

Simulation and analysis on structure of six-wing synchronous rotor in mixing process

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Abstract: The structure of the six-wing synchronous rotor is special and complex. And the forces acting on the rotors are complex, too. So, it is hard to use the traditional way to analyze these forces. Now, the simulation of the rotors during the mixing process could be analyzed by ADINA, including the displacement and stress simulation. Furthermore, the FEA results can guide the design of the rotors and promote the quality and efficiency of design.

1. Introduction

Mixing process is the first step for manufacturing rubber products, which is done by an important part called rotor[1~4]. Therefore, the rotor would bear a very strong force during mixing process. And the analysis of rotor would be important for its design. But the traditional way of analyzing the strength and rigidity of the rotors is assuming the rotor as a beam with different section [5, 6]. And the force loaded is a constant value. So, it is not accurate because of neglecting the wings and other structure of the rotors, such as the cooling structure. Now, with the development of science, the problem can be solved by ADINA. The strength and rigidity of the rotors can be analyzed accurately by the way of FEA. And ADINA is being used wildly because it can offer a program for comprehensive finite element analyses of structures, fluids, and fluid flows with structural interactions [7].

2. Models for simulation and analysis

2.1 FEA model

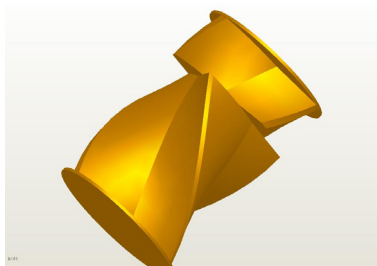


Figure 1. The 3D model of the mixing part

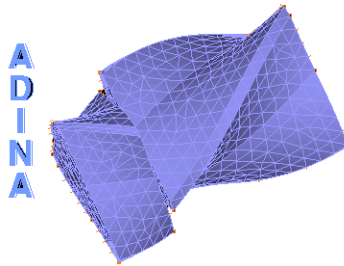


Figure 2. Finite element meshing model

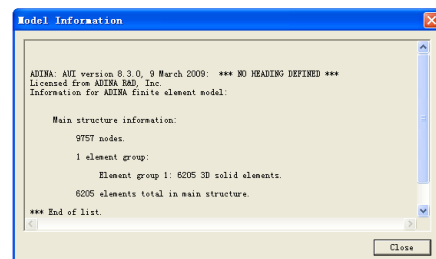


Figure 3. Results of finite element meshing

A 3D model must be built to simulate the structure of the rotors. Select the mixing part as the project of study as shown in the Figure 1. And then mesh the 3D model, getting the model of FEA as shown in the Figure 2.

Meshing is an important step of FEA. In order to guarantee the accurateness of FEA, different method of meshing can be adopted according to the different requirements of analyses. And the result of the meshing is shown in the Figure 3. There are 9757 nodes and 6205 elements in total.

2.2 Material parameters

The material of the rotors is carbon steel. And all the materials are assumed as linear elasticity material. And the material parameters are shown in the Table 1 in detail.

Table 1. Material parameters

Parameters	Value	Unit
Density	7850	[kg/m ³]
Elasticity Modulus	1.93e+011	[N/m ²]
Poisson Ratio	0.284	[NA]
Shear Modulus	7.7e+010	N/m ²
Tensile Strength	1.24e+006	[mN/mm ²]
Yield Strength	1.178e+006	[mN/mm ²]
Coefficient of Heat Expansion	1.23e-005	[1/C]
Coefficient of Heat Conductivity	44.500	[W/(m.k)]
Heat Capacity	475.00	[J/(kg.k)]

2.3 Bound Conditions

The forces loaded on the rotors should be measured according to the real conditions. But that is impossible. So, the force could only be got by the way of theory analyses. According to the theory of rotors design, the force Q formed by the ram pressure can be described as followed:

$$Q = PS \quad (1)$$

Where, Q : Force formed by the ram [N], P : Pressure [Pa], S : Area of the ram [m²].

And according to the Figure 4, the largest force is

$$F = \frac{Q}{2 \cos(90 - \alpha)} \quad (2)$$

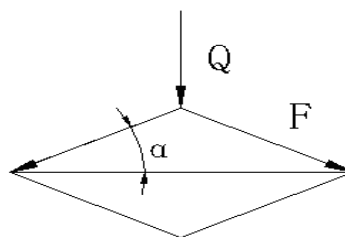


Figure 4. Loads analysis on rotor

Where, F : The largest force loaded on rotors [N], α : Engaging angle [°].

And the α of the six-wing synchronous rotor is 34°.

In addition, the freedom of motion of the rotors should be set as followed: the displacement of the points on the rotors' head face should be set 0 along the coordinate axes X, Y and Z. And the rotation should be set 0 along the X-Z and Y-Z, too. This is close to the real conditions of the rotors during the mixing process.

So, according to the theory analyses and calculate, the forces that are loaded on the rotors can be from 6.0MPa~7.5MPa (in the form of pressure). Moreover, the bound conditions and load-up conditions have been vividly shown in the Figure 5 and 6.

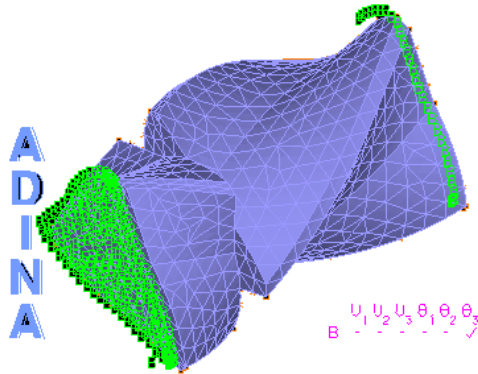


Figure 5. Boundary conditions of the rotor

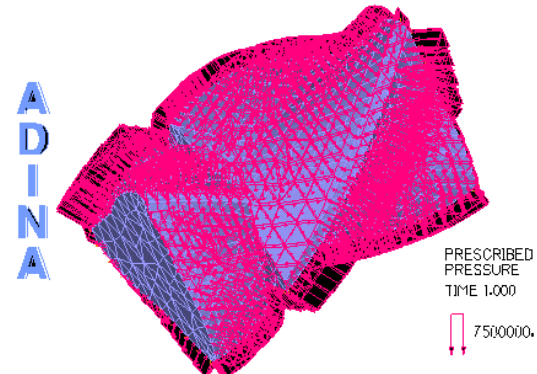


Figure 6. Load-up conditions of the rotor

3. Results and discussion

The displacement and stress of the six-wing synchronous rotor during the mixing process have been analyzed by ADINA. And the FEA results are shown in the Figure 7 and 8.

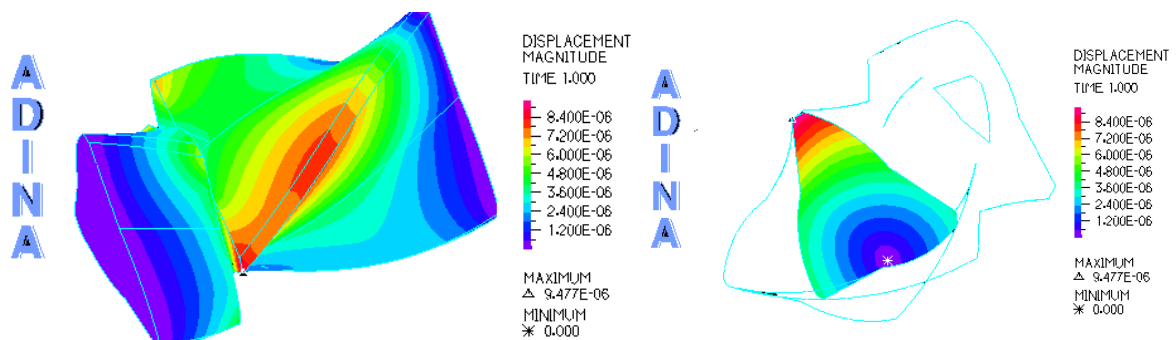


Figure 7. Nephogram of displacement

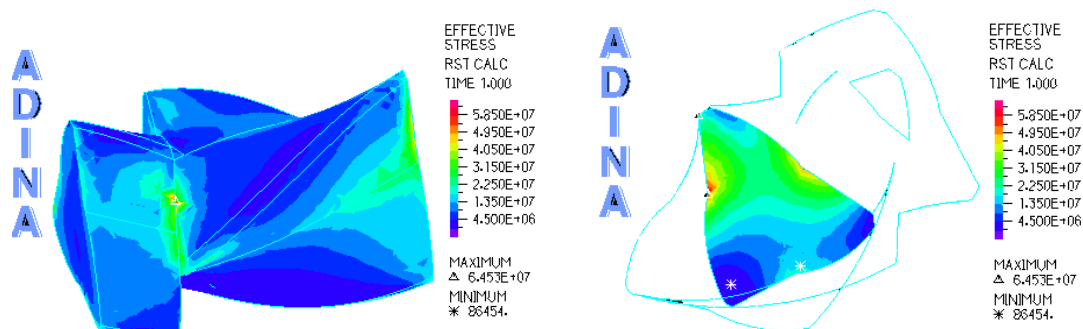


Figure 8. Nephogram of stress

According to the Figure 7, it can be judged that the dangerous points are on the wings top. Because the clearances between the wings top and the mixing room are very small. So, the wings top would suffer a large force which is formed by the distortion of the mixed rubber during the mixing process. As a consequence, the displacement of the wings top is the largest just like what has been vividly shown in the Figure 7. And the displacements of the other points on the rotor are very small. Therefore, the dangerous points are on the wings top. While according to the Figure 8, it can be concluded that the stress of the wings bottom is larger than any other points on the rotor. That is because there is

stress concentration in the area of the wings bottom. As a result, the stress is larger. And the areas could be dangerous points.

So, during the manufacturing process of the rotors, special technics should be adopted. For example, during the practice production, the Kentanium are welded on the surface of the rotors and heat treatment of the rotors' surface can be adopted to make the rotors have enough strength and rigidity. Mostly, the stress concentration should be avoided to prolong the use life of the rotors. So, some circular bead should be designed and manufactured.

4. Conclusions

The displacement and stress situation of the six-wing synchronous rotors could be got directly and accurately by the analyses of ADINA. According to the FEA results, it is easy to judge the dangerous points. And what is more important is that the results can be a guide to the design of the rotors. So, it will take less time, less energy to design and manufacture the rotors. Also, it could promote the rationality and quality of the design, and economic benefit.

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