the second method is called Sphere Method.

Ray method is computed by firing a ray normal to the surface of the model towards the material side. The point where this ray hits the other surface is considered the hit point. The distance between the start and the hit point is the "ray thickness" [3]. This method is useful for finding thin wall sections in a CAD model. See Figure 2 below.

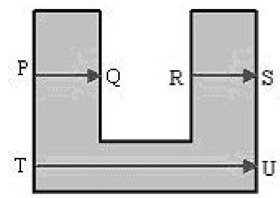


Figure 2: Ray Method

Sphere method uses a rolling sphere to calculate the wall thickness of a solid body [3]. A sphere is made at the point of thickness measurement. This sphere is expanded in the material side till it interferes with any other surface. This method is useful for finding thick wall sections in a CAD model. See Figure 3 below.

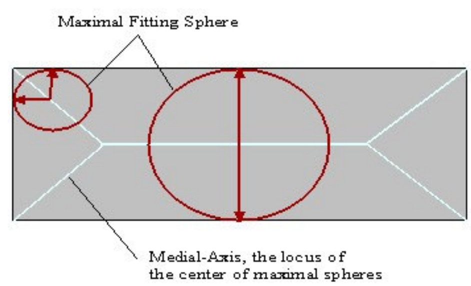


Figure 3: Sphere Method

3.2. Optimization techniques applied for Ray and Sphere Method Algorithms

For thickness computation on a CAD model, the model is first tessellated. The accuracy of the results depends on the fineness and quality of tessellation. Users specify the sag and step value as input for tessellation. Computing ray or sphere method thickness on a tessellated model is computationally expensive. Various optimization techniques have been tried out. It has been found that uniform grid gives best performance for ray method and k-d tree gives best performance for sphere method [4]. Table below shows the performance of Ray Method with uniform grid and sphere method with k-d tree. The model used for benchmarking is a 6 cylinder engine head.

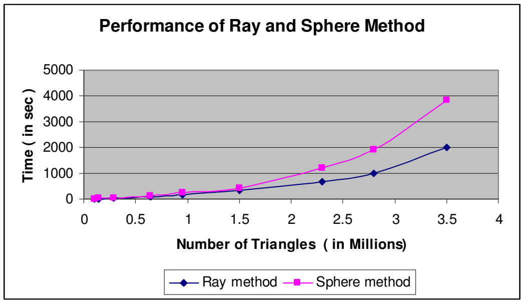


Figure 4: Performance of Ray and Sphere Method

3.3. Comparison between Ray and Sphere Method

Ray method is useful for finding thin wall sections in casting. It allows user to measure nominal wall thickness. It also helps to detect sharp edges at the boundary. Sphere method is useful for detecting thick wall sections. Heavy areas in a casting model which causes shrinks and warps and leads to increase in weight are detected by this method. Ray method is computationally less intensive and hence takes less time than sphere method.

3.4. Design for optimal wall thickness

Using automated wall thickness analysis, thickness is computed on the complete model. Thick and thin regions are detected and design changes are made. After design corrections, the design is verified again for optimal wall thickness. The process is repeated till optimal wall thickness is obtained.

The thickness method is provided as an input for computing thickness along with step and sag for tessellation. The tool first tessellates the model based on the sag and step value provided as input. It then computes the wall thickness based on the method selected. Once the computation is completed, the color coded thickness information is displayed. Using advanced visualization, critical thickness areas are detected. The location of the problem along with the cause is available. The designer then makes changes to the problems detected by the tool.

In Figure 5(a) shows a case where thick regions are identified in the design. The design is rectified and the new design is checked for optimal wall thickness. Figure 5 (b) shows design with optimal wall thickness. Thick regions are detected and eliminated early in the design cycle.

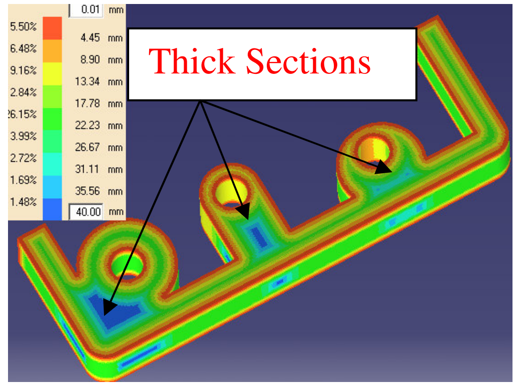


Figure 5(a): Design containing thick regions

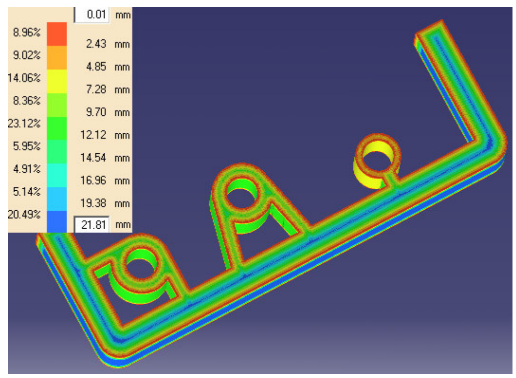


Figure 5(b): Rectified design

Figure 5: Finding thick / thin region using GeomCaliper.

3.5. Benefits of new approach

With the new approach, users can improve designs and accelerate their wall thickness measurement time. Users have gained 70 – 80% time required in wall thickness analysis process. Time required for wall thickness analysis of engine head using manual method was 2 weeks per cycle. Using advanced tools, the time reduced to less than 2 days for complete analysis. Also, design quality improved since the chances of error in wall thickness measurements are minimized. The current process is fast, easy to use and automated.

Traditional Method	**New Approach**
Time consuming process	Fast
Lot of human interaction required	Automated
Probability of errors is high	Accurate

4 Conclusion

By using automated tools for wall thickness analysis, the time taken to perform thickness analysis reduces by 75%. Also, quality of the design is improved which saves cost in downstream process. Models have optimal wall thickness. Thick areas which cause problems in casting, increase weight, require more material, are detected early in the design and are eliminated at the design stage. Similarly, thin wall sections which can cause breakage are also removed.

5 Acknowledgement

I would sincerely like to thank Geometric Limited for allowing me to use the product GeomCaliper for presenting the concept of thickness measurement for wall thickness analysis. I would also like to thank Dr. Vinay Kulkarni, for providing valuable inputs and guidance in writing this paper.

References

1. Pro/ENGINEER® product website: http://www.ptc.com
2. GeomCaliper product site : http://geomcaliper.geometricglobal.com
3. GeomCaliper product FAQ site : http://geomcaliper.geometricglobal.com/faqs.aspx
4. Sample, N, Haines, M, Arnold, M, Purcell, T. 2001. Optimizing Search Strategies in k-d Trees. Stanford University website: http://graphics.stanford.edu/~tpurcell/pubs/search.pdf