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Finite Element Analysis and Experimental Validation of Forming Process for Honeycomb Structure Seal

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Abstract In this paper, research on the forming technology of hexagonal structure seal is investigated. Also the optimal forming process of the honeycomb seal is developed and the rolling process is analyzed using finite element code, DEFORM^{TM}-3D. Because of the precision shape and the thin thickness, the honeycomb seal is not easy to manufacture in the metal forming process. Because of the whole process is very complicate, in this study only forming process of honeycomb seal is simulated using finite element analysis to find the optimum shape of honeycomb seal for turbine.

Keywords: Honeycomb structure seal, Corrugation process, Forming process, Rolling process, Finite Element Analysis,

1 Introduction

Honeycomb core products are typically custom made for the particular application. This typically requires hard tooling, for cutting the core to an exact shape and/or bending it to a final form. In addition, foam splice lines are utilized to attach pieces of honeycomb core portions together, which degrade the overall performance levels. Often, the honeycomb products require forming to the final shape which typically includes the use of heat to soften the cells. This usually leads to degradation in overall material structural properties and a weaker assembly. Honeycomb core products also typically require time consuming validation and verification testing, particularly relative to radar energy absorption.[1]

There have been studies concerned with honeycomb products[2-6], but there has been no study that tried to analyze manufacturing process using computer simulation and the results are reflected to manufacturing process design for the honeycomb core. The final objective of this study is to develop the new manufacturing process of honeycomb core.

Because of the whole process is very complicate, in this study only forming process of honeycomb seal is simulated using finite element analysis to find the optimum shape of honeycomb seal for turbine. Due to the honeycomb seal is used at high temperature, the corrugation process is applied in this simulation.

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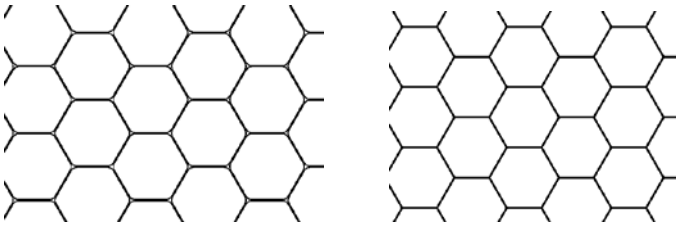
2 Definition of Honeycomb Structure Seal

The schematics of a commercial honeycomb with curved walls at the intersection points and a straight-walled honeycomb are shown in Fig.1a and b, respectively.



(a) (b)

Fig. 1. Regular hexagonal honeycomb structure: (a) commercial honeycomb with curved walls at the intersection points; (b) theoretical honeycomb with straight walls

There are five basic ways of making honeycomb core, adhesive bonding, resistance welding, brazing, diffusion bonding and thermal fusion.[1]

In the corrugation process the sheets are first corrugated, then adhesive is applied to the nodes and the sheets are stacked and cured in an oven. In Fig. 2, the whole honeycomb seal process is divided into four parts: the corrugation process, cutting process, welding process, brazing process.

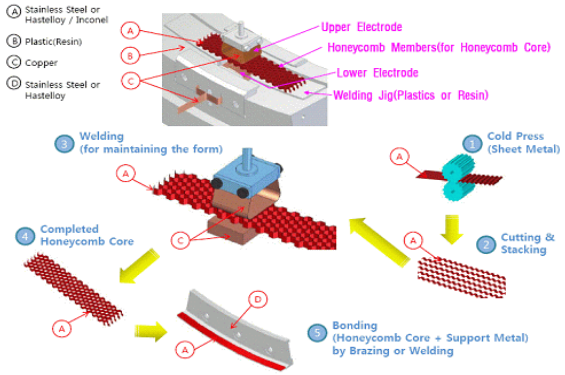


Fig. 2. Forming process to make honeycomb seal

3 Simulation

In this research, numerical approach for modeling the behavior of honeycomb is studied. The part of the honeycomb is modeled using the commercial S/W, CATIA. Also, the factors of the parameter of optimal forming process are developed and the corrugation process is analyzed. The corrugation process is simulated using finite

element code, DEFORM^{TM}-3D. The specification and material property of the honeycomb are shown in Table 1 and Table 2.

Table 1. Specification of honeycomb

Edge Length	4mm
Width	4mm
Cell wall thickness	0.1 mm
Half-Hexagonal Size	3.2 mm
Centerline fillet radius	0.02 mm
Material	Inconel-718

Table 2. Material properties of honeycomb

Density	8.19 g/cm^3
Tensile strength	1240 MPa
Yield point	1036 MPa
Elongation in 50mm	12 %
Hardness	36 HRc

In this study, the corrugate rolling process is simulated and discussed. The honeycomb member shape is the basic of the honeycomb core. The corrugate rolling process is very important in the whole process. According to Fig. 2, the gear is applied in the simulation. Also, in order to keep the sheet at the horizontal plane, a guide is necessary in the simulation. The sheet material is assumed rigid-plastic. Also the gear and guide are assumed to the rigid body. To control the honeycomb shape by twin-gear, friction coefficient is assumed 0.12.

In this part, the main purpose is to find out the honeycomb shape which is close to the standard shape in these two conditions. Then result of the shape is shown in Fig. 3.

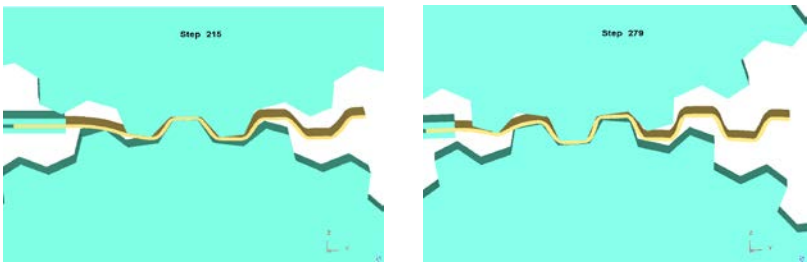


Fig. 3. Shape of Case 1 and Case 2 after simulation, respectively

From Fig. 3 we can see that the honeycomb shape after rolling process is influenced by the dedendum and addendum angle of gear.

4 Results and Discussions

We can estimate that the honeycomb corner radius is larger than the fillet on the addendum face of the Case 2. Then in the corrugation process, there is a limit of honeycomb corner radius, even though the addendum face fillet is 0.02mm or small, the honeycomb corner radius would not be reduced. Then it is worth to discuss

whether the honeycomb corner radius is changed if the addendum face fillet is enlarged. Analyzed results of Case 2 that dedendum angle is 120°, R is 0.02mm, are shown in Fig. 4. From the stress distribution and stress histogram of Fig. 4, it is possible to conclude that the stress distribution in the entrance area is similar, but in the rolling area it is small. According to the stress histogram, the average effective stress is small, which confirms the opinions insisted.

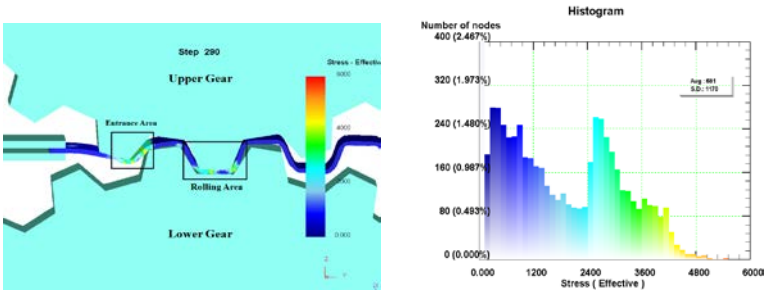


Fig. 4. Stress distribution and histogram of Case 2

5 Conclusions

Through this study it was confirmed that after the rolling process, the section of honeycomb close to the standard shape can be obtained. The results obtained are reflected to the manufacturing process design for the honeycomb core. Also research results can be extended to apply to the manufacturing of various honeycomb products.

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