ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume IX (XIX), 2010, NR2

LOADS AND STRESSES IN DISENGAGING PROCESS FOR SAFETY CLUTCHES WITH BALLS, RADIAL SPHERICAL ACTIVE RABBETS AND PRESSING SYSTEM ON EACH BALL

GAVRILĂ Cătălin, **POPA Silviu**, **MOLDOVEAN Gheorghe**
[1]Transilvania University of Braşov, Department of Product Design and Robotics
cgavrila@unitbv.ro, popa_s_silviu@yahoo.com, ghmoldovean@unitbv.ro

Keywords: safety clutches with balls, disengaging process, radial spherical active rabbets, loads

Abstract: The safety clutches with balls are frequently used in most transmissions of manufacturing machines, agricultural machines and other, because of precise torque limiting and its reliability. To avoid the engaging shocks, an improved contact between the balls and rabbets is followed. In the paper, a new safety cclutch with balls and radial active rabbets is developed. Also, the loads and stresses on the clutch parts are analised.

1. INTRODUCTION

The safety clutches with balls can have different active rabbets shapes and these can be frontally and radial disposed, depending on the available overall size. The most shapes used for the active rabbets are those trapezoidal, in the shape of a truncated cone, cylindrical and spherical [1]. The safety clutch with balls analysed by this paper, is a new construction characterised by the spherical shape of the active rabbets, radial disposed. This shape for the active rabbets makes possible a surface contact with the ball both in the complete engaged operation situation and in the reengaging process. The producer companies of the safety clutches with balls, execute this type of clutches, but usually the balls are frontally disposed, not radial.

2. CLUTCH DESCRIPTION

The proposed safety clutch is presented in Figure 1 [1], for the complete engaged operation situation and having a pressure system with cylindrical spring on every ball.

The clutch was designed to accomplish the kinematical connection between a shaft – assembled in the semi-clutch boring 3 – and a gear wheel, pulley wheel or sprocket wheel – assembled on the semi-clutch 1. The balls 2 are disposed, o one hand, in the active rabbets with spherical shape from the semi-clutch 3, and on the other hand, in the aperture (in the shape of truncated cone) of the pressure tap 5; these are pressured by the cylindrical springs 6, house force is adjusted by means of the screw stoppers 7. The pressure tap 5, together with the springs 6and the screw stoppers 7, are assembled in the semi-clutch 1, that is supported by the semi-clutch 3 by means of some radial bearing seats 4; these bearing seats together with the disc 8 also accomplish the axial constrain of the semi-clutch 1 towards the semi-clutch 3.

The active element of the clutch is the semi-clutch 3 that has tooled the active rabbets, this being presented in Figure 2. In lateral section, the rabbet profile has two sectors with different radius (*a* and *b*); the two sectors are fillet corner connected, the sector *b* being also connected to the exterior surface of the central part of the semi-clutch 3. The real active rabbet *c* is executed in the anterior rabbet and it follows its profile, but the generator surface has a spherical shape, on the central part *c*, and a cylindrical shape, on the fillet corner part *d*; both rabbets have the spherical and cylindrical parts with radius equal to the radius of the ball assembled in the active rabbet.

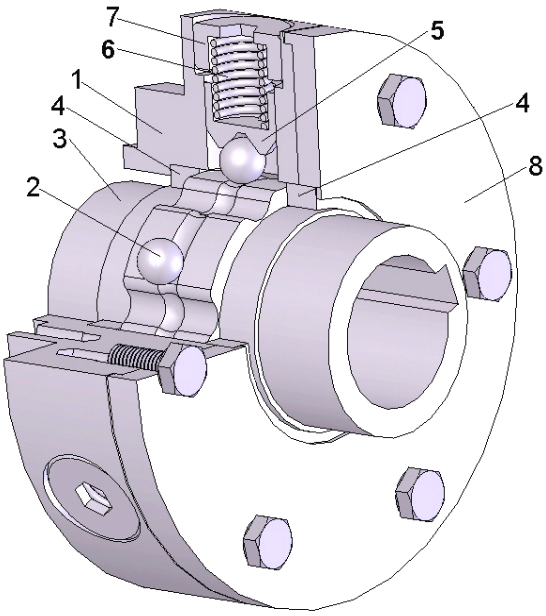

Fig. 1. Clutch view

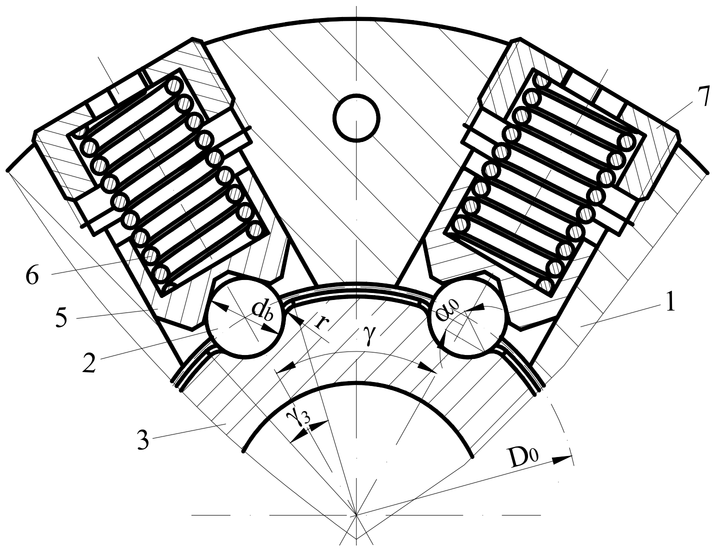

Fig. 2. Clutch transversal view

At the occurrence of some overloads in transmission, the ball 2 compresses the cylindrical spring; the ball is guided by the circular canal and reaches at the end of the disengaging process, on the cylindrical part of the semi-clutch 3.

Figure 4 presents a cross section through the safety clutch with balls and spherical rabbets radial disposed and pressure cylindrical spring on every ball. In the figure, the notations are: d_b – the ball diameter; D_0 – the balls arrangement diameter; α_0 – the angle of the active rabbet profile; r – the fillet corner radius of the active rabbet profile to the exterior circle; h – the coalescence depth of the ball into the active rabbet; γ – the angular pitch of the balls arrangement, respectively of the active rabbets; γ_3 – the angle of the active rabbet profile.

3. LOADS IN DISENGAGING PROCESS

The main goal of this analyze is to establish the loads on the clutch elements and also the torque during the disengaging process. The disengaging process starts when between the semi-clutches a relative rotation appears, because of the torque increasing over the maximal value during the normal functioning (complete engaged).

At the end of disengaging process, the transmitted torque is reduced to the remanent torque value, provided by friction between the balls and rabbets [4].

Comparative to the complete engaged situation, during the disengaging process some changes appears: the spring load increase because the suplimentar spring compression [5]; the friction between the elements decrease, as a result of kinetic friction coefficient decreasing, relared to the static friction coefficient; the angle between the ball and the rabbets and, also, the reactions application points changes the diameter value.

The analized clutch with balls, radial spherical active rabbets and pressing system on each ball is presented in Figure 3, during the disengaging process, when a relative motion appears between the semi-clutches. For this situation, the forces that appears are presented.

For calculations, are also considered the centrifugal forces for each ball 2 and the corresponding pressing cep 5. From some clutches manu-facturers recommendations [9], can be appreciated that the ratio

$F_{cf}/F=k \approx 0.05$.

The calculus relation for transmitted torque M_{td} during the disengaging process and also the relaton for the reactions, presented in table 1, result from equilibrum equ-ations for the ball – pressing cep ensemble and semi-clutch 3. The static friction coefficient between ball and semiclutch is considered μ and between the pressing cep and semi-clutch, the friction coefficient is considered μ_1.

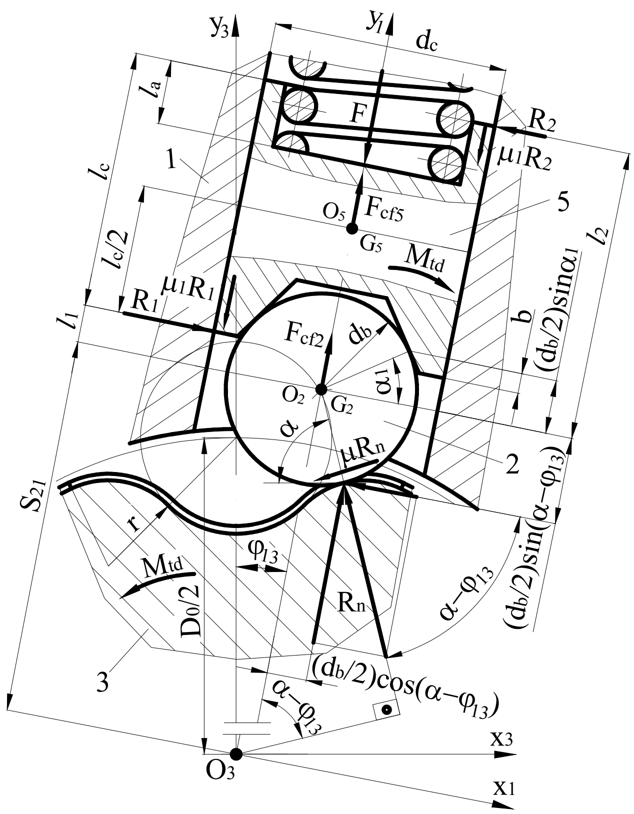

Fig. 3. Loads in disengaging process

Table 1. Relations for transmitted torque and the reactions

- Active rabbet angle

$$\gamma_3 = 2\arctan\frac{(d_b+2r)\cos\alpha_0}{D_0-(d_b+2r)\sin\alpha_0}$$

- Rotation maximum angle between ball 2 and semi-clutch1

$$\varphi_{13} \in (0, \varphi_{13\max}], \text{ unde } \varphi_{13\max} = \gamma_3/2$$

- Contact angle between the active rabbet and ball

$$\alpha = \varphi_{13} + \arccos\left(\cos(\alpha_0-\varphi_{13}) - \frac{D_0}{d_b+2r}\sin\varphi_{13}\right)$$

$$\alpha_{\max} = \frac{\gamma_3}{2} + \arccos\left[\cos\left(\alpha_0-\frac{\gamma_3}{2}\right) - \frac{D_0}{d_b+2r}\sin\frac{\gamma_3}{2}\right]$$

- Position function between ball 2 and semi-clutch1

$$S_{21} = \frac{D_0+(d_b+2r)(\sin\alpha-\sin\alpha_0)}{2\cos\varphi_{13}}.$$

$$S_{21\max} = \frac{D_0+(d_b+2r)(\sin\alpha_{\max}-\sin\alpha_0)}{2\cos(\gamma_3/2)}$$

Table 1 (continued)

- Springs supplementary compression

$$\Delta S_{21} = \frac{D_0(1-\cos\varphi_{13}) + (d_b + 2r)(\sin\alpha - \sin\alpha_0)}{2\cos\varphi_{13}}$$

- Spring force

$F = c(\delta_1 + \Delta S_{21})$, where c represent the spring rigidity and δ_1 – mounting deformation

- Normal reaction between ball and active rabbet

$R_n = F(1-k)A$, where

$$A = \frac{(l_2 - l_1)\cos\varphi\cos\varphi_1}{(l_2 - l_1)\sin(\alpha - \varphi_{13} - \varphi - \varphi_1) - [d_b\sin\varphi + (2l_1 - \mu_1 d_c)\cos(\alpha - \varphi_{13} - \varphi)]\sin\varphi_1} \quad \text{and}$$

$\varphi = \arctan\mu$; $\varphi_1 = \arctan\mu_1$

- Transmitted torque

$$M_{td} = zF(1-k)A\left[S_{21}\cos(\alpha - \varphi_{13}) + \mu\left(S_{21}\sin(\alpha - \varphi_{13}) - \frac{d_b}{2}\right)\right].$$

To reveal the main constructive and dimensional parameters influence on the transmitted torque during the disengaging process, a calculus program, which allow to analyze safety clutches with balls with different active rabbets shapes - frontally and radial disposed - was elaborated. The calculus refers to one ball, because the ball number have influence only on the transmitted torque value, not on the variation of it. The main menu is presented in figure 4, and choosing the clutch type, in figure 5. The program can be used to analyze the torque and normal reaction for complete engaged or during the disengaging process, see figure 6.

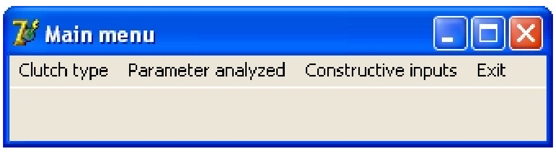

Fig. 4. Main menu

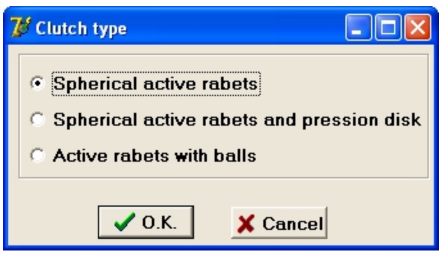

Fig. 5. Choosing the clutch type

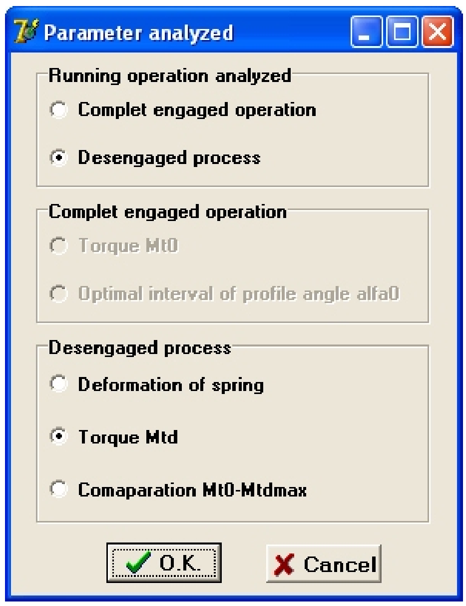

Fig. 6. Choosing the analised parameter

The torque M_{td} variation during the disengaging process is presented in figure 7, depending by ball disposing diameter D_0, and, respectively, in figure 8 depending by the ball diameter d_b.

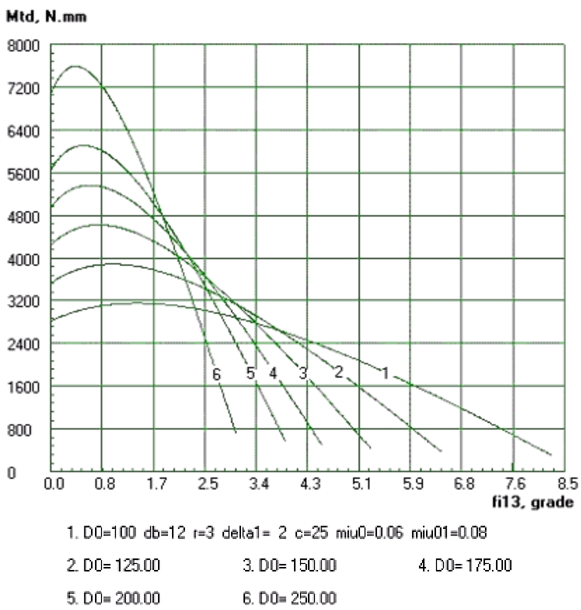

Fig. 7. Torque variation M_{td} depending by ball disposal diameter D_0

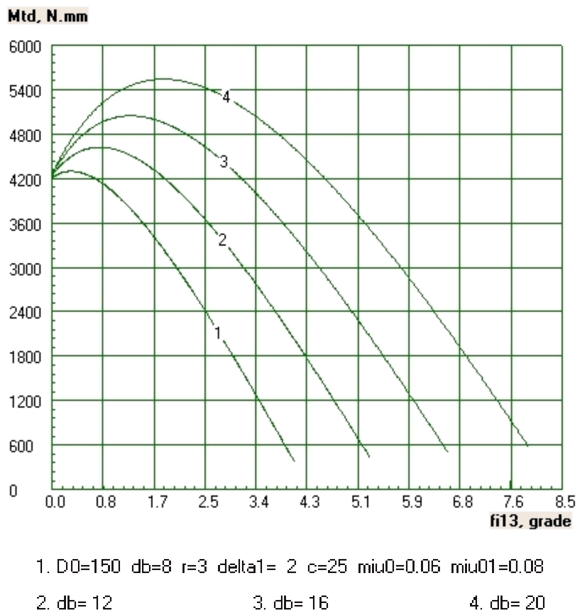

Fig. 8. Torque variation M_{td} depending by ball diameter d_b

Analyzing the diagrams, few conclusions can be withdrawn:

- The transmitted torque M_{td} during the disengaging process, has first an increasing variation, and then, a decreasing variation until to the remanent torque; the increasing variation is bigger when the disposal diameter D_0 increasing;
- The D_0 diameter increasing led to the transmitted torque M_{td} during disengaging, but, in this situation, relative angle φ_{13} between semi-clutches decrease;
- The transmitted torque M_{td} during the disengaging process increase with the ball diameter d_b increasing, with the same variation, but in the disengaging beginning moment, remains constant;
- Increasing the balls diameter d_b, the relative angle φ_{13} between semi-clutches increase.

The torque M_{td} variation during the disengaging process is presented in figure 9, depending by rabbet active profile angle α_0, and, respectively, in figure 10 depending by the friction coefficients μ_0 and μ_{01}.

Also in this case, analyzing the diagrams, few conclusions can be withdrawn:

- The transmitted torque M_{td} decrease with the rabbet active profile angle α_0 increasing;
- Increasing the rabbet active profile angle α_0, the relative angle φ_{13} between semi-clutches decrease;
- At bigger values for the rabbet active profile angle (α_0>50º), the torque M_{td} increasing is reduced and led to an increasing clutgh disengaging sensitivity;
- The friction coefficients μ_0 and μ_{01} influence on the torque M_{td} is severe reduced, the biggest influence is given by the coefficient μ_0.

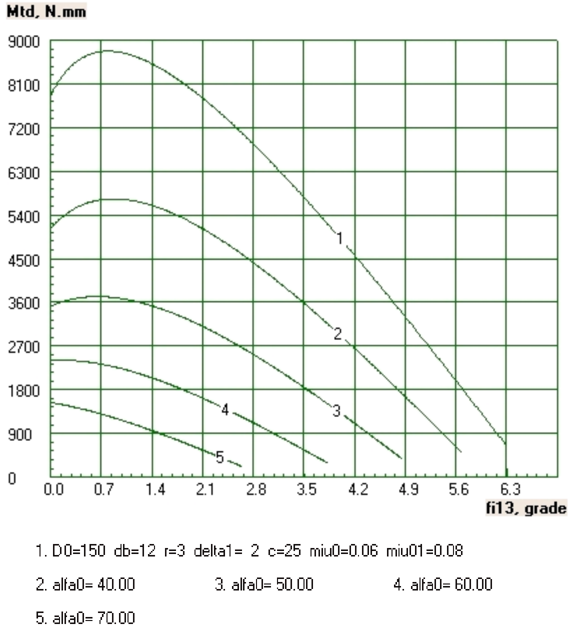

Fig. 9. Torque variation M_{td} depending by rabbet active profile angle α_0

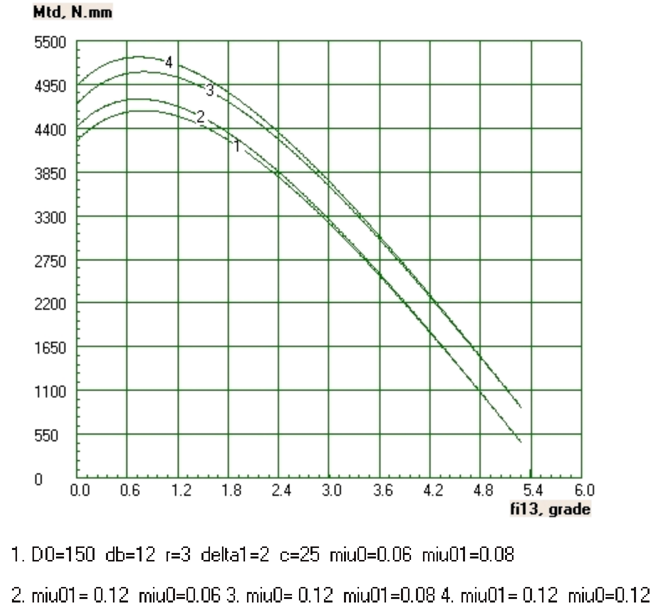

Fig. 11. Torque variation M_{td} depending by friction coefficients μ_0 and μ_{01}

4. STRESSES ON CLUTCH ELEMENTS

For determining the stresses on the clutch elements, the clutch virtual model was made, using Catia software. In this model, all the parts were considered solid bodies, made from steel. After the geometrical constraint definition, the model was exported to Abaqus Viewer, and all the components were meshed by FEM, the mesh structure and contact settings between parts were made.

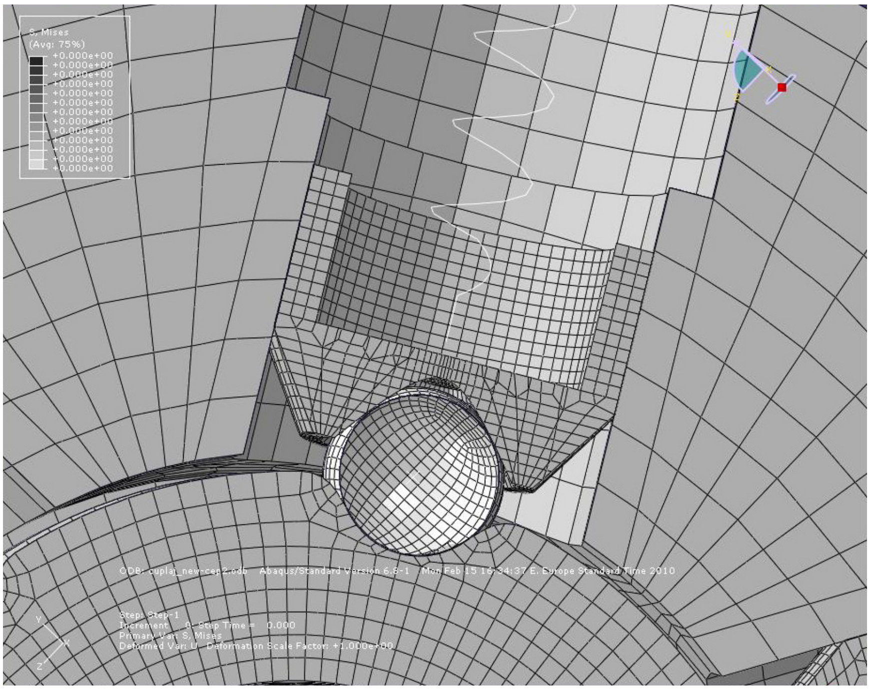

Fig. 12. Transversal section, for complete engaged clutch

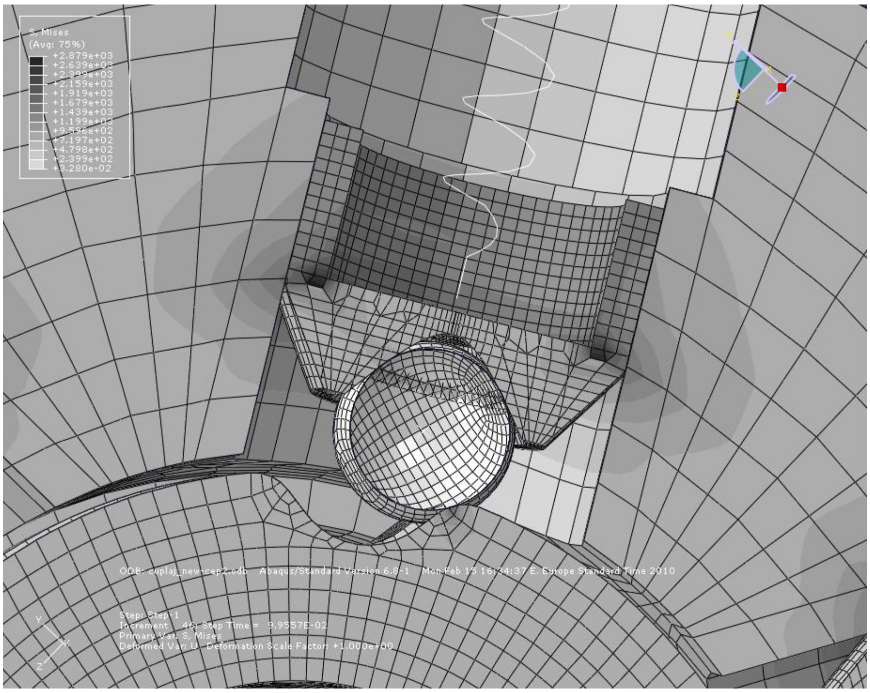

Fig. 13. Transversal section, during disengaging process

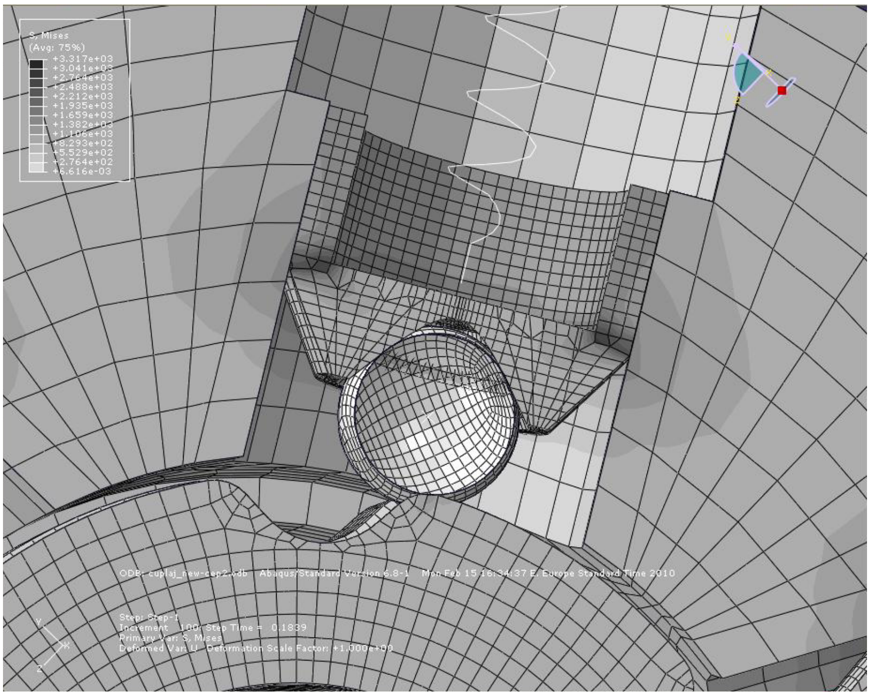

Fig. 14. Transversal section, at the end of disengaging process

After simulation, the stress on each part and displacement between parts were obtained. In figures 12, 13 and 14 are presented different relevant disengaging process phases: first, the clutch is complete engaged, then, an intermediate position during the disengaging process is presented and finally, the disengaged position is presented.

The stresses values are represented also for each phase of disengaging, if is requested by user. Based on these values, the maximum stress can be established on each part.

5. CONCLUSIONS

The paper reveals some conclusions, as follow.

- The safety clutch with balls analysed by this paper, is a new construction characterised by the spherical shape of the active rabbets, radial disposed. The clutch was designed to accomplish the kinematical connection between a shaft – assembled in the semi-clutch boring – and a gear wheel, pulley wheel or sprocket wheel – assembled on the other semi-clutch.
- The calculus relation for transmitted torque M_{td} during the disengaging process and also the relaton for the reactions are presented.
- Using the elaborated calculus program, which allow to analyze safety clutches with balls with different active rabbets shapes - frontally and radial disposed – the transmitted torque variation depending different constructive parameters as the balls disposal diameter D_0, balls diameter d_b, the rabbet active profile angle α_0 and the friction coefficients μ_0 and μ_{01}, is studied. The adequate variation diagrams are also presented.
- For determining the stresses on the clutch elements, the clutch virtual model was made. The stresses values are presented for each phase of disengaging, and based on these values, the maximum stress can be established on each part.

REFERENCES

[1] Chişu, E., Moldovean, Gh. et al. *Cuplaje mecanice intermitente.* Braşov, Editura Lux Libris, 1998.
[2] Dropmann, C., Mustardo, A., *Mechanical torque limiters still make sense. Mechanical and electronic overload protection each has its place*, Machine Design, June, 2003.
[3] Moldovean, G., *Studiul cuplajelor de siguranţă cu transmiterea intermitentă a sarcinii,* PhD Thesis, University of Braşov, 1987.
[4] Moldovean, G., Popa, S., Eftimie, E., *Relative Displacements in the Disengaging Process of the Safety Clutches with Balls and Spherical Rabbets Disposed Radial and Pressure Disk*, Proceedings of the Xth International Conference on Mechanisms and Mechanical Transmissions, Timişoara, 2008, Scientific Bulletin of the „Politehnica" University of Timisoara, Transactions on MECHANICS, Tom 53(67), Fasc. S1, p. 115-122.
[5] Popa, S., Eftimie, E., Moldovean, G., *Relative Displacements in the Disengaging Process of the Safety Clutches with Balls and Radial Spherical Rabbets,* Proceedings of the Xth International Conference on Mechanisms and Mechanical Transmissions, Timişoara, 2008, Scientific Bulletin of the „Politehnica" University of Timisoara, Transactions on MECHANICS, Tom 53(67), Fasc.S1, p. 123-126.
[6] Popa, S., Moldovean, G., Loads in the Completely Engaged Operation for Safety Clutches with Balls and Spherical Active Rabbets Radially Disposed. Bulletin of the Transilvania University of Braşov, Vol.1(50)-2008, Series I, p.157-162.
[7] Popa, S., Moldovean, Gh., Comşiţ, M. *Safety clutch with balls and spherical seats radially disposed. Description. Geometrical elements*. In: Proceedings of International Conference TEHNONAV 2008 (CD), Constanta, Romania.
[8] Popa, S., Moldovean, Gh., Velicu, R. *Spring force variation during the disengagement process in the case of a safety coupling with radial disposed balls, spherical rabbets and pressure disk*. Proceedings of the 3rd International Conference Power Transmissions 2009, Chalkidiki, Greece, p. 149-154.
[9] Mayr Power Transmissions. *K.490.06.GB. The perfect Torque Limiting Clutch* (www.mayr.de).
[10] R+W Coupling Technology. *Torque Limiters SK,* http://www.rw-america.com.