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KONVERSI ENERGI

EXPERIMENTAL AND ANALYTICAL STUDY OF DISPLACEMENT OF ARTIFICIAL BASILAR MEMBRANE (ABM) PROTOTYPE

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Abstract

In this research, we report and analyze the prototype of artificial basilar membrane (ABM) which works using sinusoidal wave and also various frequency. Design and dimension of the prototype was chosen using trapezoidal shape with 30 mm length and 2 mm to 4 mm width. Experimentally, the vibration of artificial basilar membrane is measured using Laser Doppler Vibrometer (LDV). The main result, the resonance frequencies of the prototype of ABM are showed can be reached in the range of human audio, between 20 Hz to 20 kHz.

Keywords: Artificial basilar membrane, cochlea, resonance frequency, frequency selectivity

1 INTRODUCTION

Hearing is one of the important sense of human to interact each others. One of the important organ of hearing is cochlea. Cochleae are located in the inner ear. In the normal hearing, sound wave from the environment outside the outer ear, travel through the ear canal and strike the eardrum. Vibration of this eardrum causes the three bones that are located in the middle ear vibrate, this vibration will cause the fluid in the cochlear duct fluctuate which are influence the basilar membrane to oscillated [1]. The basilar membrane is one of membrane in the cochlea. This membrane is worked as the frequency selectivity of the sound wave.

At present, the deafaid of cochlear implant consists of two parts, there are implantable stimulating electrodes and an extracorporeal device which are necessary tools in this system. Implantable stimulating electrodes consist of receiver and electrodes. In the extracorporeal device, there are batteries, processor and microphone as shown in Fig 1. This condition is inconvenient for the user. This situation motivates us to develop a fully self contained artificial cochlea. In this research, we report and analyze a prototype of artificial basilar membrane (ABM) analytical and experimental-ly. The ABM is one of the important part in the artificial cochlea.

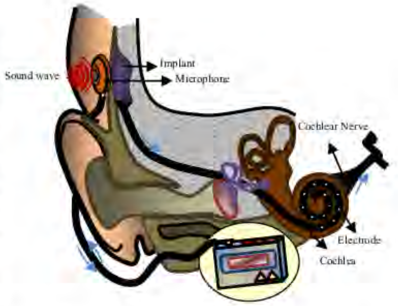
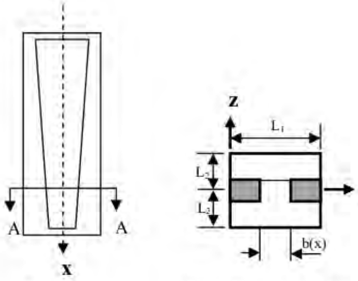


Figure 1. Present Implantable Cochlear

2 MECHANICAL MODEL AND METHODOLOGY

The actual shape of the cochlea is coiled and has a little more than 2.5 turns [2]. With the purpose of the modeling and simplifying the model of the biologi basilar membrane, the prototype of ABM can be unwrapped. Figure 2 shows the model geometric of ABM prototype. In the figure of cross section A-A, there are two channels upper and lower side of the membrane which are considered as like a scala vestibule and a scala tympani in biologi cochlea. Those channels are separated by a flexible membrane structure corresponding to the prototype of ABM.

Thickness of the ABM prototype is 40 µm with the PVDF material. The shape of the membrane is trapezoidal channel with the width of the channel is proportional 2 mm to 4 mm with 30 mm along longitudinal direction as shown in figure 2. The Young's modulus and density of the membrane are 4 GPa and 1790 kg/m^3 respectively. The acoustic wave is generated using a speaker (FORTEX, Japan). Distance between speaker and the prototype is 120 mm. Voltage of the speaker is adjusted using function generator to get the constant sound pressure at 75 and 80 dB. The frequency is controlled from 3 kHz to 20 kHz.



Top View
Cross Section A - A

Figure 2. Model geometric of the artificial basilar membrane prototype

The vibration is measured using laser Doppler vibrometer (LDV) to measure the frequency-dependence of the oscillation of ABM prototype. Lower resonance frequency is expected at the wider side, where as lager one is at narrower one [3].

3 RESULTS AND DISCUSSIONS

Kirchhoff's hypotheses are fundamental assumptions in the development of linear, elastic, small-deflection theory for the bending of thin plates [4].

The vibrating of the ABM prototype can be predict by the thin plate bending model. The direction of the shearing force and balance of the moment bending are shown in figure 3.

Method of Wentzel Kramer Brillouin (WKB) also was used to solve the equations of the mechanism in ABM problem where parameters vary slowly compared to the nwavelength of oscillations. Solution of the vibratio on ABM response [illegible] assumed with slowly varying amplitude. Interaction between the fluid and ABM is governed by linearized Euler equation. Asymptotic expansions are used in analysis to describe the behavior of a function in a limiting situation. Based on the plate bending theory, the basic equation of displacement of the ABM can be predicted using,

$$\frac{Eh^3}{12(1-\upsilon^2)}\left(\frac{\partial^4 w}{\partial x^4}+2\frac{\partial^2 w}{\partial x^2\partial y^2}+\frac{\partial^4 w}{\partial y^4}\right)+\rho h\frac{\partial^2 w}{\partial t^2}=0 \quad (1)$$

Parameters,

w : Displacement	[m]
E : Young's modulus	[4 GPa]
h : Thickness of membrane	[40 μm]
ρ : Density	[1790 kg/m^3]
ν : Poisson's ratio	[0.3]

Figure 4 shows the shape of the experimental data graph of the single cross mode. In that graph the gradient line is showed along of the side of the ABM, this indicate that the vibration of the membrane have two gradient boundary conditions at the left and right side of the ABM prototype.

Figure 5 shows contour map of the ABM prototype at frequency 9000 Hz. The biggest magnitudes are occurred at the distance 19 mm from the narrower one.

Figure 6 shows the resonance frequencies along of the ABM at 75 and 80 dB. Distribution of the resonance frequency at the both experiment are around the teoretical resonance frequency line. It is explaine that the comparison between frequency selectivity and local resonance frequency based on the plate bending theory solved by WKB asymtotic method reasonable. The results of both experiment also show that the local resonance frequency on the ABM prototype has a small change at the several point.

Figure 3. Direction of the shearing force and balance of the moment bending

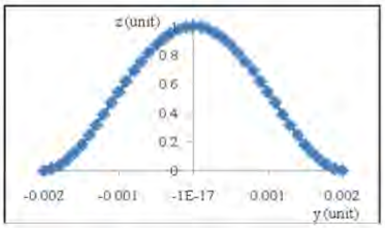


Figure 4. Shape of the Experimental Graph of the Single Cross Mode

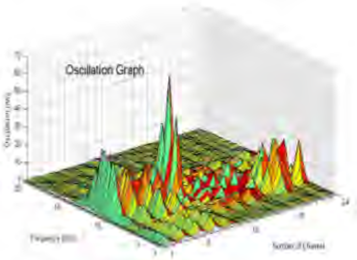


Figure 5. Contour map of the ABM prototype Resonance frequency at 9 kHz

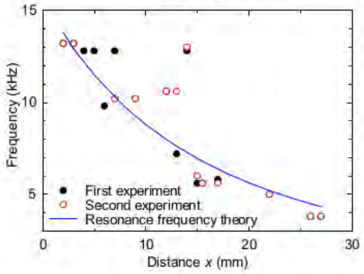


Figure 5. Resonance frequency along of the ABM at 75 dB - first experiment and 80 dB - second experiment

4 CONCLUSIONS

Distribution of the resonance frequency value of ABM showed around the theory line. This indicate that the resonant frequency theory can be used in this experiment.

The frequency selectivity is occured by the local resonance of the oscillation of the ABM. The prototype of ABM realizes the frequency selectivity in the range of audible frequency.
The frequency of the ABM increases from 3 kHz ~ 12 kHz with decreasing the position of x.

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