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University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
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NEW SOLUTIONS TO IMPROVE TECHNICAL PERFORMAMCES OF ELASTIC COUPLING

Cristina MOHORA, Constantin ISPAS, Dorel ANANIA, Bogdan LUNGU

***Abstract**: This paper is a presentation of the new types of couplings and supports with controlled elasticity and damping for the control, limitation and damping of shocks and vibrations associated to equipment and machinery. Herein below there is also a presentation of the results obtained in the first and second stage of the project CEEX 257/11.09.2006 "Performing technical solutions to reduce shocks and vibrations with the aim to improve the technical and economical performances of machines and equipments".*

***Key words:** elastic coupling, vibration, rigidity, damping.*

1. INTRODUCTION

In this paper is presented a new type of coupling device with dumping and elasticity controlled in order to limit the shocks and vibration of the machines and industrial equipments [1].

The results obtained by experimental research of the coupling devices in order to avoid the stress induced by the spindle alignment (caused by the assembly errors, bearings, or structure displacement) show that the new devices are capable to work in the high alignment errors with mechanical stress but, without vibration [2].

The new type of coupling can be made for any spindle diameter and any kind of torque. Some of this coupling can take over and transfer axial forces and torsion moments.

2. THE SERB –CEL-130 COUPLING

In the first phase of the project [3] it was presented the national and international current stage regarding the elastic couplings domain. In the projects two phases there were presented different technical project possibilities for these new couplings, able to reduce the equipments vibrations which transmit the rotation movement and the torsion moment, using inventions protected by OSIM.

In the Stage 1 and Stage 2 of the research project the design and prototype of SERB-LEL-01 coupling with "cylindrical" elastic blades (Fig. 4) were made and the results showed the following advantages:

- the coupling can be installed and dismantled without requiring the dismantling of the equipment (electric motor, pump, fan, etc);
- the coupling does not generate overloads and vibrations on large radial or angular deviations between the driving shaft and the resistant shaft;
- the vibrations generated by one of the equipment to which it is coupled to (e.g. electric motor, pump, fan, etc) are not transferred to the other equipment and they are attenuated by the coupling damping;
- the coupling may be installed and operational upon reliable and safety conditions including high explosion risk environments;
- the coupling does not require special technologies and machining for its fabrication since the coupling is robust and reliable;
- the coupling requires no maintenance .

In phase 3, three elastic couplings prototypes were made, two couplings with elastic lamelas and one coupling with rubber sticks.

The coupling prototypes were made only with mechanical splintering processing with lathe and milling machine, excepting elastic lamelas which were made from stainless steel band on a guillotine and the rubber sticks were made by mould vulcanization.

There were used two sets of couplings with elastic lamelas with 1 mm and 1.5 mm in thickness, on which were made experimental determinations for rigidity and absorbing capacity.

In Figs. 1 and 2 there are shown pictures of manufactured couplings prototypes.

Fig. 1. Elastic coupling with dumping SERB-CEL 130.

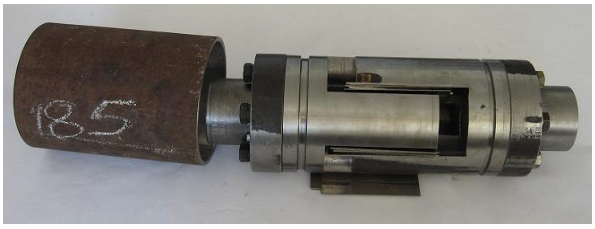

Fig. 2. Elastic coupling with assembled dumping SERB-CEL 130.

3. THE ELASTIC COUPLING PROTOTYPE MANUFACTURING

For determining the experimental results there were made 3 elastic couplings prototypes, two couplings with elastic lamelas and one coupling with rubber sticks.

The coupling prototypes were made only with mechanical splintering processing with lathe and milling machine, excepting elastic lamelas which were made from stainless steel band on a guillotine and the rubber sticks were made by mould vulcanization.

There were used two sets of couplings with elastic lamelas with 1 mm and 1.5 mm in thickness, on which were made experimental determinations for rigidity and absorbing capacity.

4. EXPERIMENTAL MEASUREMENTS

For evaluating the rigidity and amortization characteristics,

$$M = f(\Phi), \qquad (1)$$

experimental try-outs in three stages were made.

4.1. Stage 1

In stage 1, there were made experimental try-outs on different elastic lamelas sets but in similar conditions.

The purpose for these try-outs was to determine the optimal number of lamelas for mounting and their necessary thickness so the shock absorption for starting, interuptions and equipment weight variation, is made with minimum stress and a quick vibration absorption.

The try-outs were made on several elastic lamelas sets manufactured from a sheet metal with 2 mm, 2.4 mm, 1.5 mm, and 1mm in thickness.

The try-outs made on sheet metal lamela sets with a thickness greater than 2 mm indicated a semi-flexible behaviour.

Starting from deformation with the arrow between 0.9 mm and 1.1 mm (depending on lamella's thickness),

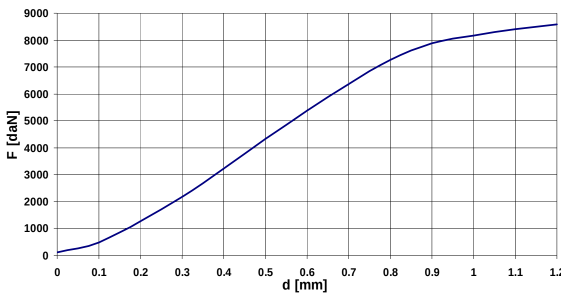

Fig. 3. The inflection characteristic for 3 stratified lamellas of 2 mm thickness.

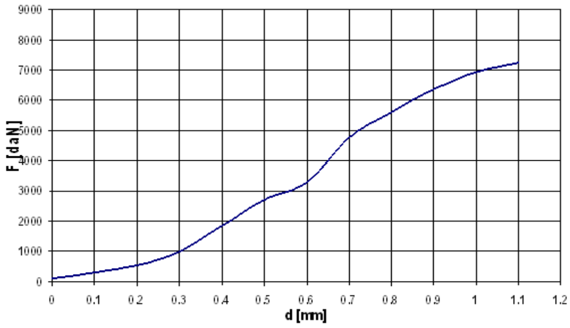

Fig.4. The inflection characteristic for one stratified lamella of 2 mm thickness.

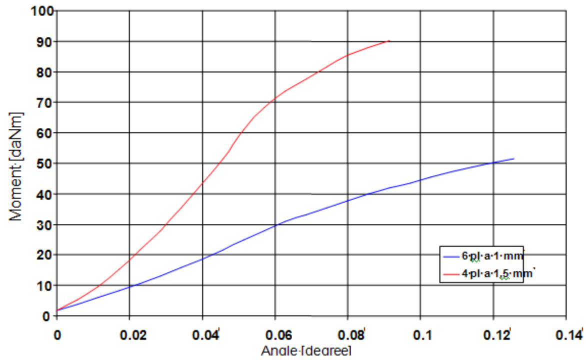

Fig. 5. Moment – angle characteristic for different lamela sets thickness.

the elastic lamellas sets pass into the flowing domain, like in Figs. 3 and 4.

4.2. Stage 2

In stage 2 there were made static experimental try-outs on elastic coupling with dumping SERB-CEL 130 mounted horizontaly with one of the coupling fixed in a profile metalic structure. In Fig. 5 it is shown a characteristic for torsion moment – revolving angle from experimental try-outs for two lamelas types.

4.3. Stage 3

In stage 3 there were made static experimental try-outs on elastic coupling with dumping SERB-CEL 130 and SERB-CEL 90 mounted on a try-outs stand.

The end shaft capable torsion moment (Mtcap) is set by STAS 8724/3-74.

The worst case scenario: the torsion moment, with knowing value, and an inflection moment, with unknown value, with shaft end diameter, d, measured in mm, and torsion moment measured in N.m:

$$M_{tcap}(d) = 27.45862 \cdot 10^{-5} \cdot d^{3.5} \qquad (2)$$

For example, for the SERB-CEL-130 coupling:

$$M_{tcap}(48) = 210.389 \qquad (3)$$

For the coupling functional characteristic simple modelling, it is accepted as a main phenomenon for elastic lamellas as being stressed using cylindrical inflection.

The spring rigidity, the plate with h thickness; the material with E elasticity and Poisson coefficient:

$$D(h) = \frac{E \cdot h^3}{12 \cdot \left(1 - v^2\right)} \quad . \tag{4}$$

The torsion moment transmitted through all the springs, considering the rotation angle, the *a*, *Rm, L* dimensions, will be considered from the drawing (Fig. 6).

The relation is deduced from the condition that the spring is leaning on a concave semi-coupling having the R_2 radius and *a* string.

The spring is worked with a concentrated force applied by the leading concave cylindrical semi-coupling.

The placement radius of leading semi-coupling cylinders is R_m.

The maximum inflection moment from the contact zone with the cylindrical semi-coupling 1: $M_i = (F_{t1} / 2)a$, where F_{t1} is the tangential force to a spring sheet made by the torsion moment and applied to R_m radius (deductible from the leading semi-coupling ensemble drawing and the execution drawing).

The total tangential force: $F_t = M_t / R_m$; The force for a spring sheet: $F_1 = F / p$; where *p* is the number of sheets (lamellas) from a spring package.

The spring characteristic: the torsion moment *Mt*-using the deformation angle Φ.

A single lamella with h thickness and *D* (*h*) rigidity:

$$M_t(h,L,a,R_m,\varphi) = 4 \cdot \frac{D(h)}{a} \cdot \frac{\varphi}{\frac{a^2}{R_m^2} + \varphi^2} \cdot L \quad . \tag{5}$$

The springs are mounted with a *w*0 pre-gripping-deformation and Φo angle.

The coupling is working as a stiff coupling, for smaller torsion forces than the moment according to Φo and for moments bigger than the moment according to Φ_{max}. For intermediary values, the coupling is working as an elastic coupling.

The maximum deformation angle is calculated when the first semi-coupling completely deforms the lamellas package. The lamellas are situated between the two *R*1 and R_2 radius cylinders.

The total moment transmitted to the coupling with *p* identical lamellas in a package and a central lamella with a different h_c thickness.

$$\begin{aligned} &M_{tc}(h_c,L,a,R_m,\Phi) = M_t(h_c,L,a,R_m,\Phi), \\ &M_{tt}(p,h,h_c,L,a,R_m,\Phi) = p \cdot M_t(h,L,a,R_m,\Phi) + \\ &+ M_{tc}(h_c,L,a,R_m,\Phi). \end{aligned} \tag{6}$$

The coupling deformation angle with *c* springs columns.

The pre-gripping angle

$$\Phi_{0t}(c,w_0,R_m,h) = c \cdot \Phi_0(w_0,R_m,h) \quad . \tag{7}$$

The maximum angle

$$\Phi_{max}(c,R_2,R_m,h,a) = c \cdot \Phi_{max}(R_2,R_m,h,a) \quad . \tag{8}$$

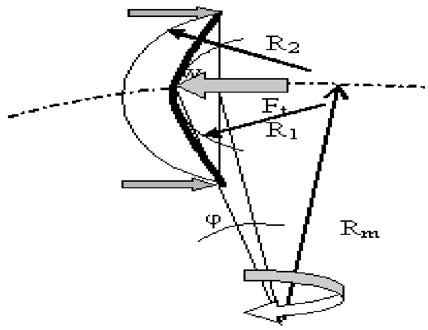

Fig.6. The dimensions defining for the torsion moment calculation.

The coupling rigidity diagram with *p* identical lamellas in a package and other with a different h_c thickness and with *c* packages for one rotation direction

$$\begin{aligned} &M_{ttot}(p,c,w_0,h,h_c,L,a,R_m,\Phi) = \\ &= M_{tt}(p,h,h_c,L,a,R_m,\Phi) , \end{aligned} \tag{9}$$

with Φ variable angle between

$$\Phi_{0t}(c,w_0,R_m,h)$$

and

$$\Phi_{max}(c,R_2,R_m,h,a) \quad . \tag{10}$$

The coupling will work as a stiff coupling, for smaller forces than

$$M_{ttot}(p,c,w_0,h,h_c,L,a,R_m,\Phi_{0t}(c,w_0,R_m,h)) \quad . \tag{11}$$

The coupling will work as an elastic coupling for moments bigger than

$$M_{ttot}(p,c,w_0,h,h_c,L,a,R_m,\Phi_{ot}(c,w_0,R_m,h)) \tag{12}$$

and smaller than

$$M_{ttot}(p,c,w_0,h,h_c,L,a,R_m,\Phi_{max}(c,R_2,R_m,h,a) \tag{13}$$

where $p = 2$, $c = 3$, $h = 2$, $h_c = 2.4$, $a = 18.24$, $R_m = 49$, $R_2 = 35.5$, $L = 100$,

$$M_{ttot}(2,3,3,2,2.4,100,18.2,449,\Phi_{ot}(3,3,49,2)) = 1.551 \cdot 10^7 \quad . \tag{14}$$

The minimum torsion moment till the coupling works like a stiff coupling MtmCEL130.

$$\begin{aligned} &M_{tmCEL130}(w_o) = M_{ttot}(p,c,w_o,h,h_c,L,a,R_m, \\ &\Phi_c(c,w_0,R_m,h)) \ . \end{aligned} \tag{15}$$

The maximum torsion moment till the coupling works like a stiff coupling MtmCEL130.

$$\begin{aligned} &M_{tmCEL130}(w_o) = M_{ttot}(p,c,w_o,h,h_c, \\ &\Phi_{max\,t}(c,R_2,R_m,h, \end{aligned} \tag{16}$$

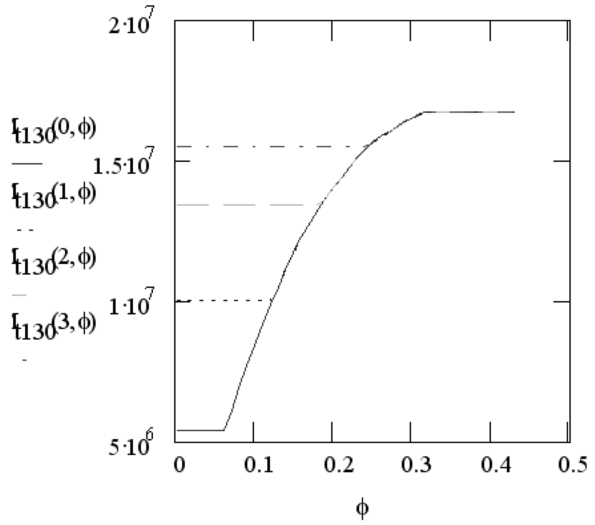

Fig.7. SERB-CEL-130 rigidity characteristic.

$$M_{tmCEL130}(w_o,\Phi)=M_{ttot}(p,c,w_o,h,h_c,L,a,R_m,\Phi)$$
$$M_{tmCEL130}(2,0.3)=1.651\cdot 10^7 \qquad (17)$$
$$M_{tmCEL130}(2,0.0.5)=1.618\cdot 10^7 .$$

The SERB-CEL-130 rigidity characteristic.

The elastic coupling minimum torsion rigidity [Nm/grad] **(**Fig. 7).

If the coupling is adjusted, using the semi-couplings relative rotation, for example, with a 7 degree angle, than the coupling will work as a stiff coupling, for smaller torsion forces than 10000 Nm and like an elastic coupling for moments bigger than the value above, till a maximum torsion moment of 16780 Nm.

Experimental results.

ORIGIN≡ 1

The coupling torsion moment determined using the leading semi-coupling torsion shaft with lever and calibrates weights.

The friction moment between bearings

$$Mf = 4.25 \text{ Nm.} \qquad (18)$$

The coupling torsion moment

$$M_t=\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ M_f & 30.95 & 34.51 & 38.07 & 41.63 & 45.19 & 48.75 & 64.95 \end{pmatrix} . \qquad (19)$$

5. RESULTS AND CONCLUSIONS

The elastic energy
With working load

$$E_i=\frac{1}{2}\cdot\sum_{j=1}^{10}(M_{t_{2,j}}+M_{t_{2,j+1}})\cdot(\Phi_{mi_{2,j+1}}-\Phi_{mi_{2,j}}) , \qquad (20)$$

E_i =1.449 J.

Without working load

$$\mathrm{E}_d=\frac{1}{2}\cdot\sum_{j=1}^{10}(M_{t_{2,j}}+M_{t_{2,j+1}})\cdot(\phi_{md_{2,j+1}}-\phi_{md_{2,j}}) \qquad (21)$$

E_d = 0.74 J.

The hysteretic loss coefficient

$$His=\left|\frac{E_i-E_d}{\frac{1}{2}\cdot M_{t_{2,11}}\cdot\phi_{mi_{2,11}}}\right| \qquad (22)$$

The linear elastic deformation energy

$$\frac{1}{2}\cdot M_{t_{2,11}}\cdot\Phi_{mi_{2,11}}=1.128\ J \qquad (23)$$

For the try-out working zone, the dumping coefficient through the elastic lamellas friction is very good (62.8 %), regarding the fact that inside the SERB – CEL – 130 coupling work 3 elastic lamellas packages in parallel, the moments corresponding to a 6.80 elastic rotation are 150 daN·m for a thickness of 1 mm for elastic couplings and 270 daN·m for a 1.5 mm in thickness package lamellas.

The field of hysteretic values 23.5 % (SERB 100) and 62.8 % (SERB 130) prove a very viable solution with the possibility to improve the amortization coefficient.

In this paper there were made and experienced new types of elastic couplings with dumping which allow radial, angular and axial assembly deviations without generating vibrations and overstressing to composing elements regarding the ones from the project.

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Authors:

PhD. Eng., Cristina MOHORA, Professor, University "Politehnica" of Bucharest,
E-mail: cristinamohora@yahoo.com
PhD. Eng., Constantin ISPAS, Professor, University "Politehnica" of Bucharest,
E-mail: ispas1002000@yahoo.fr
PhD. Eng., Florea Dorel ANANIA, Lecturer, University "Politehnica" of Bucharest,
E-mail: dorel.anania@sun.cfic.pub.ro
PhD. Eng., Bogdan LUNGU, University "Politehnica" of Bucharest,
E-mail: lungu_ib@yahoo.com