

Jaroslav HOMIŠIN¹

PATENT ACTIVITY IN THE AREA OF PNEUMATIC COUPLINGS DEVELOPMENT AND THEIR APPLICATION IN MECHANICAL SYSTEMS

Summary. Mechanical systems with combustion engines, compressors, pumps and fans, can be characterized as torsionally oscillating mechanical system (TOMS).

It is therefore necessary to control their dangerous torsional vibrations. It was confirmed that dangerous torsional vibration can be reduced to acceptable level by an appropriate adjustment, respectively by tuning the TOMS. According to several authors, the most appropriate way of system tuning is application of suitable flexible element, which is flexible shaft coupling. It turned out that one of the types of shaft couplings, which are particularly suited to meeting this objective are pneumatic flexible shaft couplings, to act as so-called pneumatic tuners of torsional oscillations. The issue of research and development of pneumatic tuners of torsional oscillations, among other things is, long-term in the focus of the author. The existence of tuners creates the opportunity to develop new ways of tuning torsionally oscillating mechanical systems. The aim of article will highlight the author's patent activity in the development of pneumatic tuners of torsional oscillations and their applications in torsionally oscillating mechanical systems.

Key words: pneumatic tuner of torsional oscillation, torsionally oscillating mechanical system (TOMS), new ways of tuning torsionally oscillating mechanical systems.

DZIAŁALNOŚĆ PATENTOWA W DZIEDZINIE KONSTRUKCJI SPRZĘGIEŁ PNEUMATYCZNYCH ORAZ ICH ZASTOSOWANIA W UKŁADACH MECHANICZNYCH

Streszczenie. Układy mechaniczne z silnikami spalinowymi, sprężarkami, pompami i wentylatorami można określić jako układy mechaniczne drgające skrętnie (UMDS). Z tego powodu konieczne jest opanowanie ich niebezpiecznego drgania skrętnego. Zostało potwierdzone, że niebezpieczne drganie skrętnie można zmniejszyć do dopuszczalnego stopnia przez odpowiednią zmianę, czyli dostrojenie UMDS. Według wielu autorów najlepszym sposobem dostrojenia układu jest zastosowanie odpowiedniego elementu elastycznego, za który uważane jest sprzęgło elastyczne łączące wały. Okazało się, że jednym z typów sprzęgieł łączących wały, które są szczególnie wskazane do osiągnięcia tego celu, są pneumatyczne sprzęgła elastyczne łączące wały, które pełnią funkcję tzw. tłumików drgań skrętnych. Problematyka rozwoju i badań pneumatycznych tłumików drgań skrętnych, oprócz innych zagadnień, od wielu lat znajduje się w centrum zainteresowań autora. Istnienie tłumików stwarza możliwość

¹ Department of Machine Parts of Mechanismus, Faculty of Engineering, Technical University Košice, Letná 9, 040 01 Košice, e-mail: Jaroslav.Homisin@tuke.sk

stosowania nowych sposobów strojenia układów mechanicznych drgających skrętnie. Celem niniejszego artykułu jest przedstawienie działalności patentowej autora w dziedzinie konstruowania pneumatycznych tłumików drgań skrętnych oraz ich zastosowania w układach mechanicznych drgających skrętnie.

Słowa kluczowe: pneumatyczne tłumiki drgań skrętnych, układ mechaniczny drgający skrętnie (UMDS), nowe sposoby strojenia układów mechanicznych drgających skrętnie.

1. INTRODUCTION

Dangerous torsional vibration has a profound impact on the life and function of most members of any mechanical system. Therefore applies the need to control dangerous torsional vibration. Currently, this problem is implemented by applying flexible shaft couplings.

It turned out that one of the types of shaft couplings, which are particularly suited to meeting this objective are pneumatic flexible shaft couplings, to act as the so called. pneumatic tuners of torsional oscillation.

The issue of research and development of pneumatic tuners of torsional oscillations, among other things is, long-term in the focus of the author. In the field of scientific research, the authors addition is the issue of proper design of new types of flexible shaft couplings, pneumatic flexible shaft couplings, he focuses also on exploring basic properties of developed pneumatic couplings. Particularly focuses on the application of the couplings in different types of torsionally oscillating mechanical systems with the objective of the optimal tuning, thus optimizing them for the achievement of minimum values of dangerous torsional vibration, or its removal. The existence of pneumatic couplings creates the opportunity to develop new ways of tuning of torsionally oscillating mechanical systems.

Developed construction of new types of flexible shaft couplings², as well as their application in mechanical systems for optimal tuning of the systems³ based on new ways of tuning resulting from claims of granted patents and utility models.

The aim of the presented article is to highlight the author's patent activity in the development of pneumatic couplings, thus pneumatic tuners of torsional oscillations and their applications in torsionally oscillating mechanical systems.

2. CHARACTERISTICS OF THE PNEUMATIC TUNERS OF TORSIONAL OSCILLATION

In the area of research and development of pneumatic couplings, thus pneumatic tuners is currently paid attention to:

- differential pneumatic flexible shaft couplings (Fig. 1) and
- differential pneumatic flexible shaft coupling with autoregulation (Fig. 2).

Differential pneumatic coupling (Fig. 1) consists of driving part (1), driven part (2), between them there is located the compression space filled with gaseous medium (air in our case). Compression space consists of three circumferentially spaced and interconnected diffe-

² [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29].

³ [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46].

rential elements. Each differential element consists of compressed and (3) and expanded pneumatic-flexible element (4).

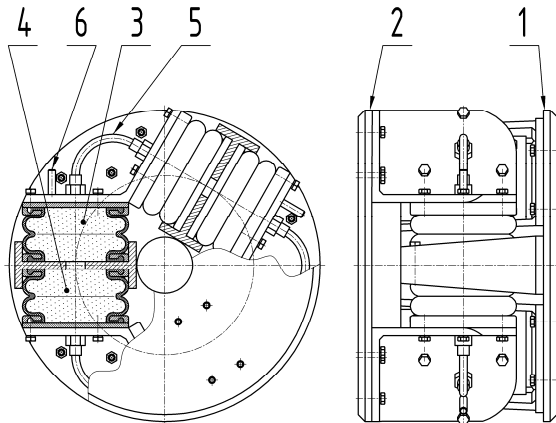


Fig. 1. Differential pneumatic flexible shaft coupling

Rys. 1. Pneumatyczne różniczkowe sprzęgło elastyczne łączące wały

Interconnection of differential elements is provided by interconnecting hoses (5). Through the valve (6), the filling of compression space of coupling, thereby changing the pressure p gas media in it. Varying pressure will ensure the fact that the coupling always works with different characteristics (Fig. 2), which is defined by the formula (1).

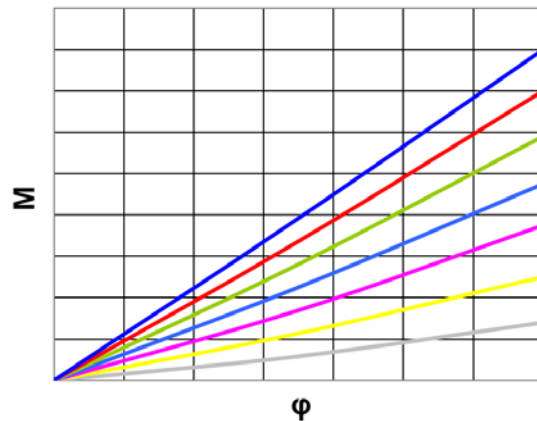


Fig. 2. Courses of static characteristics of differential pneumatic coupling a, b, c, d, e, f, g shown in the general version belong to pressure of gaseous medium at $p = 100 \div 700 \text{ kPa}$ with 100 kPa

Rys. 2. Przebiegi charakterystyk statycznych pneumatycznego sprzęgła różniczkowego a, b, c, d, e, f, g przedstawione w wykonaniu ogólnym odpowiadają wartościom ciśnienia medium gazowego w zakresie od $p = 100 \div 700 \text{ kPa}$ do 100 kPa

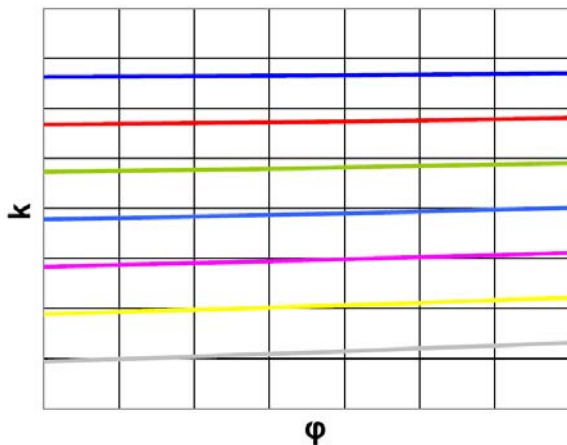


Fig. 3. Courses of torsional stiffness k of differential pneumatic coupling a, b, c, d, e, f, g shown in the general version belong to pressure of gaseous medium at $p = 100 \div 700 \text{ kPa}$ with 100 kPa

Rys. 3. Przebiegi sztywności skrętniej k pneumatycznego sprzęgła różniczkowego a, b, c, d, e, f, g odpowiadają wartościom ciśnienia medium gazowego w zakresie od $p = 100 \div 700 \text{ kPa}$ do 100 kPa

To another characteristic always belong other characteristic properties, thus still different torsional stiffness and damping coefficient. Therefore, each pneumatic coupling depending on the pressure is always defined by another course of torsional stiffness to Fig. 3, as described by the formula (2).

$$M = a_0 \cdot \varphi + a_3 \cdot \varphi^3, \quad (1)$$

$$k = a_0 + \frac{3}{4} a_3 \cdot \varphi^2. \quad (2)$$

where: φ – twist angle of coupling,
 a_0, a_3 – constants of coupling characteristics.

Torsional stiffness, as the main component in the field of mechanical system tuning has a decisive influence on the natural frequency of the system

$$\Omega_0 = \sqrt{k / I_{red}}, \quad (3)$$

where: I_{red} – reduced mass moment of inertia of mechanical system.

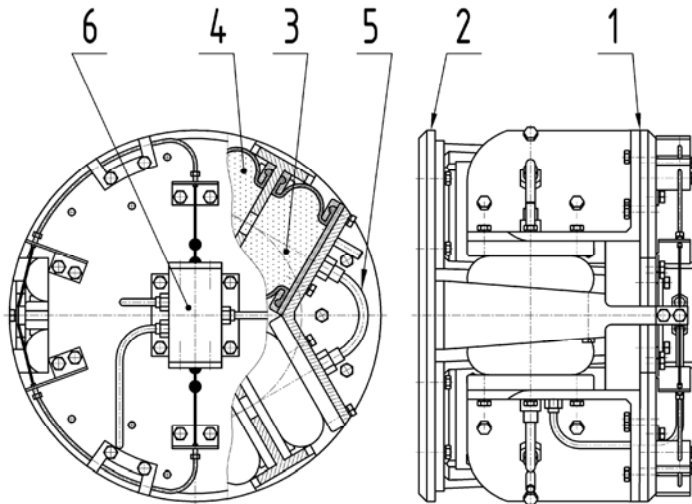


Fig. 4. Pneumatic tuner of torsional vibration
Rys. 4. Pneumatyczny tłumik drgań skrętnych

Pneumatic tuner of torsional vibrations (fig. 4), which basic principle results from the patent claims [31], [36] is compared with the differential pneumatic coupling on common structural base. The main difference is that it does not have valve, but the controller (6) to ensure a constant twist angle of coupling φ_k . The basic principle of tuner is the ability to auto-regulate twist angle due to current load change of torque on a predetermined constant angular value φ_k . This will ensure auto-regulation of gaseous media pressure in the compression space of tuner, thus adapting it to the current value of load torque.

3. PROPOSED WAYS OF CONTROLLING TORSIONAL VIBRATIONS OF MECHANICAL SYSTEMS

Change of torsional stiffness of pneumatic couplings can be realized by changing the pressure of gaseous media, out of operation (Fig. 3) or during operation (Fig. 5) of mechanical systems. This leads to two proposed ways to control torsional vibration of mechanical systems [4]:

- controlling the torsional vibration of mechanical systems out of operation, ensuring the so called tuning of the system [2], [16], [31], [39], [40],
- controlling the torsional vibration of mechanical systems during operation, ensuring the so called continuous tuning of the system [31], [33], [36], [39].

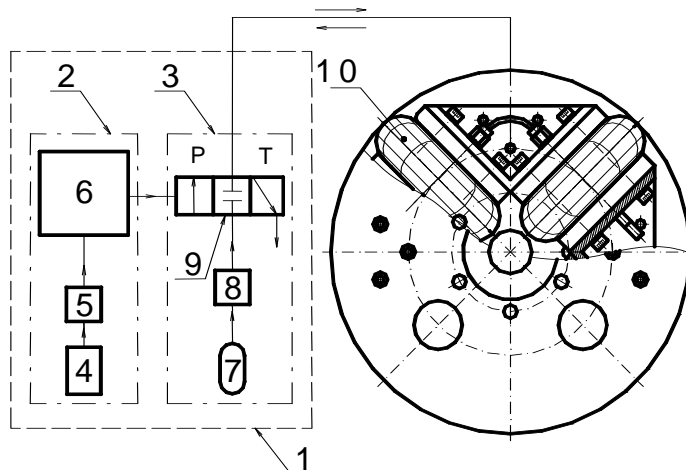


Fig. 5. A schematic representation of regulation the continuous tuning of mechanical system using a regulatory system

Rys. 5. Schematyczne przedstawienie regulacji płynnego strojenia układu mechanicznego za pomocą systemu regulacji

Under *tuning the torsionally oscillating mechanical system* coupling we mean inflating of compression space of coupling to a suitable value of the pressure of gaseous medium out of service of the system. Appropriate value of pressure of gaseous medium, and hence the appropriate value of dynamic torsional stiffness of coupling established on the basis of previously implemented dynamic calculation of the system in terms of its torsional dynamics. With such inflated pneumatic coupling will mechanical system work throughout its operations.

The essence of *continuous tuning of torsional vibration of the*

system during its operation at steady state by the application of pneumatic tuner of torsional oscillation [2], [3] shows the adaptability of the basic dynamic properties to the system dynamics, particularly the dynamic torsional stiffness.

Based on the nature of the patent [6] follows that the system must contain pneumatic tuner of torsional oscillation controlled by a regulatory system [10] – (Fig. 5).

Result of the regulatory system activity lies in the fact that due to the continuous change of the pressure of the gaseous medium in the pneumatic tuners are taken to changes its basic dynamic properties - dynamic torsional stiffness. By changing the dynamic torsional stiffness varies the natural frequency of the system, thus adapting to the frequency of i -th harmonic component of load torque so that the system is in the range of operating mode does not work in resonance with any harmonic excitation torque, thus applies the condition $\Omega_0 \neq i\omega$.

4. CONCLUSION

Based on presented results we can say that negative impact of dangerous torsional vibration is possible to reduce by application of classical flexible couplings. On this occasion it is necessary to note, that each linear or nonlinear presently used flexible coupling has only one characteristic. The change of flexible coupling characteristics, due to appropriate adaptation of its dynamic properties to the dynamic of the system, means to use a different element of flexible coupling or using a different flexible shaft coupling. In any case, it is not possible to forget the fatigue and aging of flexible materials, which finally have a major impact on the initial dynamic properties. Thus the unsteadiness of flexible coupling dynamic properties caused by aging and fatigue of their flexible elements and as well as the frequent failure rate of some other elements of the system causes the detuning of tuned torsionally oscillating mechanical system. In this case its tuning element, the flexible coupling, has no possibility to remove or reduce the increasing dangerous torsional vibration.

Taking into account the given facts we propose to use the pneumatic flexible shaft couplings developed by us in order to reduce dangerous torsional vibration by optimal tuning or rather optimal continuous tuning of torsionally oscillating mechanical systems. Based on the presented results it is possible to say that presented differential pneumatic coupling, as well as the pneumatic tuner of torsional vibration fulfill all the requirements for their application in torsionally oscillating mechanical systems. Based on the detailed analysis of realized mechanical system we can say that linear pneumatic couplings are especially suitable for mechanical systems operating with constant operating speed. On the other hand, pneumatic tuners of torsional vibrations will fulfill all the requirements of mechanical systems with a range of operating speeds.

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