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PORÓWNANIE POMIARÓW MOMENTU SKRĘCAJĄCEGO PRZENOSZONEGO W SYSTEMACH MECHANICZNYCH

Streszczenie: Znajomość parametrów obciążenia w układzie napędowym jest konieczna aby właściwie zaprojektować oraz zwymiarować elementy mechaniczne układu napędowego, w którym transmitowana/przekazywana jest moc w ruchu obrotowym. Silniki elektryczne są często sterowane za pomocą nowoczesnych falowników (przetworników częstotliwości). Obecnie, urządzenia te umożliwiają pośrednie pomiary obciążeń/momentów skrętnych, transmitowanych do układów mechanicznych napędzanych silnikami elektrycznymi. W niniejszym artykule, momenty skręcające transmitowane do eksperymentalnego układu mechanicznego, mierzone za pomocą falownika oraz sensorów momentu skrętnego (w różnych warunkach działania), są prezentowane, analizowane oraz porównywane.

Słowa kluczowe: kompresor z silnikiem tłokowym, pomiary charakterystyk skrętno-obrotowych, falownik, sensor momentu skrętnego

COMPARISON OF MEASUREMENTS OF TORQUE TRANSMITTED IN A MECHANICAL SYSTEM

Summary: It is necessary to know the load parameters of driven device, mainly in order to proper designing and dimensioning the parts of a mechanical system drive with rotating power transmission. Electric motors are often controlled by modern frequency converters, which currently allow e. g. indirect measuring of a load torque, transmitted in a mechanical system driven by the electric motor. Torque transmitted in an experimental mechanical system, measured using a frequency converter and a torque sensor at various operating conditions, is presented and compared in this article.

Keywords: piston compressor, torque-revolutionary characteristics measurement, frequency converter, torque sensor

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1. Introduction

In the practice, there is need for knowing the magnitude and character of the transmitted load torque in mechanical systems with rotating power transmission, for example for following reasons:

- proper designing and dimensioning the parts of a mechanical system,
- verification and evaluation of the accuracy of mathematical models of mechanical systems,
- to avoid the overload of a system,
- when a load torque parameter is the controlled parameter, e.g. [1-3], etc.

For direct and accurate measurement of the time course of a load torque, calibrated torque sensors are used. They are expensive and need to be installed in the drive chain of a mechanical system = disadvantages.
Relatively widespread parts of devices, where it is necessary to control their operating speed, are frequency converters. Range of application of frequency converters in recent decades was greatly expanded, namely by application of modern measuring and control components and software. Therefore, frequency converters currently allow e. g. specifically controlled acceleration and deceleration of devices, measuring of electrical quantities, avoiding overload, etc.
The objective of this article is the comparison of values of load torque static component, transmitted in an experimental mechanical system, measured using a frequency converter and a torque sensor at various operating conditions.

2. Experimental mechanical system

Experimental mechanical system (Fig.1) is made up of three-cylinder piston compressor ORLIK 3JSK-75 (4) placed on the isolated layer (5), driven through a pneumatic flexible shaft coupling (2) by three-phase asynchronous electric motor type 1LE1002-1CB2 (1) from the manufacturer SIEMENS. Motor speed is vector-controlled by frequency converter SINAMICS G120C made by SIEMENS and it is adjustable in the range 150 ÷ 1450 RPM.

The compressor supplies air into a pressure vessel with a volume of 300 l (6). The value of air overpressure in the pressure vessel p_{pN} can be read on the pressure indicator (7). Constant air pressure in the vessel during operation of the system can be set by the throttle valve (8) which throttles the flow of air escaping from the vessel into the atmosphere. The signals from the torque sensor (3) (type 7934 made by MOM Kalibergyár with a measuring range 0 - 500 Nm) and air pressure sensor (PS) in the pneumatic coupling (type TSZ made by MERET with pressure measuring range 0 – 1 MPa are amplified and processed by universal 8-channel measuring apparatus MX840 made by HBM. Signals are synchronized in time and the data are sent to the computer (PC). The accuracy of the torque sensor is 0,1% of its measuring range i.e. 0,5 Nm (combined fault – nonlinearity, hysteresis and reproducibility) [4]. Pneumatic coupling (2) is applied in the system to avoid the work of the mechanical system in or nearby the resonance area e.g. [1-3] during these measurements.

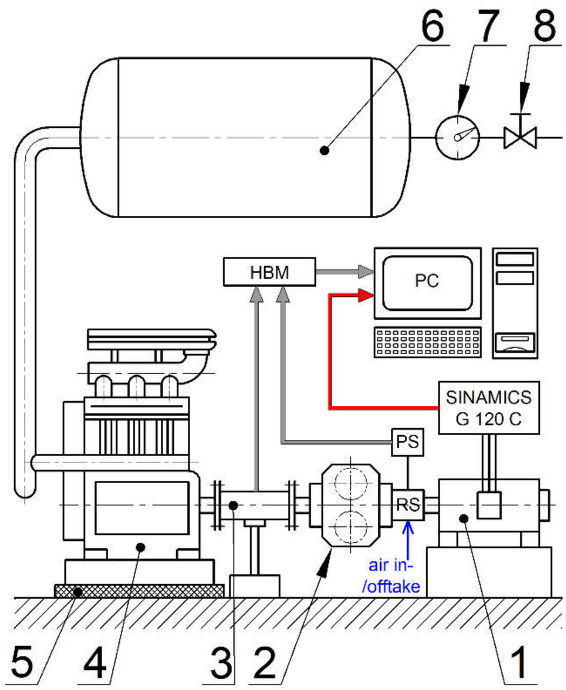

Figure 1. Experimental mechanical system

3. Conditions of measurements

Sampling frequency 1200 Hz was used for measuring of load torque courses using the torque sensor. From the measured time dependences of load torque M_k, there can be calculated i.a. following static variables:

A) Static component (mean value) of load torque M_k:

$$M_{kstat} = \frac{1}{N} \cdot \sum_{i=1}^{N} M_i, \tag{1}$$

B) RMS – effective value of dynamic component of load torque M_k:

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

where: N is number of samples,
M_i – i^{th} sample of the time record of load torque.

Using the frequency converter, only the static component of load torque M_k can be determined. PC program STARTER v 4.3 SP2 was used. The configuration file of the program for this drive was created by expert from company SIEMENS, and there was used motor nameplate data and reference [5]. The principle of torque measuring using frequency converter is measuring the consumption of electric current, motor speed and subsequent calculations, taking into account the formation and dissipation of heat in the electric motor.

Neither the torque sensor, nor the frequency converter were newly calibrated before measurement.

4. Results of the measurements

Dependences of the static component of load torque M_k on overpressure p_{pN} in the pressure vessel at a constant speed of the system 800 RPM (in the middle of the operation speed range 150 ÷ 1450 RPM of the mechanical system) were measured (Fig.2) using the frequency converter and the torque sensor.
In Fig.2 we can see that both curves have obviously degressive growing character, so their shape is very similar. The torque sensor is primarily meant to measure the load torque; therefore, it was taken as reference for calculation of percentage difference between measured dependences (Fig.3). In Fig.3 we can see that percentage difference between measured dependences is in the interval ⟨14,75%; 21,85%⟩ in whole range of measurement, but the percentage difference range is only about 7,1% in whole range of measurement. Using suitable calibration for the frequency converter, an approximate determination of the static component of the load torque, transmitted in our experimental mechanical system seems to be possible.

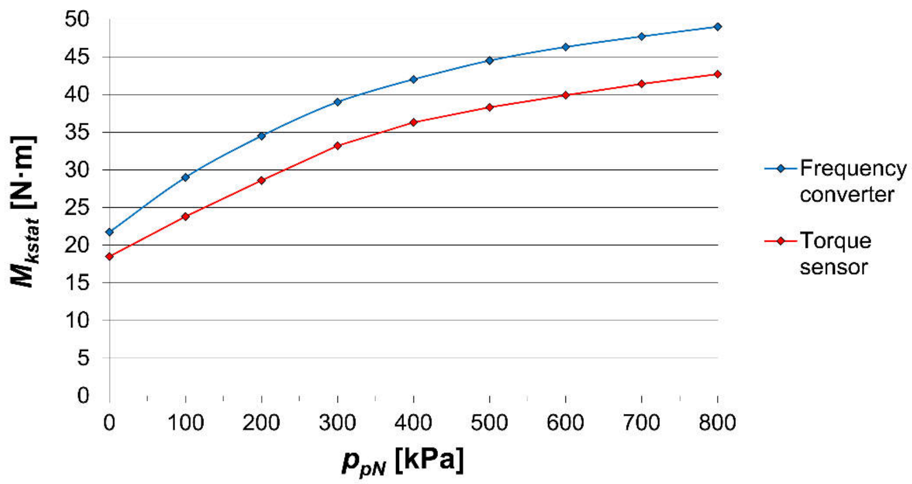

Figure 2. Measured dependences of the static component of load torque M_k on overpressure p_{pN} in the pressure vessel at a constant speed of the system 800 RPM

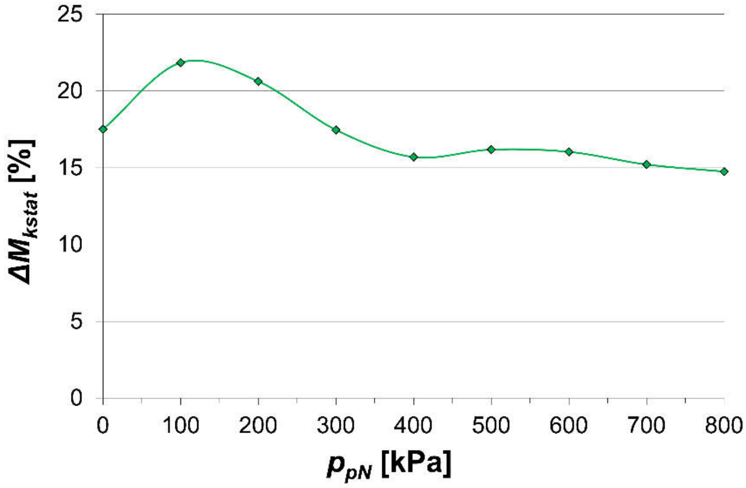

Figure 3. Percentage difference between measured dependences

Conclusion

In Fig.2 and Fig.3, we can see that the frequency converter SINAMICS G120C, after using suitable calibration, has the potential to determine approximately the static component of the load torque, transmitted in our experimental mechanical system.

To increase the knowledge of the possibility of frequency converters utilization for approximate measurement of the load torque static component in mechanical systems with rotational power transmission, it would be required to implement measurements on systems:

- with various driven devices,
- with different rated powers and magnitudes of the transmitted load torque,
- with various types of frequency converters, etc.

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