DSTA 2021 dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

An insight into amplitude-depended modulation transfer due to nonlinear shear wave interaction with contact interfaces

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Abstract: This paper discusses the influence of the excitation amplitude on the transferred side-bands due to interaction between propagating shear waves and contact interfaces. Two cases of contact model are scrutinized using numerical tool based on Local Interaction Simulation Approach (LISA), namely the frictional contact and piecewise elasticity change. It is shown for the first case that comparable values of amplitudes of the modulated pumping wave and the probing wave leads to the modulations transfer phenomenon. However, in the latter case, it is necessary for the amplitude of the modulated pumping wave to be larger than the one of the probing wave to observe a transfer of modulation. This work lays the foundation for further analysis, which will help to distinguish the input condition for monitoring the state of the structures using methods based on the shear wave modulation transfer.

Keywords: Nonlinear Shear Wave, Friction, Piecewise Elasticity, LISA, L-G

1. Introduction

The structural evaluation techniques based on the nonlinear features of the propagating ultrasonic waves have recently received a lot of academic attention. It is known, that nonlinear sources can impact the propagating ultrasonic wave, generating high-order harmonics, side-bands (cross-modulation), frequency shift or modulation transfer. The physical mechanism of these phenomena are different, and appropriate models need to be established to facilitate in-depth understanding of the experimentally observed dependences, e.g. between the wave amplitude and the modulation transfer intensity.

In this paper, a particular case of the modulation transfer phenomenon for shear horizontal (SH) waves is analysed using the Local Interaction Simulation Approach (LISA) framework. Two crack surfaces contact models are considered, the Coulomb friction model and the nonclassical piecewise elastic model [1]. For the latter, a piecewise stress-strain relation with stiffness reduction is assumed. A parametric study is conducted to check the influence of the excitation amplitude on the modulation transfer, due to nonlinear interaction of the shear waves and contact interfaces.

2. Results and Discussion

The results from two numerical models based are presented in Fig. 1. The top and bottom one corresponds to the implemented Coulomb friction model and a local piecewise elastic nonlinearity model, respectively. To observe the modulation transfer, the pumping and probing waves are excited simul-

taneously by a displacement uniformly distributed over the thickness of the plate. For both numerical cases, the pumping wave is a high frequency amplitude modulated acoustic wave with the carrier frequency f_1 = 490 kHz and the modulation frequency f_m = 21 kHz [2]. The probing wave is a mono-harmonic wave with the frequency f_2 = 85 kHz. A parametric study was performed to investigate the influence of the amplitude ratio on the manifested modulation transfer. The results presented in Fig.1 correspond to the displacement excitation amplitudes of the pumping and probing waves both equal to 1 μm for Coulomb friction model; and respectively 1 μm and 0.2 μm for the piecewise elastic crack model.

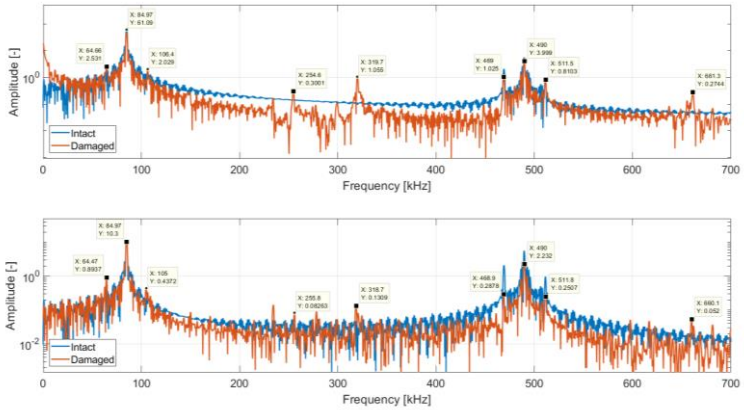

Fig. 1. Numerical results obtained from SH-LISA in frequency domain for intact and damaged structures for Coulomb friction model (top) and nonclassical local elastic nonlinearity (bottom).

Regardless of the chosen excitation amplitudes, for both models of the crack, in the frequency spectrum of results, it is possible to identify the modulation transfer sidebands ($f_2 \pm f_m$), the odd higher harmonics (2n+1) f_1 and (2n+1) f_2, and the mixed terms responsible for the generation of sidebands around the frequency $f_1 \pm 2\ f_2$. Also, for the classical friction model, the modulation transfer is always present. In contrast, for the assumed piecewise elastic model of the crack, the amplitude of the excited pumping wave had to be chosen as at least five times greater than the probing wave to observe a significant modulation transfer.

3. Concluding Remarks

In this work, the impact of the crack models and amplitude of the excitation on the frequency characteristics of guided SH waves is investigated. The simulation results show that the modulation transfer from the high frequency pumping wave to the probing wave can be observed for both implemented crack models. However, the intensity of this phenomenon is amplitude dependent and requires further research.

Acknowledgment: The work presented in this paper was performed within the scope of the research project UMO-2018/30/Q/ST8/00571 financed by the Polish National Science Centre.

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