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DESIGN OF A FABRIC WINDING UP UNIT

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Abstract

For air-spring production the fabric winding is what prepares the semi-finished materials. The rubber body, that we called the membrane is made from using several layers of fabric and rubber. Building together these layers defines the mechanical properties. During the winding up, we prepare the cut rubber or fabric layers in rolls. Quality of rolling and the performance to make the semi-finished material, depend on the machine which is used for the winding. To satisfy the higher production capacity it was necessary to create a modern construction using automated systems. To assure the ergonomic expectations was a main viewpoint too. My thesis main goal is to explain, in detail, my design and to prove the device structural solutions using finite element analysis.

Keywords*: air-spring production, fabric winding, automated systems, finite element test, tool designing.*

1. Introduction

I have studied engineering in both the University of Nyíregyháza and at the partner company Continental ContiTech Hungary Ltd. at Nyíregyháza. During the practical part of training I became familiar with parts and their production processes of transportation vehicles, especially those made from rubber, like air springs. I also had the opportunity to study the application of such parts **[1]**.

I was a member of a team responsible for a plant manufacturing parts applying textile fabric for making composite vulcanized rubber. The fabric winding up unit in the plant was obsolete, so the quality of rolls did not meet current requirements. That's why I got the task of development a new fabric wind up unit.

In this paper I demonstrate first processes of air spring manufacturing and show the role and function of the fabric winding up unit in the whole process. We can then work out the structural solutions used to explain them. We analyze the role, the function and the load resistance of the chassis, the complete piece of equipment and the auxiliary systems According to the development plan, the obsolete structure will be modernized, the growing customer needs will be met, and the protected product labeling aspects will be taken into account. After the development of the structural solutions, the technical documentation required for the production was prepared.

2. Presentation of a previously used tissue winding unit

At the beginning of the process, the calendered roll is placed in the machine, the fabric elements of which are previously cut into angles and sizes according to the area of use. This machined rubber sheet arrives on a belt to the operator, whose task is to join (endless) the cut fabric.

The worker places the sheets on top of each other by overlapping them, which are placed at an angle by the belt at the angle of the winder. They are then supplied to the unit (**Figure 1**).

The endless cards are wrapped in a so-called accompanying fabric, which, acts as a separating layer; it prevents the rubber film and the other rubber film that's pressed on the fabric, which is also made here from sticking together. This is how the ready-to-use rolls are made. The production capacity and the quality of the rolls depend on the operation of the winding unit (creasing of rubber sheets, fabric sheets is not allowed!).

3. Problems with previously used equipment

The first problem in the winding is due to the bearing of the machine. The shaft of the coil is mounted on two sides. The shaft must be inserted in and out at the end and start of winding process.

The shaft of the coil is mounted on two sides. For this purpose a pivot is made,in which a forked end of a pneumatic cylinder releases a bowed tumbler which is strengthened by a counterbalanced spring (**Figure 2**).

For this solution, insertion and removal of the shaft of the coils is easy, but the shaft has backlash in the connectors, as a result of which the winding is not of sufficient quality. Due to the axial backlash concentricity cases the tissue sheets slide over one another or they may become separated.

During winding, as the thickness of the wound material increases, so does the diameter of the coil, so a linear displacement of the bearing housing and the connection must be ensured. To solve this, there is a so-called grooved column. The connecting shaft ends themselves are able to perform linear movement in 2 grooves (**Figure 3**) with the aid of 2 rows of deep groove ball bearings. According to operating experience, the bearings were often caught in the grooves, which caused damage to the roll.

There was also problem with inserting and removing the ready roll. The weight of the wound fabric sometimes exceeds 50 kg, according to the applicable occupational safety regulations, this weight must no longer be moved by human force. For this purpose, there is a crane next to the machine, which is used to remove the roll. Using the crane, the roll can now be removed from the machine, however, positioning and safely adjusting the crane lever to the roll is a cumbersome and time-consuming process

Because of the described malfunctions and frequent maintenance of existing units a demand is raised for a new structure and design development, which is more up to date and permits more reliable operation.

Figure 1. *Old tissue winding unit.*

Figure 2. *Shaft connection to the machine.*

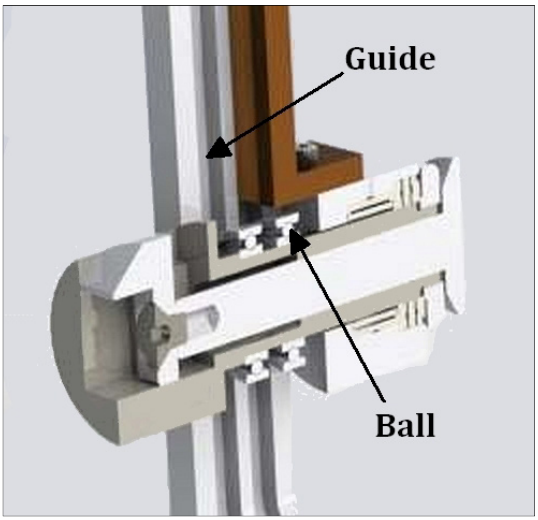

Figure 3. *Section of winding column.*

Figure 4. *Swinging beam winding unit.*

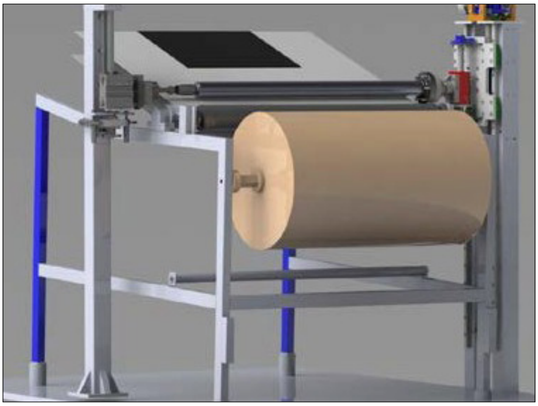

Figure 5. *Column winding unit.*

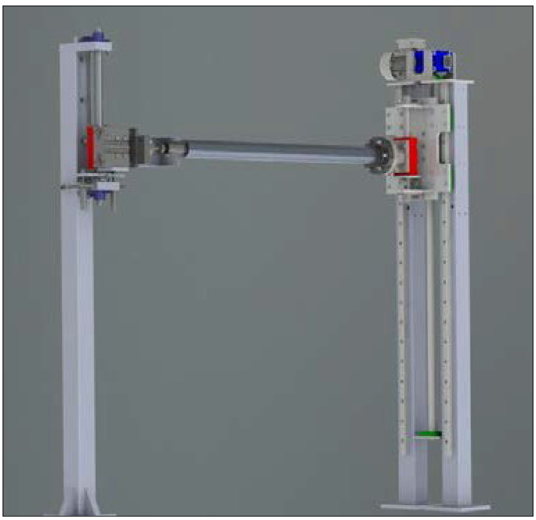

Figure 6. *Truss structure of column winding machine.*

4. Development proposals for the winding unit upgrade

After defining the task, I prepared the design of two constructions with different operating principles. Both versions have been designed with the most important requirements in mind, but their structural solutions and operation also differ significantly.

4.1. Swinging beam version

The first variant of the "Swinging Beam Winding Device" (**Figure 4**) has the notable advantage that its structure is simple, yet its operation is automated.

Operation: At the start of the process, the operator inserts the empty roll drum together with the shaft into the connectors in the arms of the machine, which the machine places on the belt of the roll table using electric motors. The design of the coils is ensured by the strap, the elimination of the difference in diameter is made possible by the free-moving arms. At the end of the winding process, the structure picks up the finished roll from the table, and it is transported by the equipment to the operator's working level. The process repeats itself.

4.2. Column winding unit

The second development version is the so-called "Column fabric winding unit" (**Figure 5**). Main features : a high degree of automation, ergonomic full of compliance. The design of the structure is complex, the design of custom-made parts is complicated, however, machining can be implemented on CNC-controlled machining equipment.

A significant advantage is that 80 percent of the parts are commercially obtainable, so in case of failure, repair can be done quickly.

4.3. Choice of construction

After elaboration of the two versions in principle, we started a plant meeting, in which we selected the most suitable solution for the company with the operators and plant managers working with the equipment.

The columnar winding version (**Figure 6**) has been proven to be most appropriate for all aspects taken into account. Thus, the complex and detailed elaboration of the structure could follow.

5. Main features of column winding machine

Basically, the equipment can be divided into two main units. In the following, I refer to the main parts as a left superstructure and as a right superstructure. Synchronized working ensures operating conditions necessary for manufacturing the semi-finished material

5.1. Superstructure on the left

The primary function of this part of the equipment is to centralize the pneumatic gripping shaft and to ensure parallelism with the strap table. These functions are provided by the elements shown in **Figure 7.**

Function: A pneumatic cylinder with a bearing rotating centering cone opens and closes. This solution ensures that the gripping axis is centralized. It was necessary to compensate for the difference in size due to the increase in the diameter difference provided by a linear axis with a vertical displacement or by this bearing housing. There are two damping cylinders under the pneumatic cylinder, the function of which is to dampen the return slip after unwinding of the cone after winding and to reset this device. The linear axis has the opportunity to position in the perpendicular direction onto the shaft which makes assembling simpler, and helps to eliminate problems possibly arising from positioning the whole truss system.

5.2. Right superstructure

The superstructure on the right is the most complex unit of the winding unit (**Figure 8**). l. Its task is to optimize the winding, to pick up the resulting loads, to move the finished coil. It has to hold and move the finished winding and weight (average 50 kg), and the auxiliary equipments without significant deformation.

We have three main requirements for the superstructure : to produce continuous and high-quality rolls, the safe movement of the semi-finished material and that the superstructure performs all these tasks in an autonomous way. There are a set of guides (1-1) on the column structure, on which the linear carriages that are mounted on the auxiliary equipment rack, can move vertically. Between the columns there is a trapezoidal screw, which is arranged on the top of the structure, driven by electric motor in the required direction. A linear axis **[2]** on the support plate compensates for the difference in diameter detailed before. The operator has to open by hand the unit at the end of the winding (security function). For this purpose, a rotating disc has been mounted on the linear bearing housing, which allows easy opening and closing.

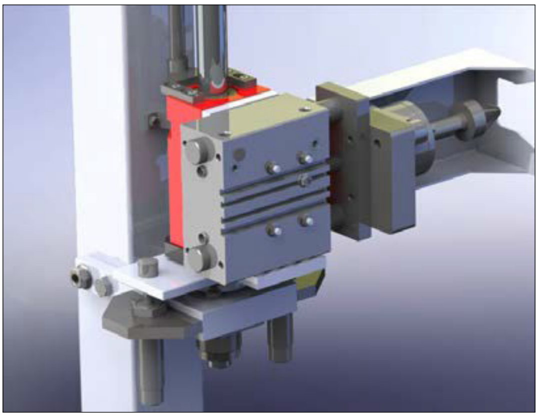

Figure 7. *Main units of left superstructure.*

Figure 8. *Right superstructure*

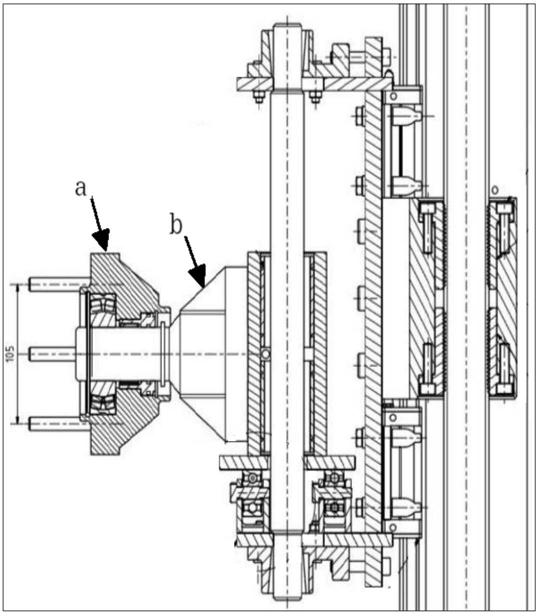

Figure 9. *Cross section of auxiliary subunit.*

Figure 10. *Pneumatic gripping shaft.*

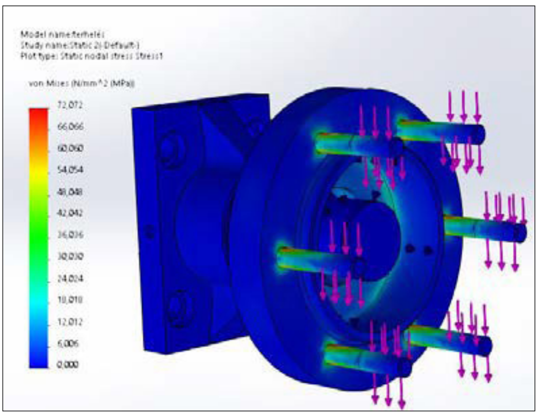

Figure 11. *Finite element investigation of connecting disc .*

The cross section in Figure 9 shows the main elements of the system. On the left side of the figure two part to be manufactured specifically are visible, structure of which I demonstrate in the following. Shaft fixing the roll is applied most frequently in manufacturing of paper and tissue (Figure 10). Name: pneumatic gripping shaft. Working principle: the rubber jaws on the shaft exert a clamping force on the elements placed on it under pressure, in this case on the roll drum, which needs to be positioned and fixed.

6. Finite element investigations

After the design of the winding unit, the finite element analysis became possible with the help of 3-dimensional models. Using the finite element module of SolidWorks software [3] I performed a strength check of the most important structural elements.

I considered a highlighted task to check structural elements exposed to the largest load which meant examination of the weight-bearing elements of the roll. I have performed the check for all part unit using simplified models.

6.1. Investigation of connecting disk

The first custom-made part is the connecting disc holding the coil axis a. The disc (part "a" in Figure 9) is subjected to forces and torques due to the weight of the coil.

Six studs fasten the disc and the shaft together. The load is transmitted through these six screws. From the simulation shown in Figure 11 it is obvious that the biggest stresses are generated in the screws. The maximum equivalent stress of the connecting disc is 72.1 MPa, and the maximum displacement is 0.19 mm (Table 1). The correctness of the sizing was confirmed by the fact that the stresses and strains were lower than the values allowed for the material in all cases.

Table 1. *Stress values of connecting disc*

Type of stress	Maximum
Equivalent stress: σ_{eq}	72.1 MPa
Maximum deflection	0.19 mm

6.2. Connecting shaft

The connector is also a unique disc manufacturing preparing component (Figure 9 part „b"). This is where the connecting disc shown in the previous section fits. The shaft stub surface is ground due to the proper fit of the bearings. The stub shaft is connected to the linear bearing housing with four screws.

In Figure 12. it can be seen that the maximum tension arises in the shoulder surface, on the tapered surface. The shoulder is needed to support the bearing. The greatest stress is 13.5 MPa, which does not exceed the maximum permissible value of the material. The allowed maximum stress of the material is σ_{red}=512 MPa.

6.3. Finite element investigation of supporting truss structure

I also performed a control test on the supporting structures. Due to the significant number and complexity of the components, the use of substituting models was justified. The test results and stress concentration locations are shown in Figures 13 and 14. The stresses do not exceed the allowed maximum value at any point.

7. Technology plans for manufacturing the individual components

Due to their complexity and design, the components of the fabric winding unit exposed to the highest load can be manufactured on a 5-axis CNC-controlled machine tool.

For this, I created the CNC machining program of the parts with EdgeCAM [4] software and also made a simulation for the machining. Figure 15. shows the surface formed at the end of the simulation, I marked the machined surfaces in green.

It can be seen that the connecting disc still does not have precisely machined surfaces with allowance (marked in blue) at the end of machining. The accurate machining according to technical drawing in the gaps of the reinforcing ribs would require a very small -sized tool which would considerably increase the machining time. The allowance left on the marked surfaces does not affect proper operation.

The machining of the connecting stub shaft (Figure 16) is a more complex task, it requires more tools and it cannot be made during a single operation. After treatment following the second approach the axle stub addition, if ete only remains, therefore, a special needs processing.

8. Drill disc device

It is not required to use the device for the production of the connecting disc if it is manufactured with a CNC-controlled machine tool. However, if the working surfaces are produced on a conventional machine tool, it is recommended to use a device that increases the machining accuracy.

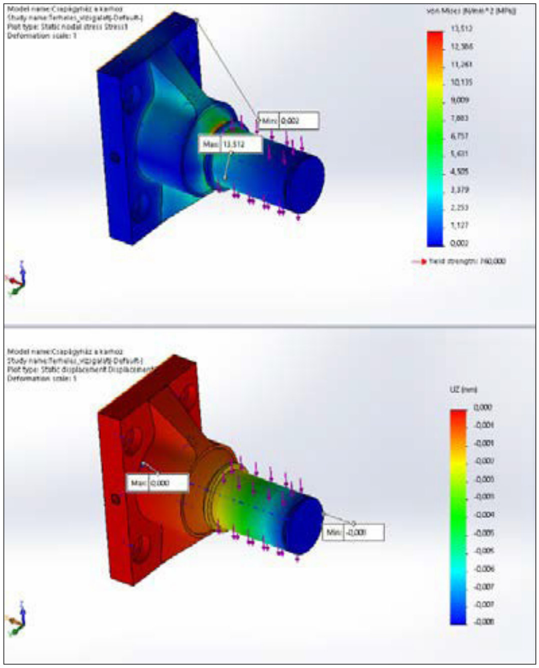

Figure 12. *Results of finite element investigation of connecting shaft.*

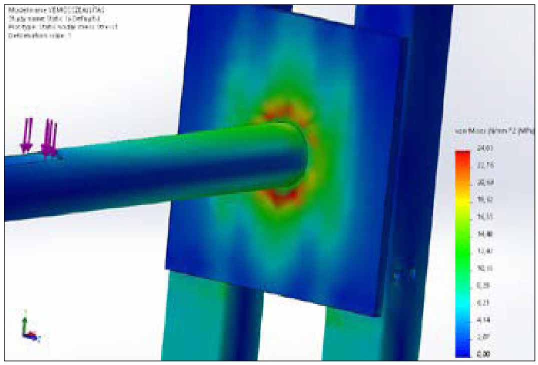

Figure 13. *Stress state of supporting plate.*

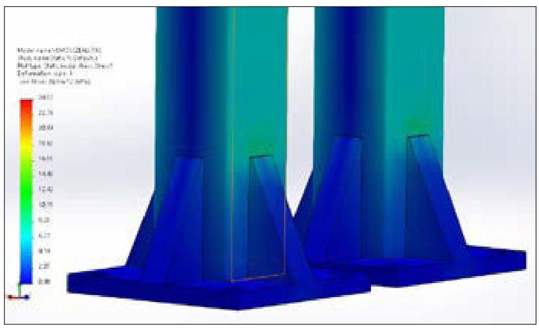

Figure 14. *Stress state of flanges*

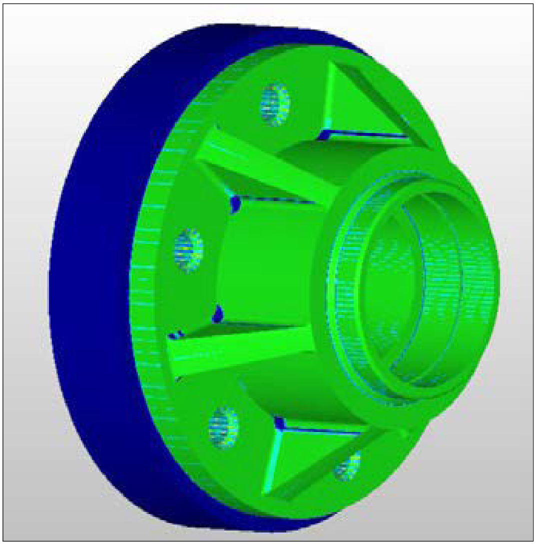

Figure 15. *Machined surfaces of connecting disc.*

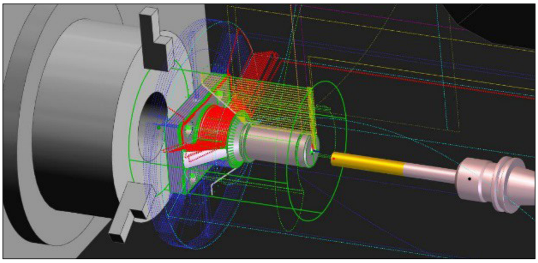

Figure 16. *Clamping sketch of shaft socket.*

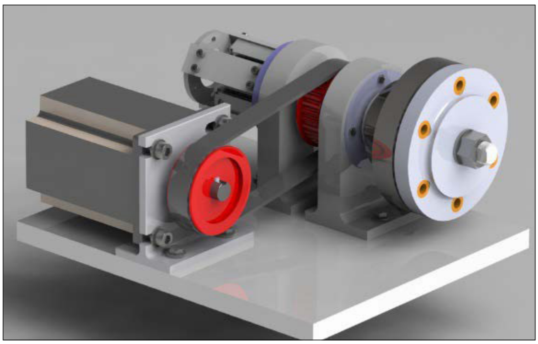

Figure 17. *Automatized drilling disc device.*

Therefore, assuming volume production, I have designed to ensure adequate accuracy of the manufacturing drilling machine dispenser (**Figure 17**).

By applying this device, manufacturing becomes semi-automated. Divisions of holes are set by stepper motors and drill bushings ensure size and position accuracy of them. During the drilling process the part is fixed by an automated clamping unit so preventing displacement.

9. Conclusions

In this paper we presented the process of functional analysis and problem exploration of a tissue winding machine. I presented the idea of two alternative solutions, and in some details, the accepted version.

Management of the factory will make a decision on practical realization of this development after detailed economical analysis of manufacturing of the machine and the process in which the new equipment is to fit.

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