Inclusion detection in viscoelastic phantom from surface vibration response

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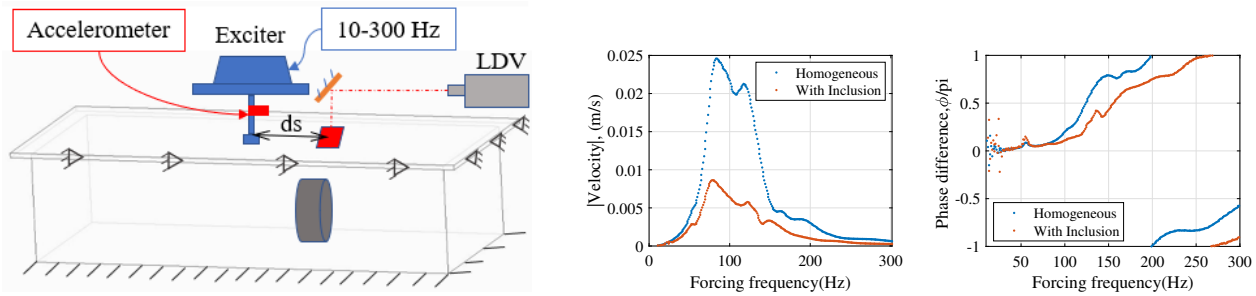
Abstract. Detection of inclusion in a hyper-viscoelastic material has many applications, especially tumor detection in the biomedical field. A solid rectangular, hyper-viscoelastic, tissue-mimicking phantom is modelled using silicon rubber polymer. A point load sinusoidal excitation is applied to the phantom surface in the transverse direction. The surface vibration response of the phantom is captured using a laser Doppler vibrometer, and the exciter response is recorded using an accelerometer. The frequency response at different locations on the phantom surface is investigated. The experiment is repeated, incorporating a small inclusion of higher stiffness, and the frequency response is subsequently compared with that of the homogeneous phantom.

Introduction

Inclusion detection in a hyper-viscoelastic material mainly applies to tumour detection (specifically breast tumours). Tumour stiffness is 4–20 times that of normal tissues. Elastographic methods use this difference in stiffness between tumour and healthy tissues for detection[1]. Palpation, palpation imaging, ultrasound elastography, and magnetic resonance imaging are the Commercial elastographic methods. Digital image elastotomography (DIET) is a recent elastographic technique that uses the surface vibration response to detect inclusion in a phantom[2][3]. This technique uses several cameras to capture the vibration response of the tissue surface. Prior studies on DIET used base- or surface-excitation of the phantom. In these studies, point load excitation was not considered. The present study explores the vibration response of the phantom surface due to point load harmonic excitation. The excitation is applied centrally to the top surface of the phantom using a modified electrodynamic exciter, and the surface response is captured, as shown in fig.1(a). The excitation frequency ranges from 10–300 Hz. An accelerometer is used to capture the exciter response, and a laser Doppler vibrometer (LDV) is used to capture the phantom surface response.



(a) Experimental set-up (b) Amplitude Response (c) Phase response

Figure 1: Experimental setup and Results

Results and Discussions

The experiment is performed on two types of phantom: a homogeneous phantom and a phantom with an offset inclusion. The inclusion is at a distance, $di = \frac{2L}{13}$ from the center, where L is the length of the phantom. The response is recorded at a distance, $ds = \pm\frac{L}{13}, \pm\frac{2L}{13}, \pm\frac{3L}{13}$ from the center, where ds is the distance of measurement location from the center. The time domain data from the sensors is processed using fast Fourier transform in MATLAB to obtain the frequency response at corresponding locations on the phantom surface. The amplitude and phase response at $di = ds = +\frac{2L}{13}$ of both types of phantom are shown in fig.1(b) and fig.1(c), respectively. The blue and red dots are the responses from a homogeneous and nonhomogeneous phantom, respectively.

As evident from the figures, the presence of inclusion causes a significant change in amplitude and phase across the frequency range. The study explores the variation of frequency response with an increase in ds and analyzes the response variation when $ds < di$, $ds = di$, and $ds > di$. The results reveal that the surface vibration response can be used to identify the presence of inclusion.

References

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