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EXPERIMENTAL TESTS ON INDEXING DEVICE WITH SPHERICAL ELEMENTS (BALLS)

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ABSTRACT: In the present paper it's present an indexing device used to protect the blooms tilting mechanisms on rolling train, the modeling and its CAD using Autodesk Inventor Professional, respectively that experimental tests on a laboratory model of the device together with the results analyzes in table and graphically form.
KEYWORDS: Tilting mechanism, indexing device, experimental trials

❖ INTRODUCTION

The proposed device is used to protect the tilting mechanisms from the blooming type rolling train if accidental increase the force from the main tilting rod.

The main rod of the tilting mechanism is a sword-sheath construction; the combination of the two components is accomplished by two bolts, which are designed to break when the force exceeds a value determined by design. The proposed protection device works on the principle of indexing systems with balls, is adaptable to the tilting mechanism rod and serves to eliminate the time when the rolling train not work to change the broken bolts with new ones. Principle sketch of the protection device with balls is shown in fig. 1.

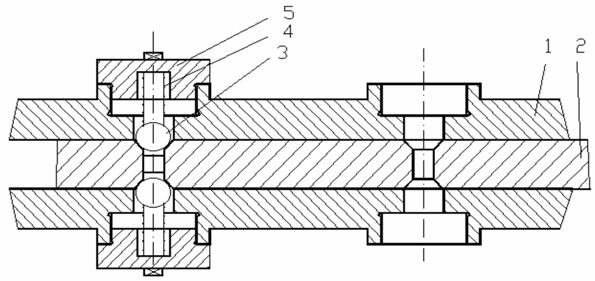

Fig. 1. Protection device with spherical elements. 1 - rod sheath; 2 - sword rod; 3 - spherical locking element (ball); 4 - compression spring; 5 - screw cap

Instead each shear bolt will be mounted a pair of spherical locking elements (balls).

If the force of the rod tilting mechanism exceeds (accidentally) the operation mode corresponding value, the balls from the device construction are retracting in space from the sheath rod, compressing the springs. In a new cycle of the tilting mechanism, in the conditions when the causes that led to accidental increased of the force from rod mechanism stops, the springs will push the balls back into the tapered channels from the sword rod, and the mechanism will still function normally, without the rolling train to be stopped, respectively the rolling process stopped.

Taking into account that the connecting rod's critical force (the spring's pressing force) is very big and because the spring's space is limited (for a little deformation), is recommended to use compression ring springs, which satisfy the conditions below.

❖ INDEXING DEVICE DESIGN

The dynamic analysis of the tilting mechanism from the rolling train 1000 mm found that the maximum force (to break the bolts) of the rod mechanism is:

$$F = 475000\ [N]$$

As noted in the bibliography, for designing the indexing device, the calculation force that this device need to give up, is obtained by amplifying the regime force system with a safety factor from the biggest force in the rod K_F = 1,116. So, the calculation force that triggers the locking device with spherical bodies is:

$$F_{max} = K_F \cdot F = 1{,}116 \cdot 475000 = 530100\ [N]$$

Calculation scheme for ball device design is shown in fig. 2.

In order to design the protection device with ball, the constructive choose the following sizes:

❖ trapezoidal channel opening semiangle, α=30-50 degrees

- ball diameter, depending on indexing device dimension, d_b = 40-50 [mm]
- trapezoidal channel depth, h = (0,2...0,5)d_b
- trapezoidal channel connection radius, r ≤ 0,5d_b
- load uneven distribution coefficient between the ball and lock body, λ=0,8
- Initial deflection for spring assembly, δ_1 = 18 [mm]
- coefficient of friction μ_o = 0,15
- longitudinal MOE E = 215000 [Mpa]
- admissible strength at the balls contact load σ_{ak} = 5000[Mpa]

Then calculate the following sizes:

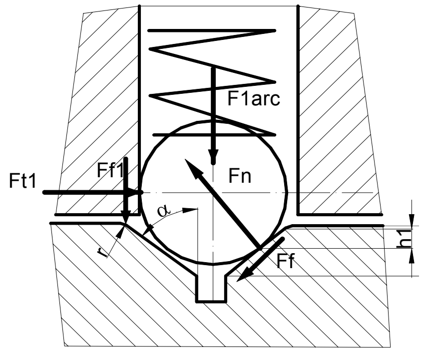

Fig. 2. Indexing device calculation scheme

- ☐ spring preloaded force: $F_{1arc} = \frac{F_{\max}}{2}\left[\left(1 \quad \mu_o^2\right) \ tg\alpha \quad 2 \quad \mu_o\right]$
- ☐ spring stiffness: $k_a \le \frac{F_{1arc}}{\delta_1}$
- ☐ normal force between the balls and trapezoidal channel: $F_n = \frac{F_{1arc}}{\lambda}\left[\left(1 \quad \mu_o^2\right) \ \sin\alpha \quad 2 \quad \mu_o \quad \cos\alpha\right]$
- ☐ resistance to balls contact load: $\sigma_{k\max} = 0{,}63\sqrt[3]{\frac{F_n \quad E^2}{d_b^2}} \le \sigma_{ak}$

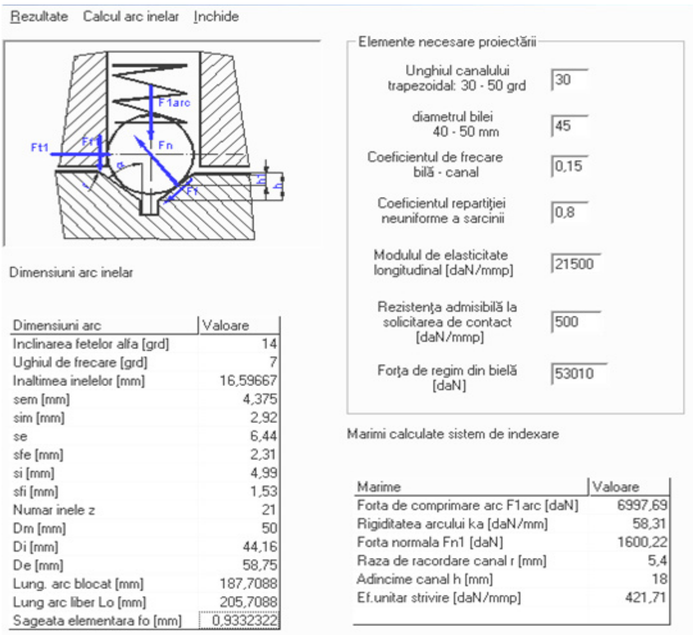

Fig. 3. Program interface

The above calculations are performed using a computer program written in Visual Basic. Program work interface is shown in fig. 3, together with calculated values displayed (including sizes for ring springs).

Based on the above calculated sizes, automatic protection device with balls was modelled 3D, in Autodesk Inventor Professional program. In fig. 4 is presents the model photo-realistic images.

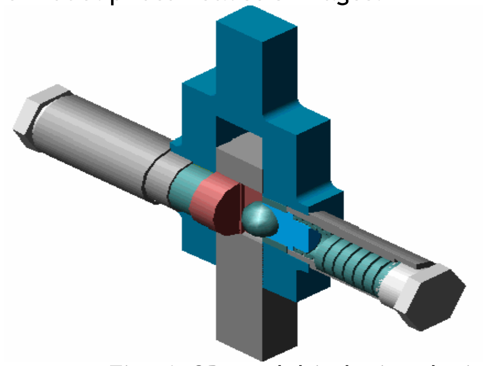
Fig. 4. 3D model indexing device

EXPERIMENTAL TESTS ON INDEXING DEVICE

In order to follow the behavior of the indexing device with spherical locking elements whose design and model were presented in paragraph 2, because of rod big dimensions where this system adapts, has been designed and implemented a small dimensions model to be tested under laboratory conditions.

Active elements of the device experimental model with nominal dimensions respectively how to make a contact between trapezoidal channel - ball - ball guide element are presented in fig. 5.

According to fig.5 trapezoidal channel angle is α = 83/2 = 41,5degrees, which is within the range 30-50 degrees, and ball diameter is 24 mm.

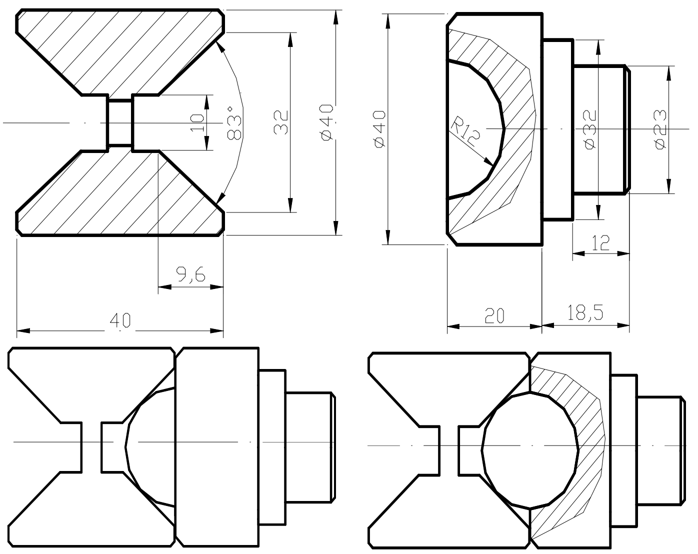

Fig. 5. Active elements geometric dimensions

The fig. 6 picture presents the active elements of the developed device model.

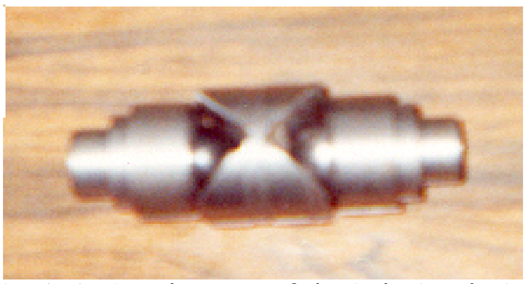

Fig. 6. Active elements of the indexing device

As a compression spring, for pressing the balls in trapezoidal channels, to the indexing device experimental model studied, does used compression springs, know their calibration curves.

Experimental tests on experimental model of protection device with balls, where made on the universal test machine, according to fig. 7.

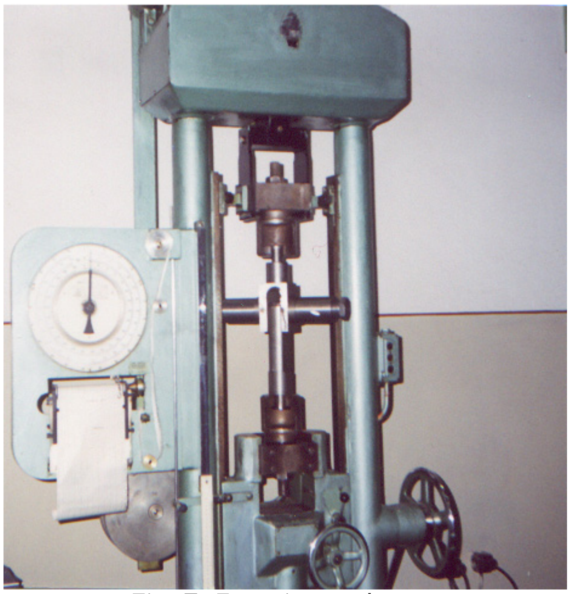

Fig. 7. Experimental tests on experimental model

The experimental tests will pursue a dependency between the preload force of coil springs and the force where device with balls will trigger (read on the test machine dial).

Table 1. Arc 1 C_1 = 3,82 [N/mm]

f[mm]	3	6	9	15	18
	4	7,5	11	19	24
	3,5	8	12	18,75	23,6
	4	7,75	12,5	20	23
Fmediu[daN]	3,833333	7,75	11,83333	19,25	23,53333
Farc [daN]	1,2	2,4	3,4	5,8	6,8
F [daN]	3,83	7,75	11,83	19,25	23,53

Compression springs preload force, will result from their calibration graphs based on their deformation, determined as the multiplication of the turns number of cover and their thread pitch (p = 1,5 [mm]).

The experimental results are processed into tables and graphics, and an example is shown in table 1 and fig. 8.

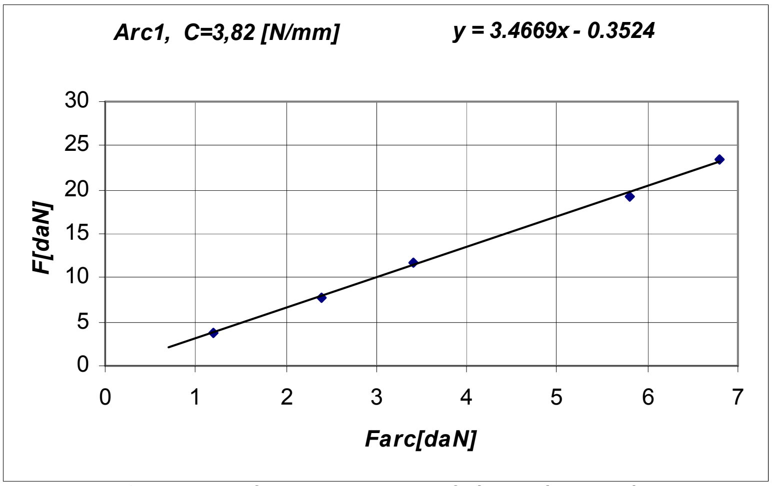

Fig. 8. Trigger force variation of the indexing device

❖ CONCLUSIONS

Indexing device with balls was bring under stress tension, aiming determining the dependence between the force where the system gives up (read on the test machine dial) and the preload force of the spring coil (determined from their calibration graphs).

We used three pairs of compression springs, different stiffness, respectively C_1 = 3,82 [N/mm], C_2 = 11,25 [N/mm] and C_3 = 6,56 [N/mm].

The construction of the device with spherical locking elements was used two balls with a 24 mm diameter and a tronconical channel with 83 degrees opening angle and a depth of 9.6 mm.

Analyzing the results of experimental tests on an experimental model of ball device, it can say the following conclusions:

- The model on small-scale of indexing device with spherical locking elements work correctly for all three pairs of springs used.
- In the tests it was found a linear increase of the force when the ball device gives up, in relation to the spring's preload force.
- For springs pairs with different stiffness, on the same preload force, the force at which the indexing device with balls starts increases with the spring stiffness.
- The force value in which the device with balls starts, depends on trapezoidal channel dimensions, decreasing with the increasing its angle.

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