Engineering Failure Analysis 79 (2017) 845–851

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Optimization of noisiness of mechanical system by using a pneumatic tuner during a failure of piston machine

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ARTICLE INFO

Keywords:
Mechanical system
Pneumatic tuner
Noisiness

ABSTRACT

The stage of construction and operation of the machines requires monitoring of the steps causing negative effects on humans and environment in the form of noise during their use. Current technologies allow for appropriate optimization of mechanical systems as part of these machines. One possible optimization of the mechanical systems is considered to be the use of pneumatic tuners. The aim of this article is to demonstrate the effect of the pneumatic tuner on noisiness of mechanical system even in case of failure of mechanical drive part. Performed experimental measurement presents the change of noise in mechanical system by changing a pressure of gaseous medium in pneumatic tuner's compression space. The solution is an issue of appropriate mechanical tuning system when there is a change of dynamic parameters of the system and thus to change the entire mechanical system noise. Subsequent obtained results set out suggestions for the use of pneumatic tuners in mechanical systems in order to achieve the lowest possible noise during their operation mode.

1. Introduction

In technical practice, machinery and their equipment are included into process of energy conversion. When converting energy, a change in movement, or more precisely a reduction of some of physical quantities characterizing mechanical parameters of energy transfer occur. Such changing characteristic parameter is considered to be an operating speed of mechanical system. During this energy conversion, there a loss - idle energy also occurs. The part of this energy changes into a vibrating motion of individual parts of the mechanical system and consequently the noise level increased. The question of noise of machineries is nowadays a very substantial issue which effects the sphere of machinery dynamics, their maintenance and technical diagnostics [1–5].

In terms of dynamics, every machine or machinery performing a mechanical movement can be considered as a mechanical system. The sources of dynamic forces induce mechanical motion of machine's surfaces. Subsequently, the vibrations of surfaces are transmitted into the air, which in technical practice are perceived as noise. The noise generated by mechanical systems has a negative impact on durability, reliability and safety of mechanical systems [6–9].

During an operating work of these mechanical systems, either transient or steady running, torsional shaking or vibrations may arise and their intensity depends on the dynamic properties of the system, e.g. natural frequency and time of excitation. The mentioned torsional vibrations and shaking become a noise source in the mechanical systems [10–13].

The signs of failures of individual parts of machines or machineries can be considered as results of increased vibration and consequential noise. Typical signs of predictable failure, manifested by increased noise are:

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http://dx.doi.org/10.1016/j.engfailanal.2017.05.044
Received 1 March 2017; Received in revised form 12 May 2017; Accepted 29 May 2017
Available online 30 May 2017
1350-6307/

- release of rotors and hub,
- fatigue failures of shaft,
- breaks of rotating machine parts,
- failures of gears and flexible couplings [14–18].

In case of our examination, a failure of piston machine, which is part of the mechanical drive, is monitored. The failure is represented by a decommissioning of one of the piston cylinder from running.

Mentioned examination includes proper tuning of the mechanical system besides in failure-free mode even in failure mode. The carried tuning affects dynamic properties of the mechanical system and thus changes noisiness of the entire mechanical system. One of the possible solutions of the optimizing of mechanical system is the use of pneumatic tuners in mechanical drive. By changing the pressure of the gaseous medium in the pneumatic compression space of tuners, it is possible to change a torsional stiffness, and hence the natural frequency of the mechanical system. According to several authors, the most proper pneumatic tuner in mechanical systems is pneumatic flexible coupling [19,20].

The basic characteristic of the pneumatic flexible coupling is a compression space, located between the drive and driven parts of the coupling. A compression space is formed by one, optionally more pneumatic flexible elements that are, or may not be interconnected. Pneumatic flexible element is filled with a gaseous medium (usually air). Construction and operating principles of the pneumatic flexible couplings allows for a wide variability of their strength and operational characteristics that belong to their exceptional properties.

For propagation of the properties of pneumatic flexible coupling, it has become an integral part of the observed mechanical system, which was created for experimental measurements to fulfill the purpose of this article. By demonstration of the effect of the pneumatic flexible couplings, the noisiness of mechanical system was monitored [21,22,23]. The main aim of the article is to present the influence of the pneumatic tuner on the noise of the mechanical system, which we examined in a failure-free mode and failure-mode of the mechanical system.

2. Preparation for laboratory experiment

To provide the noise experimental measurements, the mechanical system was assembled in laboratory conditions. The realized mechanical system (Fig. 1) consists of a three-cylinder air compressor (4), which is driven via pneumatic flexible coupling (3) by a three-phase asynchronous electric motor (1). Another part of the mechanical system located after electromotor is a two-speed gearbox (2). Specific parameters of devices are in Table 1. The mechanical system operates in the range of operating speed. A work mode of the mechanical system can be continuously varied by a changing the operating speed of the electric motor. Into the mechanical system, a three-cylinder compressor is included and it is used as a producer of torsional vibration. The failure of piston machine is simulated by decommissioning of one piston cylinder which causes a significant change in torsional vibration.

Long-lasting operation of mechanical systems, which causes fatigue and aging of particularly flexible shaft couplings, as well as randomly generated phenomena induced by change of characteristics of the drive and driven equipment, it affects the steady running of the mechanical system particularly in terms of dangerous torsional vibration and noise. As a result of the mentioned phenomena, a tuned mechanical system becomes out of tune. In this case, the flexible shaft coupling is not able to reduce and in some cases even eliminate the increasing torsional vibration, causing the noise of the whole system. To ensure proper tuning of vibrating mechanical systems, the application of the pneumatic flexible coupling is suitable solution for the mechanical system's tuning.

Changing the pressure of the gaseous medium in the pneumatic flexible coupling affects its stiffness and damping properties, thus it can optimize the whole system. Fig. 2 shows a pneumatic flexible shaft coupling designated 4-1/70-T-C used in measurements of mechanical system noise.

Torsional stiffness k is allowed to be a dynamic property that significantly affects the natural frequency of the mechanical drive. Changing the natural frequency of the mechanical drive, it is possible to avoid the resonance area [19,24,25]. In Fig. 3, courses of torsional stiffness k at various value of air pressure in the pneumatic flexible coupling depending on the load torque Mk are showed.

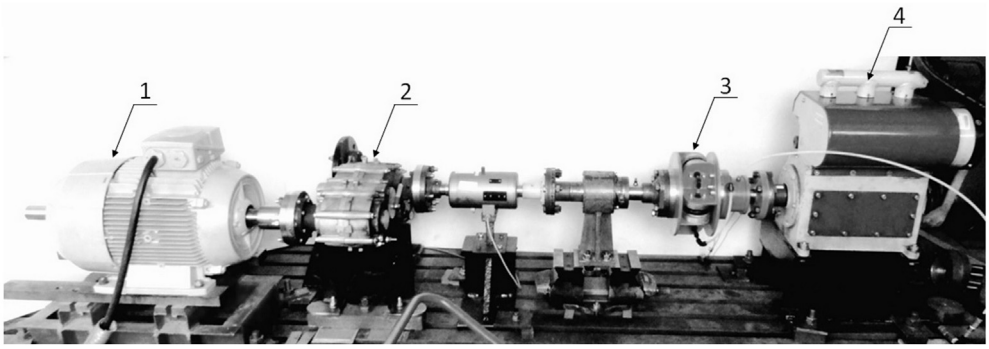

Fig. 1. Experimental mechanical system. 1 - three-phase asynchronous electric motor, 2 - two-speed gearbox, 3 - pneumatic flexible coupling, 4 - three-cylinder air compressor.