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## TORSIONAL NATURAL FREQUENCY TUNING BY MEANS OF PNEUMATIC FLEXIBLE SHAFT COUPLINGS

**Summary.** This article deals with the use of pneumatic flexible shaft couplings as device for tuning torsional natural frequencies of mechanical systems. These couplings are using air bellows as flexible elements. Their torsional stiffness can be changed by air pressure change, the natural frequencies of whole mechanical system may be adjusted on desired value.

**Keywords:** torsional vibration; pneumatic flexible shaft coupling; semi-active vibroisolation

### 1. INTRODUCTION

Development and application of pneumatic flexible shaft couplings are in the center of our department research activities for a long time [1], [2]. These couplings are able to change torsional stiffness by changing pressure in their flexible elements – air bellows. Mechanical drives with periodically alternating load torque (reciprocating engines and compressors) are prone to resonance, pneumatic flexible shaft coupling are ideal device for protecting them from excessive torsional vibration. This article deals with a problem of avoiding resonance state on an example of diesel engine – electric generator mechanical drive.

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## 2. EXAMINED MECHANICAL SYSTEM

The selected mechanical system consists of a 10-pole synchronous generator driven by a 6-cylinder diesel engine. This mechanical system works on a constant operating speed resulting from the required electric network frequency. It is necessary to use a flexible shaft coupling with a proper torsional stiffness to avoid resonance. The technical parameters of mechanical system are as follows [3]:

### Parameters of engine:

- Turbocharged diesel line engine type                      ČKD 6-27,5 A2L
- Nominal power by 600 RPM:                                       $P_M = 515$  kW
- Mass moment of inertia:     $I_M = 137$  kg.m<sup>2</sup>,

### Parameters of generator:

- Synchronous generator type                                      SIEMENS 1FC2 561-10
- Input power:     $P_G = 492$  kW
- Operating speed:     $n_o = 600$  RPM
- Number of poles:    10
- Mass moment of inertia:     $I_G = 61,0$  kg.m<sup>2</sup>

### Parameters of shaft coupling:

- Pneumatic flexible shaft coupling type                      4-1/310-T-C
- Dynamic torsional stiffness:

$$k_{dyn} = 195,6 \cdot p_{p0} + 5516 \text{ N.m.rad}^{-1} \quad (1)$$

where  $p_{p0}$  kPa is air pressure in the coupling

- Mass moment of inertia of one hub:                               $I_{1S} = I_{2S} = 29,86$  kg.m<sup>2</sup>

Static and dynamic torsional stiffness of coupling depends on air pressure  $p_{p0}$  kPa.

## 3. TORSIONAL VIBRATION ANALYSIS

This mechanical system can be considered as a two-mass torsional oscillating mechanical system, where the first mass  $J_1$  consists of masses  $J_M$  and  $J_{1S}$ , and second mass consists of masses  $J_{2S}$  and  $J_G$  (Fig. 1).

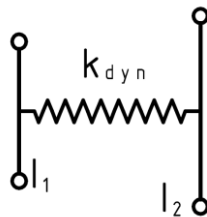


Fig. 1. Two mass torsional oscillating mechanical system

The major harmonic component of load torque for a six-cylinder four-stroke reciprocating engine is the third harmonic component, the minor harmonics are the integer multiples of half harmonic component. Minor harmonic may occur only by uneven cylinder operation.

The natural frequency of mechanical system can be computed as:

$$\Omega_0 = \sqrt{\frac{k_{dyn}}{\left(\frac{I_1 \cdot I_2}{I_1 + I_2}\right)}} \text{ rad.s}^{-1} \tag{2}$$

If resonance occurs during operation, it can be determined from Campbell diagram (Fig. 2), where the natural frequencies in RPM by different pressures (100, 200 ... 700 kPa) and harmonic frequencies of  $i$ -th order are displayed. Where the frequency of torque harmonic is equal to natural frequency, a resonance occurs.

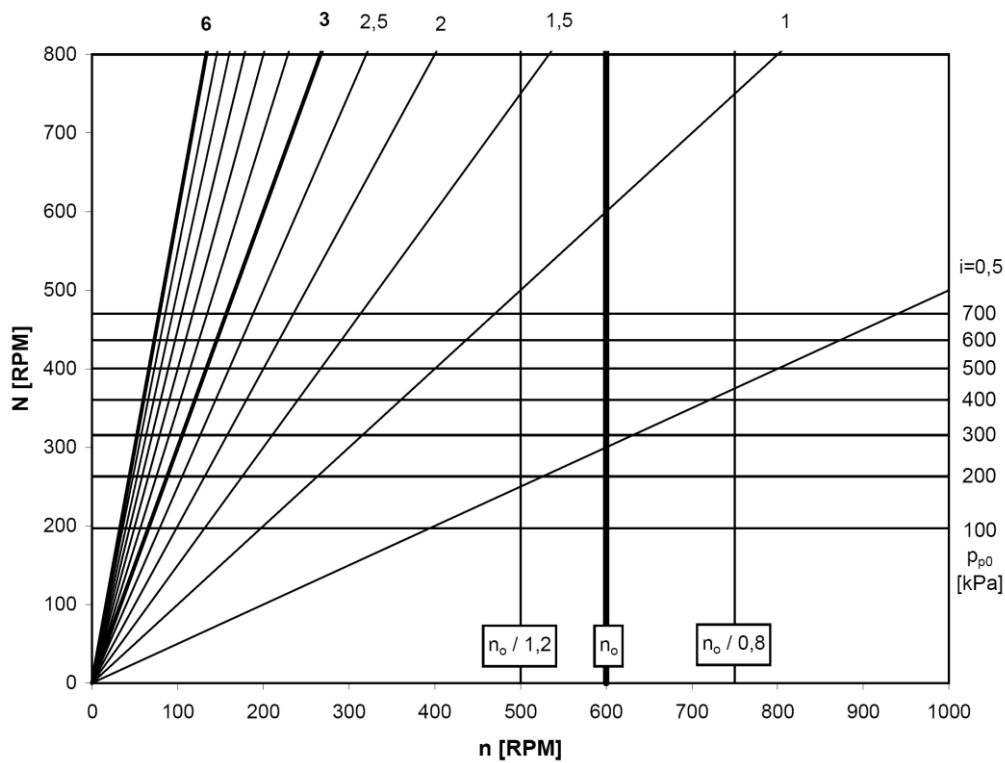


Fig. 2. Campbell diagram of examined mechanical system

Speeds where resonances occur are called critical speeds  $n_{kri}$ . How critical speeds  $n_{kri}$  depend on pressure  $p_{p0}$  is displayed on fig. 3. By the operating speed  $n_o = 600$  RPM, only one resonance from 0,5-th order may occur by pressure  $p_{p0} = 264$  kPa.

Resonance state is dangerous because of increased torsional oscillation, which can damage the whole mechanical system. According to several authors, the frequency ratio  $\eta_i = \omega_i/\Omega_0$  between  $i$ -th harmonics and natural frequency must satisfy the condition:  $0,8 < \eta_i < 1,2$ . On the Campbell diagram (Fig. 1), no resonance should lie between  $n_o / 1,2$  and  $n_o / 0,8$ . The given mechanical system can operate by pressures  $p_{p0} = 100, 500, 600$  and  $700$  kPa. By other pressures a resonance from 0,5-th order occurs near the operating speed.

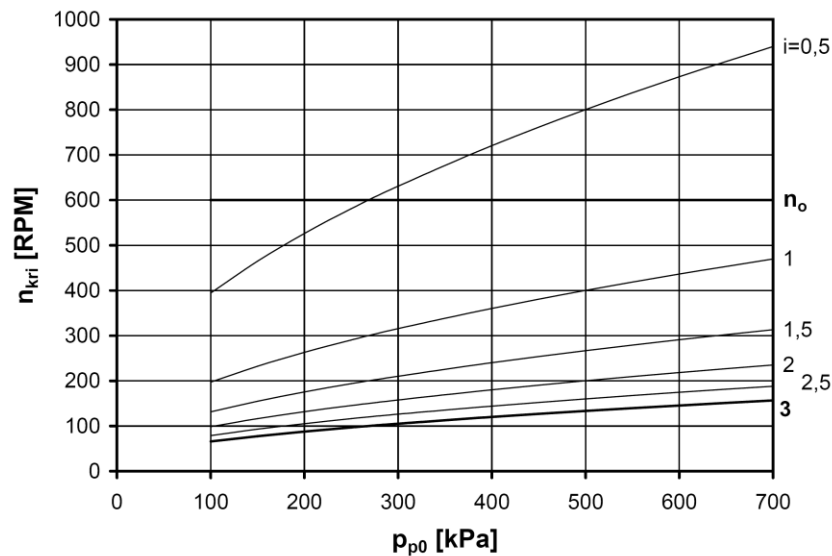


Fig. 3. Critical speeds, pressure graph

#### 4. CONCLUSION

Based on presented results, we can say that the natural frequency as well as critical speeds of a torsional oscillating mechanical system can be tuned (changed) by using a pneumatic flexible shaft coupling. Pneumatic flexible shaft couplings are therefore considered not only as plain flexible shaft couplings, but pneumatic tuners of torsional oscillation.

#### References

1. Homišin J. 2002. *Nové typy pružných hriadelových spojok: vývoj, výskum, aplikácia*. Košice: Viena. ISBN 80-7099-834-2. [In Slovak: *New types of couplings flexible shaft: development, research, application*].
2. Kaššay P. 2008. „Optimalizácia torzne kmitajúcich mechanických sústav metódou extrémnej regulácie”. PhD thesis. Košice: Technical University of Košice. [In Slovak: “Optimizing torsionally vibrating mechanical systems method Extremal Regulation”].
3. Kaššay P. 2014. „Modelovanie, analýza a optimalizácia torzne kmitajúcich mechanických sústav”. Habilitation thesis, Košice: Technical University of Košice. [In Slovak: “Modeling, analysis and optimization torsionally vibrating mechanical systems”].

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