Abstract

Machines and structures working under external excitation are exposed to a resonance. Therefore, matching of the external excitation's frequency with one of the natural frequency can lead to sudden increase of amplitude and cause the failure or destruction of the system. To protect structures and machines methods of reducing of the oscillations' amplitude have been developed. Assuming inability to remove the external excitation one can set the working frequency far from the natural frequencies or use the external damping devices. Putting constrains on the range of the accessible frequencies is useful mainly for systems working under known and restricted conditions. In a more general case with low predictability of the external forcing frequency or with necessity to cross the natural frequencies during normal operation the additional devices become the best solution, although they are subjected to the various limitations. Hence, the new solutions which extending the usefulness and increase the reliability of external damping devices are important. The largest group of devices used in mitigation of vibrations are a tuned mass dampers (TMD). The most basic TMD is consist of the mass and the spring and has the natural frequency equal to natural frequency of the damped structure while its mass is at least ten times smaller then the mass of damped body. It is attached to the main body via the spring and should oscillate in the same direction as the damped body. The TMD is extremely efficient in reducing the amplitude when the frequency of the excitation is matching with its natural frequency, but outside this range it causes the increase of the amplitude. To overcome this problem a lot of modifications of the TMD have been proposed. Generally, we can distinguish three main groups of the TMDs, i.e, the passive, semi-active and active devices. The most simple one is the passive, where no control is need and it is easiest in exploit. However, in many cases we have to control the TMD to tune it to the current working and external conditions, hence we need to use the semi-active or active device.

Nowadays, many studies are focused on possibility of optimization of the TMDs. Nevertheless, the TMDs have limited effectiveness which depend on their design and the span of the external excitation's frequency. Unfortunately, the non-constant excitation frequency reduces theirs' performance. In order to overcome that weaknesses a new type of the vibration's absorber with inerter is proposed. It is designed to damp out the oscillations of the maim mass assembly moving in the vertical direction excited kinematically by a crank mechanism. The vibration's absorber is mounted on structure and is composed of combination of the classical TMD with a continuously variable transmission (CVT). The CVT enables continuously variation of a gear ratio which is used to stepless change of the inertance. The inertance adjustment let us achieve the accurate change of the TMD's natural frequency according to current frequency of the excitation. Such possibility causes that the TMD is extremely efficient in the wide range of the frequency of excitation.

In our investigations we concern the mathematical and numerical modelling simultaneously with the laboratory tests. The frequency response curves (FRCs) are used to present how the considered device influences the dynamics of the analysed system. We demonstrate its capabilities and broad spectrum of applications. Presented FRCs let us compare the numerical predictions of system's behaviour and experimental data. The matching of results present almost identical correspondence. The device performance is outstanding in compare to currently known solutions which result in significant amplitude's reduction in a wide range of the forcing frequencies.

Further studies concerns examination of the dissipation of energy in the guiding systems. We use two guiding systems, i.e., a linear bearings for main mass and a rollers and TMD. In each case the first parameters' approximation is based on method proposed by Linag and Feeny. This method let us estimate the partition of dry and viscous frictions in the overall dissipation of the energy, however it is restricted just to linear systems and in real system like our there is a mismatch between calculated and real parameters. Hence,

we use those parameters as an initial values to additional estimation with a gray box model identification algorithm implemented in Matlab identification toolbox. The obtained results give very good correspondence between model and measurements. Hence, the simplified model of energy dissipation is good enough to correctly model response of the system.

The next part of the thesis is focus on detailed analysis of the inerter with CVT. We examine two CVTs in order to find the gear ratio characteristics and value of the inertial motion resistances. The fist one is designed by candidate and second one is out of shelf. We prove robustness and advantage of the designed CVT. In that transmission type characteristics of gear ratio is linear and the hysteresis effect does not occur. Furthermore, we investigate the possibility to increase its performance range via increasing the inertia of the flywheel. The motion of the CVT is oscillatory, hence the direction of rotations is changing periodically. We show that during the change of the direction the slip between interacting elements of the CVT does not occur. Hence, there is no reduction in the device performance.

Finally, the thesis includes the description of the influence of a nonlinear damper with variable coefficient of damping placed between the main mass and the TMD. In case of linear damper there are two points along the FRC that do not dependent on the value damping coefficient known as points P and Q. We studied how using the non-linear damper and the inerter we can change their positions. Analysis proves that suspicion of stationary character of this points is true even with nonlinear damper. However, we show we can decrease amplitude of main system by destabilization of the periodic solution or by change of the inertance of inerter.

This work concerns the novelty on inerter-based systems in a field of vibrations' mitigation. The deep theoretical and numerical study is performed together with the experimental verification. Received data shows capabilities of a combined system with the TMD and inerter equipped with the CVT. Obtained results proves basic idea leading to promising commercial implementation in mechanical structures working under external excitation with non-constant frequency.

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