**"Anomalous behavior of ultrasonic Love waves propagating in two-layer waveguides loaded with a Newtonian liquid"**

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## Background, Motivation and Objective

Despite the fact that Love surface waves have been discovered initially in seismology, as the waves occurring in the wake of earthquakes, they found recently numerous application in a benign domain of biosensors and chemosensors, following the pioneering works of P. Kiełczyński et. al. (1987-1989).
Regardless of the fact that Love waves have been discovered over one hundred years ago (1911), there are still many interesting, fundamental problems about Love waves theory, their connections to other wave motions, etc., which remain unsolved.
In this work, we analyze theoretically the properties of Love surface waves propagating in waveguides consisting of two different surface layers (upper and lower) deposited on a semi-infinite substrate. The upper surface of the waveguide is additionally covered with a semi-infinite layer of a Newtonian liquid occupying the half-space. In fact, the configuration of the waveguide represents a typical structure of the Love wave sensor, working in a liquid environment. By varying the viscosity of the Newtonian liquid covering the upper surface the waveguide, the authors have discovered a number of new intriguing phenomena displaying abrupt changing in Love wave parameters.
In particular, for some selected values of the liquid viscosity, e.g., for $\eta = 11.9\ Pas$ we have observed: 1) a dramatic change in the Love wave attenuation (approximately 15 times) and 2) a drastic change in the distribution of the mechanical displacement as a function of depth, i.e., the distance from the upper waveguide surface. This is accompanied by a pronounced redistribution of the power flow of the Love wave, i.e., the maximum of the power flow switches from the upper surface layer to the lower surface layer.
To best of our knowledge, the above phenomena have not yet been reported in the scientific literature. The obtained results can be crucial in the design of Love wave sensors, as well as in seismology.

## 2. Statement of Contribution, Methods

a) Using the Thomson-Haskell transfer matrix method, the complex dispersion equation for Love waves propagating in the considered bi-layer waveguide structure was derived in an analytical form.
b) Separating subsequently the real and imaginary parts of the complex dispersion equation, we determined the phase velocity and attenuation of Love waves as a function of frequency $f$, i.e., $v = v(f)\ and\ \alpha = \alpha(f)$.
c) For a given frequency $f$, the distribution of the mechanical displacement, as a function of depth, was calculated, as well.

## 3. Results/Discussion

By increasing the viscosity $\eta$ of the Newtonian liquid, loading the upper surface of the waveguide, we obtain the attenuation $\alpha = \alpha\ (f)$ of the Love wave as a function of frequency $f$ (from 1 to 30 MHz).
For lower values of the viscosity $\eta < 11.9$ Pas, we observed the classical parabolic dependence of the attenuation $\alpha = \alpha\ (f)$, as a function of frequency $f$.
However, crossing the viscosity $\eta = 11.9\ Pas$ (from below), we observed unexpectedly two coupled phenomena: 1) the attenuation of Love waves dropped abruptly about 15 times (at f = 2.6 MHz), with simultaneous change of the attenuation curve $\alpha = \alpha\ (f)$ from parabolic to oscillatory; 2) the maximum of the mechanical displacement switched from the upper surface layer to the lower surface layer of the waveguide. These two phenomena will certainly dramatically affect the operation of Love wave sensors. Consequently, they should be taken into account in the design process of Love wave sensors.
The results obtained of this work are related to the fundamental problems of the Physical Acoustics and can extend our knowledge about physics of the Love surface waves.