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SIMULATION ANALYSIS OF WIND TURBINE BLADE DURING RESIN TRANSFER MOLDING PROCESS

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Abstract. The wind turbine blade is a key component of wind turbine generator system, and helps capture wind energy effectively. The way of RTM resin transfer molding is generally used at home and abroad for blade manufacturing process. In order to ensure the quality of product, computer simulation analysis and experimental verification should be conducted before producing. Moldflow was used to simulate the process of wind turbine blade RTM. Based on that, variation diagrams about filling time, temperature, buckling deformation, pressure and so on are obtained. The results of analysis and comparison of with and without cooling, as well as optimize the defects existed indicate that cavitations concentrate in roots and edge of the blade, gas exhaust mold easily, there is no need to open up air vent additional; In filling stage, mold clamping force gradually increase slowly, in packing stage, mold clamping force sharply increase to reach peak, the mold clamping force disappears after packing; filling time with cooling process is longer than that without cooling process. It provides an important reference for wind turbine blade design and manufacture.

1. Introduction

Compared with many composite manufacturing processes available, resin transfer molding(RTM) is one of the most efficient and economical process due to its capabilities such as non-expensive process equipment, closed mold process, excellent control on mechanical properties, incorporation of metal inserts and attachments, low filling pressures, possibility of producing large and complex parts and low labor costs [1].

Macro-flow (resin flow between the fiber bundles) and micro-flow (resin flow within the fiber bundles) both exist during the process of resin transfer molding. Flow behavior is influenced by a lot of factors and flow principle is completely complex, so that many problems are to be solved. This comes to be the focus of study on liquid model molding process field at home and abroad [2, 3].

Analysis of resin transfer molding of blade has deep significance on development of RTM. Computer is used to simulate the molding process. Continuous modification and perfection of numerical method in practice helps computer to analyze and predict the process of molding exactly. After resin has injected into cavity during RTM process, shape of resin in saturated zone and flow front change over time, which is a transient process. The numerical method of treating free surface and moving boundary of transient fluid is the key of

pressure is the parameter which should be solved at the end.

N-S equation is the motion equation which describes momentum conservation of incompressible fluid, as follows:

$$\begin{cases} \rho\left(\frac{\partial \nu_x}{\partial t}+\nu_x\frac{\partial \nu_x}{\partial x}+\nu_y\frac{\partial \nu_x}{\partial y}+\nu_z\frac{\partial \nu_x}{\partial z}\right)=\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 \nu_x}{\partial x^2}+\frac{\partial^2 \nu_x}{\partial y^2}+\frac{\partial^2 \nu_x}{\partial z^2}\right)+\frac{1}{3}\mu\frac{\partial}{\partial x}\left(\frac{\partial \nu_x}{\partial x}+\frac{\partial \nu_y}{\partial y}+\frac{\partial \nu_z}{\partial z}\right), \\ \rho\left(\frac{\partial \nu_y}{\partial t}+\nu_x\frac{\partial \nu_y}{\partial x}+\nu_y\frac{\partial \nu_y}{\partial y}+\nu_z\frac{\partial \nu_y}{\partial z}\right)=\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 \nu_y}{\partial x^2}+\frac{\partial^2 \nu_y}{\partial y^2}+\frac{\partial^2 \nu_y}{\partial z^2}\right)+\frac{1}{3}\mu\frac{\partial}{\partial y}\left(\frac{\partial \nu_x}{\partial x}+\frac{\partial \nu_y}{\partial y}+\frac{\partial \nu_z}{\partial z}\right), \\ \rho\left(\frac{\partial \nu_z}{\partial t}+\nu_x\frac{\partial \nu_z}{\partial x}+\nu_y\frac{\partial \nu_z}{\partial y}+\nu_z\frac{\partial \nu_z}{\partial z}\right)=\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 \nu_z}{\partial x^2}+\frac{\partial^2 \nu_z}{\partial y^2}+\frac{\partial^2 \nu_z}{\partial z^2}\right)+\frac{1}{3}\mu\frac{\partial}{\partial z}\left(\frac{\partial \nu_x}{\partial x}+\frac{\partial \nu_y}{\partial y}+\frac{\partial \nu_z}{\partial z}\right). \end{cases} \quad (4)$$

In the formula, ρ is fluid density, p is pressure, ν_x, ν_y, ν_z are velocity components of fluid at time *t*, at point (*x*, *y*, *z*), g_x, g_y, g_z are external force components.

Molding cycle also is molding process, which includes mode locking, clamp, platform feed, injection, pressure maintaining, colloidal sol + cooling, push-out, die sinking, platform back. The size of product is 80.3 mm × 950.47 mm × 64.27 mm. It is suitable for 3D analysis as the shape is thick and stubby. Because of model problems, such as geometry and size, some defects appeared after the mesh division is completed, for instance overlapped elements, crossed elements, free edge, unreasonable aspect ratio, incoherent circulation, etc. If these problems are not properly solved, the quality of the model will be influenced badly, so that the analytic results may be not correct.

3. Interpretation of results

Simulation results of wind turbine blade molding process, as shown in Fig. 1-6 separately.

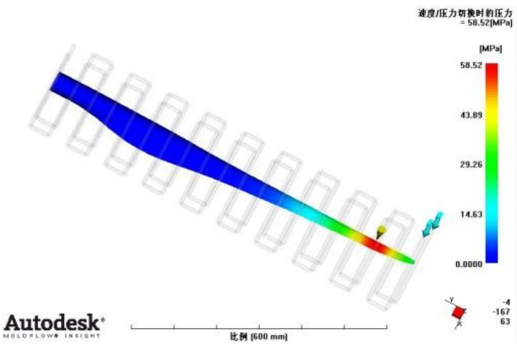

Fig. 1. Analysis of pressure when switching from velocity to pressure.

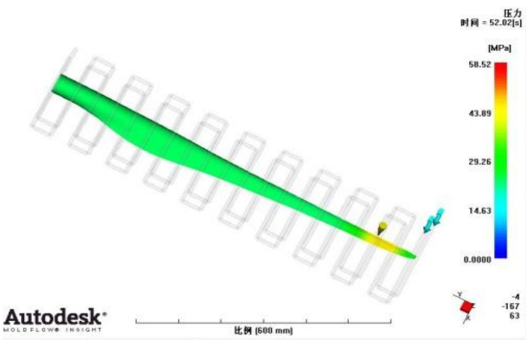

Fig. 2. Analysis of pressure.

As shown in Figs. 1, 2, pressure when switching from velocity to pressure is also the

As shown in Fig. 5, the range of temperature is 2.42 degrees which is reasonable. Temperature of entrance is low, but the temperature increases as the distance away from the entrance increases. Besides, it presents entirely that the color of middle part of pipeline is bright; the color of both sides of pipeline is dark. That is to say, temperature of pipelines lie above the blade is higher than both sides of pipeline.

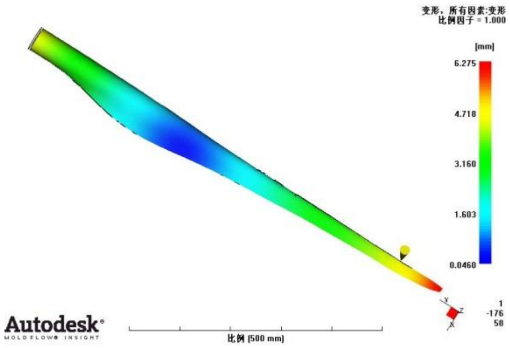

Fig. 6. Analysis of warping.

As shown in Fig. 6, warpage is largest at the part of blade tip, and which is smallest at the middle where close to the root of blade.

4. Comparative analysis

A general mold filling process involves cooling. The results of two situations, with and without cooling are represented in Figs. 7, 8 below to enable a visual comparison.

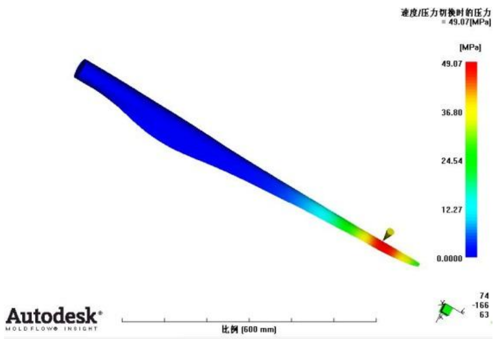

Fig. 7. Analysis of pressure when switching from velocity to pressure without cooling process.

Under the conditions of cooling and no cooling, general change law of mold filling process is the same by comparing Fig. 7 with Fig. 1. Due to the lower temperature, resin viscosity increases and resin flow rate decreases. When switching from velocity to pressure, pressure under the condition with cooling is larger than without cooling.

As shown in Fig. 8, molecular orientation shrink anisotropy is offset by cooling process, which contributes to improving warping deformation.

5. Optimization design

The variety of cavity types and designs of runner have quite a little effect on filling results [10-12]. As shown in the analysis results above, there are still some defects exist during filling process, such as the pressure when switching from velocity to pressure is rather

As shown in Fig. 9, after optimizing, the pressure when switch from velocity to pressure decreases. Efficiency is potentiated as well as wastage is reduced.

As shown in Fig. 10, two pictures clearly explain that warping deformation of blade is improved. As a result, quality of products gets great a degree enhanced through effective and reasonable optimization.

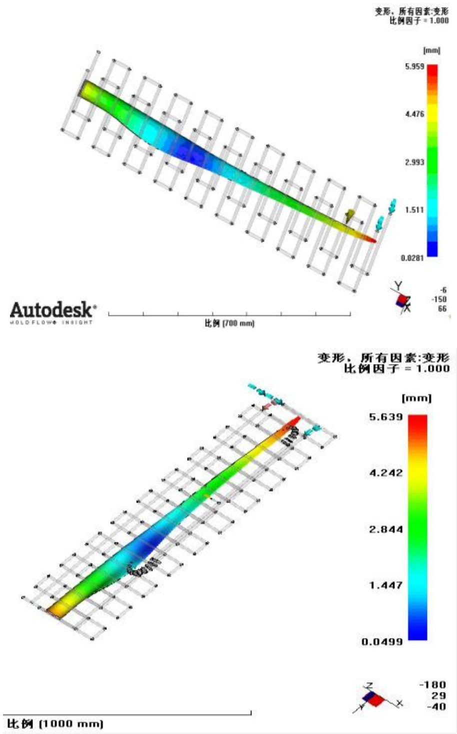

Fig. 10. Comparative analysis of warping before and after optimizing.

6. Conclusions

(1) By simulating and analyzing resin transfer molding process of wind turbine blade, the change rules of pressure, temperature and warping during molding process are researched.

(2) Contrastive analysis of filling results under the conditions of cooling and no cooling is obtained.

(3) The defects which have influence on the quality of products are optimized by changing technical process.

(4) Conclusions like maintaining process homogenize the products so that quality is improved, is reached by simulating and analyzing the molding process. Through the comparative analysis of filling processes with and without cooling, several conclusions are obtained, for example, filling time is longer, warping deformation is smaller, quality of product is better with cooling process.

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