# Computational Modelling of Vibrations Transmission Loss of Auxetic Lattice Structure

Eligiusz IDCZAK
*Institute of Applied Mechanics, Poznan University of Technology*
*ul Jana Pawla II 24, 60-965 Poznań, Poland*
*eligiusz.j.idczak@doctorate.put.poznan.pl*

Tomasz STREK
*Institute of Applied Mechanics, Poznan University of Technology*
*ul Jana Pawla II 24, 60-965 Poznań, Poland*
*tomasz.strek@put.poznan.pl*

**Abstract**

In this article dynamical properties of auxetic lattice structures will be analysed. Auxetic structures are materials, which have negative Poisson's ratio and some of these have got specific dynamic properties. Their dynamic behaviour in the frequency domain will be also shown in this article. The possibility of isolation of auxetics will show the factor VTL – Vibration Transmission Loss.

***Keywords:*** auxetics, negative Poisson's ratio, dynamic analysis, VTL factor

## 1. Introduction

Auxetic materials are materials characterized by negative Poisson's ratio which means that they expand during stretching and shrinks during compressing in the transverse directions to direction of compressing or stretching force. The Poisson's ratio (PR) of isotropic is between -1 and +0.5. Anisotropic materials have non-bounded range for Poisson's ratio.

Materials with negative Poisson's ratio (NPR), at present often referred to as auxetics, have been known for over 100 years and the key to this auxetic behaviour is the negative Poissons ratio [1]. In early 1900s a German physicist Woldemar Voigt was the first to report this property [2] and his work suggested that the crystals somehow become thicker laterally when stretched longitudinally, nevertheless it was ignored for decades.

Gibson [3] in 1982 realized the auxetic effect in the form of the two-dimensional silicone rubber or aluminum honeycombs is deformed by flexure of the ribs. The first mechanical [4] and thermodynamical [5] models were presented by Almgren in 1985 and Wojciechowski in 1987.

Evans et al. paper [6] introduces the term auxetic, from the root word for growth, to describe transverse expansion under uniaxial (longitudinal) tensile load. Re-entrant foams were reported for the first time by Lakes [7]. A negative Poisson ratio implies the substances with negative Poisson's ratio that can be readily compressed but are difficult to bend [8].

Nowadays, it is known that negative Poisson's ratio may also characterize many other structures with other shape and geometries [9]. In the literature are described also: fibre materials, centre-symmetric or gradient honeycombs, chiral structures, auxetic laminates, composites or lattice-like cell structures - sometimes are also designed the combinations of this arts of auxetics. All of them have negative Poisson's ratio. Some of these because of their auxeticity exhibit extraordinary dynamic properties and have great attention by the scientists from many countries [10-19].

Ruzzene et al. [18] in their work have presented the structural and acoustic analysis of truss-core beams. They obtained the optimal geometry of truss-core with the best as possible acoustic behaviour. Their numerical model was created by employing dynamic shape functions derived exactly from the distributed parameter model of beam elements.

Joshi et al. [15] in their works has presented dynamic, acoustic analysis of auxetic composites and its dependency on geometry or number of single repeated cells of material. Structures with negative Poisson's ratio may have unknown and unexpected dynamic behaviour e.g they can be a good isolator or protector from the resonance. The parameter which circumscribed isolation properties is Vibration Transmission Loss, which shows the range of frequency where the structure doesn't transmit vibrations. In order to determine this factor it is useful to define Vibration Transmission Coefficient $\tau_\upsilon$. The Vibration Transmission Loss (VTL) is given by the formula:

$$VTL = 10\log_{10}\frac{1}{\tau_\vartheta} \tag{1}$$

where $\tau_\upsilon$ is Vibration Transmission Cofficient (VTC) given by:

$$\tau_\vartheta = \frac{\int_0^{Lt} \omega^2 [u_y(x,\omega)]_t [u_y(x,\omega)]_t \, dx}{\int_0^{Lb} \omega^2 [u_y(x,\omega)]_b [u_y(x,\omega)]_b \, dx} \tag{2}$$

where: $\omega$ is frequency [Hz], $u_y(x,\omega)$ - displacement in *y*-direction, indices *t, b* – top and bottom layer of auxetic structure. $L_t$ and $L_b$ are lengths of top and bottom boundary of structure.

## 2. Numerical results

Auxetic lattice-like structure is designed for the analysis of dynamical properties. The structure is built of a repeated unit cell which has geometry parameters as follows: height a, width b and parameter c – height of the notch in the bottom. The Poisson's ratio of this cell is negative and equals -0.915. The single cell can be multiplicated and analysed as complex 3D structure (see Figure 2). This lattice-like structure was tested to find vibration transmission factors. For the simulations the following values were taken: a = 1 m, b = 0.5 m, c = 0.3 m.

In order to facilitate the analysis only one quarter of the 3D structure is considered The boundary conditions are: constant displacement 0.1 m on the top, on the one side of x-axis, y-axis and bottom - roller boundary and on the rest boundaries - free boundary condition.

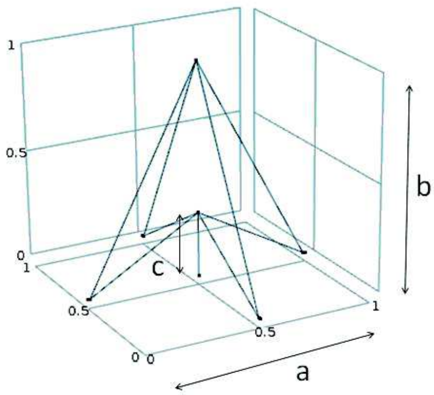


Figure 1. Three-dimensional auxetic unit cell

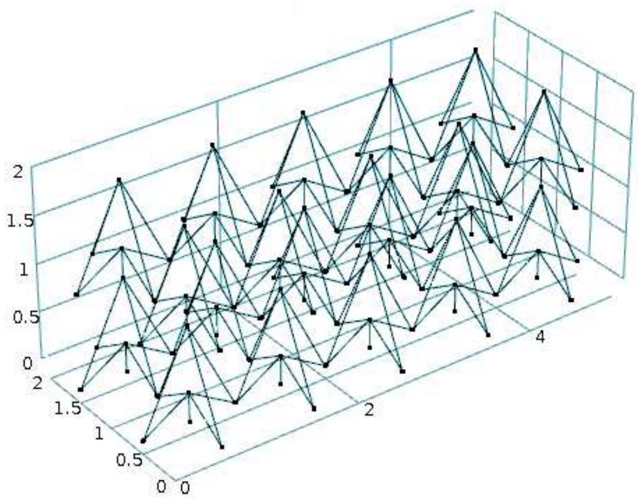


Figure 2. Three-dimensional auxetic structure

The results of simulation by the frequency analysis of the auxetic structure are presented in Figures 3 and 4. These diagrams can be used to analyse the possibility of using the structure to reduce the level of vibrations.

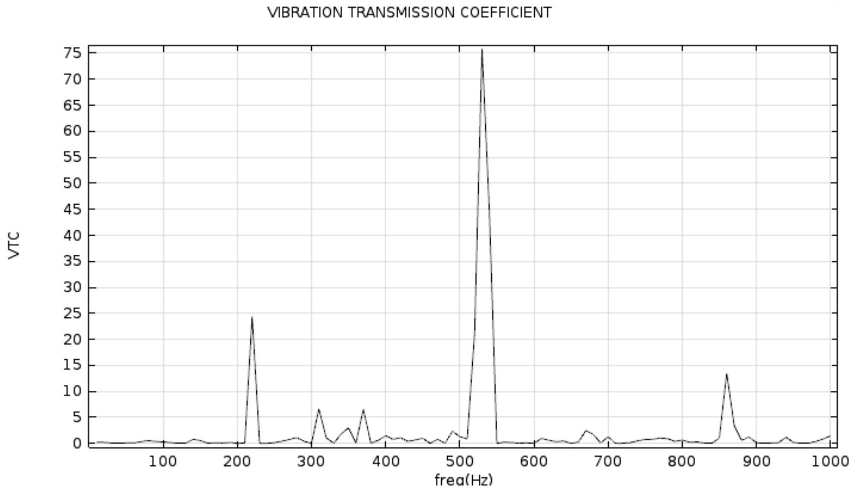


Figure 3. Vibration Transmission Coefficient (VTC) of auxetic structure

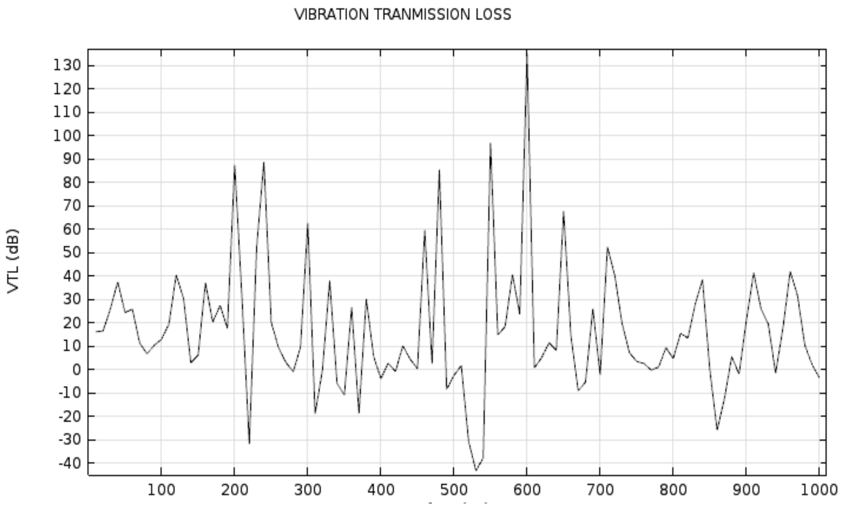


Figure 4. Vibration Transmission Loss (VTL) of analysed auxetic structure

## 3. Conclusions

A finite element model was developed to evaluate the effective properties and dynamic response of the auxetic lattice structure. The influence of the parameter structure on effective properties and dynamic response (VTL) of structure was investigated.

To cover a wide range of structural resonances, the excitation frequencies of sandwich panels varied from 0 to 1000 Hz. The range of frequency vibration which are most damped is around 200 Hz and 600 Hz. The values of Vibrations Transmission Loss for these frequencies are 90 and 130 decibels respectively. The numerical experiment confirms also the transmission loss of auxetics by some frequencies.

If the geometry parameters are changing e.g. by increasing the value of $c$ twice - to 0.15 m – the auxetic effect is smaller: Poisson's ratio is -0,2. The value of the VTL is greater in 0-1000 Hz and dampens vibration better as in the previous case. Minimal value of VTL in this situation is about -10 dB for frequency 500 Hz. In this case we observe strengthening of vibration.

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