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Jozef KRAJŇÁK[1], Robert GREGA[2]

COMPARISON OF THREE DIFFERENT GASES AND THEIR INFLUENCE ON DYNAMIC PROPERTIES ONE-BELLOW AND TWO-BELLOWS FLEXIBLE PNEUMATIC COUPLING

Summary. The flexible couplings are often used in many various mechanical systems. 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. So far we have used air but it is in our department also carried out measurements other gases and helium. The main objective of this article is to determine how various air, helium and propane-butane affects the dynamic properties of flexible pneumatic couplings. We will explore flexible one-bellow and two-bellows flexible pneumatic coupling. Both couplings have been developed in our department.

Keywords. Flexible pneumatic coupling, gas, air, helium, propane-butane, one-bellow, two-bellows, dynamic property, torsion consistency, damping, experimental measurements.

PORÓWNANIE TRZECH GAZÓW I ICH WPŁYWU NA WŁAŚCIWOŚCI DYNAMICZNE SPRZĘGŁA PNEUMATYCZNEGO Z MIESZKAMI JEDNO I DWUWARSTWOWYMI

Streszczenie. Sprzęgła podatne są często używane w wielu różnych mechanicznych układach napędowych. Pozytywnie oddziałują one na dany układ mechaniczny, a równocześnie chronią go przed uszkodzeniem. Autorzy niniejszego artykułu w zakładzie, w którym są zatrudnieni zajmują się właśnie tego typu sprzęgłami, a w szczególności podatnymi sprzęgłami pneumatycznymi. Do tych sprzęgieł jest doprowadzany gaz pod ciśnieniem. Głównym celem niniejszego artykułu jest analiza wpływu trzech gazów, takich jak: powietrzne, hel i propan-butan, na charakterystykę dynamiczną dwóch różnych sprzęgieł pneumatycznych. W artykule porównanozatem wykorzystanie różnych gazów przemysłowych, które mają różne właściwości fizyczne. Dodatkowo w celu wykazania różnic pomiędzy dwoma odmianami sprzęgieł pneumatycznych porównane zostały rozwiązania z mieszkami jedno i dwuwarstwowymi. Oba rodzaje sprzęgieł zostały opracowane w zakładzie, w którym pracują autorzy niniejszego artykułu.

Słowa kluczowe. Elastyczne sprzęgła, gaz, mieszek jednowarstwowy, mieszek dwuwarstwowe, hel, propan-butan, współczynnik tłumienia, dynamiczna sztywność skrętna.

[1,2] Department of Design, Transport and Logistics, Section of Design and Machine Parts, Letná 9, 042 00 Košice, Slovak Republic, e-mail: [1]jozef.krajnak@tuke.sk, [2]robert.grega@tuke.sk,

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 pneumatic couplings and capturing dangerous torsion vibrations in the mechanical systems by an application of those couplings. According to the many authors [1-4, 5-8], 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

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. The article compares the different gases that have different physical properties. We explore flexible one-bellow pneumatic shaft coupling with marked *4-1/70-T-C* and flexible two-bellow pneumatic shaft coupling with marked *4-2/70-T-C.* Both couplings have been developed in our department.

2. COMPARATIVE 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 [7].

Fig. 1. Flexible one-bellow pneumatic coupling *4-1/70-T-C*
Rys. 1. Sprzęgło pneumatyczne z mieszkami jednowarstwowymi *4-1/70-T-C*

Fig. 2. Flexible two-bellows pneumatic coupling *4-2/70-T-C*
Rys. 2. Sprzęgło pneumatyczne z mieszkami dwuwarstwowymi *4-2/70-T-C*

Flexible one-bellow pneumatic coupling (*fig. 1*) and two-bellow (*fig. 2*) has four pneumatic elements evenly spaced around the perimeter. Two-bellows coupling has coupling is larger and more massive.. These properties are its effect on the dynamic properties of the couplings.

3. COMPARATIVE TECHNICAL GASES

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. 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	helium	air	propane-butane
Specific gas constant [J $kg^{-1}K^{-1}$]	2079	287,04	163,39	724%	100%	57%
Compressibility Factor	1,0005	0,9992	0,97505	100%	100%	98%
Gas density [kg/m^3]	0,169	1,202	2,145	14%	100%	178%
Viscosity [Poise]	0,0001863	0,0001695	0,0000708	110%	100%	42%
Molecular weight [g/mol]	4,003	28,950	50,102	14%	100%	173%
filling speed coupling [-]	0,38	1	1,26	38%	100%	126%
	values			percent		

The measurements we used a helium gas marked *HE-4,6*. The technical gas contains *99.996%* helium. Next we used a gas mixture of propane and butane gas in the percentage ratio of *50%* propane and *50%* butane.

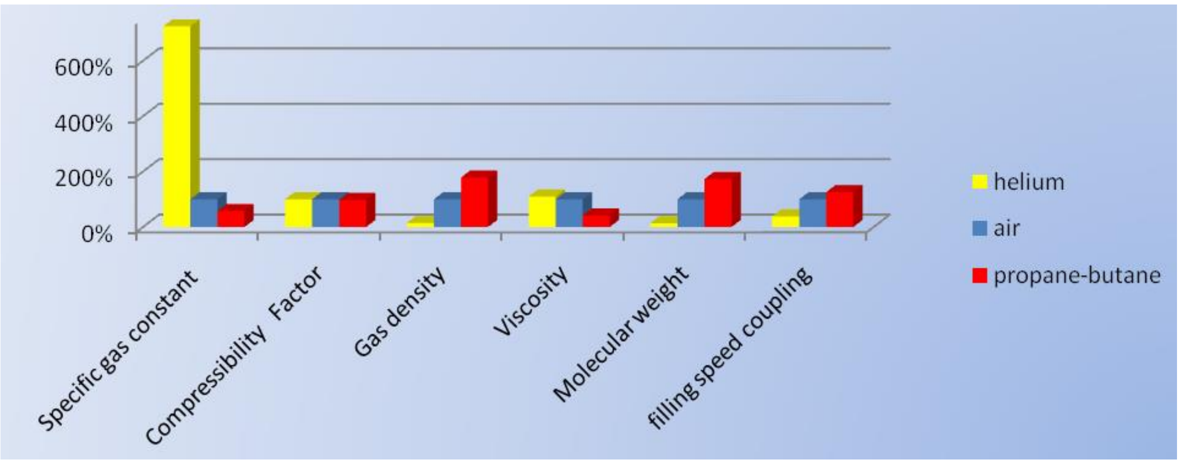

Fig. 3. Compare physical propertie of technical gases
Rys. 3. Porównanie właściwości fizycznych gazów przemysłowych

If we define the physical properties of the air is constant, *100%* as at *fig. 3* we can watch how the differences in the properties of other gases [5].

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 [6]. Within a few tens of measurements, we had about *96 570* values which we then successively evaluated. Example during the free oscillation can be seen in *fig. 4.*

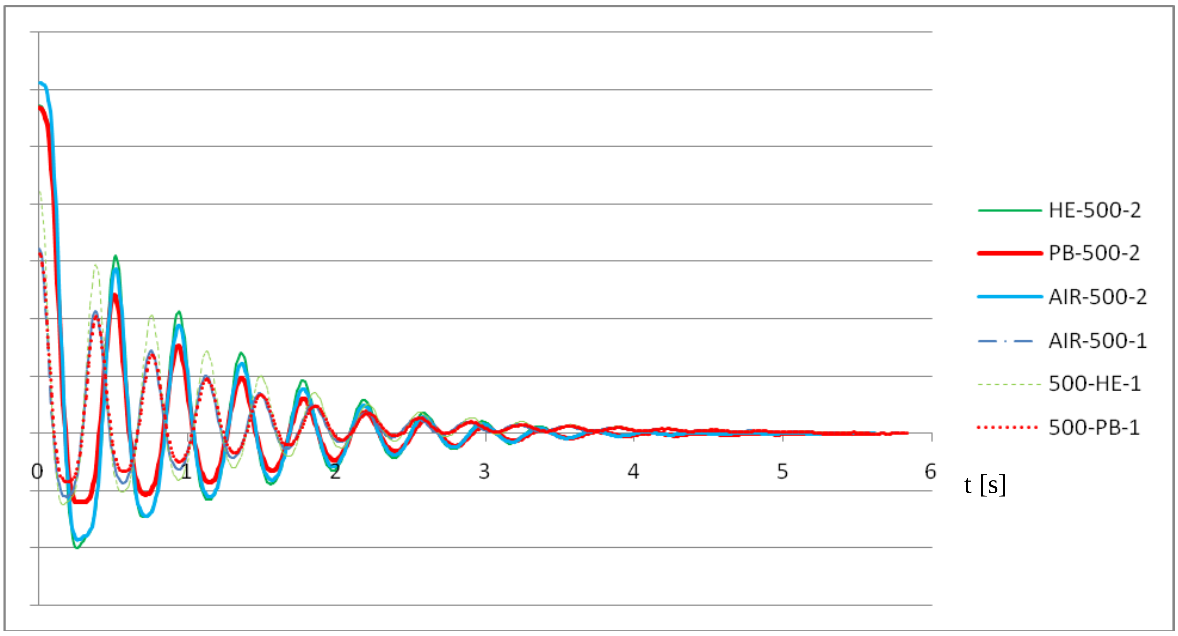

Fig. 4. Compare deviations of the dynamic behavior of one-bellows flexible pneumatic coupling and two-bellows flexible pneumatic coupling filled with helium, air and propane-butane at *500 kPa* pressure with time *t*

Rys. 4. Porównanie dynamicznych przebiegów ugięć elastycznego sprzęgła pneumatycznego napełnionego helem, powietrzem oraz propanem-butanem do ciśnienia *500 kPa* w zależności od czasu *t*

On *Fig. 4* we see that the traces deviations flexible one-bellow pneumatic coupling *4-1/70-T-C* and two-bellow pneumatic coupling *4-2/70-T-C* depending on the pressure and pneumatic flexible elements are pressured *500 kPa*. 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 can also see that the one-bellow coupling achieves other than coupling displacement two-bellows.

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. Using tangible moments of inertia specified in tab. 2 pre one-bellow coupling and two-bellows pneumatic coupling. Values for two-bellow pneumatic coupling are larger because the coupling is bigger and transmits a higher torques. Using these values, we then find the value of the dynamic torsional rigidity k_{dyn} and value of the damping coefficient *b* both couplings between pressures of *100* to *600 kPa*.

Table 2

Tangible moments of inertia

[kg*m^2]						
	100 kPa	**200 kPa**	**300 kPa**	**400 kPa**	**500 kPa**	**600 kPa**
4-2/70-T-C	5,509001	7,019138	8,552215	9,566620	11,07675	12,60983
4-1/70-T-C	3,064709	3,368651	4,344806	5,284203	6,223600	7,789262

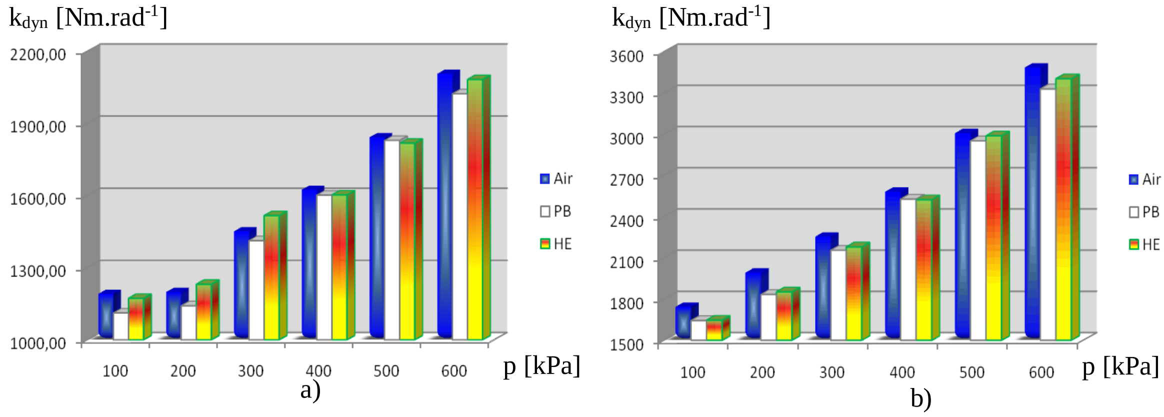

Fig. 5. Dynamic torsional rigidity k_{dyn} values for the one-bellow a) and two-bellows b)coupling with helium, air and propan-butan, depending on the pressure *p*

Rys. 5. Wartości dynamicznej sztywności skrętnej k_{dyn} dla sprzęgła pneumatycznego z mieszkami jednowarstwowymi *a)* i sprzęgła pneumatycznego z mieszkami dwuwarstwowymi *b)*, napełnionego helem,powietrzem oraz propanem-butanem w zależności od ciśnienia *p*

Measurements have shown that with increasing pressure increases the value of the dynamic torsional rigidity k_{dyn}. One-bellow coupling reaches k_{dyn} range *1111 Nm.rad^{-1}* to *2106 Nm.rad^{-1} (fig. 5a)* depending on the pressure and gas. Two-bellows coupling reaches value k_{dyn} range *1644 Nm.rad^{-1}* to *3485Nm.rad-1* (*fig. 5b*). Values is based on change the coupling gas filled the air reaches the greatest value.

Value of the damping coefficient *b* varies with the pressure in the pneumatic coupling and gas such as pressurized. One-bellow coupling (*fig. 6a*) has a value in the range of *10 Nm.s* to *12,3 Nm.s* for pressures in the range of *100* to *600 kPa*. Two-bellows coupling (*fig. 6b*) has a value in the range of *24,5 Nm.s* to *18,8 Nm.s* for pressures in the range of *100* to *600kPa*. Coupling filled with helium reaches the smallest value damping than one-bellow so well in two-bellows coupling. Effect of propane-butane is starting to show up from *300-400 kPa* pressure when the coupling achieves the greatest value of damping.

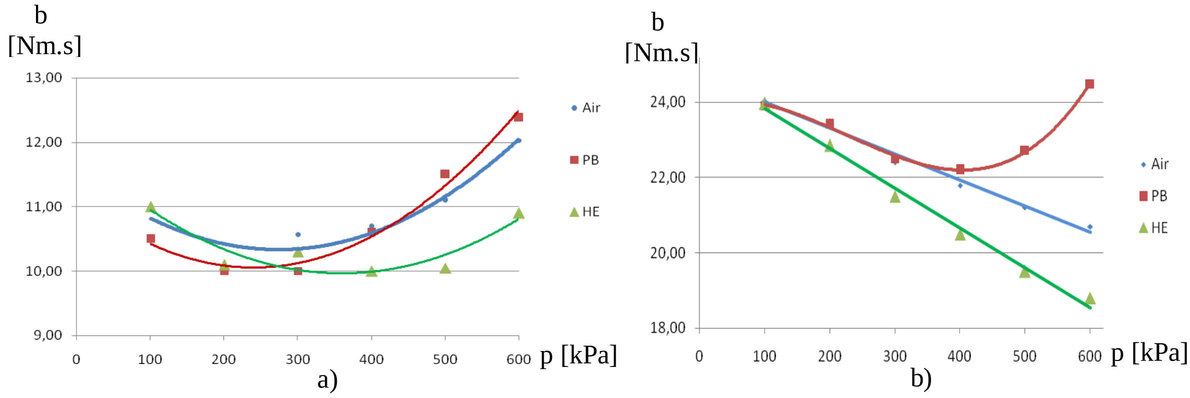

Fig. 6. The values of the damping coefficient *b* for coupling and filled with helium, air and propán-bután on the pressure *p*

Rys.6. Wartości współczynnika tłumienia *b* dla sprzęgła napełnionego helem, powietrzem oraz propanem-butanem w zależności od ciśnienia *p*

5. CONCLUSION

The pneumatic coupling is gaseous medium a significant effect on the mechanical properties of coupling and thus the entire mechanical system. In our case, we compared three different gases helium, air and propane-butane. These gases were used in the one-bellow and two-bellows flexible pneumatic shaft coupling.

After performing measurements and evaluation, we can conclude that the coupling is filled with air reaching the highest value of the dynamic torsional rigidity as a coupling filled with helium gas and propane. Coupling filled with helium reached comparable results of the dynamic torsional rigidity with coupling filled with propane-butane. Significant changes occurred in the evaluation of thermal damping. Coupling filled with helium reached lower values. Significant change occurred in the higher pressures of *400* to *600 kPa* where he began to show the impact of heavier and denser gas and coupling filled with propane.

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Bibliography

1. Homišin J.: Nové typy pružných hriadeľových spojok: vývoj, výskum, aplikácia. TU, SjF, Košice 2002.
2. Homišin J.: Controlling torsional vibration of mechanical systems by application of pneumatic flexible shaft couplings. Zeszyty Naukowe. Transport. Z. 72. Politechnika Śląska. Gliwice 2011. P. 33-40.
3. Homišin J., Urbanský M., Kaššay P.: Investigation of various factors influence on dynamic load of mechanical system by pneumatic coupling application. Zeszyty Naukowe. Transport. Z. 76. Politechnika Śląska. Gliwice 2012. P. 13-18.
4. Homišin J.: Ovládnutie torzného kmitania a ním vybudených vibrácií mechanických sústav. Technika. Vol. 8, No. 5, 2010, p. 40-42.
5. Matematické fyzikálne chemické tabuľky pre stredné školy, 3. dopl. vyd. Bratislava, SPN, 1974. P. 341.
6. Krajňák J., Homišin J., Grega R., Kaššay, P.: Effect of helium on mechanical properties of flexible pneumatic coupling. Zeszyty Naukowe. Transport. Z. 73. Politechnika Śląska. Gliwice 2011. P. 63-69.
7. Łazarz B., Wojnar G., Madej H., Czech P.: Influence of meshing performance deviations on crack diagnostics possibility. Transactions of the Universities of Košice. Research reports from the Universities of Košice. Vol. 3. Košice 2009, p. 5-8.
8. Sága M., Vaško M., Kopas P., Jakubovičová L.: Identification of the hysteretic material model parameters and application on energy fatigue curve. Machine modeling and simulations. XV Polish – Slovak Scientific Conference on MMS 2010. Krasiczyn, Poland 2010.