ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2013
Seria: TRANSPORT z. 81 Nr kol. 1896

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EXAMINATION OF MECHANICAL SYSTEM RESPONSE TO GASEOUS MEDIA PRESSURE CHANGES IN THE PNEUMATIC COUPLING

Summary. In order to continuous tuning of the torsional oscillating mechanical system during its operation, we are making use of application of the pneumatic flexible shaft couplings, developed by us. By the gaseous media pressure change in pneumatic couplings we can change its torsional stiffness and thereby the dynamics of whole system too. In term of dynamics is necessary to know the character of transitional effects, which are arising at continuous tuning of mechanical system, so at gaseous media pressure changes in pneumatic coupling. Therefore the paper will pay attention on the ground of experimental measurements to examination of torsional oscillating mechanical system response to various gaseous media (in this case air) pressure changes in pneumatic coupling during operation of given system.

Keywords. Continuous tuning of system, pneumatic flexible shaft coupling, gaseous media pressure change, torsional stiffness change, transitional effect of mechanical system.

BADANIE REAKCJI UKŁADU MECHANICZNEGO NA ZMIANY CIŚNIENIA MEDIUM GAZOWEGO W SPRZĘGLE PNEUMATYCZNYM

Streszczenie. W celu płynnej regulacji układu mechanicznego drgającego skrętnie w trakcie jego pracy, a więc podczas eksploatacji, stosujemy elastyczne sprzęgła pneumatyczne łączące wały. Za pomocą zmiany ciśnienia medium gazowego (powietrza) w sprzęgłach pneumatycznych zmieniamy ich sztywność skrętną, a przez to również dynamikę całego układu. Z punktu widzenia dynamiki należy poznać charakter stanów przejściowych układu mechanicznego, które powstają podczas jego płynnego strojenia, a więc podczas zmian ciśnienia medium gazowego w sprzęgle pneumatycznym. Dlatego też artykuł zajmuje się badaniem odpowiedzi układu mechanicznego drgającego skrętnie na różne zmiany ciśnienia powietrza w sprzęgle pneumatycznym podczas pracy danego układu na podstawie przeprowadzonych pomiarów eksperymentalnych.

Słowa kluczowe. Płynna regulacja układu, elastyczne sprzęgło pneumatyczne łączące wały, zmiana ciśnienia medium gazowego, zmiana sztywności skrętnej, stan przejściowy układu mechanicznego.

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1. INTRODUCTION AND OBJECTIVE OF PAPER

Air pressure value in compression space of pneumatic coupling has direct influence on its torsional stiffness value. Torsional stiffness value of flexible coupling has direct influence on natural frequency (frequencies) of torsional oscillating system, wherein is given coupling applied. By suitable air pressure change in compression space of pneumatic coupling we can therefore change – suitably adapt dynamics of the system in regard to existing sources of torsional oscillation excitation. This fact we are using with advantage at continuous tuning of torsional oscillating mechanical system (Fig. 1) during its operation [1]. By suitable value of torsional stiffness *k* it is possible to bring out the resonances from individual harmonic components of excitation in regard to operation speed range (OSR) of the system [1], [4].

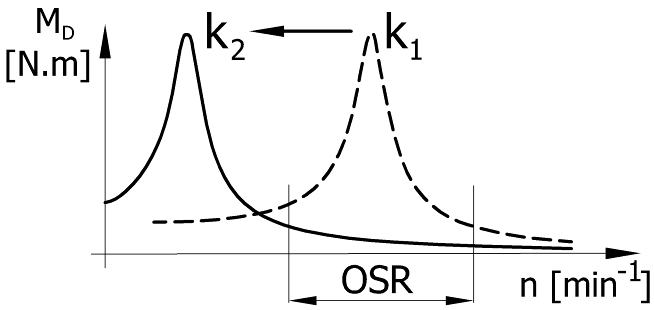


Fig. 1. Mechanical systems tuning principle
Rys. 1. Zasada strojenia układów mechanicznych

At application of continuous tuning of mechanical system occur in the coupling air pressure changes (in term of their time dependence and size) during operation of mechanical system. In order to pneumatic flexible coupling really would be a tuner and not an exciter of torsional oscillation, it is necessary to know the character of transitional effects of mechanical system at air pressure change in coupling during system operation. Therefore the objective of paper will be examination of speed and response form of specific torsional oscillating mechanical system (Fig. 2) to various air pressure changes in compression space of pneumatic coupling during given system operation on the ground of experimental measurements results.

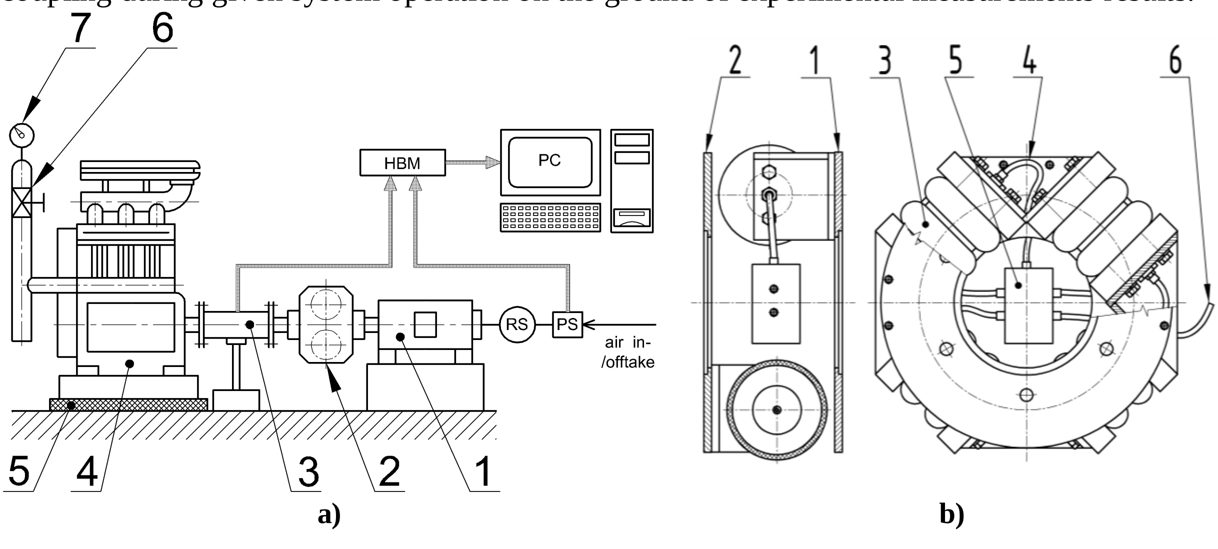


Fig. 2. a) Examinated torsional oscillating mechanical system, b) Applied pneumatic coupling
Rys. 2. a) Badany układ mechaniczny drgający skrętnie, b) Stosowane sprzęgło pneumatyczne

2. EXAMINATED TORSIONAL OSCILLATING MECHANICAL SYSTEM

Mechanical system in Fig. 2. a is created of the 3-cylinder air compressor ORLIK 3JSK-75 (4), which is stored on the isolated layer (5) and is driven through pneumatic coupling (2) by the DC electromotor of type SM 160 L (1). Rotational speed of electromotor is adjusted with thyristor regulator of type IRO in range 0 ÷ 1000 r.p.m. Compressor is without flywheel, whereby by it excited torsional effects are increased [1]. The size of system loading depends on pressure in output piping of compressor, which is adjusted with throttle valve (6). Pressure in output piping we can abate from manometer (7). Given compressor is able to produce pressure air with maximum overpressure 800 kPa. Air in the pneumatic coupling is supplied through drilled shaft of electromotor and rotation supply (RS) from air pressure tank.

Signals from torque sensor (3) (type 7934, producer MOM Kalibergyár with measuring range 0 ÷ 500 N.m) and pressure sensor (PS) (type TSZ, producer MERET with measuring range of overpressure 0 ÷ 1 MPa) are amplified and processed by universal 8-channel measuring aperture MX840 from producer HBM. Signals are synchronized in time and data is sending to PC [3].

Compression space of pneumatic coupling of type 4–2/70–T–C (Fig. 2. b) is created by four pneumatic-flexible elements (3); they are tangential arranged on its perimeter. Compression space is situated between driving (1) and driven (2) flange. Such as construction insures a possibility of torque transmission in both senses of rotation, because under coupling twisting are two pneumatic-flexible elements extended and two compressed. By supply hose (6) through the distributor (5) is realized filling of compression space with air.

The way of mutual interconnection of pneumatic-flexible elements according to Fig. 2. b, through distributor (5) was chosen so that air pressure in whole compression space was changed as equally as possible at inflation and exhausting during mechanical system operation. It is very advantage in term of torsional stiffness of coupling dependence change [5].

3. CONDITIONS OF MEASUREMENT

All measurements were realized at overpressure in output piping of compressor 80 kPa, which characterizes the maximal overpressure. For measurements of monitored values (time dependences of load torque (LT) M_k, transmitted by coupling and overpressure in compression space of coupling p_{pS}) was used the sampling frequency 1200 Hz.

From measured time recording of load torque M_k, that was transmitted by pneumatic coupling were in selected measurements following static values evaluated:

A) Mean value M_{SZ} – static component of LT M_k:

$$M_{sz} = \frac{1}{N}.\sum_{i=1}^{N} M_i \tag{1}$$

B) *RMS* – effective value of dynamic component of LT M_k:

$$RMS = \sqrt{\frac{1}{N}.\sum_{i=1}^{N} (M_i)^2} \tag{2}$$

Where: N - is number of samples,
M_i - is sample of time recording of LT nr. i.

For computations of M_{SZ} and *RMS* in accordance with formulas (1) and (2) were in software to measuring equipment MX840 created computation channels, that enable monitoring and recording of M_{SZ} and *RMS* values directly in time. Given computational channels utilize at computations the running average.

4. RESULTS OF EXPERIMENTAL MEASUREMENTS

Transitional effect at air pressure change in pneumatic coupling during system operation is characterized by the regions of unsteady time dependences of monitored values.

To be possible to examine the transitional effects at air pressure changes in pneumatic coupling, were in first step measured dependences of torsional oscillation size on overpressure p_{pS} value in given pneumatic coupling at various rotation speed frequencies of system from 5 to 10 Hz, in differentiation 1 Hz (Fig. 3). Air overpressure in pneumatic coupling was changed from 0 to 700 kPa, in differentiation 50 kPa.

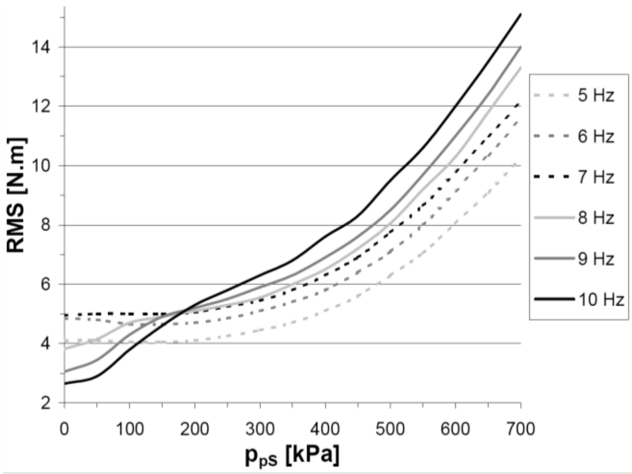


Fig. 3. *RMS* dependences on overpressure p_{pS} in coupling at various speed frequency of system
Rys. 3. Zależności *RMS* od wartości nadciśnienia p_{pS} w sprzęgle przy różnych częstotliwościach obrotów układu

In following figure (Fig. 4) it is possible to observation the *RMS* dependence change at varying air pressure decrease in compression space of coupling from overpressure value 700 kPa to 50 kPa. Rotation speed frequency was 10 Hz. At every curve in given figure is inscribed total time duration of deflation. It is possible to observe, that is pressure change slower, the more accurately are curves copying shape of curve for 10 Hz in Fig. 3. At total time duration 26,63 s the curve in Fig. 4 is already almost exactly copying curve for 10 Hz in Fig. 3. Slower we will deflate, so lowering the pressure, the oscillation of system is during deflation stabilizing to lower values.

Next were realized measurements in order to examination of speed and response form of mechanical system at rapid pressure changes at speed frequency of system 9 Hz (Fig. 5, 6). From given dependences it is possible to assert, that mechanical system is responding to pressure change in coupling immediately by the *RMS* value change according to curve for 9 Hz in Fig. 3. *RMS* values are changing until moment when pressure in compression space is coming to equalized and stabilized value. Times of stabilization at rapid pressure changes in compression space would be possible to shorten in this case especially through enlarging of diameter and shortening of supply hose length. By this modification the airflow-resistance from pressure tank to coupling would reduced. Modification can cause compression space volume change, which is equal to difference of volumes of initial and new pipe, what be going to have influence on torsional stiffness of coupling. Therefore we must make provision for compression space volume change in computations.

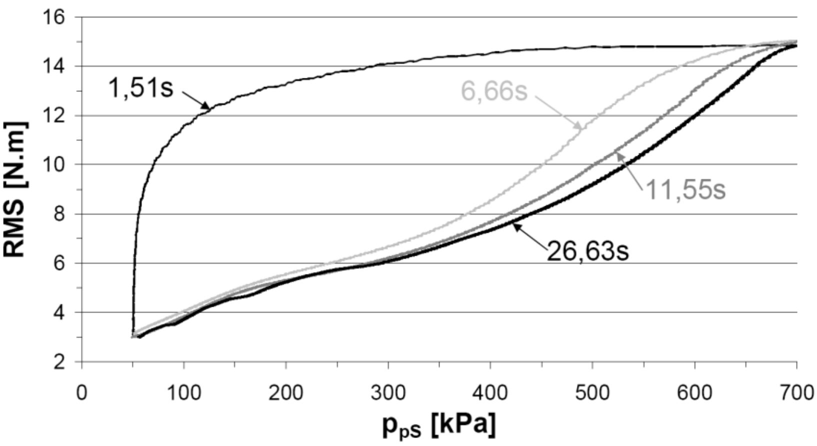
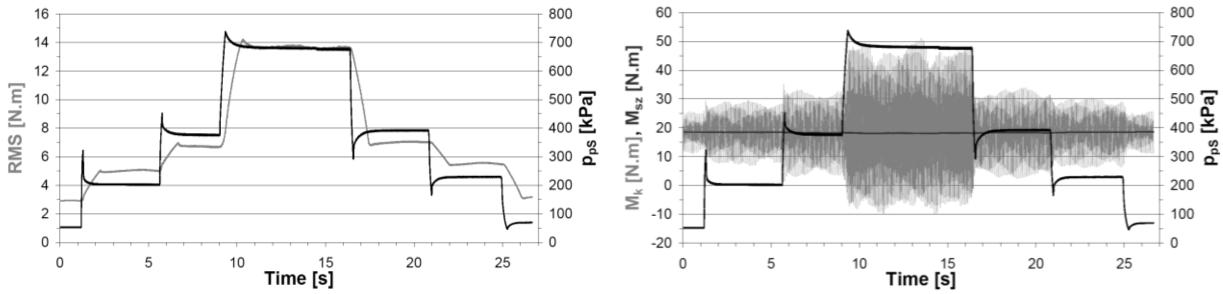
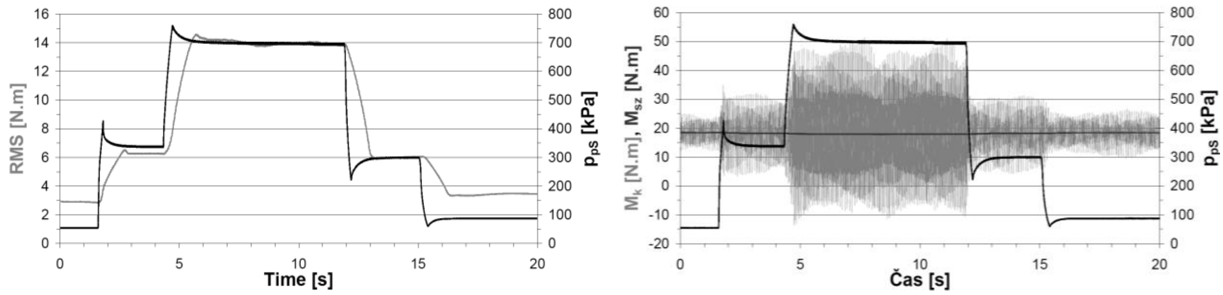


Fig. 4. Dependence of *RMS* change at varying overpressure p_{pS} time durations in coupling
Rys. 4. Przebieg zmiany *RMS* przy zmieniających się okresach trwania spadku nadciśnienia p_{pS} w sprzęgle



a) b)

Fig. 5. Time dependences of a) *RMS*, b) LT M_k and its static component M_{SZ} at rapid overpressure p_{pS} changes in coupling
Rys. 5. Przebiegi zmiany a) *RMS*, b) momentu obrotowego M_k i jego składowej statycznej M_{SZ} podczas szybkich zmian nadciśnienia p_{pS} w sprzęgle



a) b)

Fig. 6. Time dependences of a) *RMS*, b) LT M_k and its static component M_{SZ} at rapid overpressure p_{pS} changes in coupling
Rys. 6. Przebiegi zmiany a) *RMS*, b) momentu obrotowego M_k i jego składowej statycznej M_{SZ} podczas szybkich zmian nadciśnienia p_{pS} w sprzęgle

In (Fig. 7) it is possible to observe the response of given mechanical system, which is working at rotational speed frequency 6 Hz, to rapid pressure changes. Pressure change in compression space at inflation is so quick, that *RMS* value even doesn't come in time for the value according to curve for 6 Hz in Fig. 3.

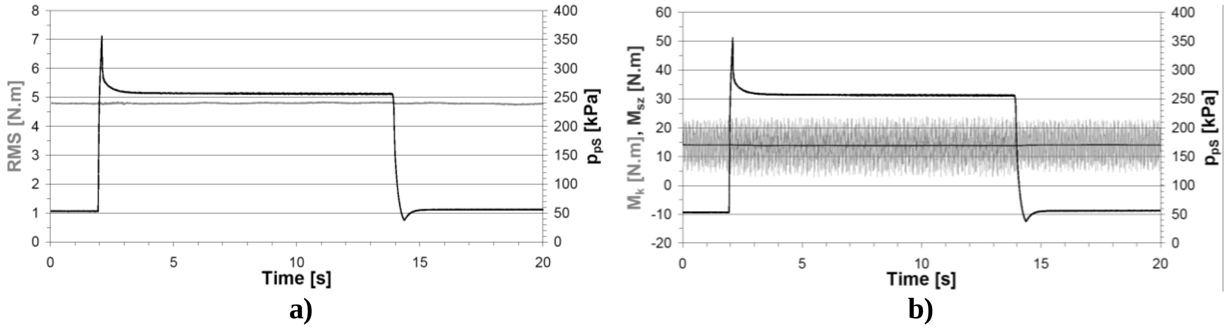


Fig. 7. Time dependences of a) *RMS*, b) LT M_k and its static component M_{SZ} at rapid overpressure p_{pS} changes in coupling

Rys. 7. Przebiegi zmiany a) *RMS*, b) momentu obrotowego M_k i jego składowej statycznej M_{SZ} podczas szybkich zmian nadciśnienia p_{pS} w sprzęgle

In Fig. 5. b, Fig. 6. b and Fig. 7. b it is possible to see, that the static component of LT M_{SZ} during measurement is keeping up to constant value and air pressure changes in pneumatic coupling don't have influence on it. It is by reason of that the static component of LT M_{SZ} depends only on overpressure in output piping of compressor (80 kPa) and its rotational speed. These parameters aren't changing during given measurements and we say that the system is working in steady state [2].

5. CONCLUSION

From measured dependences (Fig. 5, 6, 7) it is possible to assert, that given torsional oscillating mechanical system respond to air pressure change in pneumatic coupling immediately. It is possible to exactly change of dynamic component of transmitted load torque, so tuning of torsional oscillating mechanical system during its operation (Fig. 3, 4, 5, 6). This fact is possible for reason, that by air pressure change in compression space of pneumatic coupling we change directly torsional stiffness of coupling and herewith the natural frequency of system.

From measured dependences (Fig. 5, 6) we can see too, that time durations of transitional effects at rapid air pressure changes correspond with stabilization durations of overpressure in compression space time dependences. In term of tuning speed is therefore proper for coupling design, that in their compression space come to pressure time dependence compensation and stabilization as soon as possible, because as late reach pneumatic coupling required properties. Herewith come to shortening of transitional effects time duration especially at rapid pressure changes.

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This paper was written in the framework of Grant Project VEGA: „1/0688/12 – Research and application of universal regulation system in order to master the source of mechanical systems excitation".