Global Journal of Researches in Engineering
Mechanical and Mechanics Engineering
Volume 13 Issue 3 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

The Characteristics of Torsionally Flexible Metal Coupling

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GJRE-A Classification : FOR Code: 030204

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The Characteristics of Torsionally Flexible Metal Coupling

Dr. Hab. Inż. Krzysztof Filipowicz

Abstract - The paper presents construction torsionally flexible metal coupling, description of test stands and the methodology for determining the static characteristics of a metal coupling of high torsional flexibility. In addition, the paper presents preliminary tests results which enable to determine the above characteristics.

Keywords : machines, construction of machines, driving device, couplings.

I. Introduction

The tendency to increase the effectiveness of technological processes and at the same time the efficiency of machines through growth of power with simultaneous optimisation of their size and mass often leads to the increase of dynamic interactions of particular units of the machines. The dynamic interactions taking place in the power transmission system components are definitely disadvantageous. Broad research has shown that even relatively small dynamically affecting force can cause considerably bigger internal forces and displacements to appear than significantly bigger statically affecting force.

From the experiments regarding exploitation and the information of machine shops stems the fact that the level of knowledge about constructing and the insufficiently examined problems with the process of utilization need further research. The efficacy and reliability of machines are shaped during the processes of construction, manufacturing and exploitation. Sufficient knowledge about working load affects the decisions made at all three of those phases and that has a close link to the durability of particular elements and units of the machines. In the process of construction nominal external load is taken into account with a certain reserve, e.g. with the aid of the factor of implementation K_A (formerly overload K_p). However, assessing other factors that have influence on the load of the elements of the machine, like e.g. those stemming from faulty performance and assembly as well as the interaction between cooperating elements, is hampered because of their random character and unspecified synergism in generating dynamic loads.

Decreasing the dynamic loads between particular elements of the power transmission system components of a mill, which usually include engine, mechanical gear and actuator can be accomplished through the accurate selection of couplings linking those respective elements. Thanks to couplings it is possible to considerably reduce the dynamic loads in the power transmission system components caused by both external and internal factors. This function is best fulfilled by torsionally flexible couplings characterised by adequate resilient and deadening features.

In the majority of the machines used in mining, building and road industry most of the power transmission system components is liable to random loads both in the phase of start and steady flow as well as stop. Those power systems are prone to be affected by overloads, shock loads and frequent starting under great load. An excellent instance of the above is the power system of a drag chain conveyor. Difficult operating conditions require the usage of couplings with great flexibility susceptibility. Currently the most loaded power transmission systems of mining machines employ one or two liner flexible couplings, liquid couplings of various kinds (e.g. SH, TV produced by Voith Turbo GmbH, etc.) or different types of integrated power transmission systems, like WB/CST DBT, that comprise of epicyclic gearbox and multiple-plate coupling. The aforementioned examples of couplings are characterised by specific advantages and disadvantages described in technical literature.

The Institute of Mining Mechanisation developed a completely new construction, namely torsionally flexible metal coupling, which fulfils most of the requirements of application as regards the considerably loaded power transmission systems of mills [1, 2, 3, 4].

Through the mitigation of torque alterations this coupling causes the absorption of energy, which affects the stabilisation of torsional vibration and the beneficial change of its flow. This contributes to a significant reduction of dynamic loads and thereby ensures the accurate performance of the power transmission system of a mill. And this means the increase of durability and reliability of its constituents.

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II. The Construction of Torsionally Flexible Metal Couplings

One of the constructional forms of bidirectional torsionally flexible metal coupling is shown in figure 1.

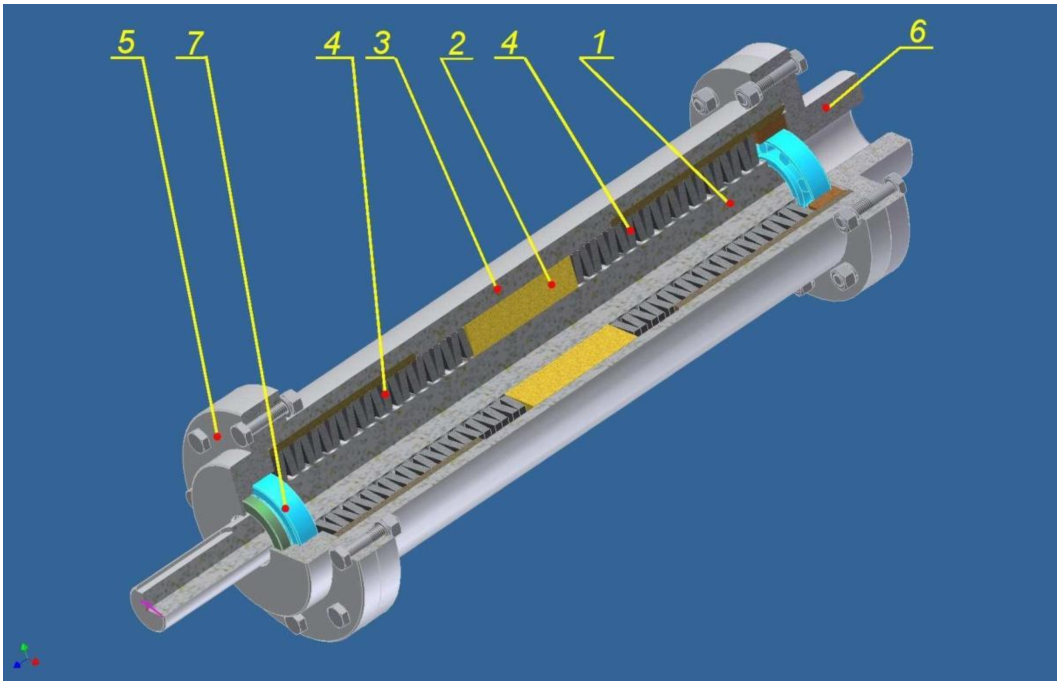

Figure 1 : Two-way- flexible torsional metal coupling prototype construction. 1 – Screw-threaded coupling shaft, 2 – Splinded sliding sleeve with internal screw thread, 3 – Housing with cut splines, 4 – Disk spring set, 5 – Cover plate, 6 – Coupling hub, 7 – Cone bearings

The tenet of torsionally flexible metal coupling rests in the operating torque affecting the active part of the coupling directly through the shaft (1) and then being conveyed to the sliding sleeve (2) with the aid of a multi-start thread. The increasing value of the torque causes the rotation of the shaft (1) against the sliding sleeve (2) and at the same time the torque converter housing (3). The axial force that is thus produced in the multi-start thread initiates plane motion of the sliding sleeve alongside the crankshaft centreline (release lever axle).

The limitation of the motion of the sliding sleeve to plane motion is achieved through motor splined coupling positioned between the sleeve (2) and the torque converter housing (3). Plane motion of the sliding sleeve causes simultaneously the compression of a set of dished plate springs (4) that is especially selected to match the assumed qualities of the coupling. The compression of the springs causes the internal elastic strain force to affect the set. This force in every temporal, fixed location of the sliding sleeve counterbalances the axial force produced in the multi-start thread, which is the result of the external insert momentum operating. Every temporal overload of the power system with the insert momentum triggers additional compression of the resilient elements of the coupling and decreasing the load causes their annealing.

III. Determining the Static Characteristics Of The Coupling

The static characteristic of a flexible coupling is a dependency of the torque M_{obr}, which turns the coupling by the specific angle of rotation φ between the active and the passive element of the coupling. The changes of the torque in this case should be very slow.

$$M_{obr} = f(\varphi) \tag{1}$$

Where: M_{obr}– The torque moment on the flexible coupling, Nm, φ - Relative angle of rotation of the coupling elements, radian or degrees.

The shape of the static characteristics depends on the construction of the coupling, the material used for the flexible connecting link i.e. the elastic-damping system and the very shape of the connecting link. In case of couplings with flexible rubber elements or elastomers which are most commonly used in power transmission systems of working machines, the characteristic is nonlinear with damping which makes it hard to choose the proper coupling for the power transmission system.

a) *The testing stand and methodology of determining the static characteristics of a flexible coupling*

The testing stand used to determine the static characteristics of a coupling is used to test the mechanical couplings built in the Institute of Mining Mechanisation at the Silesian University of Technology, as shown in Fig.2.

The electric motor (1) powered by the inverter, which enables the smooth regulation of the rotational speed from 0 to 1700 min^{-1}, is connected with the tensometric torque meter (5) used to test the torque moment $M_{obr} = M_{stat}$. The value of the measured torque is read and recorded by means of a computerised measuring apparatus (7) of type SCXI produced by National Instruments. One of the elements of the tested flexible metal coupling - the housing (2) is directly attached to the output shaft of the torque meter. The other element of the coupling - the output shaft - is attached to the hydraulic disc brake (3) which is controlled from the pressure supply system (4).

The output shaft of the coupling i.e. the passive element of the coupling is attached to the rotary disc with an angular scale 0°÷360° (6). An indicating needle attached to the coupling housing was used to read the relative angular displacement of the elements $\varphi = \varphi_{stat}$.

When the coupling is secured at the testing stand by means of a fully blocked hydraulic brake, one of the elements of the flexible clutch may no longer turn. The electric motor is activated by means of an inverter and the static torque M_{stat} is gradually increased. The torque moment changes every 10 Nm in order to reach the maximum M_{max} = 100Nm. At the same time the relative angular displacement of the coupling elements φ_{stat} on the angular scale of the disc is read by means of an indicating needle attached to the movable housing. The precision of the reading is ± 1°. The readings of the dependency of the torque M_{stat} on the relative angular displacement φ_{stat} is carried out with and without the load. The aim of this procedure is to determine the histeresis loop which presents the value of the mechanical energy damping in the coupling.

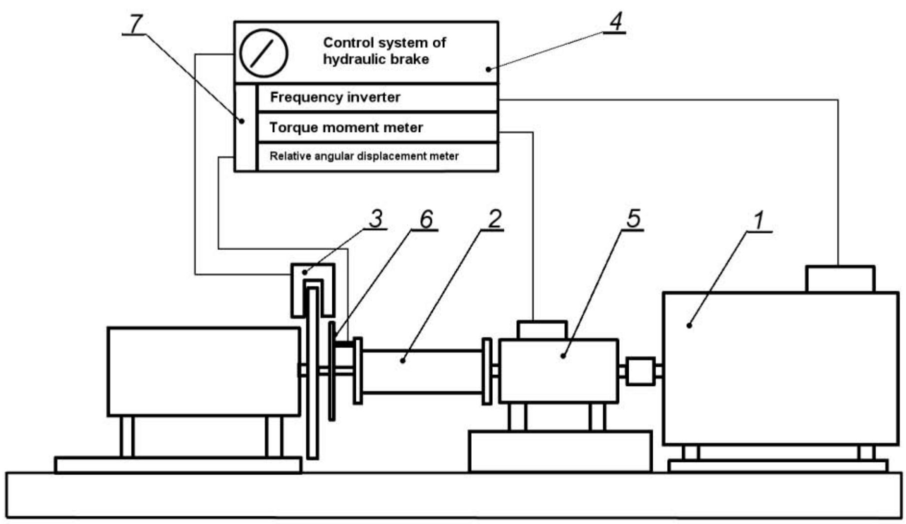

Figure 2 : The testing stand used to test the mechanical couplings, where: 1 – Electric motor, 2 – Tested flexible coupling, 3 – Hydraulic disc brake, 4 – Control system of hydraulic brake, 5 – Torque meter, 6 – Disc with an angular scale, 7 – Measuring-recording set

b) *The static characteristics of a torsionally flexible metal coupling*

The tests enabled to determine the basic static characteristics of the four options of a torsionally flexible metal coupling for spring sets as shown in table 1. Figures 3 are the graphic illustration of the determined static characteristics of different options of the coupling.

The tests were carried out with the use of couplings with four different sets of disc springs. The choice of these sets was based on the analysis of disc springs characteristics arranged in packs and forming sets. The sets were chosen so that with the maximum torque moment M_{max} = 100 Nm, the springs would work below the accepted working range, that is 75% of the maximum deflection.

Table 1 contains the data regarding the disc springs used in the coupling and the sets that were placed in it.

Table 1 : The sets of the disc springs used in the coupling

Coupling Number	Type of disc springs DIN 2093	The number of springs in the pack	The arrangement of the pack
1	40 x 20,4 x 2,5	5	<<<<< >>>>>
2	40 x 20,4 x 2,5	4	<<<< >>>>
3	40 x 20,4 x 2,25	4	<<<< >>>>
4	40 x 20,4 x 2	4	<<<< >>>>

When the coupling characteristics are linear as those obtained in the tests, we can determine the coefficient called the torsional rigidity of the coupling k for each of them. For the determined linear static characteristics, the dependency is expressed as follows:

$$k = \frac{M_{stat}}{\varphi_{stat}} \qquad (2)$$

Where : M_{stat} – the static torque moment on the coupling, Nm φ_{stat} – the corresponding relative angular displacement of the coupling elements, radian or degrees.

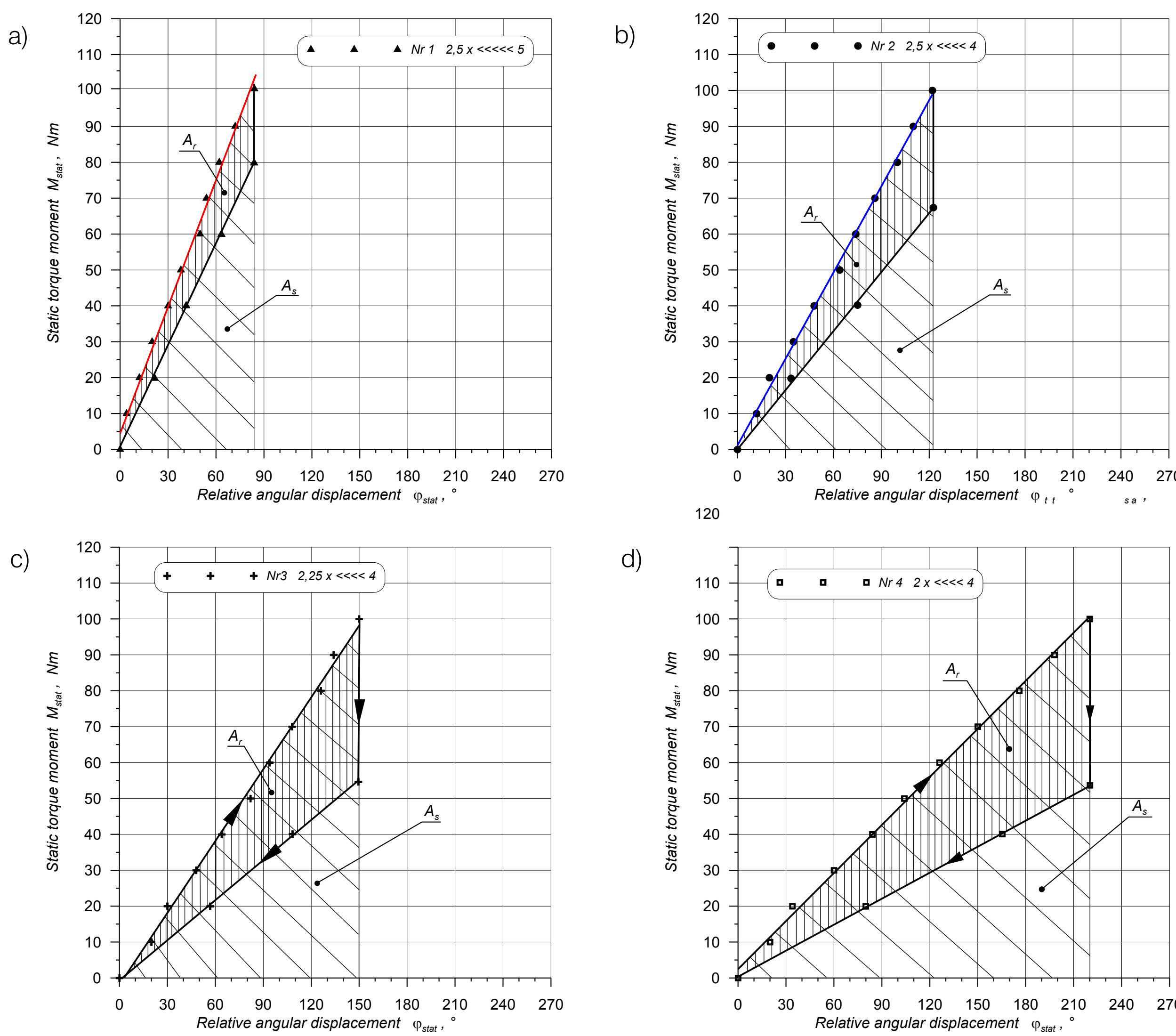

Figure 3 : The illustration of some static characteristics of torsionally flexible metal coupling, where: a – Coupling no. 1, b – Coupling no. 2, c – Coupling no. 3, d – Coupling no. 4

The flexible metal coupling is not only rigid but it also absorbs energy. The histeresis loop was obtained during loading and unloading and it presented the histeresis losses of the mechanical energy in the coupling called damping. In the flexible metal coupling damping is achieved by means of constructive friction in screw joints mainly.

The value of the mechanical energy damping in the coupling is specified by the damping coefficient that is determined as follows:

$$\psi = \frac{A_r}{A_s} \tag{3}$$

Where:

A_r – damping during one working cycle, Nm · degrees.

A_s – elastic strain during one work cycle, Nm · degrees.

The obtained torsional rigidity coefficients as well as the damping coefficient for the tested options of the torsionally flexible metal coupling are presented in Table 2.

Table 2 : The obtained torsional rigidity coefficient k and the damping coefficient ψ

Coupling Number	Type of disc springs	The torsional rigidity coefficient k, Nm/°	The damping coefficient ψ
1	40 x 20,4 x 2,5	1,77	0,20
2	40 x 20,4 x 2,5	0,80	0,33
3	40 x 20,4 x 2,25	0,67	0,45
4	40 x 20,4 x 2	0,45	0,47

IV. Summary

The preliminary tests carried out to determine the static characteristics of a torsionally flexible metal coupling lead to the following general conclusions:

- The proposed testing stands as well as the methodology of the static characteristics test enable to quickly and correctly determine the static characteristics with acceptable precision and repeatability of the achieved measurements results.
- The determined static characteristics of the torsionally flexible coupling are linear with damping of linear correlation coefficient r = 0,98.
- The position and slope of the static characteristics and values of the torsional rigidity and damping coefficients are strictly linked with the application of the disc springs sets in the coupling, the more rigid the springs the greater torsional rigidity of the coupling and the lower the damping coefficient.
- The coupling characteristics can be shaped by the proper choice of disc springs sets, though one has to take into consideration the condition of the proper performance of the spring i.e. up to 75% of its maximum strain.
- The torsionally flexible metal coupling enables to obtain significant angles of the relative angular displacement of the elements even up to a few hundred degrees; the obtained angles are determined by the applied sets of disc springs.

The presented conclusions clearly indicate the advantageous features of the presented constructive solution of the flexible coupling. None of the mechanical couplings which have been used so far in road, building and mining machinery has the above characteristics and the static characteristics as those mentioned above. Classic flexible couplings enable to obtain angles of mutual torsion only up to a few degrees, in most cases with difficult to describe nonlinear characteristics.

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