Investigation of shear wave interaction at a frictional hysteretic interface

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Abstract. This work presents analysis and experimental assessment of higher harmonic generation due to the interaction of a shear wave with surfaces in frictional contact. The motion between the surfaces is first assumed to obey symmetric stick-slip hysteresis. Subsequent experimental measurements obtained from contacting steel samples exhibit asymmetrical features. Consequently, a new asymmetric hysteresis model is introduced, which is subsequently evaluated using a harmonic balance approach. The model and experimental findings are found to have both qualitative and quantitative agreement.

Introduction

In the literature, three modes of relative motion of contacting surfaces can be considered, namely breathing, shearing and tearing [1]. As the breathing motion is well described and analysed in the context of wave transmission across the interface, the shearing movement has not received so much attention. The Coulomb friction law is a common choice for describing tangential forces at the shearing interface, as shown in [2]. However, in [1], the experimental results showed hysteretic behaviour of the shearing motion is much stronger than it would be caused by the Coulomb's friction force. Thus, two steel specimens, as shown in Fig. 1, are manufactured and placed in frictional contact. The experimental setup is shown in Fig.1, as well. In contrast to [2], the analytical model used herein formulates the friction law using a relative velocity between surfaces. A harmonic balance (HB) solution approach is then used to evaluate the analytical model – more details are provided in [3].

Results and discussion

Bottom part of Fig. 1 presents results from both the experimental investigation and the harmonic balance solution, assuming symmetric (left) and asymmetric (right) stick-slip hysteresis in the analytical model. The experimental results demonstrate that the measured hysteretic contact is asymmetric with respect to the vertical axis. Thus, a new hysteretic stress-strain relation of an asymmetric pattern was introduced to incorporate two sets of transition ratios (as will be discussed during the presentation). As evidenced in Fig. 1, subsequent evaluation of the asymmetrical model with the harmonic balance approach exhibits stronger qualitative and quantitative match with experimentally-measured higher harmonics than does the symmetrical model, in both positive and negative values of the velocity response. The developed HB-based analysis of nonlinear shear wave propagation between surfaces in frictional contact is expected to be a useful tool for deepening understanding of higher harmonic generation in structures incorporating dry friction damping, to include jointed structures and dry friction-damped turbine blades.

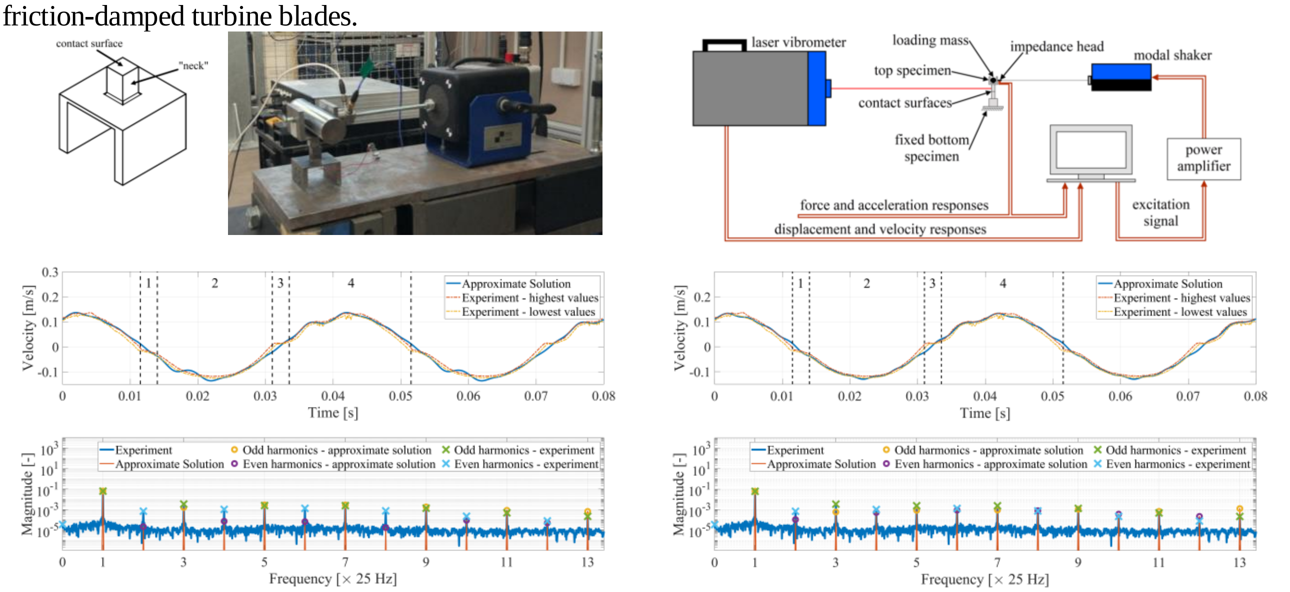

Figure 1: (top-left) Depiction of system and experimental apparatus; (top-right) data acquisition for measuring higher harmonics; and experimental validation of the theoretical results: (bottom-left) symmetric hysteresis; (bottom-right) asymmetric hysteresis.

References

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