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A 3D Knowledge-Based On complicated Mould Design system

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This paper presents the basic structure of an interactive knowledge to design and manufacture the complicated mould profile with the help of CAD/CAM system. The basis of this system arises from an analysis of the mould design process for to design the complicated sandwich structures for aerospace industries. This system covers both the mould design process and mould knowledge management. CAD mould design integrates the intelligent design process and knowledge management with many developed interactive tools in a commercial solid modelling software environment. Manufacturing process of this mould including G-code generation with CAM software and Computer Numerical Control machining.

Keywords: CAD/CAM, G-code, Mould Design

1. Introduction

The core parts in Sandwich panels are continuously being improved by developing new structural geometries with minimum weight and compact volume for automobile, aeroplane, marine and construction industries to offer superior mechanical properties. The general method of 3D finishing of a free-form surface is to use a ball endmill to trace along the part surface by maintaining an acceptable tolerance (Chang et al. 1991). Gouging is the main problem in 3D finishing. When a ball endmill cutter is used, the cutter radius must be smaller than the smallest radius of concave curvature to avoid gouging (Lee and Chang 1991). Choi and Jun (1989) introduced an algorithm which avoids gouging by comparing each cutter contact (CC) point with adjacent CC points which locate within the projection of the ball endmill on the XYplane. Another approach is to use a polygon surface to verify gouging (Kuragano et al. 1988). When there is a self-intersection in the polygon surface, the portion bounded by the self-intersection lines is trimmed. The existing methods rely on discrete point data approximation, which does not guarantee the avoidance of gouging. Consequently, a robust procedure to extract machining constraints directly from a free-form surface description is desirable.

This paper introduces fundamental CAD/CAM concepts of a sophisticated geometric structure which can be used for designing sandwich panels for various engineering applications. In ProEngineer (3DCAD) a new part model accurately captures a design from a concept through solid feature-based modelling and enables us to graphically view the product before it is manufactured. This system integrates the initial mould design with both knowledge base and interactive commercial CAD/CAM.

2. Surface design and mould machining

The contoured mould was designed in commercial CAD/CAM software and manufactured to a high precision using a computer-controlled numerical milling machine (CNC) which is composed of following steps:

1. A part model design by scoping the design parameters of the structure.
2. Create a part model by following the required design parameters.
3. Transfer the part model to triangulate surfaces in ProToolmaker(CAM) to create the CNC programme in G codes.
4. Set the raw materials in Haas CNC milling machine and manufacture the desired mould through roughing and finishing operations.

2.1 A part model design by scoping the design parameters of the structure:

The proposed mould design is the combination of two different sectional profiles which is presented in fig 1.And the detail design of the cell is mentioned in fig 2.

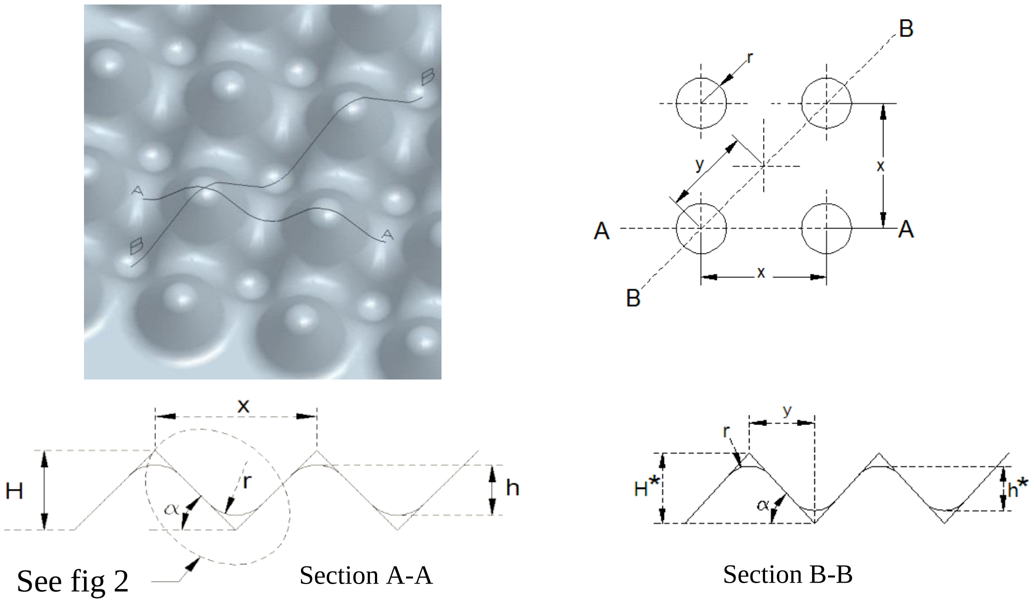


Figure1: Plan view and section Geometry of contoured profile

section A-A,
From Fig 1, r refers to the radius of the curve, which is 4 mm for the proposed design, α is the angle, H is the theoretical height and h is the actual height of the profile.

As shown in fig.2, the radius of the curvature can be calculated as:

$$r = q + s \tag{1}$$

Where

$$q = r\cos\alpha$$

By substitution the value of q in equation (1)

$$s = r(1 - \cos\alpha) \tag{2}$$

The actual height h can be found as:

$$h = H - 2t \tag{3}$$

Where

$$t = p\tan\alpha - s$$

$$p = r\sin\alpha$$

By substituting the value of t in equation (3), the relation between theoretical and actual heights can be described as:

$$h = H + 2r\left(1 - \frac{1}{\cos\alpha}\right) \tag{4}$$

Finally, the actual height can be defined as:

$$h = x\frac{\tan\alpha}{2} + 2r\left(1 - \frac{1}{\cos\alpha}\right) \tag{5}$$

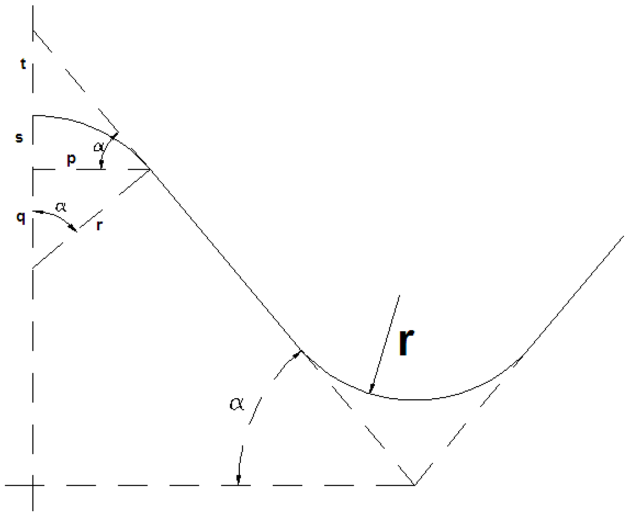


Figure 2: detail design of the cell

For section B-B

The radius and slop of the cell is same as in section A-A. But theoretical and actual heights are H^* and h^* respectively.

An important measure of the geometry can be calculated as:

$$y = \frac{x}{\sqrt{2}} \tag{6}$$

The theoretical height H^* can be defined as:

$$H^* = y\tan\alpha \tag{7}$$

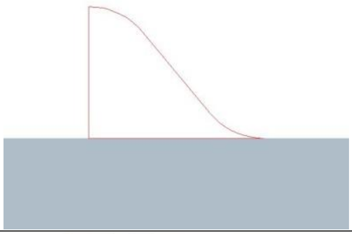
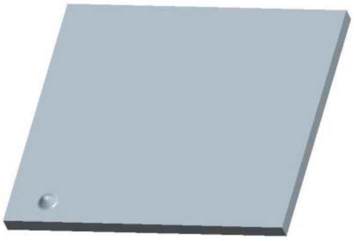
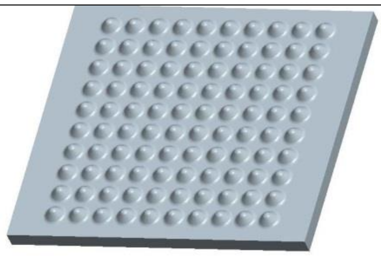
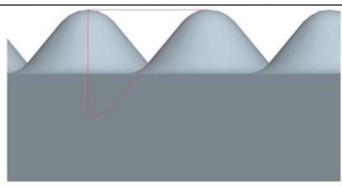
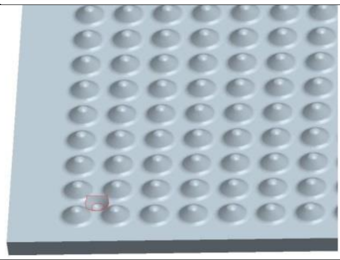
The actual height h^*in section B-B, can be found as:

$$h^* = H^* - 2t \tag{8}$$

By substituting the value of t and H^* in equation (7), the actual height can be defined as:

$$h^* = x\frac{\tan\alpha}{\sqrt{2}} + 2r\left(1 - \frac{1}{\cos\alpha}\right) \tag{9}$$

__2.2 Create a part model by following the required design parameters:__

1. To avoid irregularity on a smooth surface, the 3D CAD drafting process was carefully designed. The basic geometry is simple even though due to the complexity to pattern, a virtual design of the contoured shapes was started from a plain flat 3d shape in ProEngineer software as shown in step1	
2. A basic convex geometry of radius 4mm was drawn with an angle of 50^{O} and 20 mm width, as per the design data in A-A plane.	
3. The geometry of step 2 was revolved about the vertical axis drawn in the sketching plane to get the convex shape.	
4. In this step, the revolved shape was patterned/duplicated. There were 10 members duplicated in both, X and Y direction each at a distance of x=20 mm.	
5.In this step, the concave geometry was drawn as per the design data in B-B plane. For this drawing, the edges of the existing entity were used by selecting it with Use Edge tool.	
6. The geometry of step 5 was Revolved about the vertical axis drawn in the same plane and material removed from the model to create the concave shape.	

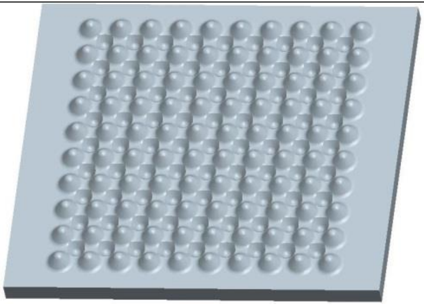
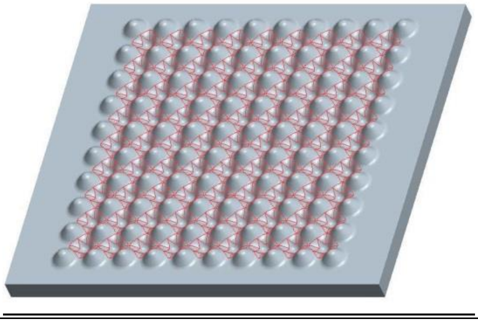
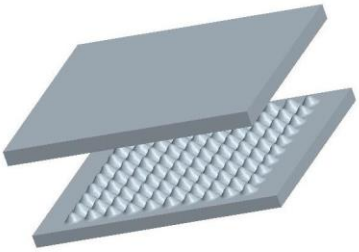
7. In this step, the revolved shape was patterned/duplicated. There were 9 members duplicated in both, X and Y direction each at a distance of x=20 mm.	
8. Round tool was used to remove the material by creating smooth transitions between existing geometry. The rounds were created by selecting edges are constructed tangent to the surfaces adjacent to the selected edges.	
9. The Shell feature was selected to hollows out the inside of a solid model, by leaving a shell of a specified wall thickness. The entire plane surface was Selected to remove from the model to create final contoured ply of 0.2mm.	
10. Finally, the rectangular sketch was extruded to the contoured ply, drawn in step 9 to create the top and bottom parts of the mould as mentioned in the step10.	

Table1: Steps to create a part model by using ProEngineer software

2.3 Transfer the part model to triangulate surfaces in ProToolmaker(CAM) to create the CNC programme in G codes:

In this section, the 3D part model was converted to IGES format and opened in ProToolmaker in order to create the manufacturing process. ProToolmaker is virtual manufacturing software which could simulate and modify the manufacturing process in a digital environment. When the file had loaded in ProToolmaker, a graphics window was opened and started to triangulate the surfaces for viewing. Triangulation converts the geometric surfaces into triangles. These triangles were used for both, to display on the screen and the machining process. Initially a roughing program was created to remove the bulk waste material from the workpiece with a toroidal carbide cutter, had 6mm diameter and 1mm corner radius was used in CNC machining. Cutting speed and feed used for this operation were 130m/min and .2mm/rev respectively. A Depth cut of 1mm was used in each passes in z direction. In this stage final finishing was left in as shown in fig 3.

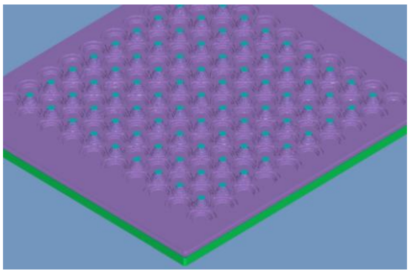


Figure 3: Material left for finishing is 0.5mm in x, y and z direction.

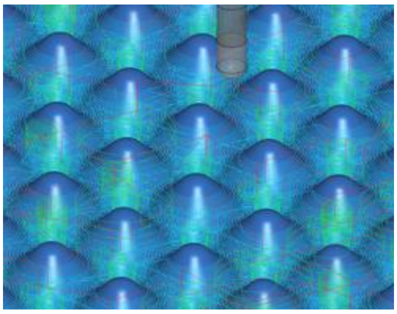


Figure 4: Milling cutter on smooth concave profile.

To get the final smooth profile as shown in fig 4, a carbide ball end milling cutter with 2 cutting edge was used with the cutting speed of 150m/min, feed per tooth 0.05mm and Depth cut of 0.1mm.The small concave radius of 4 mm was produced on final profile by using ball end mill cutter of 3mm radius.

2.4 Set the raw materials in Haas CNC milling machine and manufacture the desired mould through roughing and finishing operations:

Three axis Haas CNC milling machine was used to manufacture the mould. A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. In NC system, operating instructions are given to the machine as G-codes. The work piece was clamped to the machine bed which can move horizontally in X and Y axis. And the milling tool can move in Z axis which is perpendicular to the horizontal plane.

The toroid end mill has two cutting edges with a radius of 1mm, each cutting edge almost overlapping at the centre line of the cutter. This design eliminates the unfavorable cutting action that takes place at the tool centre of a conventional full radius end mill, where the cutting speed goes down to zero. Cutting speed and feed used for this operation were 130m/min and .2mm/rev respectively. A depth cut of 1 mm was used for the roughing operation.

A ball nose endmill has a semisphere at the tool end are ideal for machining three dimensional contoured shapes or work pieces with complex surfaces. The stepover value (along with the tool size) will determine whether the model has a smooth finish, or tooling marks are visible. Models with a smaller stepover take longer to cut. Stepover is the distance the tool moves over between subsequent passes. A ball nose end mill cutter with 6mm diameter and 0.1mm stepover were used to finish the mould. The used Cutting speed and feed for this operation were 150m/min and .05mm/rev respectively.

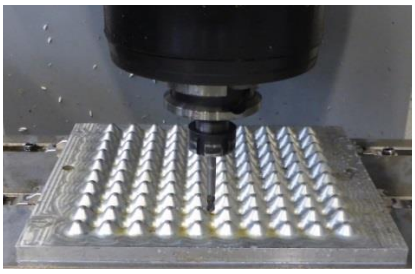


Figure 5: Milling cutter and work piece in Haas CNC milling machine

3. Conclusions

This paper present the method of complex shaped mould design by using computer aided manufacturing technique. The proposed technique explained the automation of complex surface machining for better machining quality. The design process of the framework as a sequence of different steps develops the design pattern to shape the final contoured mould.

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