ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2013
Seria: TRANSPORT z. 81 Nr kol. 1896

Jaroslav HOMIŠIN[1], Pavol ČOPAN[2], Matej URBANSKÝ[3]

EXPERIMENTAL DETERMINATION OF CHARACTERISTIC PROPERTIES OF SELECTED TYPES OF FLEXIBLE SHAFT COUPLINGS

Summary. The introductory chapter of submitted article deals with a description of two selected flexible shaft couplings, specifically with Hardy flexible coupling and pneumatic flexible coupling *4–2/70–T–C*. However, considerable attention is devoted to experimental measurements in order to obtain the desired properties of these couplings - static and dynamic properties.

Key words. Hardy coupling, pneumatic flexible shaft coupling, static torsional stiffness, dynamic torsional stiffness, coefficient of viscous damping.

DOŚWIADCZALNE WYZNACZANIE CHARAKTERYSTYCZNYCH WŁAŚCIWOŚCI WYBRANYCH RODZAJÓW SPRZĘGIEŁ PODATNYCH

Streszczenie. We wprowadzeniu zawartym w niniejszym artykule przedstawiono charakterystyki dwóch wybranych sprzęgieł podatnych, a dokładnie podatnego sprzęgła Hardy i pneumatycznego sprzęgła podatnego oznaczonego symbolem 4–2/70–T–C. Jednak szczególną uwagę poświęcono badaniom doświadczalnym zorientowanym na uzyskanie pożądanych właściwości sprzęgieł – statycznych i dynamicznych właściwości.

Słowa kluczowe. Sprzęgło Hardy, pneumatyczne sprzęgło podatne, statyczna sztywność skrętna, dynamiczna sztywność skrętna, współczynnik tłumienia wiskotycznego.

1. INTRODUCTION

Mechanical systems, in which are important sources of excitation, such as the internal combustion piston engine, compressor, fan or similar device, is called the torsionally oscillating mechanical system (TOMS). Variable load torque of these machines causes under certain circumstances formation of torsional oscillation. This undesirable effect causes an increased dynamic mechanical stress of the mechanical system, which can result in mechanical failure of its individual parts. Due to the reduction of the effects of torsional

---

[1] Faculty of Mechanical Engineering, The Technical University of Košice, Košice, Slovak Republic, e-mail: jaroslav.homisin@tuke.sk
[2] Faculty of Mechanical Engineering, The Technical University of Košice, Košice, Slovak Republic, e-mail: pavol.copan@tuke.sk
[3] Faculty of Mechanical Engineering, The Technical University of Košice, Košice, Slovak Republic, e-mail: matej.urbansky@tuke.sk

oscillation, we must properly tune the mechanical systems. Under appropriate tuning of the system we understand the appropriate adjustment of dynamic properties of a flexible shaft coupling (dynamic torsional stiffness and damping coefficient) to dynamics of mechanical systems.

On this basis, the main objective of the present article will be determination and processing of the results of experimental measurements on two flexible shaft couplings and their mutual comparison. Specifically, it will be a flexible shaft coupling Hardy and pneumatic flexible shaft coupling with the type designation *4–2/70–T–C* developed by us [6].

2. BRIEF DESCRIPTION OF EXPERIMENTALLY MEASURED FLEXIBLE SHAFT COUPLINGS

Fig. 1a shows a commonly used flexible shaft coupling Hardy, whose elastic element between the driving and driven flange is presented by whole-rubber disc. On the other hand, an elastic element of pneumatic coupling (*fig. 1b*) being developed by us is its compression space filled with a gaseous medium. Compression space consists of four around the perimeter tangentially spaced and interconnected dual-bellows springs. During the working load two opposite springs are stretched while the other two ones are pressed, which allows transfer of load torque in both senses of rotation.

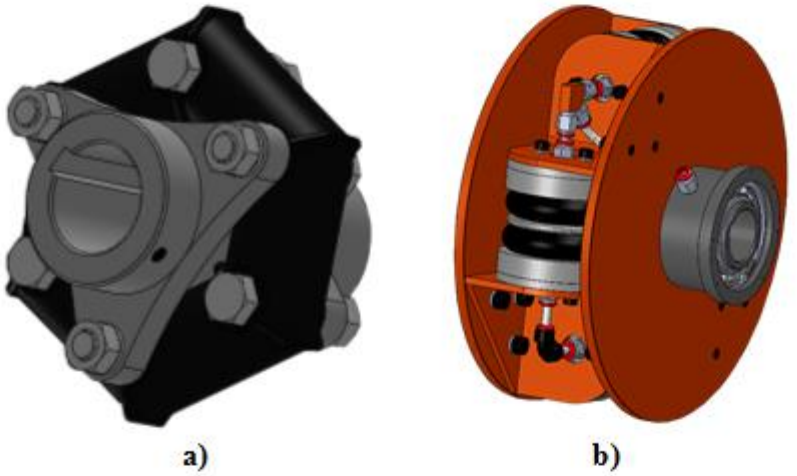
a) b)

Fig. 1. Flexible shaft couplings: a) Hardy coupling, b) pneumatic coupling of type 4–2/70–T–C
Rys. 1.Sprzęgła podatne: a) sprzęgło Hardy, b) sprzęgło pneumatyczne typu 4–2/70–T–C

3. STATIC PROPERTIES OF FLEXIBLE SHAFT COUPLINGS

To the group of characteristics of couplings we include static operating characteristics with which we can accurately define the selected type of flexible couplings, because they offer a comprehensive view of the issue, and the following properties are mostly derived from them. They are detected by static method of measurement, i.e. by method in which the coupling does not rotate, respectively does not oscillate, but is loaded only with static torque. The group of static properties includes:

- static characteristic of coupling,
- static torsional stiffness.

Static characteristic of clutch gives different ratios in flexible coupling and is defined as the dependence of the static torque M_{kstat} (constant at the time) on the mutual rotation of the two coupling discs φ. The following *fig. 2* shows the courses of static characteristics of the couplings constructed from experimentally measured values of the fifth load halfcycle, as provided *STN 01 1413*. The courses show that unlike Hardy coupling, static characteristics of pneumatic coupling have slightly nonlinear character, therefore we consider coupling as nonlinear. In the case of a merger of the both graphs, the course the static characteristics of Hardy coupling would almost coincide with the course of static characteristics of pneumatic coupling for the pressure of gaseous medium in the compression space $p_{pS}=500\ kPa$.

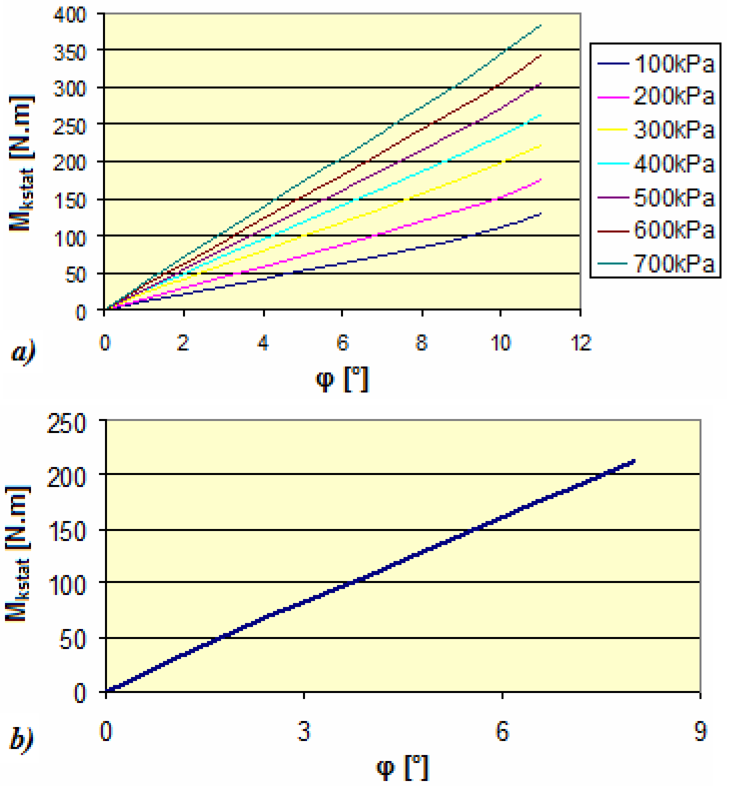

Fig. 2. Courses of static characteristics of flexible couplings: a) coupling 4–2/70–T–C, b) Hardy coupling

Rys. 2. Charakterystyki statyczne sprzęgieł podatnych: a) sprzęgło 4–2/70–T–C, b) sprzęgło Hardy

Those courses can also be described by equations of regression curves, which have the following form:

Hardy coupling:
$$M_{stat} = 0{,}0536\varphi^3 - 0{,}841\varphi^2 + 29{,}765\varphi, \tag{1}$$

coupling 4–2/70–T–C (at 500kPa):
$$M_{stat} = 0{,}0411\varphi^3 - 0{,}544\varphi^2 + 28{,}592\varphi. \tag{2}$$

The calculation of the static torsional stiffness k_{stat} is based on the the conditions of linearity of flexible couplings. Equations of their courses, depending on the angle of twist are obtained by differentiating of the equations of regression curves describing the static characteristics. They have the following quadratic form for those couplings:

Hardy coupling:
$$M_{stat} = 0{,}1608\varphi^2 - 1{,}682\varphi + 29{,}765, \tag{3}$$

coupling 4–2/70–T–C (at 500kPa):
$$M_{stat} = 0{,}1233\varphi^2 - 1{,}088\varphi + 28{,}592. \tag{4}$$

The following *fig. 3* shows the courses of the static torsional stiffness k_{stat} depending on the angle of mutual rotation of coupling discs φ, where we can observe their convex shape. While at Hardy coupling k_{stat} is in the range from $1454{,}5\text{-}1705{,}4\ N.m.rad^{-1}$, at the pneumatic coupling values are in the range from $557{,}9\text{-}2273{,}2\ N.m.rad^{-1}$.

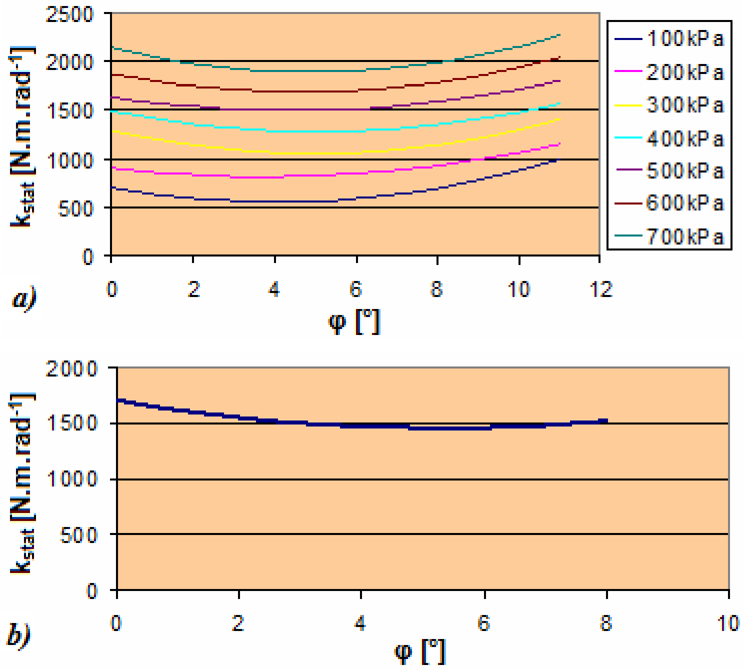

Fig. 3. Courses of k_{stat} of flexible couplings: a) coupling 4–2/70–T–C, b) Hardy coupling
Rys. 3. Charakterystyki k_{stat} sprzęgieł podatnych: a) sprzęgło 4–2/70–T–C, b) sprzęgło Hardy

After merging of the both graphs, the course k_{stat} of Hardy coupling would just copy the course of k_{stat} of pneumatic coupling again at the pressure *500 kPa*, what also corresponds to the derivative of equations of static characteristics.

4. DYNAMIC PROPERTIES OF FLEXIBLE SHAFT COUPLINGS

For dynamic calculations of flexible couplings it is necessary to establish their dynamic properties, which, like static properties belong to the group of operational properties. The term dynamic properties we can understand as the reaction of the coupling on speed and size of the twist due to influence of dynamic loading. They are detecting by dynamic measurement methods, in which clutch does not rotate, simulated is the only variable component of the torque in the form of oscillation [5]. But despite a stationary coupling, those measurements show results close to actual values. Among others, we include in this group:

- dynamic torsional stiffness,
- viscous damping coefficient.

The actual experimental measurement of dynamic properties was realized under the following conditions:

- measurement was made after evaluation of the results of static tests,
- measurement was performed by the method of free oscillation,
- measurements was carried out at four values of preloads M_n, that were determined experimentally with torque sensor,
- value of air pressure in the compression space of pneumatic coupling p_{pS} was changed in the range of *0-700 kPa*.

4.1. Results of dynamic tests

Dynamic torsional stiffness is defined as a result of rapid deformation of flexible coupling members, therefore we can record it only at the dynamic tests, namely by method of the free oscillation (used in this case) and by the method of oscillation with free mass on exit. The dynamic torsional stiffness k_{dyn} achieves at lower pressures of gas in compression space of pneumatic coupling relatively higher values than static torsional stiffness, while at the Hardy coupling values of k_{dyn} roughly coincide with the values of k_{stat}.

The following *fig. 4* shows the courses of the dynamic torsional stiffness of couplings, depending on the preload M_n, showing:

- at the pneumatic flexible coupling, courses are with increasing preload almost constant and values of k_{dyn} are in the range of $904,7\text{-}2235,9\ N.m.rad^{-1}$,
- the course of Hardy coupling has growing character, and values of k_{dyn} are in the range of $1268,1\text{-}1450,2\ N.m.rad^{-1}$.

In the case of a merger of the both graphs, the course of dynamic torsional stiffness of Hardy coupling would be somewhere among courses of k_{dyn} of pneumatic coupling corresponding values of gas pressure $p_{pS} = 300\text{-}400\ kPa$.

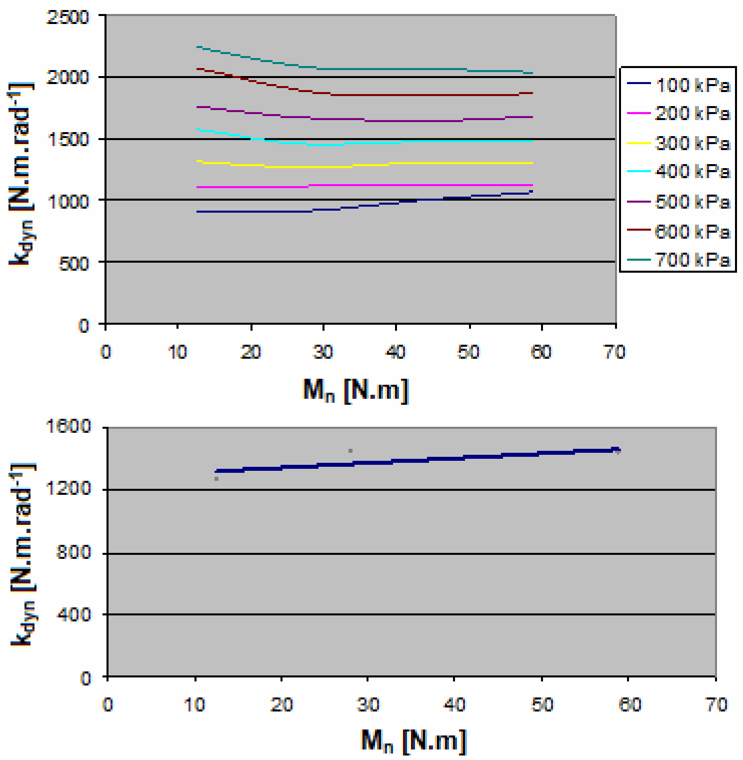

Fig. 4. Courses of k_{dyn} of flexible couplings: a) coupling 4–2/70–T–C, b) Hardy coupling
Rys. 4. Charakterystyki k_{dyn} sprzęgieł podatnych: a) sprzęgło 4–2/70–T–C, b) sprzęgło Hardy

Unlike courses of the dynamic torsional stiffness of couplings, courses of viscous damping coefficient b have descending - ascending character depending on preload in both cases (*fig. 5*). However, after the merger of both graphs, course of a viscous damping coefficient b of Hardy coupling would be far below the courses b of pneumatic coupling, because the values of b of Hardy coupling are in the range of $6,76\text{-}8,93\ N.m.s$, while the values b of pneumatic coupling are in the range $8,66\text{-}16,08 N.m.s$.

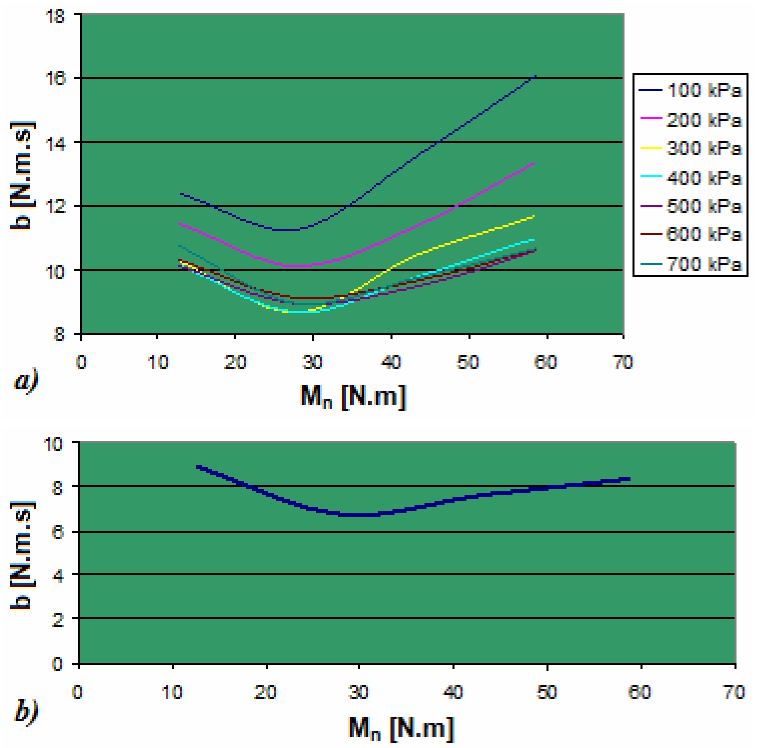

Fig. 5. Courses of b of flexible couplings: a) coupling 4–2/70–T–C, b) Hardy coupling
Rys. 5. Charakterystyki b sprzęgieł podatnych: a) sprzęgło 4–2/70–T–C, b) sprzęgło Hardy

5. CONCLUSION

The aim of the article has been, besides a brief summary of selected flexible couplings, to obtain their operational characteristics - static and dynamic properties based on experimental tests. The essence of these experimental measurements was to obtain a comprehensive overview of the conduct of the couplings during operation.

For experimental tests in the laboratory of our department we selected following two flexible shaft couplings - Hardy flexible coupling and its replacement in mobile stend of TOMS - pneumatic flexible coupling *4–2/70–T–C* of a new design. After processing and evaluation of measurement os results it can be stated that:

➢ the courses of static characteristics and static torsional stiffness k_{stat} of Hardy coupling are at the same measurement conditions almost identical with the courses of pneumatic coupling when the air pressure in the compression space is $p_{pS} = 500\ kPa$,

➢ the course of dynamic torsional stiffness k_{dyn} of Hardy coupling is somewheres among the courses of pneumatic coupling at the air pressure $p_{pS} = 300\text{-}400\ kPa$,

➢ the course of the viscous damping coefficient b of Hardy coupling is far under the courses of pneumatic coupling.

From the above it follows that the change of pressure of the gaseous medium in the compression space pneumatic coupling can also change its operating characteristics. This means that the pneumatic flexible coupling has a variety of static and dynamic properties, while Hardy flexible coupling has these characteristics constant.

Acknowledgements

This paper was written in the framework of Grant Project VEGA: „ 1/0688/12 – Research and application of universal regulation system in order to master the source of mechanical systems excitation”.

Bibliography

1. Čopan P.: Stanovenie charakteristických vlastností pružných spojok a ich vzájomná komparácia. Diplomová práca. Košice 2011.
2. Homišin J.: Nové typy pružných hriadeľových spojok. Vývoj – Výskum – Aplikácia. Košice 2002.
3. Homišin, J.: Vlastnosti pružných spojok. Strojárstvo, No. 11, 2000, p. 42.
4. Homišin, J., Grega R.: Vlastnosti pružných spojok - nevyhnutnosť ich poznania. Strojárstvo, No. 12/2000 – 1/2001, p. 64.
5. Krajňák J., Grega, R.: Comparison Of Various Gases And Their Influence On Dynamic Properties Of Flexible Pneumatic Coupling. Zeszyty Naukowe. Transport. Z. 76. Politechnika Śląska. Gliwice 2012. P. 31-36.
6. Krajňák J., Kaššay P. Grega R.: Advantage of high-flexible coupling 4–2/70–T–C application in comparison to the Periflex couplings. Transactions of the Universities of Košice. No. 3 (2009), p. 21-24.