A sectioning method for constructing the mid-surface of thin-walled die-cast and injection moulded parts

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Abstract

This report presents a method for constructing the mid-surface of CAD-models of parts requiring tooling for their manufacture. The mid-surface is constructed by sectioning the CAD-model in a sufficient number of places along the draft direction. In each section the mid-segments of the sectioned material is constructed. The complete mid-surface is obtained by connecting the individual mid-segments with the closest located mid-segment in the adjacent sections. The intended use of the method is computer implementation to automatically derive the mid-surface from CAD-models to be used as target geometry for FEA shell element meshing. The feasibility of the method is demonstrated by applying it to a CAD-model. In this example a target surface is constructed using both the conventional and the sectioning method. The target surfaces are used to create shell element FEA models. When solved, the natural frequencies of the two models are almost the same. This shows that the sectioning method is an alternative way of creating the target geometry.

The intention is to use the method to create an automatic tool for mid-surface extraction with better performance than today's commercially available tools.

Keywords: FEA, Finite element analysis, idealisation, mid-surface, shell element, meshing, thin-walled, target geometry

Introduction

A situation often encountered in industrial engineering analysis is that nearly tooling ready CAD-models of parts requiring dies or tooling for their manufacture are to be analysed using FEA. Examples of manufacturing methods are die-casting and injection moulding.

The CAD-models, describing the geometry of the part as a detailed solid model, often need idealising before it can be analysed. The purpose of the FEA may for example be to extract the neutral frequencies of the part by creating a shell element model of it. This may require that the mid-surface of the CAD-model is extracted. The mid-surface is subsequently used as a target surface for the shell element meshing.

Software for mid-surface extraction exists, and is often included in commercial FEA software packages. These programs are often based on surface paring methods, such as described by (Rezayat 1996). However, the programs are hard to use on real life die-cast and injection moulded parts, where the complexity is high (Stolt 2006). To tackle this problem this report proposes a method that simplifies the problem from general 3D problem to 2D problem in a number of sections. This is realized by utilizing the fact that the parts, due to the production method have a clearly defined tooling draft direction. The computer implementation of the method is thought to automatically derive the mid-surfaces of the CAD-models more accurately than existing tools does. The method can also directly measure the material thickness in each section for assigning them to the properties of the shell element mesh. This will save the analyst time in the idealisation step of the FEA work.

The sectioning method

By sectioning the CAD-model at a number of levels along the draft direction the extraction of the CAD-model's mid-surface is largely simplified. Instead of extracting the mid-surfaces directly, the mid-segments of the sectioned material in each section are constructed. The mid-surface is obtained by connecting the 2D mid-segments by surfaces. The number of sectioning planes must be adjusted so that the details of the model are captured and the precision requirement is met. A reasonable distance between two sections is assumed to be approximately the same as the element size. The resolution can possibly be adapted to the variation in geometry. A drastic change in the appearance of the section may require a higher resolution locally.

Subsequently, the individual mid-segments of each section are connected to the nearest mid-segment in the neighbouring sections. The two segments are joined by forming a loft surface between the two segments. To allow separation from the tooling, die-cast and injection moulded parts often have draft angles on their walls. The draft angles are normally 1-5 degrees, meaning that the material thickness is varying along the draft direction. The presented method provides means of reading the wall-thickness on each level. This information could be passed on to assign the correct shell element thickness on each level when meshing. This will save the analyst the work of having to assign the element thickness manually.

Computer implementation

The automation of the method is thought to provide a tool that more effectively than existing tools for mid-surface extraction can provide help for the analyst in the idealisation step. To derive the mid-segments in each section, the geometry of the elements describing the boundary of the sectioned material is read. Examples of such boundary elements are 2D lines, arcs, and splines. The mid-segments can thereafter be derived by seeking in the normal direction of each geometrical element for a similar geometrical entity that runs in parallel located approximately in one material thickness distance from the segment. If such an entity is found the medial segment of the two is created. This method is further elaborated in (Stolt 2006). With all medial segments in place the neighbouring section planes can be examined to find the closes located mid-segments in the adjacent sections. This will form pairs of nearby segments located in different sections. A loft surface can then be inserted to connect the two segments.

A case of application

The part shown in Figure 1 below is used to test the method. The part fulfils the requirements to be produced by die-casting or injection moulding. The wall thickness in the part is 2mm. The material is aluminium with the following properties:

Young's modulus E=70Gpa
Poisson's ratio ν=0.346
Density ρ=2710kg/m^3

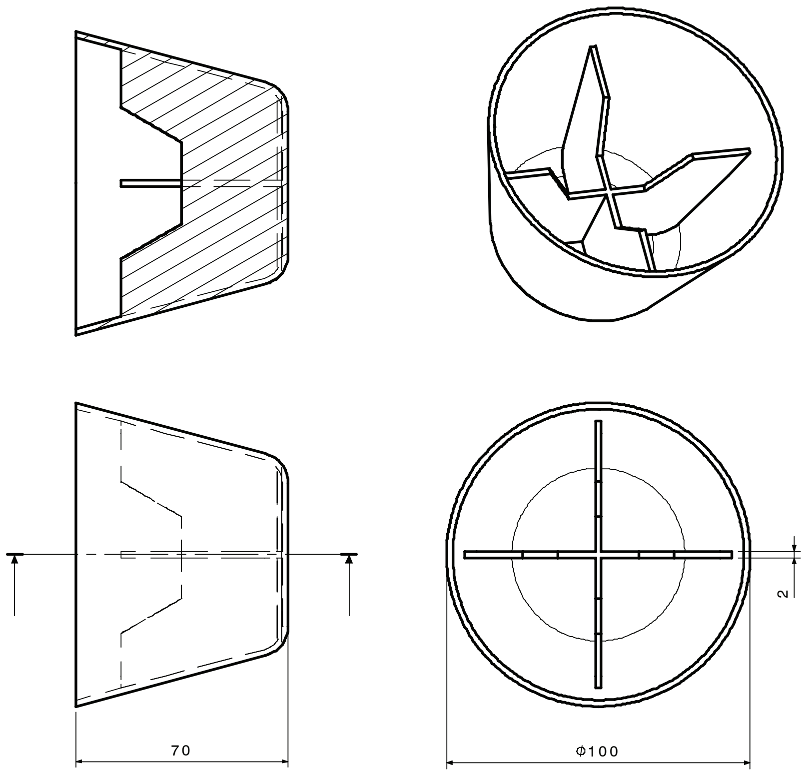

Figure 1: Example model.

The CAD-model is sectioned in 11 levels as shown in Figure 2 on the next page. Note that the 2 mm material thickness has, in the figure, been exaggerated to more clearly show how the mid-segments are formed in each section.

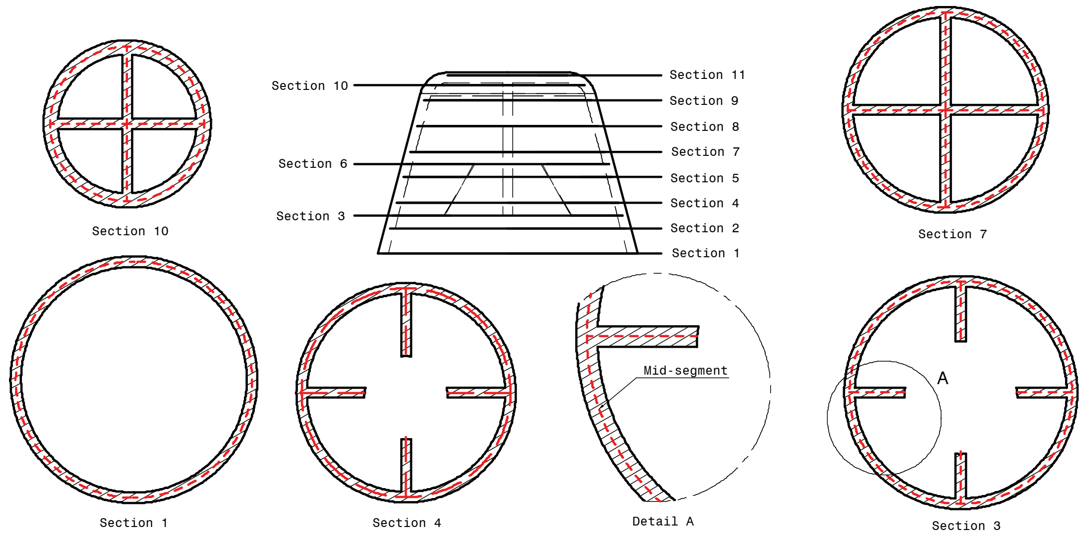

Figure 2: The medial segments of the sections.

The medial segments of each level are paired with the medial segment on the closest located level. The two segments are connected by a loft surface. Figure 3 show the resulting target surface obtained by the sectioning method. In Figure 3 a target surface created by a conventional method is also shown for comparison. The different levels are clearly visible on the sectioned surface.

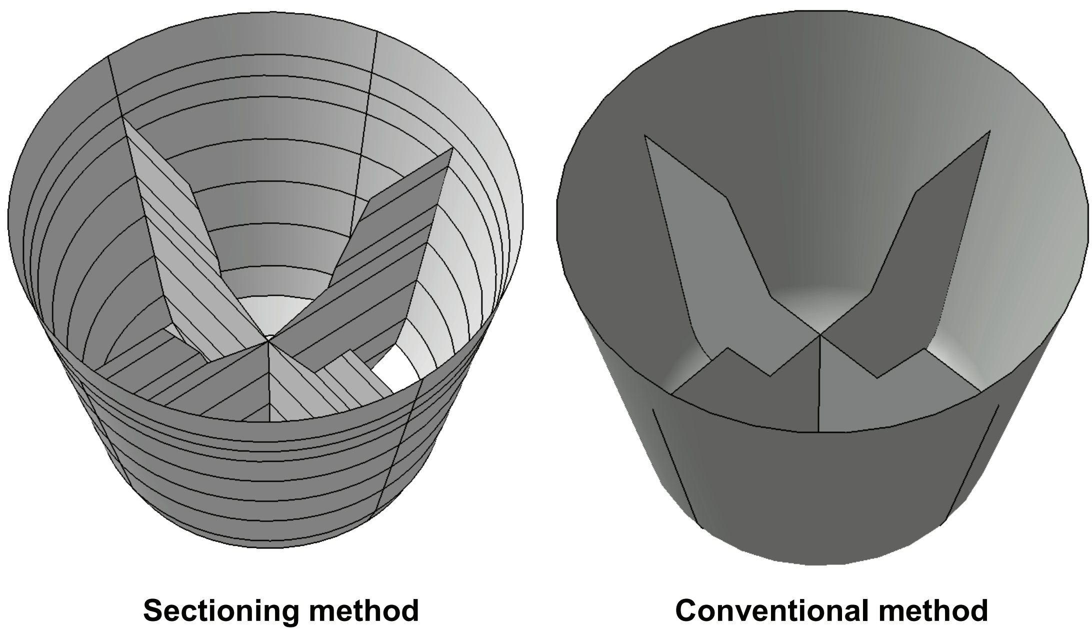

Figure 3: Resulting target surfaces.

The target surfaces are meshed using 3 mm quadrilateral parabolic shell elements. The thickness of all elements is set to 2 mm. The meshes are shown in figure 4.

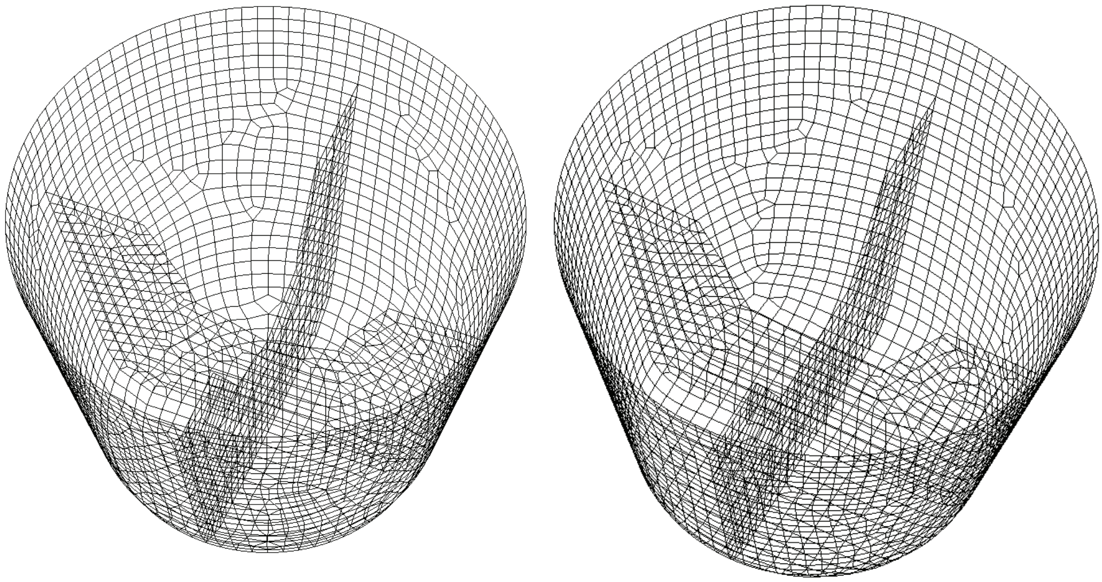

Figure 4: Shell element meshes applied to the target surfaces.

The FE-models are solved. The five lowest natural frequencies in Hertz are show in the table below. The differences between the two meshes, denoted by “Delta” in the table, are small, less than 1% for mode 1-4.

Mode	Conventional	Section	Delta	%
1	902	897	5	0,554324
2	2755	2738	17	0,61706
3	2757	2739	18	0,652884
4	3307	3295	12	0,362867
5	3767	3648	119	3,159012

Table 1: Natural frequencies in Hertz for mode 1-5.

Conclusions

The feasibility of the sectioning method for extracting the mid-surface from die-cast and injection moulded parts has been shown. The example was manually conducted in a CAD system with integrated FEA solver. However, the automation of the method is thought to result in a mid-surface extraction tool capable of extracting the mid-surfaces more efficiently than commercially available tools. The method also provides means of directly determining the wall-thickness in each section.

References

Rezayat, M. (1996). "Midsurface abstraction from 3D solid models: general theory and applications." Computer-Aided Design **28**(11): 905-915.

Stolt, R. (2006). *From CAD to FEA : a design automation perspective.*
Göteborg 2006
Chalmers University of Technology ;
School of Engineering Jönköping University.