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flexible couplings; rubber material; element temperature;
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INFLUENCE OF TEMPERATURE ON CHARACTERISTICS PROPERTIES OF FLEXIBLE COUPLING

Summary. The presented article deals with issue of characteristics changes of flexible shaft couplings used in drive systems of transport devices (dynamic torsional stiffness and damping coefficient) which is caused by influence of increase or decrease of flexible elements temperature. The influence is presented on a unit and percentage change of dynamic characteristics of four selected flexible couplings with rubber, plastic and pneumatic flexible elements. Identification of influence of flexible element temperature was done through experimental measurement on kinematic excitation device with free mass on the output.

WPŁYW TEMPERATURY ELEMENTU ELASTYCZNEGO NA WŁAŚCIWOŚCI CHARAKTERYSTYCZNE SPRZĘGIEŁ ELASTYCZNYCH

Streszczenie. Niniejszy artykuł jest poświęcony zagadnieniu zmiany właściwości charakterystycznych (dynamicznej sztywności skrętnej oraz współczynnika tłumienia) sprzęgieł elastycznych łączących wały, stosowanych w układach napędowych urządzeń transportowych, pod wpływem wzrostu lub obniżenia temperatury elementu elastycznego. Wpływ ten został przedstawiony na przykładzie zmian jednostkowej oraz procentowej właściwości dynamicznych czterech wybranych typów sprzęgieł elastycznych, łączących wały z gumowymi, plastikowymi oraz pneumatycznymi elementami elastycznymi. Określenie wpływu temperatury elementu elastycznego zostało przeprowadzone w formie pomiarów eksperymentalnych, wykonywanych na urządzeniu ze wzbudzaniem kinematycznym oraz swobodną masą początkową.

1. INTRODUCTION

Flexible couplings can significantly affect behaviour of transport device drive system through its operating characteristics. It is well-known fact in flexible shaft couplings issue [4]. However, it is important to note that in different operating conditions it is not guaranteed stability of these properties [5]. These properties affect a number of factors such as frequency, preload, amplitude, but also the impact with which few people contemplated, such as temperature element, effect of static torque or number of cycles. Instability of the operating characteristics of flexible couplings can in some cases cause detuning of mechanical systems, and associated increased stress on various parts of the mechanical system.

Most mechanical systems operate under the combined load, resulting in flexible coupling transmits simultaneously static and dynamic component of load torque. The dynamic stress of flexible couplings with flexible rubber elements occur just due to good damping capacity, thus converting mechanical energy into heat, the flexible heating elements. In addition to its low thermal conductivity there is sufficient heat dissipation inside the material. At high frequencies or large amplitudes can cause overheating of the element above the permissible value stated by the manufacturer. So the temperature increase of rubber element is simply a natural phenomenon associated with normal operation of such a flexible coupling. Therefore we decided to explore the influence of flexible element temperature on the characteristics of flexible couplings, and therefore clearly defined dependence of the dynamic torsional stiffness and damping coefficient of the flexible element temperature experimental measurements [3].

2. DESCRIPTION OF STUDIED FLEXIBLE COUPLINGS

For the purpose, identification of influence of flexible elements temperature on characteristics of flexible couplings, was chosen four followings very often used, flexible shaft couplings with identical nominal torsional moment M_N = 150 N.m (for pneumatic couplings at pressure 173 kPa), concretely:

- pin flexible shaft coupling B-flex RB 116-4 (producer RATHI) – fig. 1,
- tyre flexible shaft coupling Periflex® PNA 10R (producer STROMAG) – fig. 2,
- insert flexible shaft coupling Gurimax® GVW 100 (producer STROMAG) – fig. 3,
- pneumatic flexible shaft coupling of type 3-1/110-T-C (producer FENA – Poland) – fig. 4.

Fig. 1. Pin flexible coupling RB 116-4
Rys. 1. Trzpieniowe sprzęgło elastyczne RB 116-4

Fig. 2. Flexible coupling Periflex® PNA 10R
Rys. 2. Oponowe sprzęgło elastyczne Periflex® PNA 10R

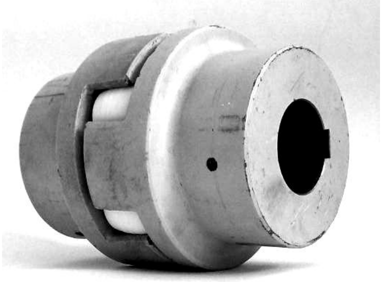


Fig. 3. Insert flexible coupling Gurimax® GVW100
Rys. 3. Zębate sprzęgło elastyczne Gurimax® GVW100

Fig. 4. Pneumatic flexible coupling 3-1/110-T-C
Rys. 4. Tangencjalne pneumatyczne sprzęgło elastyczne 3-1/110-T-C

3. DESCRIPTION OF DEVICE AND MEASURING METHOD

Identification of influence of flexible element temperature on characteristics of flexible shaft couplings was realized on kinematic excitation device with free mass on the output fig. 5. Flexible coupling is fixed between load swing arm with known mass moment of inertia and four-hinge mechanism, which is driven by electric motor [7]. When measuring the properties of flexible couplings are based on deviations in the primary (input) and secondary (output) arm, as well as their mutual phase shift. The procedure of measurements made at that device is described in detail in the literature [1].

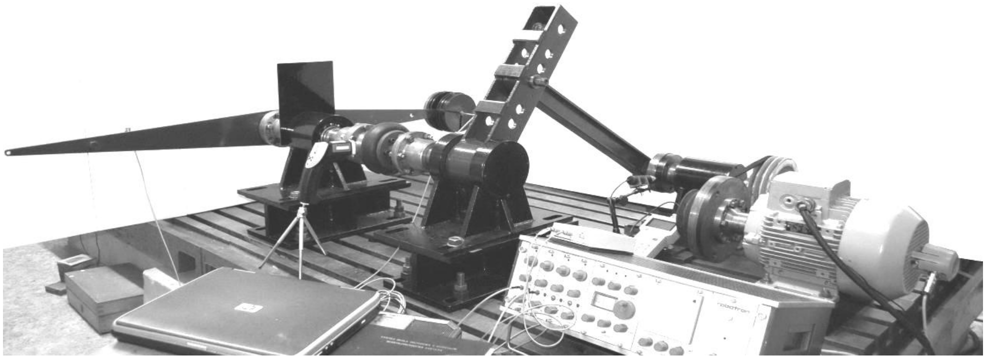


Fig. 5. Kinematic excitation device with free mass on the output
Rys. 5. Urządzenie z kinematycznym wzbudzaniem oraz swobodną masą początkową

Identification method of influence of flexible element temperature was determined as follows characteristics of all flexible couplings was detected at a frequency of 7 Hz, preload same nominal torsional moment M_N with adjusting the input amplitude to 1,25°.

4. RESULTS OF EXPERIMENTAL MEASUREMENT

Based on the experimental results by which increase of temperature in investigated flexible coupling was monitored, it is possible to claim that each of investigated flexible coupling remarked rapid growth of temperature fig. 6.

Seeing that increase of temperature was discovered in all investigated coupling we were interesting in how temperature will influence at dynamical attributes of these coupling.

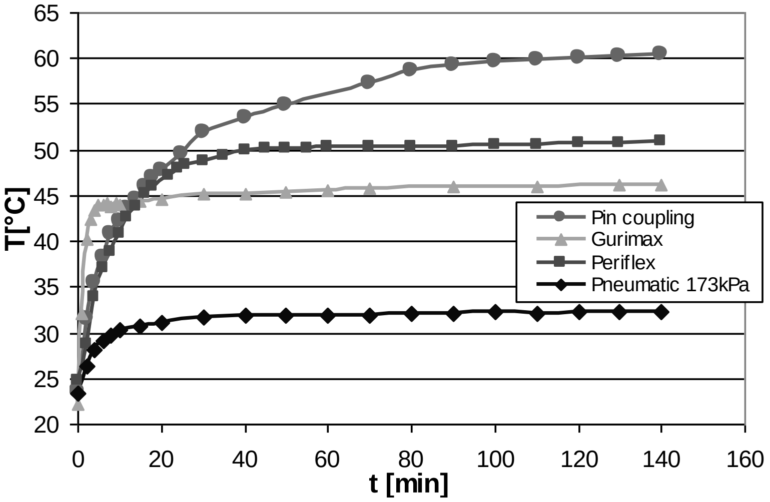
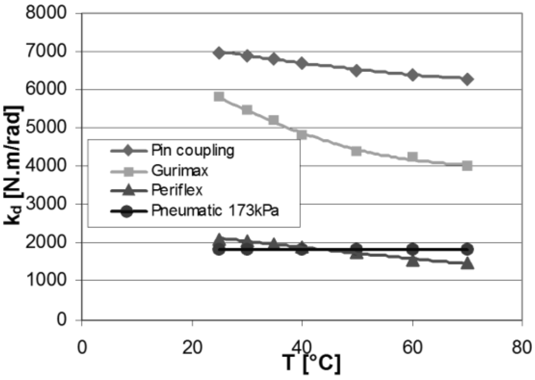


Fig. 6. Dependency temperature at the time loading
Rys. 6. Zależność temperatury elementu od czasu obciążenia

Measuring of dynamic torsional stiffness and damping coefficient was done at flexible element temperatures from 25°C to 70°C. Above this temperature, the elastic elements were not heated because it had temperature, which is generally given as a threshold to avoid a sudden deterioration of rubber material. Flexible couplings are heated primarily by oscillation at higher frequencies to ensure the heating elements of the whole volume. Where necessary, especially in pneumatic flexible couplings, in addition to all the closed coupling bag into which hot air is blown through a hole through the dryer. On the other site through another hole was control element temperature with non-contact thermometer [3].

After heating the flexible element to a temperature of 70°C was performed first measurement. Further measurements were performed during cooling flexible elements at 10°C then at 5°C, while the coupling is still maintained in working mode at lower frequencies.

Dependence expressing the influence of flexible element temperature on the dynamic torsional stiffness and damping coefficient is shown in fig. 7 and fig. 8. The fig. 9 and fig. 10 present unit change to further illustrate the changes of dynamic properties of flexible couplings. The fig. 11 and fig. 12 present percentage changes taking into account the initial torsional stiffness and damping coefficient [3].



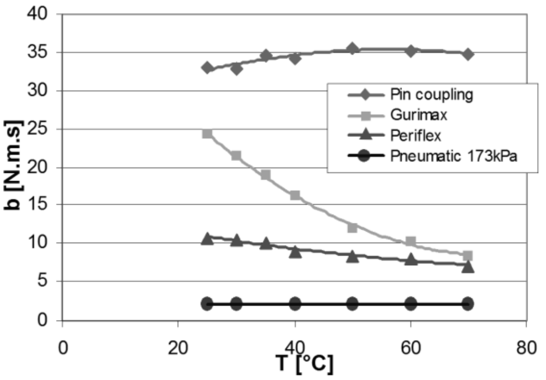
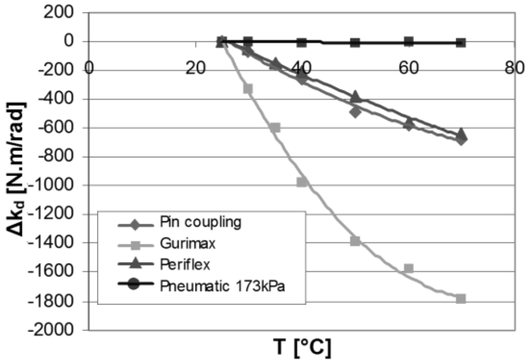


Fig. 7. Dynamic torsional stiffness – flexible element temperature dependence
Rys. 7. Zależność dynamicznej sztywności skrętnej od temperatury elementu elastycznego

Fig. 8. Damping coefficient – flexible element temperature dependence
Rys. 8. Zależność współczynnika tłumienia od temperatury elementu elastycznego



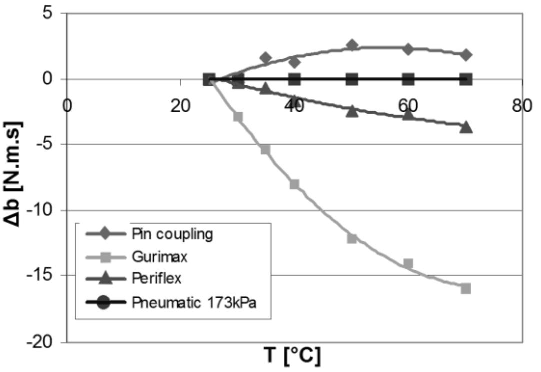


Fig. 9. Unit change of dynamic torsional stiffness depends on flexible element temperature
Rys. 9. Jednostkowa zmiana dynamicznej sztywności skrętnej w zależności od temperatury elementu

Fig. 10. Unit change of damping coefficient depends on flexible element temperature
Rys. 10. Jednostkowa zmiana współczynnika tłumienia w zależności od temperatury elementu

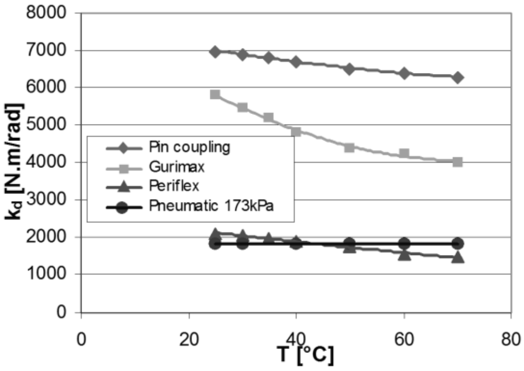


Fig. 11. Dynamic torsional stiffness – flexible element temperature dependence

Rys. 11. Procentowa zmiana dynamicznej sztywności skrętnej w zależności od temperatury elementu

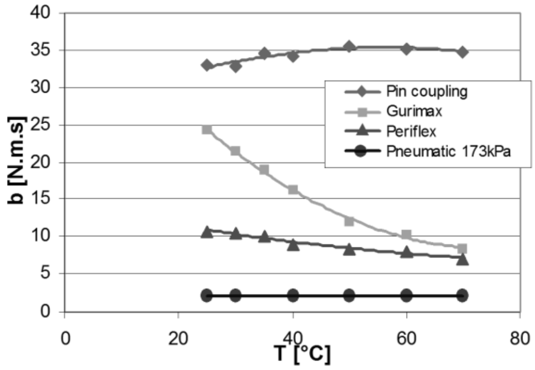


Fig. 12. Damping coefficient – flexible element temperature dependence

Rys.12. Procentowa zmiana współczynnika tłumienia w zależności od temperatury elementu

Already in theory, it is clear that the properties of rubber materials are temperature dependent. Based on this, the experimental measurements clearly confirmed this dependence to a significant change in the dynamic torsional stiffness and damping coefficient of the investigated flexible shaft couplings. Each flexible coupling, however, responds to the other rate of contributing factors. It depends both on the type of material used, the volume of material to be actively involved in the transmission of torque, but also on how is the burden of a flexible material.

Four rubber flexible elements barrel-shaped of pin coupling are exposed to pressure, while burdened with a pulsating cycle is still only half of each element. Although the volume of rubber material of flexible elements is less, it was reported negligible change in dynamic properties. Pin flexible coupling due to the increasing temperature of flexible elements softens, and dynamic torsional stiffness decreased by nearly 10%. Paradoxically, damping coefficient of this coupling increased by more than 5%.

Selected type of insert flexible coupling has polyurethane flexible element in the shape of the toothed ring with six evenly spaced teeth around the circumference of circular shape. Teeth trio is always in gear by action of the torque. Trinity is loaded with pressure, while another trio is relieved. At the moment of transfer, each loaded tooth involved in the full volume.

Insert flexible coupling experienced the most significant change in dynamic properties of all tested flexible couplings and in percentage terms this represents a 30% decrease in dynamic torsional stiffness and more than 60% decrease in damping factor!

Element of Periflex flexible coupling is made of rubber and is loaded by shear stress. To transfer torque has the proportion of flexible element in almost the whole volume. Since the largest rubber volume was confirmed by a significant influence of flexible element temperature on characteristics and accounted for 30% change in both the dynamic properties.

Influence of pneumatic flexible element temperature is reflected in its rubber-cord packing, as well as the gaseous medium in which it is located. While rubber cord cover the impact of rising temperatures becomes more flexible and reduces the torsional stiffness of the flexible coupling, while the gaseous medium increases with increasing temperature its pressure, thereby increasing the torsional stiffness of flexible coupling. This fact provides for pneumatic flexible coupling at surveyed pressure 173 kPa perfect stability dynamic torsional stiffness as well as damping coefficient. In general we can say that the influence of flexible element temperature for pneumatic flexible coupling showed absolutely negligible in all studied flexible couplings.

Overview of unit and percentage changes in dynamic torsional stiffness and damping coefficient of the flexible element temperature change from 25°C to 70°C is shown in tab. 1.

Table 1
Dynamic properties changes by element temperature influence

Flexible coupling	**Δk**		**Δb**	
	unit change [N.m/rad]	**percentage change [%]**	**unit change [N.m.s]**	**percentage change [%]**
Pin coupling	- 683,6	- 9,8	- 1,82	+ 5,5
Insert coupling	- 1784,0	- 30,8	- 15,9	- 65,6
Periflex	- 639,3	- 30,5	- 3,65	- 34,1
Pneumatic 173kPa	- 11,2	- 0,6	- 0,01	- 0,6

The course of temperature dependence of flexible elements in all flexible coupling is within the specified range of temperatures usually quasi-linear, respectively slightly nonlinear. It is therefore possible to describe the dependence of simple quadratic equations. . The equation of dynamic torsional stiffness and damping coefficient depending on the temperature of the element are listed in tab. 2.

Table 2
Equals for dynamic torsional stiffness and damping coefficient depends on temperature

	Dynamic torsional stiffness k_d [N.m/rad]	**Damping coefficient b [N.m.s]**
Pin coupling	$k_d = 0,1488.T^2 - 30,069.T + 7656,1$	$b = -0,0028.T^2 + 0,3121.T + 26,577$
Insert coupling	$k_d = 0,7647.T^2 - 112,03.T + 8123,5$	$b = 0,0063.T^2 - 0,9484.T + 44,153$
Periflex	$k_d = 0,0517.T^2 - 19,964.T + 2582$	$b = 0,0008.T^2 - 0,1548.T + 14,217$
Pneum. 173kPa	$k_d = 0,0027.T^2 - 0,4083.T + 1817,5$	$b = 3.10^{-6}.T^2 - 0,0004.T + 2,0857$

5. CONCLUSION

If we think in terms of the dynamics of the flexible coupling to critical tuners the drive systems of transport devices for us is the value of torsional stiffness, but also damping coefficient, very important. These parameters, however, in the most flexible couplings with rubber or plastic material does not guarantee stability and vary depending on the number of operational factors. It is important to know how to influence all these factors on the critical parameters of flexible couplings to get them in the design of flexible coupling are taken into account [6]. One of the most important factors is the influence of flexible element temperature

This effect is manifested mainly in the coupling with a larger rubber volume, which actively participates in the transmission of torque. Therefore, this influence is very much reflected by the flexible coupling Periflex, which has the largest proportion of rubber material to transfer torque. But even more, the effect of element temperature led to the insert flexible coupling, since the flexible element is made of plastic. In this respect, the greatest stability characteristics at different temperatures flexible elements ensure pneumatic flexible shaft couplings, since it occurs in the rubber-cord carton and the gaseous medium at a mutually opposite influence of temperature effect.

Bibliography

1. Gurský P.: *Metodika identifikácie vlastností pružných spojok pre zariadenie s kinematickým budením.* In: Novus Scientia 2009: 11. celoštátna konferencia doktorandov Strojníckych fakúlt technických univerzít a vysokých škôl: 25.11.2009 Košice SjF TU, Košice 2009, s. 302–306.

2. Gurský P., Krajňák J., Neupauer P., Kardoš F.: *Vplyv pôsobenia statickej zložky záťažového krútiaceho momentu na charakteristické vlastnosti pružných spojok.* In: 51. Medzinárodná vedecká konferencia katedier častí a mechanizmov strojov zborník referátov: 08.-10.9.2010, Košice-Slovenský Raj, Košice 2010, s. 49–54.
3. Homišin J.: *Nové typy pružných hriadeľových spojok*. Vývoj-Výskum-Aplikácia. Košice, Vienala 2002.
4. Homišin J., Gurský P.: *Significant Advantages of Flexible Couplings with Pneumatic-Flexible Elements*. Pneumatyka, Vol. 77, No. 4, Poland 2010, p. 24–28.
5. Zoul V.: *Dynamické vlastnosti pružných spojek a způsoby ich zišťování*. VS, 673.09, VÚML, ČKD, Praha 1970.
6. Kaššay P., Grega R., Krajňák J.: *Determination of objective function for extremal control of torsional oscillating mechanical system*. Transactions of the Universities of Košice, č. 3 (2009), s. 17–20.
7. Homišin, J., Kaššay, P.*: Comparison of Tuning in Shipping System Using pneumatic Tuners of Torsional Oscillations*. Machine Modeling and Simulation, Scientific and Technical Society at the University of Žilina, Žilina 2009, s. 147–154.
8. Kaššay, P., Homišin, J.: *Extremal control in torsional oscillating mechanical systems*. Machine Modeling and Simulation, Scientific and Technical Society at the University of Žilina, Žilina 2009, s.155–160.
9. Kaššay P., Gurský P., Urbanský M., Neupauer P.: *Úvod do problematiky prechodových dejov v torzne mechanických sústavách.* Košice, Slovenský raj. 51. MVK KČSaM, 2010, s. 119–124.
10. Pešík L., Vančura M.: *Additional Air Volume Impact on Characteristics of Pneumatic Spring-*Support of Driver's Seat. 49th International Conference of Machine Elements and Mechanisms Department. Západočeská univerzita v Plzni, Plzeň 2008, s. 219–222.
11. Pešík L., Vančura M.: *Adaptable Spring Support of Driver's Seat*. Acta Mechanica Slovaca. 4-A/2007. Technická univerzita v Košiciach, Košice, Slovensko 2007, s. 165–172.

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