Stress analysis of the winding head frame for the production of the composites

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Abstract: New technology for production of composite materials is to wrap the plastic core using fibers with specific properties. Subsequently wrapped core is poured using polymer matrix and thereby allow it to obtain parts with excellent mechanical properties with low weight. For the production of such parts, the winding head is used. The supporting frame of this head is divided and has a C-shaped. Two rotary wheels, which are fixed through bearings in the paths of the frame, carry fibers wound on coils across aluminum rings. Due to the tension that occurs when the fibers are pulled during winding, some deformation of the frame does exists in the area, where the frame is. This work shows the behavior of the frame during the winding process.

Keywords: aluminum frame; tension; winding process

1 Introduction

Currently there is growing production of composite materials having improved mechanical properties in compare with conventionally used materials. For composite frames a method of winding a plastic core using carbon fibers can be used. For this production process construction of winding head is designed. It is composed in basic of an aluminum frame and two rotary rings which are fitted with coils. On the coils are wound fibers. The rotating wheels are mounted in the frame by means of bearings. During winding the fibers are fixated on the surface of the core. By dragging cores through the head a force in the fibers is generated, which is transmitted to the head structure as shown in Fig. 1. The force is caught in the construction on an aluminum frame. Deformation of the frame depends on value of the force in combination with speed of rotation of the rotating rings.

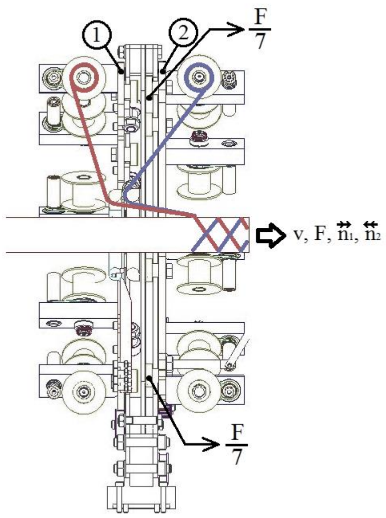

Fig. 1: Scheme of the winding head.

During the process of winding the core is pulled through the center of the winding head under force of 100 N. This force is given by dragging fibers over aluminum rings and brake resistance in the coils. Through the fibers, the force comes to the rotary wheel. Rotary wheels have speed 36 RPM and they have different direction of rotation. Each wheel is fitted with seven bearings, which are fixed in the paths located in support frame. This leads to deformation of the supporting frame, which is exposed to a cyclic stress. The supporting frame is divided and his shape looks like number C. During the process bearings go across the space in the frame and they do an impact on his edges, as shown in Fig. 2. At this moment the shape of the supporting frame is burdened by stress in direction of head axis.

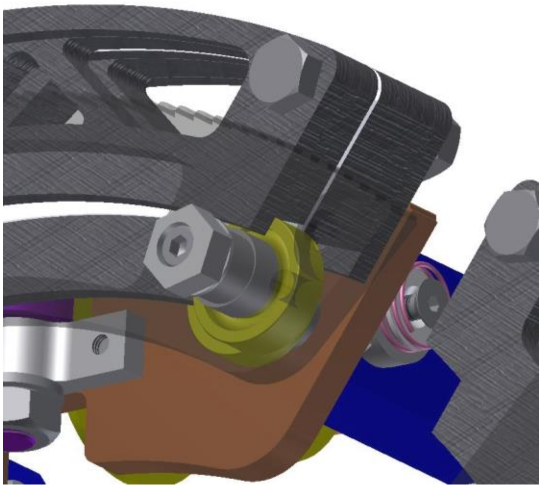

Fig. 2: View on the bearing making impact into the groove of the frame.

2 Material and methods

2.1 FEM analysis of the base frame

Based on the CAD geometry a FEM model has been built [1, 2, 3]. Result of the analysis shows, how the frame behaves during the process. Frame arms are loaded by cyclic bending and vibration. Vibrations caused by impact of bearings on the frame with frequency 0, 2 Hz. Results of FEM analysis are shown Fig. 3 and Fig. 4. Fem analysis showed the places where the greatest deformations occur during the winding process. Frame arms are loaded by the cyclic tension in the direction of base frame axis. This arms are created, when the base frame is gonna be divided. In this case it is possible to wrap closed frames. Areas, where it is possible to find the highest values of deformation, are placed at the begininnig of the arms. Diameter of the inner ring is 300 mm. So when the bearings act on the ends of arms, it is possible to measure behavior of both arms in the direction of base frame axis.

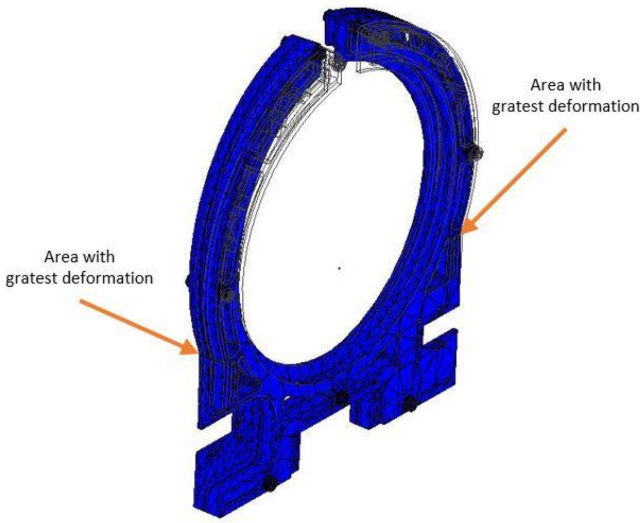

Fig. 3: Isometric view of the model.

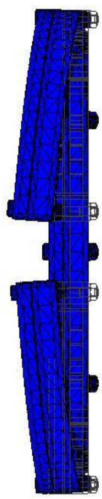

Fig. 4: Top view of the model.

During the process, arms of the base frame are loaded by bending stress in the direction of the wrapped core motion. Bending is invoked by braking coils rotation. The size of friction indicates the tension in layed fibers. Fibers transmit power to the two rotating wheels, which are caught on the base frame. Base frame has a sandwich construction type and is composed of six aluminum sheets. Combining of aluminum sheets give solid structure with two arms, forming a circle. The circle is divided, however, giving rise to the possibility of increased stress in both arms. Arms are mostly strained at their ends, where they are bend. At the same time there are impacts of bearings into ends of base frame arms. This reality is given by divided design of the base frame. During the process, bearings are going in orbit paths created in the base frame. Where the frame is divided, bearings are going into a free space. When the bearing try to return back into path, it occurs an impact. This activity creates impulses in a bending stress. Bending stress is given by Eq. (1), Eq. (2).

$$\sigma = \frac{M_o}{W_o} \tag{1}$$

$$M_o = F.r, W_o = \frac{h.b^2}{6} \tag{2}$$

Where F is a force caused by the coils braking system, r is length of arms, W_o is section modulus in bending.

2.2 Experiment

According to the simulation results an experiment was compiled. Experiment include measuring of the base frame deformation during the winding process. This indicates show optimal settings of components having an influents on the winding process.

To determine the deformation value of the base frame, an experiment was performed. Strain values were determined using two strain gauges, which have been glued to place with the occurrence of maximum deformation [4], as shown in Fig. 5. These places were found using FEM simulation. For testing two strain gauges of the type 3/120LY41 were used. Properties list of the strain gauge show: sensitivity +0.2%, nominal resistance $120\Omega \pm 0.3\%$, gage factor tolerance $2.02 \pm 1\%$. Strain gauge measures the elongation by Eq. (3).

$$\varepsilon = \frac{\Delta l}{l} \tag{3}$$

Where l is the length of the sample. By the elongation value it is possible to calculate the size of bending stress using Hook's law. The experiment was performed during the real winding process for 5 seconds. This period represents the displacement of the head in the direction of its own axis in 1 meter. During that time, execute each rotary wheel 3 turns.

Fig. 5: View on strain gauges glued on the base frame.

3 Results

The output from the strain gauges are the values of elongation. With Hook's law these values can be converted to values at the bend. This makes it possible to observe the behavior of the base frame arms during the winding process. The graphs placed below shows the tension at locations where the strain gauges are glued. Bending of both arms are in the same direction. Because each strain gauge was stuck on the other side of the frame, they are in one graph negative values (pressure) and the second positive (tensile). The average value of elongation in the graph showed in Fig. 6 is -22. The average value of elongation in the graph showed in Fig. 7 is 5. From the results it is seen that both arms are not stressed equally. This may cause gravity. Because the head is during the winding process in a vertical position, first arm is above the second one. The upper arm is used only as a guide for bearings. The lower arm bears the weight of rotating wheels. Bearings thus increasing rigidity of lower arm. In both graphs there are shown some kinds of jumps that are created due to impact bearings on the frame body. During the three turns of ration wheel, it is seen in one arm 21 impacts from the graph. In two arms it is therefore absorbing 42 impacts. To optimize the operation of the winding head would be advisable to colligate frequency of bearings impacts on both rotary wheels. Technically it is possible, because the spacing between each bearing on both rotating wheel are provided identically. Then, the frame structure will absorbed only half number of impacts.

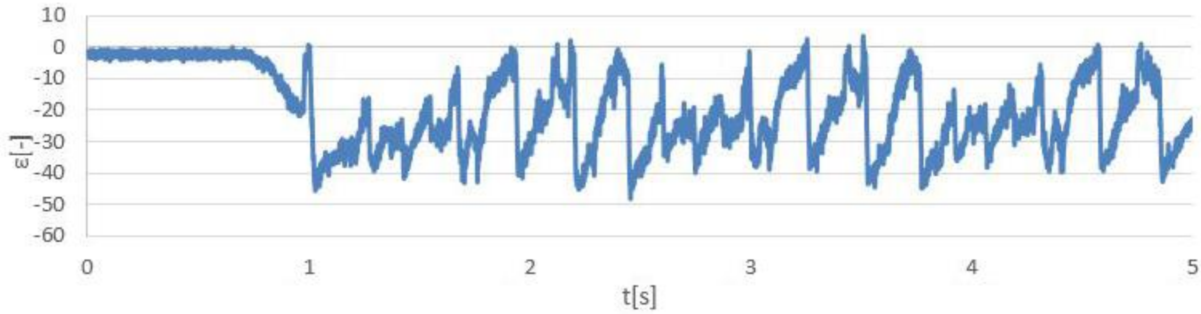

Fig. 6: Strain gage on the upper arm (pressure).

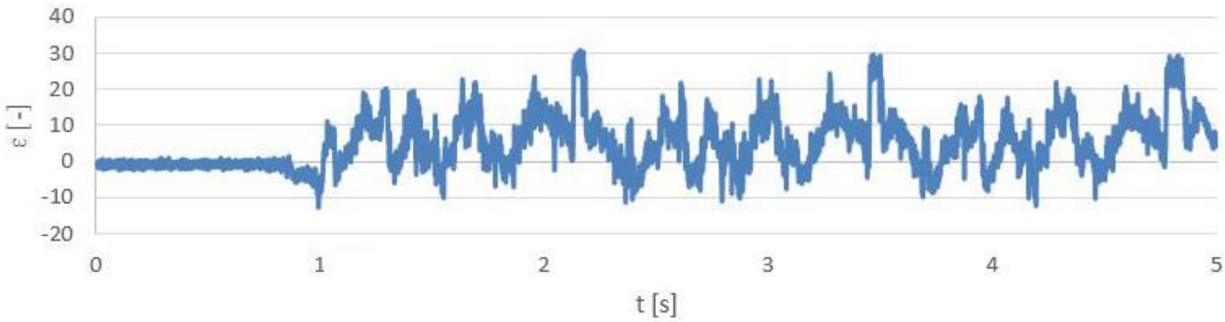

Fig. 7: Strain gage on the lower arm (tensile).

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