Mechanical Impedance of Cerebral Material

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ABSTRACT
The tentative variation of the mechanical impedance, of a cylindrical sample of cerebral material, has been achieved by Vibrometer Laser according to the frequency. The studied matter is supposed homogeneous, isotropic and stationary. A multilayered mechanical model has been associated to the studied sample to simulate its vibration. The theoretical expression of mechanical impedance has been determined while taking the mechanical/electric analogy as a basis. A good adjustment of theoretical model parameters permitted us to have a good agreement theory/experience of the mechanical impedance variation according to the sample vibration frequency.

Keywords: Vibrometer Laser; Mechanical Impedance; Viscoelastic; Cerebral Material; Model

1. Introduction
The head is part of the body most threatened by the fatal injuries in accidents. Brain injuries cause approximately 56,000 dead and 83,000 disabled in the United States each year [1]. The typical duration of loading in road accidents is between 1 ms and 50 ms, according to the rigidity of the impacted area. This interval is approximately between 20 Hz and 1000 Hz frequency. It is therefore essential to carry out measures to the Interior of this frequency band. Because of the impossibility of technical and legal studies of human in vivo, they have been supplanted by studies in vitro performed in low proportion on humans [2-4], and largely on animals like pigs [5-8] and monkey [9-11].

The aim of this work is to develop a model to simulate the variation of the impedance mechanical \( Z = \frac{F}{v} \) of studied system, we have associated the mechanical model to 5 channels (types Kelvin-Voigt) \( \) that we used in 2009 [14] to characterize brain matter of pork in terms of modulus of elasticity and depreciation internal. The vibration of the sample is then equated with the vibration of 5 overlapping cylindrical layers on the other. Each layer is then height \( h_5 = h/5 \) diameter \( d \) and mass \( m_5 = M/5 \).

To resolve the problem we have used the analogy of
Figure 1. (a) The experimental device; (b) Diagram of the experimental device.

Figure 2. KV model [14].

Figure 3. Electrical model analogous to our KV mechanical model.

other end (upper surface) is free (is not subject to any constraints), in this case, in our electric model output should be short-circuited ($V_5 = 0$). On this circuit transfer matrix is given by:

$$[T] = \begin{bmatrix} 1 + \frac{Z_5}{Z_s} & -Z_5^* \\ -\frac{1}{Z_5} & 1 \end{bmatrix}$$  \hspace{1cm} (1)

where $Z_5^*$ and $Z_5$ are the equivalent impedances to the inductance and the resistance in series with the capacity respectively:

$$Z_5^* = jL_5 \frac{2\pi f}{(2)}$$  \hspace{1cm} (2)

and

$$Z_5 = R_5 + \frac{1}{jC_5 \cdot 2\pi f}$$  \hspace{1cm} (3)

Allowing us to write:

$$\begin{bmatrix} 0 \\ I_5 \end{bmatrix} = [A] \times \begin{bmatrix} V_0 \\ I_0 \end{bmatrix}$$  \hspace{1cm} (4)

with $[A] = [T]^T = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$

It follows that

$$\begin{cases} 0 = A_{11}V_0 + A_{12}I_0 \\ I_5 = A_{21}V_0 + A_{22}I_0 \end{cases}$$  \hspace{1cm} (5)

The two Equations (5) and (6) allows us to deduce that

$$\frac{V_0}{I_5} = \frac{A_{21} - A_{22}A_{11}}{A_{12}}$$  \hspace{1cm} (7)

By returning to our mechanical model (KV model) and taking into account the analogy mechanical/electrical, theoretical expression of the mechanical impedance $Z_{th} = F/v$ can then be written as (7). Except that (2) and (3) and electrical impedance will be replaced by their mechanical analogues:

$$Z_5 = \alpha_5 + \frac{k_5}{j2\pi f}$$  \hspace{1cm} and
Figure 4. Superposition theory/experience of mechanical impedance modulus.

\[ Z^* = jm \omega \pi \]

2.3. Determination of the Parameters of the Model

By introducing the \( k_s(f) \) values and \( \alpha_s(f) \) already calculated in 2009 (Table 1) [14] we could calculate the values from the MATLAB software, and corresponding to each frequency of vibration of the sample. The module on KV model to 5 mass layers depending on the frequency theoretical mechanical impedance variation is then determined.

3. Results

The next curve represents the theory/experience the mechanical impedance module overlay. From the Figure 4 we can see that the values of \( k_s(f) \) and \( \alpha_s(f) \) already determined in 2009 [14], model very well the mechanical impedance of the studied system.

4. Conclusions

Our model (5-layer mass) type Kelvin-Voigt, with variable parameters based on the frequency is very well to simulate changes in mechanical impedance module of cylindrical sample of pork brain tissue.

The theoretical mechanical impedance \( Z_{th} = F/v \), that was used in this study, can be used in finite element model of brain to simulate the mechanical impedance.

This mechanical impedance represents a maximum in the surrounding of 400 Hz. It means that deformation is maximal at this frequency.

So, we can note that this frequency vibration can cause damage on the brain tissue.

REFERENCES


