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EFFECT OF HELIUM ON MECHANICAL PROPERTIES OF FLEXIBLE PNEUMATIC COUPLING

Summary. The mechanical devices very often use flexible pneumatic couplings. These flexible couplings have positive attributes for the particular mechanical system and also protect it from damage. At our department, we are interested in that type of couplings, specifically in the flexible pneumatic couplings. The compressed gas is supplied into the couplings. We supply the gas while coupling is running and also in quiescent condition. Those couplings use gaseous medium, in this case air. The main objective of this article is the application of helium gas in the pneumatic flexible couplings and study the impact of these gases on the mechanical properties of pneumatic couplings.

WPŁYW HELU NA MECHANICZNE WŁAŚCIWOŚCI ELASTYCZNYCH SPRZĘGIEŁ PNEUMATYCZNYCH

Streszczenie. Mechaniczne urządzenia często posiadają elastyczne sprzęgła pneumatyczne. Takie elastyczne sprzęgła wpływają pozytywnie na dany system mechaniczny, a także chronią go przed uszkodzeniem. Nasz Wydział interesuje się typami sprzęgieł, szczególnie elastycznymi sprzęgłami pneumatycznymi. Do tychże sprzęgieł doprowadza się sprężony gaz. Dostarczamy gaz, kiedy sprzęgło działa, a także w stanie biernym. Takie sprzęgła używają czynnika gazowego, w tym wypadku powietrza. Głównym celem tego artykułu jest zastosowanie helu jako czynnika gazowego w pneumatycznych elastycznych sprzęgłach i badanie jego wpływu na mechaniczne właściwości pneumatycznych sprzęgieł.

1. INTRODUCTION

Nowadays, there are many issues relating to the environment, treatment of industrial waste, ecologization of production and products. These issues are closely related to the mechanical devices which reduce negative impact on environment as vibration, noise while preserving the individual parts of machinery from mechanical damage. The flexible pneumatic couplings can be also included in that group of mechanical devices.

At the Department of Machine Design, Transport and Logistic at the Faculty of Mechanical Engineering, there is long term research related to the development of the flexible pneumatic couplings and capturing dangerous torsion vibrations in the mechanical systems by an application of those couplings. According to the many authors [1, 2, 3, 4], the most appropriate solution of dangerous torsion vibration capturing is appliance of adequate flexible pneumatic coupling. Those couplings use gaseous medium, in this case air.

The main objective of this article is the application of helium gas and air in the pneumatic flexible couplings and study the impact of these gases on the mechanical properties of pneumatic couplings. The article will compare different gasses from the viewpoint of gas flow and its compressibility.

It will work out change of the value of the torsional rigidity k of the pneumatic coupling and damping coefficient b.

2. FLEXIBLE COUPLINGS

Flexible couplings, except the transmission of torque, it should protect mechanical systems against torsion oscillation not only in a phase of starting and braking but also during the whole working mode. These couplings usually move radial frequency to the lower frequency such as zone of working operations. Significantly reduce the dynamic stress in the mechanical propulsion system. By its flexibility it is able to attenuate the burst of drive and thus protect particular parts against damage [5, 8].

Experimental measurements are made at Flexible two-bellows pneumatic coupling 4-2/70-T-C (fig. 1). This coupling has four tires two-bellows pneumatic elements equally spaced around the perimeter. Gaseous medium is supplied uniformly to all elements of the elastic through the middle. Effect of gaseous media should be more prominent in comparison with one-bellows coupling, which contains only one-bellows elements with lower [6].

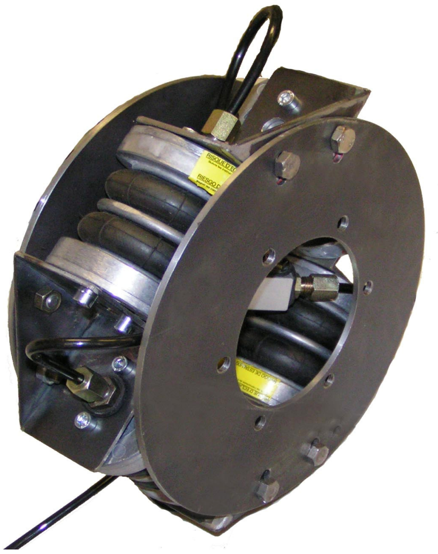

Fig. 1. Flexible two-bellows pneumatic coupling 4-2/70-T-C
Rys. 1. Elastyczne dwu-miechowe pneumatyczne sprzęgło 4-2/70-T-C

3. COMPARATIVE GAS

In our air shaft couplings are used in air. Air as the gas mixture has many advantages but also has some disadvantages. It contains 78% nitrogen, 21% oxygen, 0.9% argon and trace amounts of various substances (e.g. helium, hydrogen, carbon monoxide). These are only theoretical values completely dry air (0% moisture), which does not occur. Air contains many percent of water (as steam), or humidity, then the real normal air that we meet as tires, contains 45 – 55% nitrogen. Air is the cheapest gas because it is freely available, is not

flammable or otherwise dangerous to humans.
Another gas that we use in our helium pneumatic coupling is bearing *HE-4,6*. Helium *HE-4,6* contains 99,996% helia. Helium also is not flammable or dangerous for humans. However, it has one big disadvantage and that is its price.

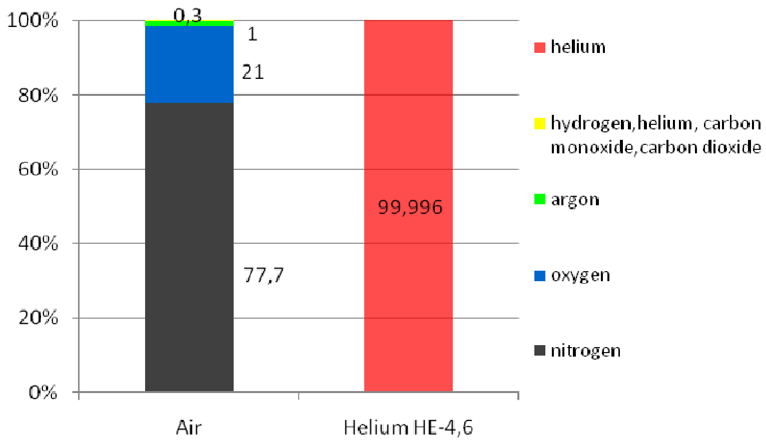

Fig. 2. Percentage composition of helium and air
Rys. 2. Skład procentowy helu i powietrza

4. EXPERIMENTAL MEASUREMENTS

For the coupling we have performed static and dynamic measurements. These measurements were performed in the laboratories of our department on the test bench. Static measurements, we investigated the static characteristics of the flexible pneumatic coupling and coupling filled with air filled with helium gas. From these characteristics we can determine how to change the angle of twist couplings, maximum torque and static torsional rigidity of the pneumatic couplings. Dynamic measurements are performed free oscillation. By this method, we found the value of the dynamic torsional rigidity and the damping.

For present fig. 3 we see the static characteristics of a flexible shaft couplings naplnenj pneumatic air and helium. These torque depending on the angle of twist were made on the measuring device laboratories in our department. Coupling was burdened torque up to a maximum allowable twist angle of 11.5°. Maximum torque is dependent on the pressure in the coupling and see that with increasing pressure also increases its value. While at a pressure of 100 kPa, the maximum M_K=98Nm at a maximum allowable pressure 700 kPa value is M_K=320Nm. For better comparison of the static characteristics of air filled couplings marked lines and static characteristics of helium filled couplings marked points. We conclude that the static characteristics of the couplings filled with air and helium are comparatively equal and no significant differences.

After these measurements was performed on the same plant dynamic measurement of the free oscillation. Measurements are performed at pressures from 100 kPa to 700 kPa value. For each measurement, we coupling burdened bias equal to the rated torque is 1/3 maximum torque. The result was the following waveforms shown in fig. 4 for p=700 kPa.

By following relations were compiled and evaluated relevant dynamic properties [5]:

- displacement of two adjacent peaks of the same sign:

$$N = \frac{\ln \dfrac{\varphi_{Ai}}{\varphi_{Ai+1}}}{t_{i+1} - t_i} = \frac{b_e}{2.I_P} , \tag{1}$$

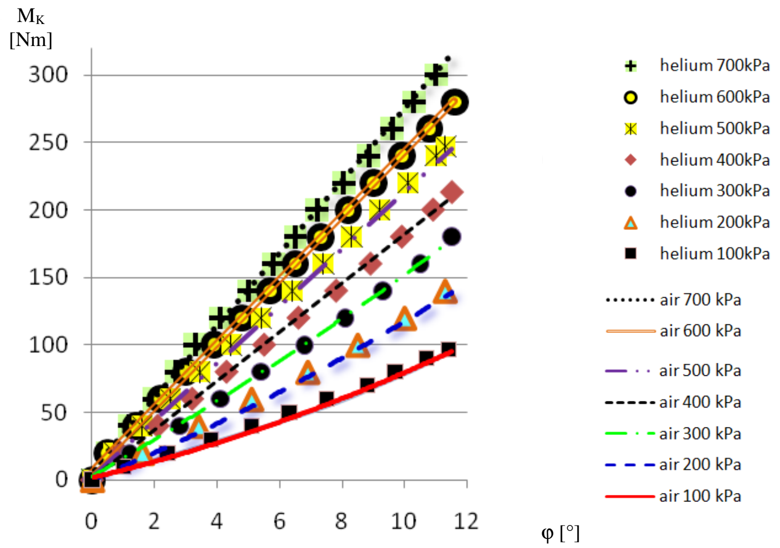

Fig. 3. Static characteristics of two-bellows pneumatic coupling 4-2/70-T-C
Rys. 3. Statyczna charakterystyka dwu-miechowego pneumatycznego sprzęgła 4-2/70-T-C

- for the average frequency between the two peaks of equal sign:

$$\Omega = \frac{2.\pi}{t_{i+2} - t_i}, \tag{2}$$

- damping coefficient:

$$b_e = 2.I_P.N, \tag{3}$$

- torsional rigidity:

$$k_{dyn} = I_P.\Omega^2. \tag{4}$$

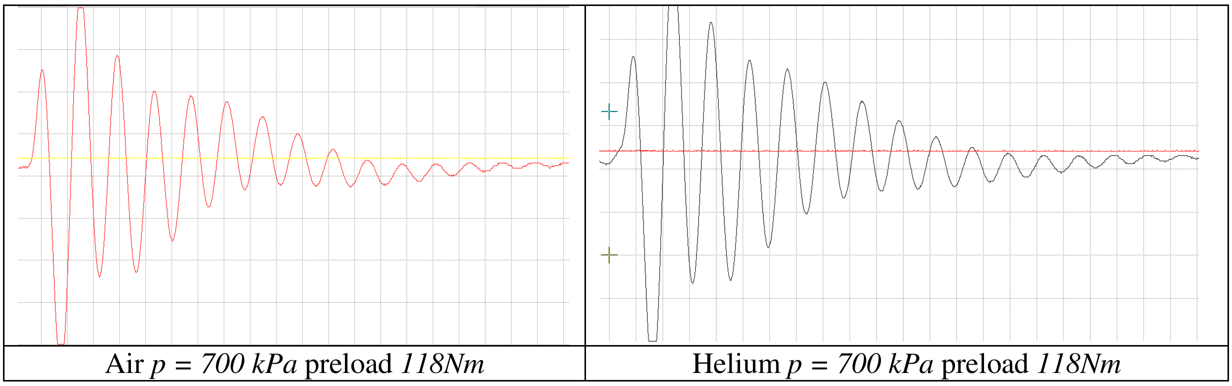

Fig. 4. Traces of free oscillations of coupling filled with helium and air
Rys. 4. Wykresy drgań gasnących w sprzęgle wypełnionym helem i powietrzem

Table 1

The value of preload for different pressures

Pressure [kPa]	100	200	300	400	500	600	700
Preload [Nm]	33	45	60	72	85	100	118

For better comparison we have for obscuring some pressure during the free oscillation (fig. 5). On the picture we see during the free oscillation of pressure at 700 kPa preload 118 Nm. Traces of the coupling filled with helium are shown in green dashed line for coupling and courses are filled with air red solid line. We can say that for the 700 kPa pressure and at all other pressures amplitude deviations in the coupling filled with helium levels higher than the amplitude for the coupling filled with air. The size of these amplitudes has a significant impact especially on the damping coefficient of coupling. It can be concluded that the use of various gases also occurs at a certain time displacement amplitude, which results in a change in the dynamic torsional rigidity k_{dyn} .It is true that $t_{n\text{-}Air}<t_{n\text{-}Hel}$.

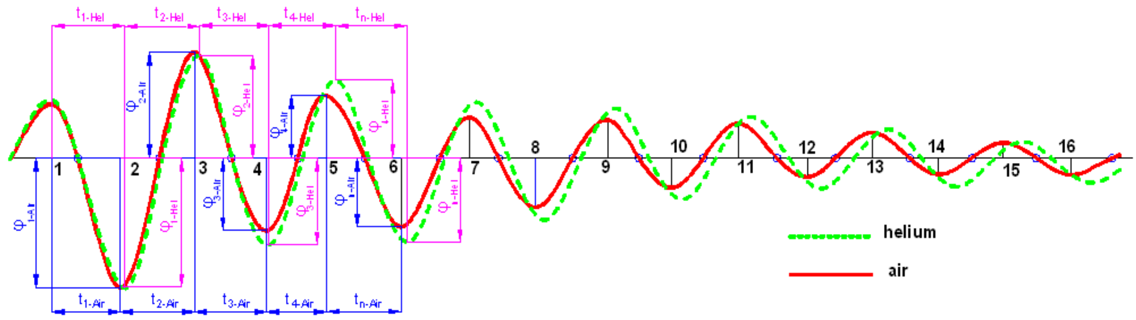

Fig. 5. Comparison of the dynamic behavior of helium and air pressure of p = 700 kPa
Rys. 5. Porównanie dynamicznego zachowania ciśnienia helu i powietrza p = 700 kPa

After processing the results and using relations (1) and (3) we compare the values of the damping coefficient for two-bellows pneumatic coupling filled with air and helium filled coupling. We see that the value of damping coefficient *b* varies depending on the pressure in the pneumatic coupling.

Depending on the pressure that this value decreases. Filled with air for a coupling varies from 20.2 Nm.s values for pressure of 100 kPa to 14.3 Nm.s after much pressure for 700 kPa. For helium filled coupling varies from values 15,9 Nm.s for pressure 100 kPa to worthy 12,5 Nm.s for pressure 700 kPa. We conclude that the coupling filled with helium reaches smaller values of the damping coefficient *b* as coupling filled with air.

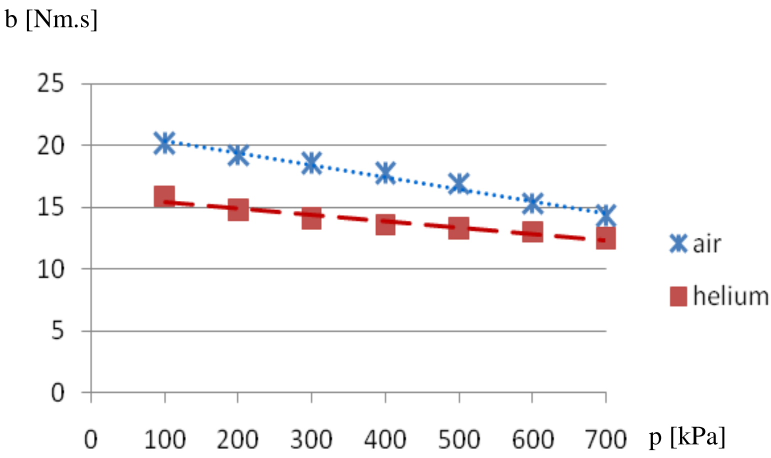

Fig. 6. The values of the damping coefficient *b* for coupling and filled with helium filled air, depending on the pressure *p*
Rys. 6. Wartości współczynnika tłumienia b dla sprzęgła wypełnionego helem i powietrzem, zależności od ciśnienia *p*

Further investigation and using the relations (1) and (4) we compare the values of the dynamic torsional rigidity k_{dyn} for two-bellows pneumatic coupling filled with air and helium filled coupling fig. 7. We see that the value of dynamic torsional rigidity varies depending on the pressure in the pneumatic coupling. With increasing pressure, this value increases, the pressure reached for each value of the dynamic torsional rigidity coupling filled with helium lower values than the dynamic torsional rigidity coupling filled with air. Filled with air for a coupling varies from values 779 $Nm.rad^{-1}$ for pressure 100 kPa to worthy 1880 $Nm.rad^{-1}$ for pressure 700 kPa. For helium filled coupling varies from values 719 $Nm.rad^{-1}$ for pressure 100 kPa to worthy 1798 $Nm.rad^{-1}$ for pressure 700 kPa.

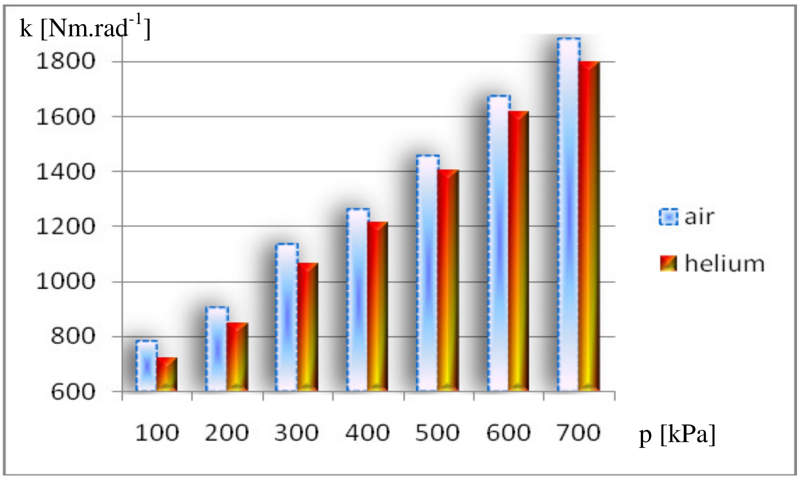

Fig. 7. Dynamic torsional rigidity k_{dyn} values for the coupling with helium and air, depending on the pressure *p*

Rys. 7. Dynamiczna sztywność drgań k_{dyn} – wartości dla sprzęgła z helem i powietrzem, w zależności od ciśnienia *p*

5. CONCLUSION

The gas medium has important influence on properties of the flexible pneumatic couplings. The gas currently uses; it has the most important advantage that it is for free and almost unexhaustible. We have worked out that another gasses have different mechanical properties which could improve mechanical properties of the coupling and thus all mechanical system in which they work.

Static measurements show that the helium gas used in the flexible coupling achieves almost the same characteristics as the static air and this means that the values of maximum torque, angle of twist coupling and static torsional consistency are almost identical.

However, significant changes occurred in the dynamic properties. Figure 5 it is clear that the coupling filled with helium as the amplitude reaches another coupling filled with air. These assumptions were confirmed in the evaluation of damping and dynamic torsional rigidity. We conclude that the coupling filled with helium reaches lower than the damping coupling filled with air. Differences of these values are on the threshold of 20%. And also we can say that the coupling filled with helium reaches lower values as dynamic torsion coupling filled with air and there are differences in the range of about 5%.

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