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CONVERSION OF VULCANISATION PRESS

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Abstract

The topic of this thesis is the modification and modernization of a vulcanizing press. First, the necessity of modifying the vulcanizing press is thoroughly justified, followed by a presentation of the modernization process steps, analyzing the requirements, expected outcomes, and benefits. During the modification, a frequency-controlled three-phase electric motor replaced the pneumatic cylinder in the new design. This motor transmits power to the input shaft via a worm gear, which is connected to the rotating shaft through a rubber plug coupling. The rotating shaft was fitted with new bearings, which were installed in a custom-made bearing housing. The thesis provides a detailed explanation of how the pneumatic rotary actuators of two press travel beams were converted to electric operation. After designing the necessary components for modernization, the manufacturing technology was also developed. A schedule was created for constructing the new design, based on which the vulcanizing press was successfully modified. The article also reports on operational experiences following the modification.

Keywords*: : machine design, automation, energy saving.*

1. Introduction of the Vulcanizing press

The selected equipment for conversion is a three-chamber vulcanizing press used for manufacturing cylindrical air springs (**Fig. 1**). The machine has two heating circuits, separated by a bellows-like rubber element. For product assembly, we use building machines, which are accompanied by servicers. These servicers are machines that allow us to store and dispense rubber film and fabric in rolls. The cutting of rubber elements to the required length and angle takes place here, which is currently done automatically in the factory, though manual control is also available. During execution, the worker places the rubber element onto a conveyor belt, where positioning is assisted by a laser projector. The projector is positioned above the conveyor and projects a simple line diagram onto it to ensure that the product always has the correct geometry. The program and belt stepping are performed in a single step using a foot pedal. A unique feature of the air springs produced here is the use of building tubes, which

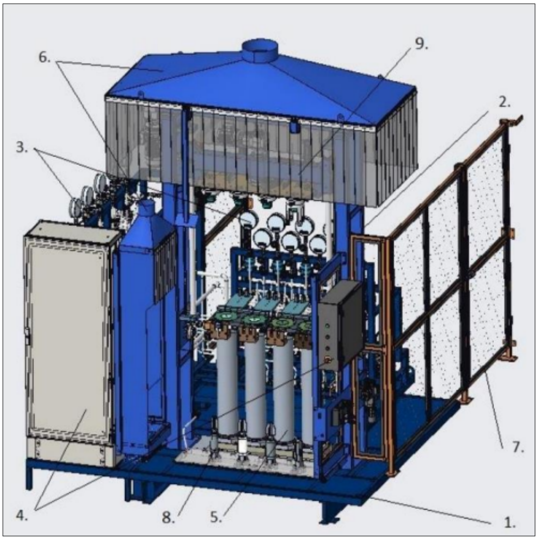

Fig. 1. *Structure of the Vulcanizing Press 1. Base frame 2. Machine frame 3. Technological stands (2 pcs) 4. Electric cabinet 5. Vulcanising chambers (4 pcs) 6. Exhaust hoods (2 pcs) 7. Safety fence 8. Cooling units (4 pcs) 9. Traveling beam*

are later automatically placed into the chambers by the vulcanizing press. The vulcanization process begins by smoothing the product onto the building tube with compressed air at a predetermined pressure and duration. This step is crucial to eliminate any air bubbles that may have formed during assembly. Next, a steam control valve is activated, filling the first chamber with steam. Once the desired pressure is reached, the next valve is activated, initiating the process in the subsequent chamber. The vulcanization process then begins, and after the pre-determined time in the recipe, the final product is completed. At this stage, the machine automatically removes the finished product and, in the next step, picks up the raw products from the cooling spikes and places them into the machine for processing.

2. Introduction of the Modified Subassembly

The traveling beam ensures the insertion and removal of the building tubes and rubber bellows tube. Its movement is carried out by two pneumatic actuators and is equipped with a chain-based fall protection mechanism. The guidance of the traveling beam is ensured by positionable guide columns. The table mounted on the traveling beam is rotated using a drive mechanism. In the previous design (Fig. 2) this was performed by a pneumatic rotary actuator, but in the new version, it is electrically motorized. The table is locked in its end positions by a pneumatically operated actuator. On the underside of the table, three gripping devices (or four on newer vulcanizing presses) have been installed. The new machines feature two types of gripping jaws, which will be discussed in more detail in the development recommendations section.

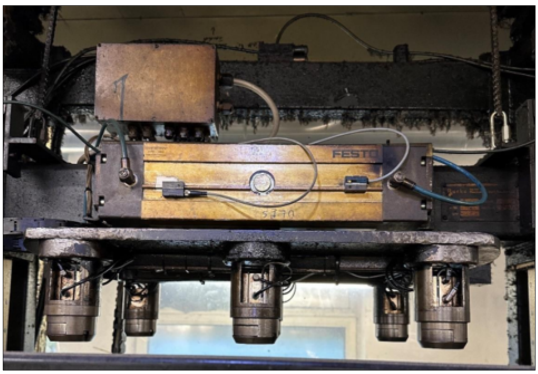

Fig. 2. *The Traveling Beam.*

3. Designing the Modification of the Vulcanizing Press

The need for this modification was recently identified as part of the company's annual discussions focused on cost reduction and reducing harmful emissions. Protecting our climate is a critical task, with the global goal of limiting temperature rise to below 2 degrees Celsius. To support this, Continental has set a target to operate in a completely carbon-neutral manner by 2050. As a result, the decision was made to replace the current pneumatically operated rotary actuator in the traveling beam with an electrically operated system. This modification offers advantages not only in terms of cost reduction and environmental protection but also ensures smooth end-position damping during rotation. The existing rotary cylinder is considered an outdated design because, in the event of a malfunction, repairs would result in extended machine downtime. By implementing this modification, we address two key issues: reducing future machine downtimes and contributing to sustainability efforts (Fig. 3).

4. Development of the New Design

The first step in the design process was measuring the existing distances, as these dimensions were fixed, and we did not intend to modify other parts of the press. Based on these measurements, a bearing housing was designed to replace the rotary cylinder. This housing contains two different types of bearings. One of the bearings is a toroidal roller bearing, chosen for its ability to handle exceptionally high radial loads efficiently. The second bearing is a single-row tapered roller bearing, which absorbs unidirectional axial loads. This bearing combination ensures that the rotary mechanism safely accommodates both radial and axial forces.

4.1. Selection of the Electric Motor

For this task, a manufacturer from the Hungarian market was selected, prioritizing reliability

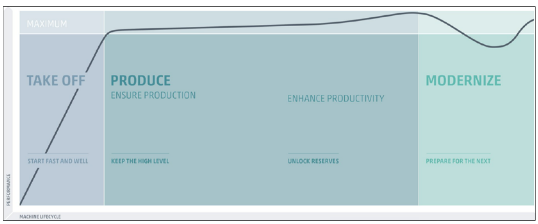

Fig. 3. *Machine Lifetime and Performance.*

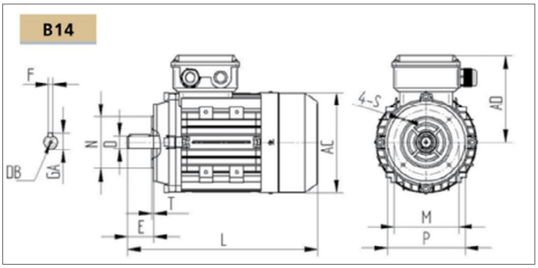

Fig. 4. *The Selected Electric Motor.*

Fig. 5. *Worm Gear Reducer.*

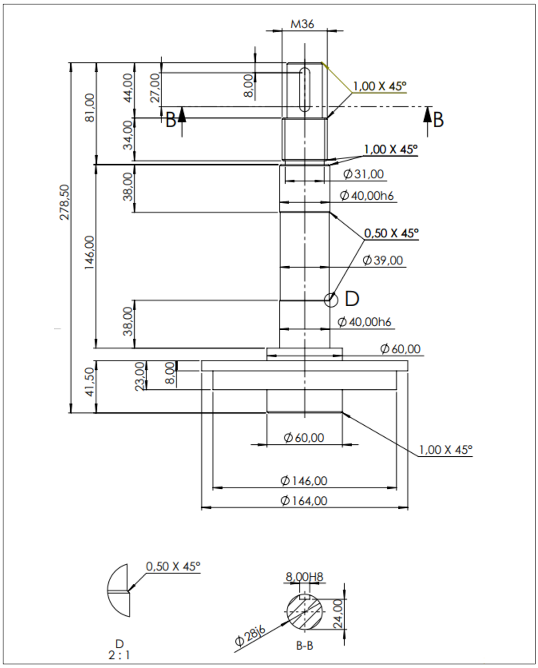

Fig. 6. *The rotating shaft.*

while also considering cost-effectiveness and energy efficiency. This resulted in the choice of the following three-phase electric motor (Fig. 4):

TípTypeusa: Agisys TMS 712-6 B14 [1]

P = 750 W

n = 925 [1/min]

Furthermore, to reduce the rotational speed, a worm gear reducer (Fig. 5) was selected. This gear mechanism ensures smooth and controlled movement while improving torque transmission efficiency. The combination of the electric motor and the worm gear reducer optimizes the operation of the modified system, enhancing both performance and durability.

Type: Bonfiglioli VF 49 P1 45 P71 B14 B3 [2]

i = 45

4.2. Shaft material selection

Having successfully selected the drive, the next step was to dimension the shaft and select its material. Taking into account the significant loads, a steel with high strength and toughness was chosen: 42CrMo4 (1.7225 → EN 10250), which is also popularly used in the automotive industry, for the production of axle joints, drive shafts and molds. Its main mechanical characteristics:

R_m = 1100 MPa

$R_{p0,2}$ = 750 MPa

4.3. Shaft dimensioning

The shaft was dimensioned for complex loads using classical calculation methods. The allowable stress corresponding to the selected material type (42CrMo4) was taken into account, and a three-fold safety factor was calculated (σmeg= 250 MPa), which resulted in a minimum shaft diameter of d= 21.03 mm. The geometry of the rotating shaft is shown in Fig. 6.

The length of the latch was determined by taking into account two types of surface pressure (t1, t2), and shear stress was checked. The length of the latch was thus 35 mm.

4.4. Dimensioning of bearings

Based on the dimensioning described in point 4.3, and taking into account the standard bearing dimensions, a bearing with a diameter of d=40 mm was selected. Since the shaft is loaded in both axial and radial directions, the selected bearing pair consists of a toroidal roller bearing and a tapered roller bearing. After performing the appropriate calculations, we obtained the following basic loads:

C1 = 21,42 kN

C2 = 47,43 kN

The choosen bearings:

- SKF C 2208 V - t- Full complement CARB toroidal roller bearing [3]
- SKF 33208 - Single row tapered roller bearing [4]

The other dimensions of the lower shaft were given by the parameters of the current machine, since the pneumatic cylinder performing the vertical movement was not changed, as was the height of the vulcanization chambers (Fig. 8). It was also necessary to design the bearing housing. This was fixed by welding to the closed section of the machine's cross-member, the distance from which was also fixed so that the axis of rotation would not move. Thus, based on these, we were able to determine the dimensions of the bearing housing, for which a bearing clamping cover was made, and spacer tubes placed between the bearings (Fig. 9).

5. Complex development of the vulcanizing press conversion

As a first step in the design process, we measured the existing distances, since these were given dimensions, and we did not want to modify the rest of the press. So, for the given distance, we designed a bearing housing in place of the turning cylinder, in which two different bearings were placed: one a toroidal roller bearing, the purpose of which is to easily handle the extremely high radial loads of the machine, and the other a single-row tapered roller bearing, which takes up the unidirectional axial loads. With this bearing pair, our turning mechanism can easily withstand both loads in both directions (Fig. 7).

After the bearing housing was fixed to the machine housing by welding, and the bearings were positioned with spacers and a bearing clamping cover, we screwed the lower shaft to the rotating plate, and the bearings are located on this shaft. The other free end of the shaft is connected to a rubber plug coupling, in which the fastening is done with a locking groove and a worm screw. The shaft entering the worm gear is connected to the other half of the rubber plug coupling in a similar way. The three-phase electric motor is connected to the worm gear, the speed of which is controlled by a frequency converter. The following changes were also necessary for the proper operation of the new design of the turning gear: A sensor had to be installed that monitors the rotation of the shaft. Furthermore, the turning mechanism had two end positions, so that previously there was no need for a locking mechanism against rotation, but after the conversion, a locking mechanism became necessary. The solution was to install a locking shaft that is moved by a pneumatic cylinder (Fig. 8). Furthermore, the frequency converter had to be placed in a new switch cabinet, because it no longer fitted in the old one. This had to be wired and the PLC program had to be modifie (Fig. 10).

Fig. 7. *The selected toroidal roller and tapered roller bearings*

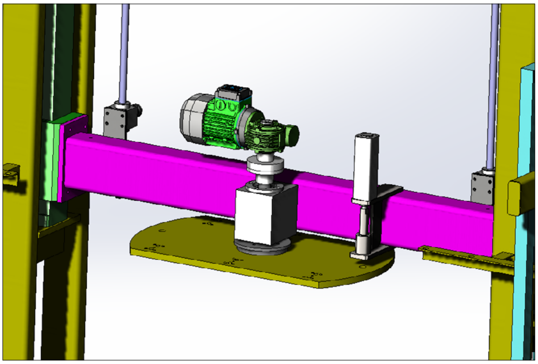

Fig. 8. **SolidWorks model of new construction**

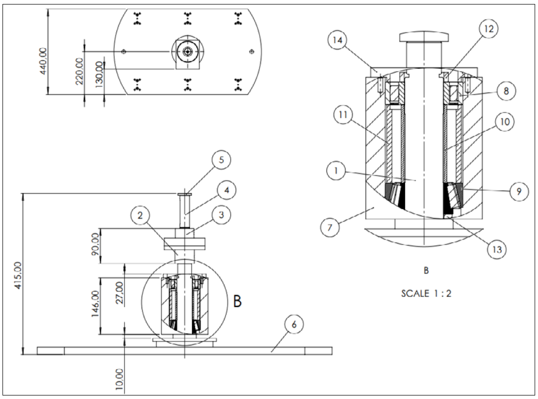

Fig. 9. *Bearing housing*

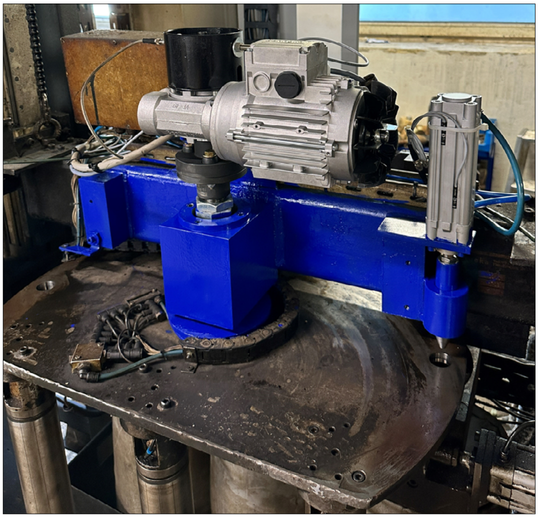

Fig. 10. *The electrically operated translational travelling beam.*

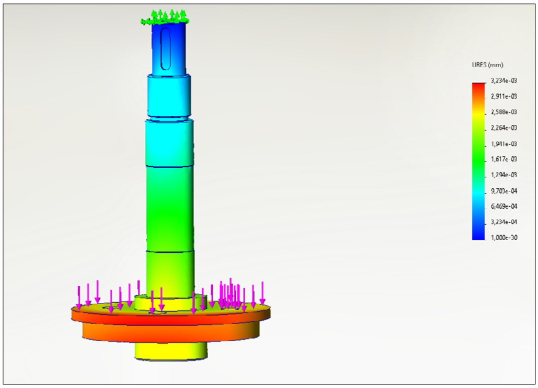

Fig. 11. *Lower shaft deflection.*

6. Finite Element Analysis

To check the dimensioning of the turning gear shaft, We performed a finite element analysis. The deflection of the lower shaft and the stress arising in it were examined under a load of 1500 N. The load was calculated from the weight of the vulcanizing tubes and the plate rotor, which are connected to the lower shaft. For this, a double safety factor was chosen. The analysis was performed in SolidWorks. As can be seen in **Fig. 11**, the largest deflection is located in the lower part of the workpiece, its value is 0.003 mm, which is negligible and does not affect the operation and the production process.

The highest stress in the translation shaft, in accordance with the previously calculated value, occurred in the smallest diameter, its value is $6.454 \cdot 10^6$ N/m^2 which is below the permissible $7.5 \cdot 10^8$ N/m^2 and is therefore satisfactory (**Fig. 12**).

In the following, we examine what damage the torque of the electric motor would cause if the translation process were to be interrupted somehow and the narrowest cross-section were loaded with maximum torque. In this simulation, the bottom of the shaft was walled in and loaded with the rounded value of the previously calculated torque, 350 Nm.

As shown in **Fig. 13.**, the highest stress is indeed on the part connected to the clutch, its value was 2.15·108 N/m^2, while the maximum allowable stress for the shaft material is 7.5·108 N/m^2, so the shaft complies with this as well. The shaft is thus able to hold the weight loaded on it without deformation, and in the event of a possible machine failure or malfunction, it is able to withstand the maximum torque exerted by the electric motor.

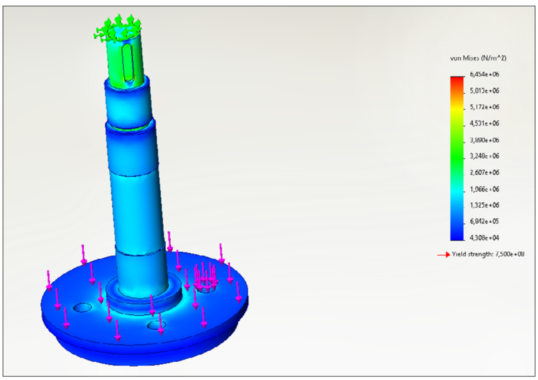

Fig.12. *Stresses arising in the axis of the turning gear.*

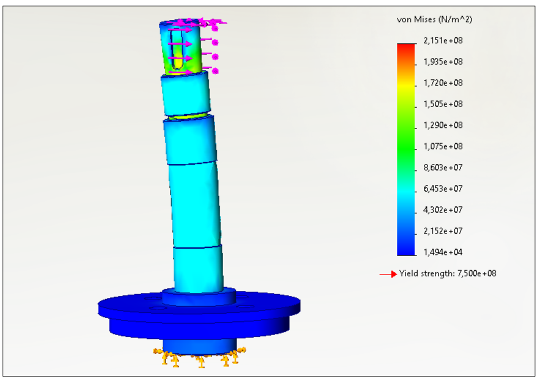

Fig. 13. *Stresses in the slewing gear shaft in case of overload.*

Fig. 14. *Pneumatic cylinders.*

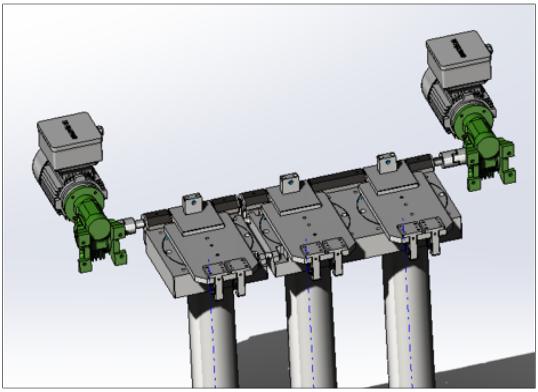

Fig. 15. *Lid opening mechanism conversion.*

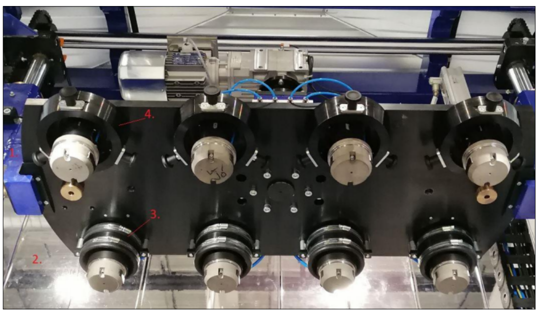

Fig. 16. *The gripping structure of the new presses.*

7. Further development opportunities and suggestions for the company to improve the vulcanizing press

7.1. Lid opening mechanism conversion

In order to explore further development possibilities, the other pneumatically operated parts of the machine were examined to see which mechanisms could be replaced with electric motor-controlled ones. What was most striking was that the chambers were closed by a pneumatic cylinder each (**Fig. 14**).

There were several problems with this design, firstly the sealing of the pneumatic cylinder end cushion could not withstand the permanently high heat, so the cushioning does not work in the long term, and therefore the closing occurs with a shock. Secondly, due to the brittleness of the welds, the design broke several times, and these often had to be repaired. So again there would be several compelling reasons for development. The solution proposed here would be to connect the chambers with a shaft, in which the chamber covers would be opened with the help of appropriately installed latches, and the shaft would be connected to the stub of the three-phase electric motor with a rubber-lined coupling (**Fig. 15**).

According to the development plan, the chamber blocks would also be replaced. The conversion would require a fairly large investment, so it did not fit into the company's 2024 budget, but the idea has not been discarded, as the conversion would not only result in savings, but would also extend the life of the machine. Furthermore, the development would provide a solution to problems such as eliminating holes already filled with thread repair agents due to broken covers or broken screws.

7.2. Modification of gripping structures

Another development proposal idea was given by one of our new vulcanizing machines. As mentioned earlier in the introduction of the vulcanizing press, the new presses have a different gripping structure (**16. ábra**). This way, the machine was supplemented with a new function, because they have a so-called finished product removal function. One row is basically capable of gripping the building tube (1.), while the other row (2.) is capable of gripping the product in addition to gripping the building tube with the help of a rubber bellows (3.). On the row (1.), where tools capable of gripping the building tube are located exclusively, a holder (4.) was also installed for the gripping jaws, which can receive the so-called “crown”, the device required for lifting the tube equipped with the rubber bellows in the chambers. The product is pulled down by automatically stopping the machine at a pre-programmed height, the rubber bellows are inflated and the operators have to blow air between the product and the building tube at the bottom of the finished product with an air gun, while pushing the product slightly upwards with their other hand, which is wearing a heat-resistant glove. When they leave the danger zone (area fenced off with a light curtain), by pressing the green button, the press continues the process and places the building tubes on the cooling pins. Then the carriage starts up again to the previous height and pulls the products off the tube. This method can further speed up the process, since currently the product is removed from the already placed tubes with a similar process, which is not very convenient. The development would not only take steps towards a more automated production process, but would also provide a solution to safety and ergonomic problems.

8. Conclusion

In the recent period, two presses have been successfully converted, and we have been following every step of the process, from ordering parts, negotiating with external contractors, to coordinating the production process of the parts. The operating experience after the conversion is favorable, the converted presses have been working well for a long time, so it can be stated that the conversion was successful. There were no malfunctions or downtimes, the presses delivered the expected results, the problems related to the previous translation unit completely disappeared and thus we extended the service life of the machine. It is expected that the above-mentioned further development opportunities will be realized next year.

Acknowledgement

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