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COMPARISON OF VARIOUS GASES AND THEIR INFLUENCE ON DYNAMIC 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. Those couplings use gaseous medium, in this case air. The main objective of this article is to determine how various gaseous medium affects the dynamic properties of flexible pneumatic couplings. The article compares three different gases have different physical properties.
Keywords. Flexible pneumatic coupling, gas, air, helium, propane-butane, dynamic measurements, torsion consistency, damping, experimental measurements.

PORÓWNANIE RÓŻNYCH GAZÓW ORAZ ICH WPŁYWU NA WŁAŚCIWOŚCI DYNAMICZNE ELASTYCZNYCH SPRZĘGIEŁ PNEUMATYCZNYCH

Streszczenie. W urządzeniach mechanicznych bardzo często są stosowane elastyczne sprzęgła łączące wały. Takie sprzęgła elastyczne pozytywnie oddziałują na dany układ mechaniczny, a równocześnie chronią go przed uszkodzeniem. W naszym zakładzie zajmujemy się właśnie tego typu sprzęgłami, a konkretnie elastycznymi sprzęgłami pneumatycznymi. Do tych sprzęgieł jest doprowadzany sprężony gaz. Dotychczas sprzęgła były napełniane medium gazowym powietrzem. Głównym celem niniejszego artykułu jest sprawdzenie, w jaki sposób różne media gazowe wpływają na właściwości dynamiczne elastycznych sprzęgieł pneumatycznych. W artykule zostały porównane trzy różne gazy, które odznaczają się różnymi właściwościami fizycznymi.
Słowa kluczowe. Elastyczne sprzęgła pneumatyczne, gaz, pomiary dynamiczne, powietrze, hel, propan-butan, współczynnik tłumienia, dynamiczna sztywność skrętna.

1. INTRODUCTION

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

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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. Mastering this dangerous torsional vibrations can greatly reduce respectively eliminate negative impacts on the environment (vibration, noise) and at the same time protect the individual parts of machinery from mechanical damage. We still have perform these couplings gaseous medium air. The gaseous medium has a significant influence on the elastic properties of the pneumatic coupling shaft and the mechanical properties of the whole system, which is included in a given coupling.

The main objective of this article is to compare three different gases from a physical point of view and their influence on the dynamic characteristics of pneumatic shaft coupling. This article evaluates the dynamic properties of flexible shaft coupling pneumatic marked 4-2/70-TC filled with air, helium and propane-butane. Find out how to change the dynamic torsional rigidity and damping coefficient when coupling these different pressurized gases.

2. 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 lowest cost gas because it is a freely available, is not flammable or dangerous to humans.

Other gases that we use in our pneumatic couplings have different mechanical properties than air. For measurement, we decided to use gas and helium gas mixture of propane and butane. In *tab. 1* is a comparison of their physical properties.

Table 1

Physical properties of technical gases

	helium	air	propane-butane	propane	butane	
Specific gas constant	2079	287,04	163,39	183,78	143	J $kg^{-1}K^{-1}$
Compressibility Factor	1,0005	0,9992	0,97505	0,9821	0,968	-
Gas density	0,169	1,202	2,145	1,91	2,38	kg/m^3
Viscosity	0,0001863	0,0001695	0,0000708	0,0000708	0,0000708	Poise
Molecular weight	4,0026	28,95	50,1015	44,096	56,107	g/mol

Source: Mathematical, physical and chemical tables

The measurements we used a helium gas marked *HE-4,6*. The technical gas contains *99.996%* helium. Helium is not flammable or dangerous for humans. It has a big disadvantage is its high price.

Next we used a gas mixture of propane and butane gas in the percentage ratio of *50%* propane and *50%* butane. The use of this gas was in two ways. The first advantage is its easy availability in the form of cylinders. The second advantage was its physical properties. As can be seen in *Fig. 1* and *Fig. 5* the propane reaches values significantly different than air like helium respectively, so that gives us an excellent view of how gas properties change can change the dynamic properties of flexible pneumatic coupling.

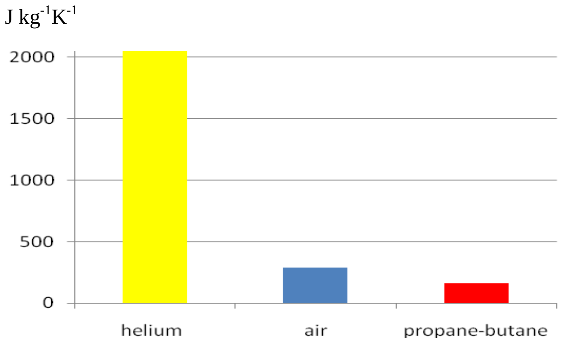

Fig. 1. Compare specific gas constant
Rys. 1. Porównanie stałej gazowej

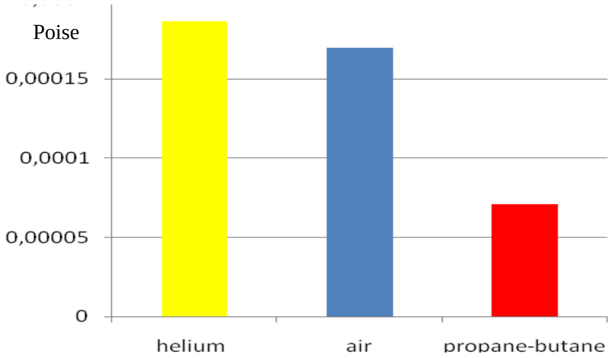

Fig. 2. Compare viscosity
Rys. 2. Porównanie wartości lepkości

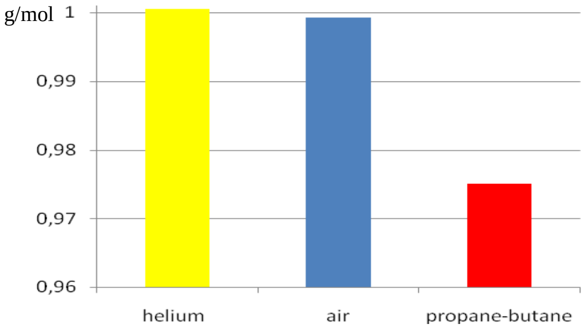

Fig. 3. Compare compressibility factor
Rys. 3. Porównanie współczynnika sprężalności gazów

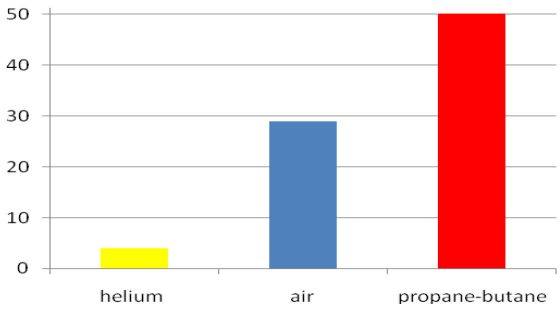

Fig. 4. Compare molecular weight
Rys. 4. Porównanie masy cząsteczkowej

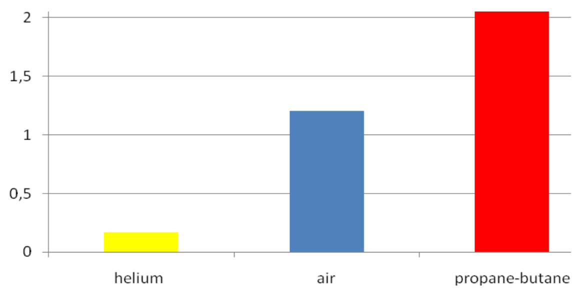

Fig. 5. Compare gas density
Rys. 5. Porównanie gęstości poszczególnych gazów

On *Fig. 1* we see that the value of a specific gas constant is by far the largest for helium. Air and propane have this constant comparatively small. *Fig. 2* and *Fig. 3* shows the values of viscosity and compressibility factor value. We can see that gas propane-butane achieves significantly lower values than air and helium gases. Different properties of these three gases shown in *Fig. 4*, which shows the values of molecular weight and are shown in *Fig. 5* where the density of various gases. The simplicity can be said that propane-butane gas is one of the densest and heaviest gases and helium the lightest of technical gases with minimum weights [3].

3. FLEXIBLE COUPLING

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. Experimental measurements are made at flexible two-bellows pneumatic coupling 4-2/70-T-C (*Fig. 6*). 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.

Fig. 6. Flexible two-bellows pneumatic coupling 4-2/70-T-C
Rys. 6. Elastyczne dwuwarstwowe sprzęgło pneumatyczne łączące wały 4-2/70-

4. DURING THE DYNAMIC MEASUREMENTS

These measurements were performed in the laboratories of our department free oscillation. By this method, we found the value of the dynamic torsional rigidity and damping coefficient value [4]. Example during free vibration can be seen in *Fig. 7*.

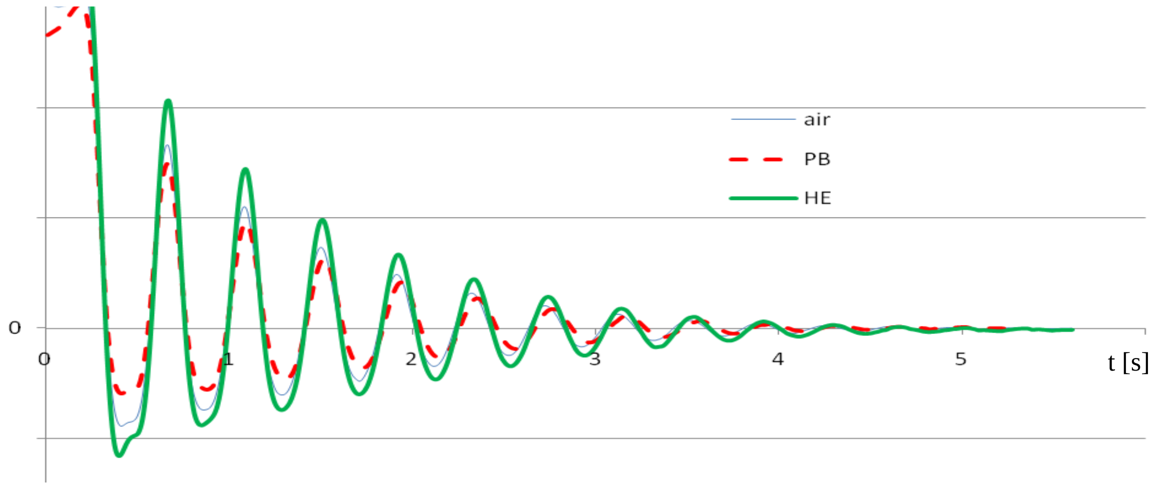

Fig. 7. Compare deviations of the dynamic behavior of flexible pneumatic coupling filled with helium, air and propane-butane at 600 kPa pressure with time *t*
Rys. 7. Porównanie dynamicznych przebiegów ugięć elastycznego sprzęgła pneumatycznego napełnionego helem, powietrzem oraz propanem-butanem do ciśnienia 600 kPa w zależności od czasu t

On *Fig. 7* we see that the traces of deviations flexible shaft coupling pneumatic *4-2/70-T-C* depending on the pressure and elastic elements are pressurized pneumatic pressure of *600kPa*. Physical properties of helium, especially its high viscosity, very low density and weight make it achieves maximum deflection in air and compared with propane gas. Gas propane-butane due to its low weight, high viscosity and density, poorer compressibility reaches the lowest displacement coupling. We conclude that the theoretical basis of various physical properties of gases are shown in sizes deviations pneumatic flexible shaft coupling.

Dynamic measurements are performed for the gases helium, air and propane-butane gas pressures ranging from *100* to *600 kPa* since we were limited to a maximum pressure in the cylinder of propane-butane. We conclude that with increasing pressure differences were significant deviations. Measurements at low pressures of *100* to *300 kPa*, did not show significant differences deviations. Based on these values, we could determine the value of dynamic torsion coupling k_{dyn} and coupling damping coefficients *b* filled with helium, air and propane-butane gas. On *Fig. 8* we see a dynamic torsional rigidity values for the coupling k_{dyn} filled with air, helium gas and propane-butane, depending on the pressure range from *100* to *600 kPa*. We conclude that at low pressure with coupling filled with propane-butane almost the same values k_{dyn} filled with helium gas as a coupling. These values are lower than those coupling filled with air. Value k_{dyn} coupling filled with air moving from *1743 Nm.rad*$^{-1}$ only *3485 Nm.rad*$^{-1}$. Coupling filled with helium gas ranges from *1646 Nm.rad*$^{-1}$ only *3404 Nm.rad*$^{-1}$, and propane-butane is from *1644 Nm.rad*$^{-1}$ only *3330 Nm.rad*$^{-1}$.

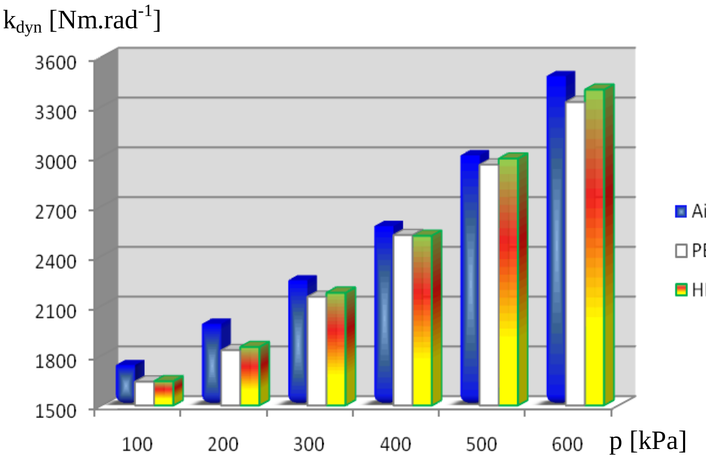

Fig. 8. Dynamic torsional rigidity k_{dyn} values for the coupling with helium, air and propan-butan, depending on the pressure *p*

Rys. 8. Wartości dynamicznej sztywności skrętnej k_{dyn} dla sprzęgła napełnionego helem,powietrzem oraz propanem-butanem w zależności od ciśnienia *p*

After processing the results we compare the values of the damping coefficient *b* for flexible two-bellows pneumatic shaft couplings Fig. 9. The value of the damping coefficient *b* varies depending on the pressure in the pneumatic coupling. Depending on the pressure, this value decreases. The coupling filled with helium gas is changed from *23.96 Nm.s* values for pressure of *100 kPa* to a value of *18.8 Nm.s* pressure *600 kPa*. Coupling filled with air reaches higher values. The damping coefficient varies from *24 Nm.s* values for pressure of *100 kPa* to *20.7 Nm.s* after much pressure to *600 kPa*. Coupling filled with propane-butane gas at low pressures reaching *100* to *300 kPa* damping value same as to that of air. The effect of this gas is increased to the value of *400 kPa*. When the pressure reaches *600kPa* size to *24.5 Nm.s.*

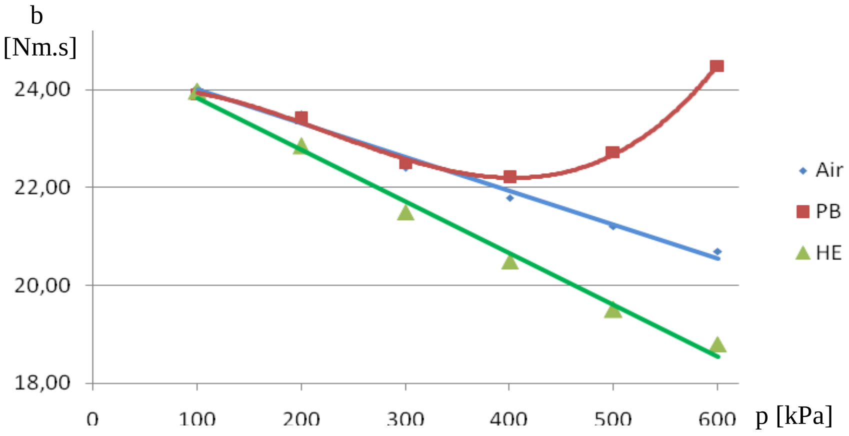

Fig. 9. The values of the damping coefficient *b* for coupling and filled with helium, air and propan-butan on the pressure *p*

Rys. 9. Wartości współczynnika tłumienia b dla sprzęgła napełnionego helem, powietrzem oraz propanem-butanem, w zależności od ciśnienia *p*

5. CONCLUSION

The pneumatic couplings gaseous medium has a significant influence on the mechanical properties of coupling and thus the entire mechanical system. The type of gas has a significant impact because all gas has different physical properties. In our example we compared three different gases, helium, air and propane-butane. These gases have different physical properties are studied and their different effects on the dynamic characteristics of pneumatic couplings, which were applied.

After the measurement and evaluationcan be said that the coupling filled with air reaching the highest values of the dynamic torsional rigidity than coupling filled with helium gas and propane-butane. The difference in these values is at the limit of *8%*. Coupling filled with helium gas reached comparable results with dynamic torsional rigidity coupling filled with propane-butane. Showed no major differences to a maximum deviation of these values was 2%. More significant changes occurred in the evaluation of the damping coefficient. Coupling filled with helium gas reached lower values than the damping coefficient coupling filled with air. Coupling filled with air reaching the same damping value as coupling filled with propane-butane at the lower pressures. Significant change occurred in the higher pressure of 400 to 600 kPa where he started to show significant effect heavier and denser gas and coupling filled with propane-butane reaching the highest values. At a pressure of 600 kPa, the differences in value ranging up to a limit of *23%*.

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