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Wedge pneumatic flexible shaft coupling suitable for mechanical power transmission

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Abstract At our Department we deal with the development of pneumatic flexible shaft couplings intended for mechanical power transmission. These new types of shaft couplings in addition to other flexible couplings are able to change their torsional stiffness by adjusting the air pressure in their flexible elements. Pneumatic flexible shaft coupling with wedge elements was developed to improve the properties of pneumatic flexible couplings, especially the nominal and maximal torque and maximum twist angle. The goal of this article is to present the static properties of this newly developed type of flexible shaft couplings. Due to the reason that flexible pneumatic coupling with wedge elements isn't manufactured yet, we used a mathematic model of this coupling

Keywords air spring, mathematical model, pneumatic flexible shaft couplings, static load characteristics, static torsional stiffness wedge pneumatic elements.

1. INTRODUCTION

Previously known flexible shaft couplings are manufactured with metal, rubber or plastic flexible elements. The most widely used flexible couplings in engineering are flexible shaft couplings with rubber flexible elements. In addition that they compensate radial or axial displacement, they are characterized by a non-linear Coupling torque transmission characteristics. There are also known their initial dynamic properties, i.e. dynamic torsional stiffness and damping coefficient. Durability and hence the life-time of rubber flexible element is closely connected with the heating of the coupling and hence the heating of its flexible elements. Permanent heat causes progressive fatigue of flexible elements. With fatigue rubber materials lose its original dynamic properties. In this case, positive non-linear characteristics of the original shaft coupling changes to (unknown) characteristics with completely different dynamic properties. Consequently, the currently used flexible shaft couplings are losing their basic mission – appropriate tuning of mechanical systems ensuring the flexible load transfer torque in these systems [1-49]. The above disadvantages of the current flexible shaft couplings are removed and the requirement demanded for new types of couplings are fulfilled with pneumatic flexible shaft couplings with wedge flexible elements, namely pneumatic tuner of torsional vibration with wedge flexible elements, developed at our department [19, 20].

Therefore, the aim of this paper is to inform the technical community with the design, work principle and theoretically determined fundamental characteristics of pneumatic torsional vibration tuner with wedge flexible elements developed by us.

2. DESIGN, BASIC NATURE AND OPERATING PRINCIPLES OF DEVELOPED PNEUMATIC TORSIONAL VIBRATION TUNER WITH WEDGE FLEXIBLE ELEMENTS

Pneumatic torsional oscillations tuner with wedge elastic elements (*fig. 1*) consists of driving hub *(1)* and driven hub *(2)* with the supporting surface *(3)* and *(4)*, among which are air-spring units. Each pneumatic flexible unit comprises of two flexible elements, namely a compressed flexible wedge element *(5)* and also extended wedge flexible element *(6)* Interconnection between wedge flexible elements *(5)* and *(6)* and thus between the compression spaces are provided by throttle openings *(7)*. If compression space of couplings is filled with gaseous medium through valve *(8)* to a predetermined pressure, this keeps the driving hub *(1)* against the driven hub *(2)* in the basic position. Transmitted oscillating load torque causes deflection of the driving body *(1)* against the driven body *(2)*. As a result, creates, as already mentioned, the compression of gaseous medium in compression chambers of wedge flexible elements *(5)* and *(6)* proportional to the load.

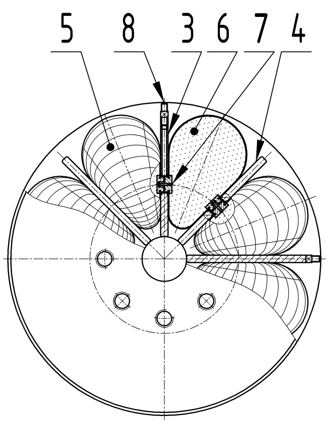

Fig. 1 Pneumatic tuner of torsional vibration with wedge flexible elements type *8 – 1/110 – T – C*

Simultaneously the oscillating component of the torque load causes pulsing of the gaseous medium in the compression chamber of coupling, which forces a flow of medium through interconnecting throttle openings *(7)* proportional to oscillation.

The basic nature of pneumatic tuner's design is that the loading torque is transferred from the driving hub to the driven hub by compression space, which consists of air-filled flexible pneumatic units [17, 18].

3. BASIC CHARACTERISTIC PROPERTIES OF PNEUMATIC TORSIONAL VIBRATION TUNER WITH WEDGE FLEXIBLE ELEMENTS

Since that this type of flexible tuner isn't currently manufactured, it was necessary to determine its basic characteristics theoretically based on a mathematical model. All dimensions necessary to calculate the static load characteristics are shown on *fig 2*.

For static load characteristics computations the following conditions were considered:

- volume of the interconnecting and filling lines are neglected, as well as reduction of the tire volume by the flange of element,
- we considered only the gas volume enclosed inside the tire of element,
- compression volumes of wedge elements are interconnected,
- neutral surface of the tire lies in the middle of the tire‘s thickness,
- the length of meridial fibres of neutral surface was considered constant [17],
- the contact surface between elements and hubs is planar,
- in the part where flexible elements do not touch the supporting surfaces, meridial fibres of neutral surface are circular arcs [17], touching the equidistants of supporting surfaces,
- wedge elements has been designed so that contact surface between hub and maximally stretched element forms a circle with a diameter of 30 mm,
- under static loading, the gas compresses and expands isothermally [17],
- equal absolute values of loading torque work and mechanical work of compressing air.

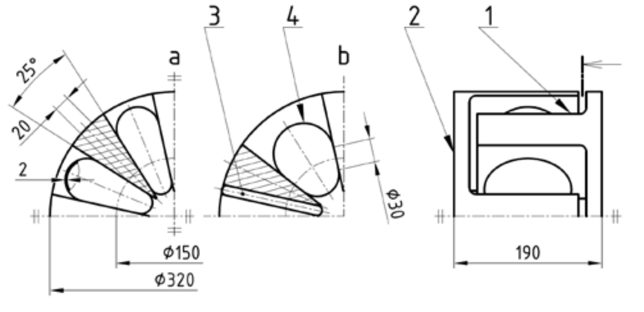

Fig. 2 Dimensions of pneumatic tuner of torsional vibration with wedge flexible elements type *8 – 1/110 – T – C* in neutral position (a) and by maximal distortion (b)

Static characteristics of designed pneumatic tuner evaluated from mathematical model is shown on *fig. 3*. The obtained results show that by changing the pressure of gaseous medium, the pneumatic tuner is capable to work with different static load characteristics, so it can work with different characteristic properties (torsional stiffness and damping coefficient).

From the static load characteristics, the nominal torque M_N and the maximum torque M_M of pneumatic tuner were identified (fig. 4), as well as the static torsional stiffness k_S depending on static load torque M_S (fig. 5) and on twist angle φ (fig. 6) for gaseous medium pressure p = 100 ÷ 7 00 kPa.

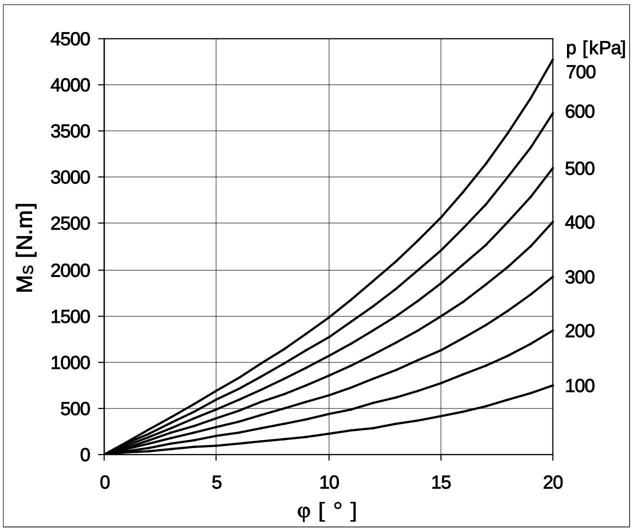

Fig. 3 Static load characteristics of pneumatic tuner for gaseous medium pressure range p = 100 ÷ 700 kPa

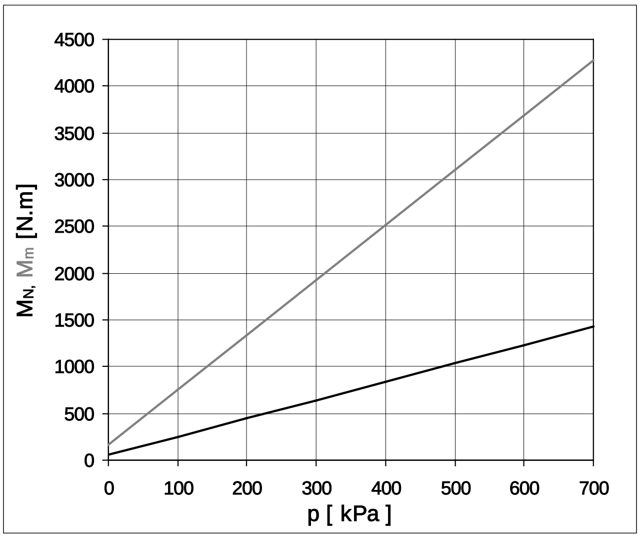

Fig. 4 Maximum torque M_{max} and nominal torque M_N of pneumatic tuner dependent on initial pressure of gaseous medium p

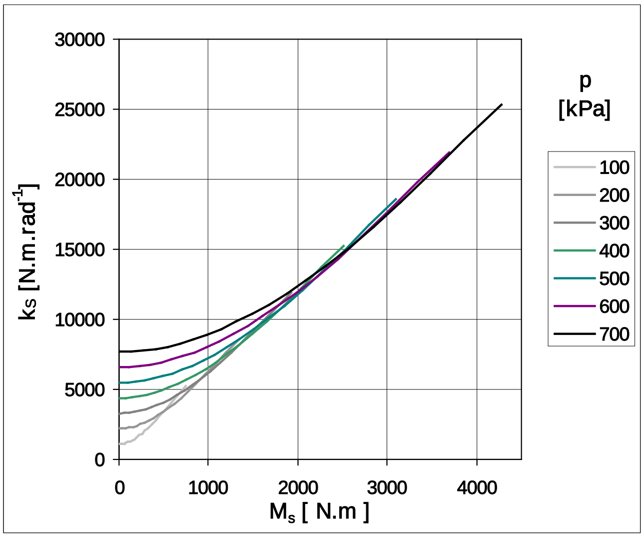

Fig. 5 Static torsional stiffness kS dependent on static torque MS for pneumatic tuner pressure range p = 100 ÷ 700 kPa

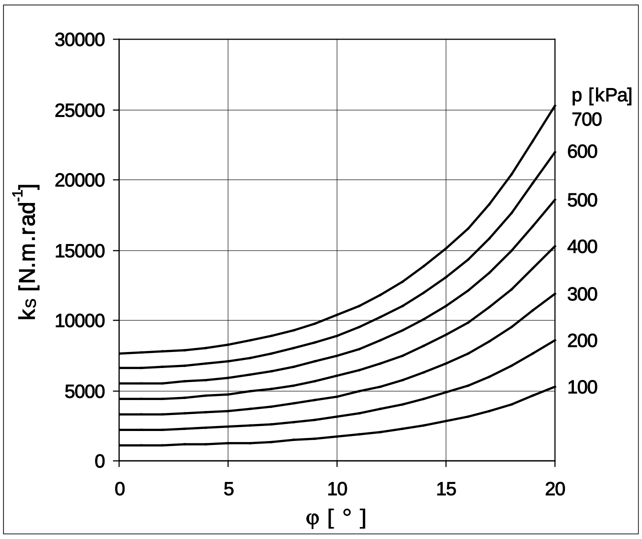

Fig. 6 Static torsional stiffness k_S dependent on static twist angle φ for pneumatic tuner pressure range p = 100 ÷ 700 kPa

4. CONCLUSION

With torque load transfer by pneumatic compression chamber of tuner filled with gaseous medium, we achieve compression of the medium proportional to load, by which is currently characterized the constant flexible load torque transmission in the system of driving and driven machine. Creating a throttle opening in the supporting surfaces between the compressing and simultaneously the expanding wedge flexible element, occurs the flow of gaseous medium characterized by a throttle work by oscillating torque load transmission. Throttle work arising from the flow of gaseous medium through throttle openings, is proportional to the damping work of pneumatic tuner.

The advantage of the solution is characterized by continuous flexible transmission of load torque with damping of torsional oscillations and torsional shocks in the system of driving and driven machine, and it is secured by the gaseous medium used as elastic material in the coupling. Gaseous media, throughout its lifetime isn’t subject to aging, resulting the pneumatic tuner doesn’t lose its initial positive dynamic properties, unlike the previously used flexible materials.

Another advantage of proposed solution is the application of wedge flexible elements, which allows the use of more flexible elements and simultaneously increase the utilization of space between the coupling hubs, compared to the previous design solutions. Increased number of flexible elements makes the pneumatic compression volume more flexible, what is presented by a relatively large twisting angle φ = 20 °, and also able to transfer approximately 3-times higher torque compared to other pneumatic flexible shaft couplings with similar external dimensions.

In conclusion, the design of the compression space of this air tuner ensures its inclusion to the category of highly flexible tuners, thus pneumatic tuners of torsional vibration with low torsional stiffness.

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