Free balls in rotating or non-rotating tracks can mitigate rotor vibration

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Abstract. Vibration is an undesired response that increases the dynamic loads in rotor systems. The current study demonstrates the effect of a ball moving freely in a circular track on reducing the vibration of an unbalanced rotor, whether due to automatic balancing or energy absorption. We mount the circular track on a ball bearing to prevent its rotation as a part of the primary rotor, proposing a new design for a ball-in-Track Nonlinear Energy Sink (BIT-NES). Thanks to the design that allows fixing the racetrack to the rotor using four screws, we can compare the suppression effect of the new absorber with that of a typical automatic ball balancer (ABB), in which the racetrack rotates as a part of the rotor. For a small radius track, the modified absorber can reduce the rotor vibration at low angular speeds compared to the typical ABB.

Introduction

Rotor vibration resulting from imbalance is a source of uncomfortable operation that reduces the lifetime of rotary machines and possibly damage them. A typical automatic ball balancer (ABB), composed of a ball free to move in a circular track rotating as a part of the primary rotor, can counteract rotor imbalance and mitigates its vibration. The experiments demonstrated that the ABB works effectively at high angular speeds above the rotor critical speed [1], as the ball was located automatically in a proper position to counteract the system imbalance reducing its amplitudes. However, the ABB can result in more vibrations at low angular velocities, because the reaction forces with the track drive the ball away from the desired position. Ball-in-Track Nonlinear energy sink (BIT-NES) is an advanced vibration absorber similar to the ABB in structure but differs in its principle of operation. A recent study [2] has explained how the BIT-NES absorbs the lateral vibration of a prism subjected to airflow in wind tunnel tests. Based on the targeted energy transfer (TET) concept, the ball rotates to absorb energy from the primary system and dissipates it through friction with the NES track walls during rotation.

This study proposes a modified design of a BIT-NES, in which the racetrack, integrated on a ball bearing, does not rotate as a part of the rotor shaft. We tested the modified BIT-NES effect in reducing the vibration amplitude of a vertical unbalanced rotor. Moreover, four screws can lock the circular track of the device to resemble a typical ABB. Comparing the suppression effect of the typical ABB to that of the proposed BIT-NES illustrates the impact of the ball track relative rotation with the rotor system.

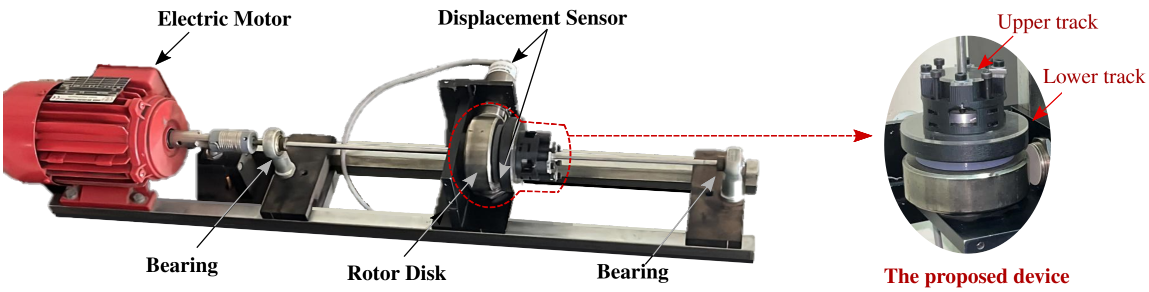

Figure 1: Experimental Setup, simply supported rotor coupled with the proposed BIT-NES.

Results and discussion

The NES main body is coupled with the rotor shaft through a ball bearing in order that we can neglect its rotation. The developed BIT-NES (Fig. 1) has two circular tracks; a racetrack surrounding the ball bearing with a 3 cm mean radius and an upper one with a smaller mean radius of 1 cm. A 2.5 gm ball can occupy one of the two tracks. Besides, the design enables fixing the track with the rotor by four screw bolts to resemble a typical ABB, in which the racetrack rotates as a part of the rotor. The ABB reduces rotor vibration at high angular velocities above the rotor critical speed. However, it increases the amplitudes at lower angular speeds. In the case of a non-rotating track, the BIT-NES of the smaller radius could reduce the rotor amplitudes at low angular speed compared to a typical ABB. While for the larger radius track, the proposed device increases the rotor amplitudes. Furthermore, the ABB is more efficient in mitigating rotor vibrations at higher angular velocities.

References

[1] Michael Makram et al. (2017) Experimental investigation of ABB effect on unbalanced rotor vibration. JCSMD **7**:225-231.
[2] M. Selwanis, G. R. Franzini, C. Béguin, F. P. Gosselin (2022), How a ball free to orbit in a circular track mitigates the galloping of a square prism. Nonlinear Dyn.