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ABSTRACTS

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Dynamic aspects of design and maintenance of the rotating machinery applied in the mining industry

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1 Introduction

An operation of many machines and devices applied in the mining industry is characterized by rotational motion of their fundamental working tools. To this broad group belong several types of beater mills and beater crushers used in main production processes as well as blowers, rotor pumps, compressors and others regarded as auxiliary units. Majority of them are driven by electric motors by means of flexible couplings and by spur- or planetary gears. The still increasing work efficiency requirements to these machines, commonly observed nowadays, result in more and more dynamic character of their nominal operation. Namely, all these machines transmit now greater and greater power, they work with bigger and bigger rotational speeds, with greater and greater flow velocities and pressures as well as with raising impact force values caused by the comminution processes. These operational performances cause high steady-state or transient dynamic over-loadings which usually excite several types of mechanical vibrations. These vibrations often lead to more or less detrimental exploitation consequences in the form of dangerous material fatigue defects and too fast tribological wear of the responsible structural elements as well as to harmful noise generation, transmission of damaging oscillations to the surrounding environment and to many others. Thus, these dynamic aspects and particularly the vibratory effects should be more and more seriously taken into consideration during design and maintenance phases of such machines, in addition to the common traditional engineering routines applied till present. This postulated modernized approach ought to reduce to thorough and complete dynamic analyses associated with experimental verifications in the frameworks of design and prototyping phases as well as to advanced on-line monitoring and fault detections during a regular maintenance. It is worth emphasizing that for this reason there should be applied modern mechatronic methods based on more and more advanced control and diagnostic algorithms using several sensors, controllers, actuators, transducers and other electronic devices.

As it follows from practical engineering observations and scientific literature studies, e.g. in [1-3], such modern approaches to design and maintenance are mainly practiced in the case of typical flow rotating machines, i.e. for compressors, turbines, pumps, fans and blowers. But very little attention for this purpose seems to be focused to beater mills and crushers which can be also regarded as classical rotor-machines, because of their highly dynamic character of operation. According to the above, in this paper some important aspects of dynamic analyses necessary to achieve a correct design and possibly trouble-free maintenance of the high-speed beater mills, crushers and other rotor-machines are going to be considered.

2 Objects of investigations

The dynamic investigations will be devoted to the typical high speed beater mills, beater and hammer crushers as well as to the medium-speed blowers commonly applied as auxiliary devices for the ball-, rod- and roller-bowl mills. All these units are usually characterized by mutually similar structures [4-5]. Namely, the working-tool parts of them consist of heavy beater wheels or impellers attached to the bearing shaft in the form of overhung rotors creating in this way a rotor-shaft. This rotor-shaft is commonly supported by rolling bearings and directly driven by an electric motor, i.e. by means of a flexible coupling only, but without any gear stage [6-7] . The schematic view of such object is presented in Fig. 1. It is worth noting the characteristic feature of these devices, namely

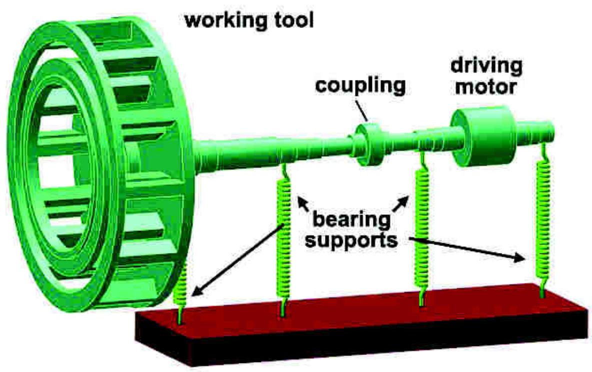

Fig. 1. Scheme of the rotor-machine.

3 Final remarks

In the paper dynamical aspects for design and maintenance of the selected group of machines applied in the mining industry are considered. These machines and devices are driven by the asynchronous motors and they are characterized by rotational motions of their fundamental working tools [8-10]. Thus, the dynamic investigations have been performed in the way typical as for the rotating machinery, i.e. in the form of bending (lateral) and torsional vibration analyses. Moreover, in these studies there was also investigated a mutual interaction between the mechanical and electrical part of the considered objects. Contrary to the traditional engineering approaches usually applied so far for design and maintenance of these machines, for the computations carried out here the advanced mechanical and electro-mechanical models and computer techniques have been used. By means of these modern computational tools the main attention was focused on qualitative aspects of dynamic behaviours typical for beater mills and crushers as well as for blowers and compressors.

From the results of bending vibrations analyses performed for the listed above machines characterized by heavy beater wheels or impellers designed in the form of overhung rotors it follows that their dynamic loadings caused by unbalances turned out to be particularly dangerous for fatigue life of their the most responsible elements. These unbalances are more dangerous than dynamic loadings associated with natural working processes, since they are caused not only by unavoidable manufacturing inaccuracies, but first of all by gradual and progressive material, thermal or erosive damages of working tool surfaces. The bending vibrations of the rotor-shafts of these machines induced by these unbalances can be a source of too fast material fatigue often leading to cracks and even to catastrophes, of dynamic over-loadings of bearing supports usually being transmitted to the environment as well as of harmful noise generation. According to the above, these detrimental and dangerous effects have to be thoroughly taken into consideration during routine design phases of these machines as well as they should be on-line monitored during regular operation in order to asses a degradation level of the working tools.

The torsional vibrations have been investigated here as entirely associated with electrical vibrations in driving motor windings in the form of electromechanical interaction analysis. From the results of performed computations it followed that steady-state operation conditions of the considered machines are not a source of essential torsional vibrations, contrary to quite frequently repeated start-ups of these devices, which can cause very severe or even dangerous transient oscillations. Here, mutual interdependencies between the electrical parameters of the driving motor and dynamic properties of the driven mechanical part significantly influence magnitudes of these vibrations. It turned out that the most important role play stiffness characteristics of the flexible couplings, an ability of negative electromagnetic damping generation by the asynchronous motors as well as a character of motor supply voltage control during start-up processes. First of all, in order to avoid severe transient torsional vibration amplitudes the asynchronous motors with inverters should be applied to control properly the supply voltage influencing runs of the driving motor torques. Then, start-ups usually last longer, but without remarkable oscillations, if system parameters had been properly selected before. Namely, the flexible couplings with non-linear characteristics seem to be more convenient, since they have an ability to mistune possible resonances. Next, the asynchronous motors with greater starting torques can assure shorter start-ups in time and thus also faster passages through eventual resonance frequency zones. Moreover, such asynchronous motors are able to generate less negative electromagnetic damping which is very dangerous from the viewpoint of an excitation of transient resonances and operational instabilities.

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