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ABSTRACT

Analysis of Dynamic Characteristics of Conceptual Vibration Reduction System

Mechanical vibrations are an inherent part in the operation of machines. Striving to improve the efficiency of machines usually results in extra dynamical loads, and increasing dimensions or downsizing causes substantial changes in dynamical properties. This creates new challenges related to the dynamical behaviour of machines. Overcoming these challenges translates into their excellent performance and failure-free operation. In the case of production machines, oscillations as a general rule deteriorate the product quality. Therefore, to reduce undesirable vibration, the machine-building industry now faces the need to find effective and economical solutions which are easy to operate and environmentally friendly at the same time.

The main aim of the dissertation was to develop a novel Conceptual Vibration Reduction System (CVRS) for three different types of production machines and perform a dynamical analysis of the achieved solution. The underlying assumption was that the device should be simple in terms of design and, due to this simplicity, reliable and economically attractive. Additionally, considering the structure of the machines where the novel system was supposed to be implemented, the new device had to be relatively flat. The proposed system works on the principle of a Tuned Mass Damper (TMD). TMDs are mainly found in civil engineering (bridges and skyscrapers) and in their classical form they are a set of elastic elements, inertia elements and dissipation elements (e.g. dampers). In the presented device the role of the elastic element is performed by a flat plate to which smaller plates are attached acting as vibrating masses. The damping is exclusively the effect of natural phenomena – e.g. friction occurring between the plates. The CVRS thus has no classical dampers, which reduces the device cost and makes it very compact.

Because the machines under consideration operate with different rotational speeds of the main shaft, their dynamical assessment prior to and after the CVRS installation was made using order analysis. The machines which are new designs demonstrated such high amplitudes of vibration within the range of their operating rpm values that their effective operation was impossible. The CVRS reduced the maximum vibration amplitude in all three types of machines, which solved the problem. A number of measurements were performed on the machines and the results confirmed the CVRS effectiveness. In the case of the first machine type, without the CVRS the maximum vibration displacement was by 50% and

in the case of the second machine type by 57% bigger compared to the values measured after the CVRS was installed. In the case of the third machine type, the maximum vibration acceleration without the CVRS was by 37% higher than the values measured for the machine after the CVRS was mounted on it. These benefits of vibration reduction are achieved by means of a device which, due to the materials used to construct it, is environmentally friendly and fully in line with the principles of sustainable development. The CVRS is recyclable and 100% passive, which means that it needs no external supplies of energy to operate.

On the way to achieve the main aim, the dissertation presents a discussion of vibration modelling, using both the analytical and the numerical approach. A review is then made of different methods of vibration reduction in many fields of technology. Considering that measurement is one of the basic sources of information about the dynamical state of machines and structures, considerable attention is given to issues related to experimental evaluation of the dynamical state of technical facilities. This concerns measuring techniques on the one hand, and the obtained vibration signal processing on the other. A correct performance of dynamical measurements, combined with a professional interpretation of results, is often the only way to find the source of vibrations, establish their character and determine the structure response. Ultimately, it makes it possible to develop effective methods of reducing unwanted oscillations.