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ZMIANY WYKŁADNIKA POLITROPY W PROCESACH TERMODYNAMICZNYCH ZACHODZĄCYCH W OŚRODKU GAZOWYM WEWNĄTRZ SPRZĘGŁA WAŁU

Streszczenie: Artykuł opisuje procesy termodynamiczne ośrodka gazowego w elementach sprężystych umieszczonych w podatnym sprzęgle służącym do łączenia wałów. Zbadano w jaki sposób wykładnik politropy zmienia się w wyniku zmiany właściwości niektórych czynników. Czynniki wpływające na zmianę współczynnika obejmują: zmianę strat ciepła, zmianę prędkości obrotowej, zmianę temperatury otoczenia, zmianę ciśnienia w elemencie sprężystym i zmianę współczynnika przenikania ciepła między gazem a płaszczem sprężystym członek chodzi o płaszcz tych miechów.

Słowa kluczowe: wykładnik politropowy, procesy termodynamiczne, temperatura otoczenia, element pneumatyczny, ciśnienie

BEHAVIOUR OF CHANGE RELATING TO THE POLYTROPIC COEFFICIENT IN THERMODYNAMIC PROCESSES WITHIN GASEOUS MEDIUM INSIDE THE SHAFT COUPLING

Summary: The paper describes thermodynamic processes of gaseous medium in elastic elements placed in a flexible coupling of the shaft. Examines how the polytropic coefficient changes as a result of changing the properties of some factors. Factors that affect the change in the coefficient include: change in heat loss, change in drive section speed, change in ambient temperature, change in pressure in the resilient member and change in heat transfer coefficient between gas and resilient jacket of the member.

Keywords: polytropic exponent, thermodynamic processes, ambient temperature, pneumatic element, pressure.

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1. Introduction

Flexible mechanical couplings are often used in mechanical engineering as well as in other industries. These resilient elements are mostly used to transmit torque, vibration damping and noise. The load torque transmission is one of the most common modes of power transmission in mechanical systems. An accompanying feature of power transmission is the emergence of torsional vibration, noise and vibration. Of course in these processes, heat is generated as a side-effect. It is necessary to examine the amount of heat generated in these facilities. [3,13,22]. Thermodynamic processes of the gaseous medium in the pneumatic coupling can be determined by numerical methods [1,6,7,9].

At the Department of Design and Transport Engineering we have been dedicated to flexible pneumatic couplings for a long time. These are formed by a rubber-corded coating which is filled with gaseous medium, mostly air. Flexible pneumatic elements are periodically pressed in operation. This compression results in an increase in the temperature of the rubber parts. This is an undesirable phenomenon that can lead to a change in the mechanical properties of the elastic element (and thus to the change of the clutch parameters) as well as to the accelerated aging of the material. [12,14,15,18,19].

The aim of the paper is to describe the thermodynamic processes of the gaseous medium in the resilient elements located in the resilient coupling of the shaft. We want to describe how the polytropic coefficient changes as a result of changing the properties of some factors. Factors that affect the change in the coefficient include: change in heat loss, change in drive section speed, change in amplitude, change in ambient temperature, change in pressure in the resilient member and change in heat transfer coefficient between gas and resilient jacket of the member.

2. Basic values of polytropic coefficient for different states in gases

It is necessary to know the value of the exponent for various calculations of pressure and load characteristics of air springs γ air state changes (polytropic coefficient γ). In the calculation of car suspension, it assumes that the deformation of the air springs is carried out at the polythropic exponent during the oscillating movement of the sprung materials $\gamma = 1{,}3$, for unsprung masses approximately at adiabatic change ($\gamma = 1{,}4$). Isothermal deformation is assumed in the lateral stability calculations of the vehicle ($\gamma = 1$) for springs not interconnected, for interconnected springs isobaric change is sometimes assumed simplified ($\gamma = 0$). When calculating the oscillating motion of pneumatically resiliently stored stable and mobile objects, it is possible to consider a change in polytropical ($\gamma = 1{,}3$).

Basic thermodynamic processes in gases are described by the equation:

$$pV^{\gamma} = C, \tag{1}$$

Where: C is constant (depends on temperature and amount of gas),
p – pressure,
V – volume,
γ – polytropic coefficient.

Depending on what happens in the gaseous medium, such a value γ shall (tab.1).

Table 1. Polytropic exponent values

value γ	put in the gas
0	isobaric
1,0	isothermal
1,4	adiabatic
∞	isochoric

If we solve the gaseous medium in the pneumatic element in the flexible shaft coupling then γ ranges in range *1,0* until *1,4*. A value of 1.0 characterizes the isothermal process - at which time any increase in gas temperature is removed and absorbed into the volume of its flexible rubber envelope. Value $\gamma = 1,4$ means an adiabatic process characterized by the absence of energy exchange between gas and surroundings. Of course, this situation cannot be achieved in practice, but the heat exchange is often negligible and the process is then almost adiabatic.

It is possible to record the gas volume and pressure values during the process.

By logarithmic definition equation we get.

$$\ln p + \gamma \ \ln V = \ln \ C \quad \Rightarrow \quad \ln p = \ln C - \gamma \ \ln V. \tag{2}$$

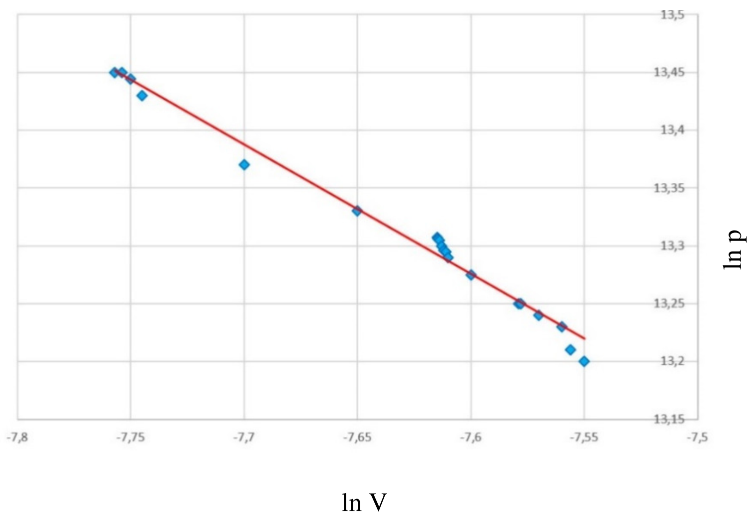

Figure 1. Dependence of ln p on ln V

In Fig. 1 we noticed the dependence of the logarithm of pressure on the logarithm of volume, we should get a straight line, which is the polytropic exponent. Values are obtained from 20 second intervals and are together 20.

It is clear from the picture that not all points are exactly on the line. This is due to the fact that at any time a different amount of heat is stored in the flexible rubber-cord material, which depends on the precise course of the gas process. This means that the gas can reach different pressure values for the same volume depending on how much heat is currently stored in the material. For normal parameter values we can replace this dependence by a straight line.

3. Dependence of individual exponents in thermodynamic processes

When implementing processes we have to introduce some standard values of quantities and then we can observe a change of some parameter with respect to given conditions. These default values are shown in Table 2.

Table 2. Standard values of quantities

quantity		value
ambient temperature	T_0	22°C
amplitude of elastic element volume changes	A	7,7 mm
speed of the driving part	n	800 min^{-1}
pressure inside the elastic element	p_0	600 kPa
thermal conductivity of the elastic element material	λ	0,0158 Wm^{-1}K^{-1}
the proportion of heat loss in the elastic element	η	0,188%
heat transfer coefficient between gases and a sheath of the resilient element	α	3,5 Wm^{-2}K^{-1}

In practice, there are no pure adiabatic or isothermal events. Real events are always polytropical. There is a partial exchange of heat with the surroundings.

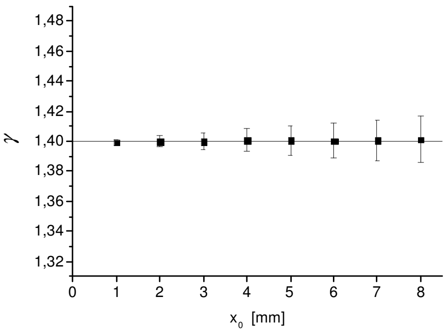

Figure 2. Dependence of γ from the amplitude of the elastic element volume changes

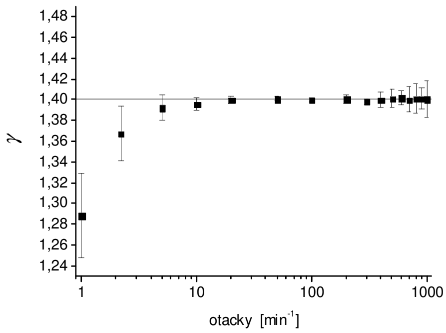

Figure 3. Dependence of γ from shaft speed

Fig. 2 shows that the polytropic exponent practically does not depend on the amplitude of the volume changes. There is no reason for this - the polytropic exponent describes how well the heat exchange takes place between the gas enclosed in the elastic element and its rubber sheath. The change in deformation of the elastic element placed in the flexible pneumatic coupling will not significantly affect the change of the polythropic exponent. This is changing as the amplitude $A = x_0$ changes the value. It is an estimate of the uncertainty of value γ. In practice, this means a graph of dependence ln p from ln V still less corresponds to the line.

In Fig. 3 shows the change in polythropic exponent as a function of speed. You can see that at low speed the value is small 1,29. As the speed value increases, it stabilizes to a constant value of 1.4. This value stabilizes even at a completely low speed 10 min^{-1}. Since we are normally in the 100-1000 min^{-1} range, this change in polytropic exponent is only on the theoretical level.

Increasing the proportion of heat loss in the resilient element results in an overall increase in its temperature, but the heat exchange between the gaseous medium and its envelope is not likely to be affected. The graph obtained is in line with this statement, γ is always around 1.4 (Fig. 4).

In Fig. 5 we can observe the course of change of polytropic exponent from ambient temperature. The flexible element as a whole adapts to the ambient temperature. That is, if this is equal to 10 °C, then the initial temperature of the gas inside the elastic element and its envelope will equal and will also be 10 °C. However, the heat exchange between the gas and its envelope depends only on the temperature difference and therefore should not be affected by changing both temperatures. We can see that the value of the polytropic exponent is constant and still reaches 1.4.

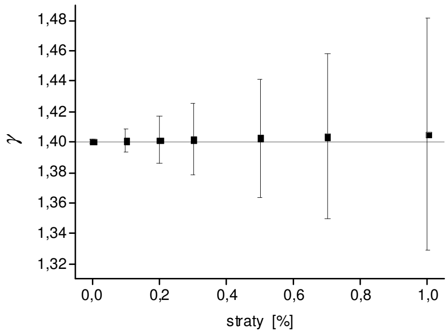

Figure 4. Dependence of γ from the loss share

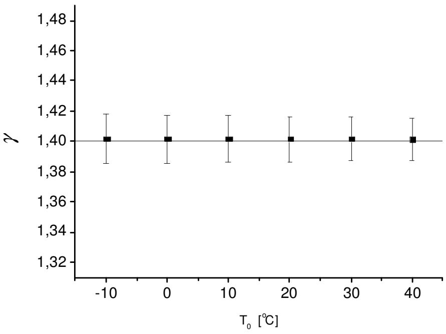

Figure 5. Dependence of γ from ambient temperature

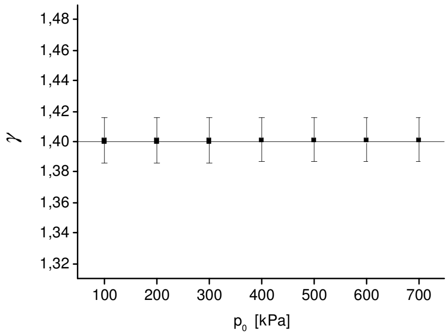

Figure 6. Dependence of γ from the pressure in the elastic element

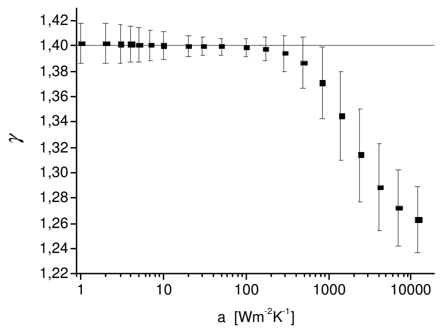

Figure 7. Dependence of γ from the heat transfer coefficient

Fig. 6 shows that under the selected standard conditions (see Table 2) the polytropic exponent γ from pressure p_0 not depend.

Fig. 7 shows the dependency γ from the heat transfer coefficient between the gas and the envelope of the elastic element. With increasing heat transfer coefficient α the heat exchange between the gas and the material of the resilient element increases, resulting in an approximation of the action in the gas of the isothermal action. This means a gradual decrease of the polytropic exponent from 1.4 (adiabatic process, no heat exchange - with heat transfer coefficient equal to 0) to the value *1,0* (however, we would achieve this asymptotically at infinitely high values α). Significant decreases occur at values α much greater than the actual figures.

The values of the polythropic exponent were always calculated on the basis of 20 measurements at regular 20-second intervals under constant ambient conditions. All results were recorded and evaluated in detail.

4. Conclusion

The polytropic exponent plays a very important role in thermodynamic processes in elastic elements. These resilient elements are located in resilient pneumatic couplings and they play a very important role in terms of torque transmission. The graphs represent the dependencies of the polythropic gas exponent in the elastic element from individual parameters. It can be seen that according to their values the action in the gas varies from adiabatic to isothermal and therefore it is not generally possible to classify it clearly. However, for all possible parameter settings, the graphs predict a polytropic coefficient practically equal to 1.4 corresponding to the adiabatic event.

The graphs show that the change in the value of the polytropic exponent is not affected by the amplitude of the elastic element x_0, dependence on the proportion of losses, ambient temperature or pressure in the elastic element. Changes in the value of the polythropic exponent cause speed in the driving part. However, changes are only visible at low speeds that are not common in real operation. Significant changes in the polytropic exponent also occur when the heat coefficient changes. However, it can be seen that a significant decline occurs only at values much greater than the actual figures.

In conclusion we can state that polytropic coefficients do not significantly change its value and reach a constant value as long as it is in real operating conditions and we do not go into theoretical and in practice unrealistic conditions.

The article was written in the framework of Grant Projects: VEGA 1/0473/17 "Research and development of technology for homogeneous charge self-ignition using compression in order to increase engine efficiency and to reduce vehicle emissions" and KEGA 041TUKE-4/2017 "Implementation of new technologies specified for solution of questions concerning emissions of vehicles and transformation of them into the educational process in order to improve quality of education."

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