ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #1, May 2017, http://www.imtuoradea.ro/auo.fmte/

NUMERICAL SIMULATION OF THE OPERATION OF SAFETY CLUTCHES

Marius Beniamin FAZECAS[1], Ioan STROE[2]
[1]University of Oradea, Romania, mfazecas@uoradea.ro
[2]"Transilvania" University of Brasov, Romania, stroei@unitbv.ro

Abstract**—**The paper presents the study of the behaviour of safety mechanical clutches with shearing pins by numerically simulating the operation regimes for different types of pins and pin material. General analytical relations are derived for kinematic and dynamic modelling of the operation process. A software is developed in order to resolve by means of numerical methods the analytical relations, as well as to obtain graphs that emphasize the behaviour of the clutch during its operation. The software enables the determination of torque and limiting moment, as well as the selection of the desired geometric parameters. The static and dynamic diagrams can be plotted. The static and dynamic characteristics are drawn for the starting regime, take-up of moment shocks and load decoupling.

Keywords—Clutch, safety, modelling, kinematic, dynamic.

I. INTRODUCTION

THE mechanical clutches have an important role within mechanical drives. Their main purpose is to transfer the torque and rotational movement without altering the input parameters within the drive. Depending on the application, the clutches can fulfil different additional functions, the safe and reliable operation of the system depending on them I. Drăghici [1], Al. Chișiu [2]. The safety clutches perform the coupling and decoupling by means of intermediate elements. The relative movement between the two semi-clutches results in an operation with large shocks and torsional vibrations. From this point of view, the paper targets the modelling of the safety clutch's operation through the formulation of kinematic and dynamic general analytic relations. In the conducted study the developed dynamic models have led to a software that enables the numerical determination of the analytic relations. This software allows the graphical representation of the clutch's characteristics during operation.

The automatic disconnection between shafts takes place when the drive experiences overloads during operation. A reliable and safe operation of the safety clutches is imposed, and at an established value of the torque, the cut-off of the kinematic flux is required, thus protecting the system. The cut-off can take place through three different processes: with cut-off; with temporary cut-off; without cut-off, I. Drăghici [1], Al. Chisiu [2], R. Schnabel [3].

The mechanical clutches with shearing pins cut off the kinematic flux and are thus used for uncommon, random overloads.

II. SAFETY CLUTCH WITH SHEARING PINS

The safety clutch with shear pins operates in the domain of limiting moments (1), and is used in mechanical drives where overloads are infrequent.

$$\mathbf{M_{t\,lim}(1+\Delta) \le M_{t\,max\,a}} \tag{1}$$

where:

$M_{t\,lim}$ - moment at which decoupling starts or ends;

$M_{t\,max\,a}$ – maximum torque accepted by the shearing pin's strength;

Δ - relative error of the safety clutch's operation start.

The decoupling takes place through the shearing of the pins when the design moment, M_{tc}, is exceeded, moment which is function of the layout diameter, D, of the shearing pins of diameter, d (2), their number, z, and shearing resistance, τ_f.

$$\mathbf{M_{tc} = \frac{\pi d^2}{4} z\tau_f \frac{D}{2}} \tag{2}$$

The shearing pins can be smooth or notched, the latter having a high precision. The material out of which these can be made is steel with medium carbon content. I. Drăghici [1], C. Dropmann, A. Mustardo [4], ComInTec SRL [5].

The pins are dimensioned according to the equation of the shear strain (3)

$$\mathbf{\tau_f = K_0 \sigma_r} \tag{3}$$

Equation (2) gives the diameter of the pins

$$\mathbf{d = \sqrt{\frac{8M_{tc}}{\pi z D \tau_f}}} \tag{4}$$

Fig. 1 and fig. 2 show the assembly drawing and the picture of the studied, designed and fabricated clutch, respectively M. B. Fazecaş [6], E. Chişu, G. Moldovean [7].

III. OPERATION PROCESS MODELLING OF THE SAFETY CLUTCH

Modelling the operation process of the safety clutches required the derivation of the kinetic and dynamic analytical modelling equations.

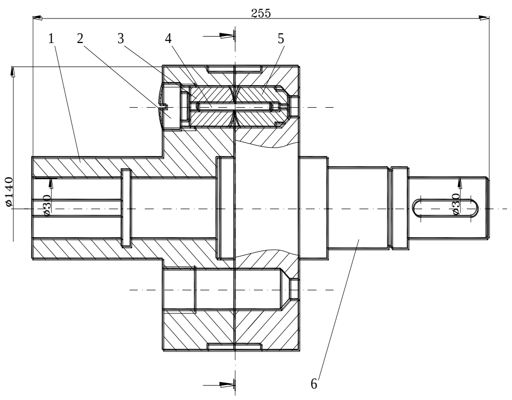

Fig. 1. Assembly drawing of the clutch

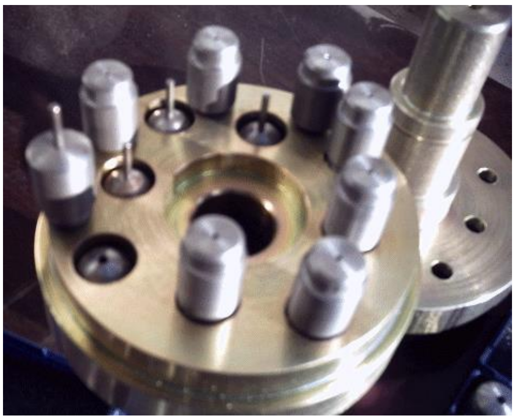

Fig. 2. Photo of the safety clutch with shearing pins

The objectification – through results – of the developed dynamic models led to the implementation of a ***software*** which allows the numerical determination of the analytic equations, as well as the graphic visualisation of the phenomena taking place during operation E. Eftimie [8], E. Eftimie [9], E. Eftimie [10]. The interface of this software can be seen in fig. 3.

A. Geometric and functional clutch definition

The software was developed based on the following objectives:

1) Powerful software;
2) Generality of the algorithm;
3) Structured fitted for further improvement;
4) Analysis that allows kinematic and dynamic modelling;
5) Numeric simulations and graphic display of the clutch's operation E. Eftimie [9].

The software allows the selection of the electric motor type, rated torque, design torque and limiting torque. It also allows the selection of the geometrical parameters of the shearing pins, their type and number, as well as the material.

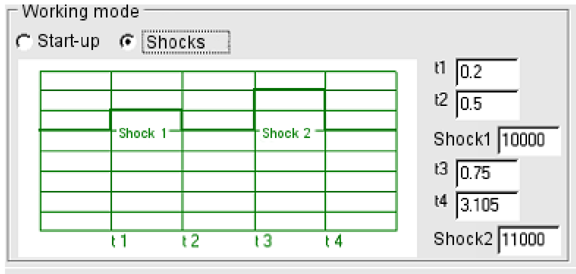

Fig. 3. Geometric and functional definition

In addition, the software enables the alteration of the momentum of the two semi-clutches, the operation regime, the value of the shocks and their duration.

The graphical interface in fig. 4 allows:

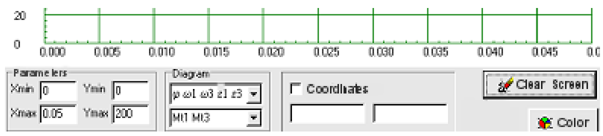

Fig. 4. Graphical window of the software

Plotting the kinematic and dynamic diagrams, setting the minimum and maximum values; selection of the desired color for the graphs.

In the following different operation regimes represented by diagrams for conducted kinematic and dynamic analyses are presented. A safety clutch, with its geometric parameters and momentum shown in fig. 3, will be analysed.

B. Clutch start-up regimes

To simulate the start-up process without shocks the momentum will be neglected. The acceleration of the driving semi-clutch is done through the difference in the two torques M_{t1} –M_{t3} I. Stroe [11], S. Popa, G. Moldovean [12].

For asynchronous motors of different power and torque the operating point is different. An asynchronous motor with P=11 (kW) and n=720 (rpm) has its start-up after ≈ 40 (ms), at torque M_{t0} = 320985 (Nmm) and angular velocity ω_0= 34,3 (rot/s), whereas a motor with P=7.5 (kW) and n=780 (rpm) has its start-up after ≈60 (ms), and the operating point corresponds to M_{t0} = 222563 (Nmm) and ω_0= 33,7 (rot/s). In fig. 5 and fig. 6 the start-up diagrams for P=7.5 (kW) and n=780 (rpm) are presented.

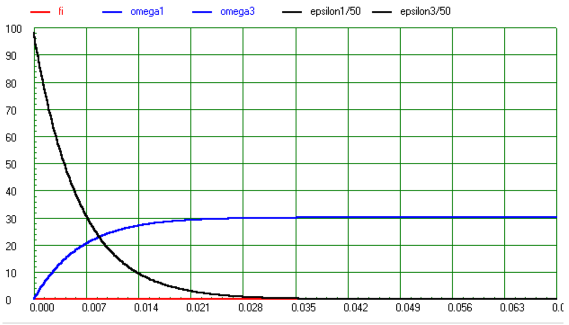

Fig. 5. Kinematic diagram at start-up.

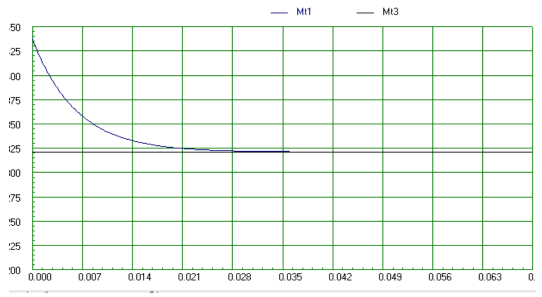

Fig. 6. Dynamic diagram at start-up

C. Taking small value shocks

In order to study the behaviour of the safety clutch with shearing pins a series of situations in which the clutch is subjected to shocks of small value under the conditions of altering the most important geometric and design parameters. Fig. 7 and fig. 8 show the dynamic diagrams for small shocks to which pins of diameter d=6.25 mm, made out of OL 37 and OL 42 material, respectively, were subjected M. B. Fazecaș [6].

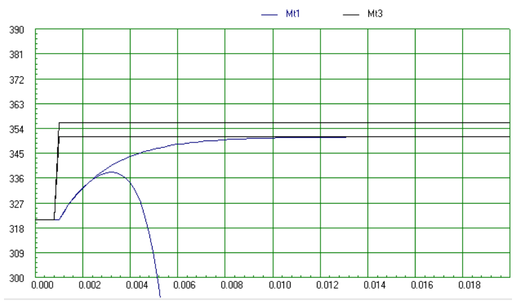

Fig. 7. Shocks of small value – OL 37 material. Dynamic diagram

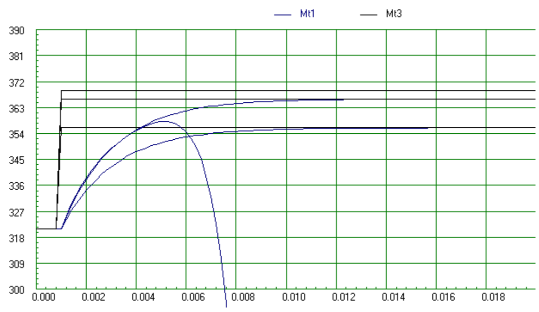

Fig. 8. Shocks of small value – OL 37 material. Dynamic diagram

After analysing the diagrams, the following conclusions were drawn:

The clutches can withstand shocks of very small value, for a long period of time, the operation point being characterized by larger torques and smaller angular speed;

Shocks with a value larger than the shearing moment cannot be resisted;

By carefully combining the geometric parameters, such as pin layout diameter, pin diameter, material etc., various value of the shearing moment can be obtained with a higher or lower decoupling precision;

By changing the pin's diameter the shearing moment decreases and thus the decoupling precision increases;

By keeping the same pin diameter for the pins but changing the material the shearing moment increases, the clutch withstanding larger shocks;

Depending on the value of the shock that can be resisted, the new operating point is reached with a sudden decrease in the acceleration of the two semiclutches; this decrease is larger;

When larger shocks are taken the acceleration drops and de operating point experiences a sudden decrease.

D. Decoupling

The decoupling process is studied for different shearing pins, but for the same value of the shock, diameter and material, fig. 9 M. B. Fazecaș [6].

An increase in shearing moment for the notched pin is observed, making thus the shock resistance possible. This increase is caused by the increase in rupture stress coefficient, which in turn leads to the increase in rupture stress through shear strain. The notched pin ruptures at higher shocks, compared to the smooth pins, due to the increase in shearing moment.

In fig. 10 the decoupling for two different types of pins of the same diameter and material at the same shock value. The notched pin ruptures at a larger acceleration value of the two semiclutches, for longer time, compared to the smooth pin, whose rupture takes place at smaller shocks.

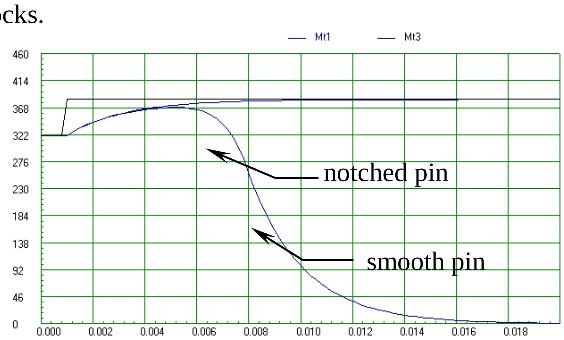

Fig. 9. Shock resistance of notched and smooth pins

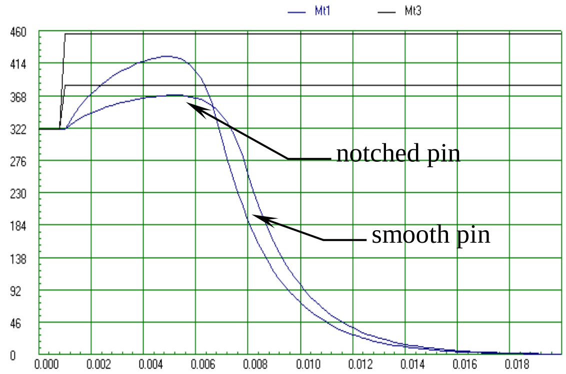

Fig. 10. Rupture of notched and smooth pins

Fig. 11 depicts the increase in momentum for the follower, with the purpose of increasing the rupture time of the pin. The resistance moment increases rapidly, after which it returns to the value of the design moment, and the pin's rupture takes place after a longer time.

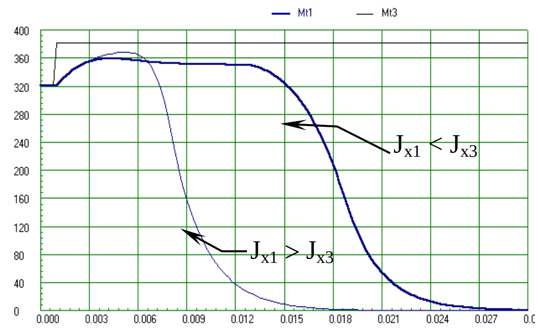

Fig. 11. The influence of the momentum at the driving part of the clutch ($J_{x1} < J_{x3}$). Dynamic diagram.

IV. Conclusion

The kinematic and dynamic modelling, as well as the numerical simulations have led to the conclusion that the operation of the safety clutch with shearing pins is influenced by the following parameters: pin diameter d, pin type – notched or smooth, the ratio of momentum of the driving and following elements of the clutch J_{x3}/J_{x1}.

A strong relation between the design and functional parameters exists: the pins diameter, number, material and type, that have an influence on the rupture stress by shearing, the layout diameter, the limiting torque that has to be transmitted to the clutch.

The shearing moment resulting from combining these parameters is not equal to the limiting torque. It is recommended to choose those combinations that result in a value of the shearing stress smaller than that of the limiting torque.

By increasing the momentum a drop in the maximum admisible shock value of the driving semiclutch takes place, during the full rupture of the pins

The safety clutches with shearing pins cannot withstand shocks that are larger than the shearing stress.

References

[1] I. Drăghici, "The calculus and construction of clutches", "Calculul şi construcţia cuplajelor", Editura Tehnică, Bucharest, 1978.

[2] Al. Chisiu, "Machine elements", "Organe de masini*"*, Editura Didactica si Pedagogica, Bucharest, 1976

[3] R. Schnabel, "*Machine Couplings. When Machines Collide*", Machine Design, 64, July 9, 1992, pp. 37-39.

[4] C. Dropmann, A. Mustardo, "Mechanical torque limiters still make sense. Mechanical and electronic overload protection each has its place", Machine Design, June, 2003.

[5] ComInTec SRL, Via Dell'Artigiano 9, 40050 Villanova di Castenaso, Bolgna, Italy. *Torque limiters – Safety couplings (Catalogo Limitatori di coppia – Giunti di sicurezza) DSS – DSR,* Available on www.comintec.it, accessed on April 2014.

[6] M. B. Fazecaş, "Theoretical contributions on the strength and life of the coupling" (In Romanian: "Contribuții teoretice privind rezistența și durata de viață a cuplajului"), PhD Thesis, *Universitatea Politehnica Timişoara*, 2007.

[7] E. Chişu, Gh. Moldovean, D. Velicu, Gh. Mogan, A. Jula, V. Florea, E. Eftimie, R. Velicu, I. Stroe, "Intermitent mechanical clutches" (In Romanian: "Cuplaje mecanice intermitente"*)*, Braşov, RO: Editura Lux Libris, 1999, pp. 174-203.

[8] E. Eftimie, "Safety Clutches in Static and Dynamic Working Regime", *Annals of the Oradea University, Fascicle of Management and Technological Engineering*, Volume VI (XVI), 2007, pp. 850-855.

[9] E. Eftimie, Kinematic and static modelling of the safety clutches with balls. *Annals of the Oradea University, Fascicle of Management and Technological Engineering*, Oradea, may 2006, p. 663-668.

[10] E. Eftimie, "Safety Clutches in Static and Dynamic Working Regime", *Annals of the Oradea University, Fascicle of Management and Technological Engineering*, Volume VI (XVI), 2007, pp. 850-855.

[11] I. Stroe, "Elastic and Safety Clutch with Axially Distributed Elastic Dowels*." IJSR – International Journal of Scientific Research*, Volume 3, issue: 12, December 2014, pp.121-122.

[12] S. Popa, G. Moldovean, "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, pp.157-162.