Mathematical Analysis on the Physiological effects of Noise

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Abstract *- Mathematical analysis on the effects of human health due to traffic noise is explained in the present paper. Locations at various noisy zones have been indentified to adopt few individuals response due to longer exposure to the traffic noise. The study is aimed at computing the variations of physiological parameters due to noise effects. These effects are mainly studied as velocity of blood flow at constricted location in the human artery, the flux of the flow, wall shear stress, pressure gradient are calculated for various noise data recorded on NH-4. The study is focussed to estimate the changes in systolic and diastolic blood pressures due to this constriction. The constriction (narrowing of the artery) is also due to the longer period exposure to the noise at the level* ($\geq 65 dB\ (A)$)*. The encountered effects are noticed at greater than 80-100dB (A) levels causing the vibrational energy into cochlea of the ear. The prolonged noise exposure gives the change in physiological condition mainly the threshold shift in the diastolic blood pressure as 9mm Hg which becomes the permanent onset of diastolic blood pressure. The model consists of analytical formulations for equations of motion and analytical solutions have been carried out to compute the values of velocity, flux, wall shear stress, pressure gradient of blood flow in artery due to traffic noise effect.*

Keywords: *Noise, stress, Amplitude, Blood, Flow.*

I. Introduction

The sound starts as a disturbance of the air which produces sound waves. The visible ear receives such sound waves and channels them down the outer ear canal. As a result they hit the eardrum and make it to vibrate so that the vibrations generated will pass through the hammer, anvil, stripping up to the oval window inside the complex fluid of cochlea. The change in the vibrational energy causes the impairment of nerve impulses. These impairment of nerves by which noise caused waves transmit to the brain along with the auditory nerves. The acute effect of the nerve impulses that are mediated through the sympathetic nervous system damage the flow of blood associated with peripheral circulation and also the disfunction of the heart.

Over the past few years many researchers studied the physiological effects of noise on human health. Peterson E A et. al. [1] studied the variations of blood pressure due to noise rise. Ahrlin U et. al. [2] discussed the effects of environmental noise on human health. Debasish Paul et. al. [3] discussed the work efficiency reduction of individuals in the place of their work due to noise from traffic. Adam Senetra et.al. [4] studied the correlation between prices of the apartments and road traffic noise levels in Dsztyn, the capital city of region of Warmia and

Mazury in north-eastern Poland. P B Vyas et.al. [5] explained about the sound absorption coefficient of wood of selected trees to control noise level and also Evaluation of the environmental noise level of Mehsana city. Adrian et. al. [6] studied the process of underwater noise modelling, explored the factors that affects predictions of noise exposure and illustrated the consequences of errors and uncertainties in noise modelling. Lvjiang Yin et. al. [7] discussed a new low-carbon mathematical scheduling model to have flexible job-shop environment that optimizes productivity energy efficiency and noise reduction. Sujit Kumar De et al [8] Then we develop appropriate triangular fuzzy sets. Thereafter, centre of gravity method has been utilized upon net membership function and score functions (to the cases of adaptations) for defuzzifications. AdityaKamineni et al [9] proposed model can be effectively used for the highway traffic noise prediction especially for the heterogeneous traffic, as the difference between the measured and predicted noise levels are within 1 to 10 dB (A). Waldemar Paszkowski et al [10] proposed the method which can be applied in the tasks concerning supporting the evaluating and forecasting noisepollution in the urban environment, taking particularly into account noise annoyance. XueqiZhanget. al.[11] explored the impact of monitoring point location on prediction results and policy recommendations for environmental noise management.

By the evidence of above literature the present study attempts to determine the wall shear stress effects due to longer period exposure of noise and the onset of rise in the systolic blood pressure with respect to various traffic noise levels with the adoption of few individuals for providing the changes in their blood pressure and heart rate values. The mathematical formulation proposed gives the evidence that blood pressure rise will be as a result of noise exposure causing human health effects.

II. Formulation

The geometry of axisymmetric tube with For Constriction is given by,

$$R(z) = R_0 + \left(\frac{\propto D_1}{D_2}\right)\left(\sin\left(\frac{2\pi z}{\lambda}\right)\right) \tag{1}$$

Where $R -$ Radius, $R_0 -$ initail radius (without noise) (unconstructed aorta), z-axial direction scale, λ – wavelength, $\propto$- height of the wall constriction, $\frac{D_1}{D_2}$ - Non dimensional distance

Equation of Continuity

$$\frac{\partial v}{\partial r} + \frac{\partial u}{\partial z} + \frac{v}{r} = 0 \tag{2}$$

Equations of Motion:

$$\frac{\partial v}{\partial t} + v\,\frac{\partial v}{\partial r} + u\,\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial r} + \gamma\left[v_{rr} + v_{zz} - \frac{v}{r^2} + \frac{1}{r}v_r\right] \tag{3}$$

$$\frac{\partial u}{\partial t} + v\,\frac{\partial u}{\partial r} + u\,\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + \gamma\left[u_{rr} + u_{zz} + \frac{1}{r}u_r\right] \tag{4}$$

To introduce $u = -\frac{1}{r}\frac{\partial \psi}{\partial r}, v = \frac{1}{r}\frac{\partial \psi}{\partial z}$and eliminating $\frac{\partial p}{\partial r}$ and $\frac{\partial p}{\partial z}$ to obtain

$$\left[\frac{\partial}{\partial t}+\frac{1}{r}\frac{\partial\psi}{\partial z}\frac{\partial}{\partial r}-\frac{1}{r}\frac{\partial\psi}{\partial r}\frac{\partial}{\partial z}-\frac{2}{r^2}\frac{\partial\psi}{\partial z}\right]\nabla^2\psi=\gamma\nabla^4\psi \tag{5}$$

Where $\nabla^2=\frac{\partial^2}{\partial z^2}+\frac{\partial^2}{\partial r^2}-\frac{1}{r}\frac{\partial}{\partial r}$

$$\nabla^4\psi=\nabla^2(\nabla^2\psi) \tag{6}$$

Introducing non dimensional forms (Normalization)

$$z^*=\frac{z}{\lambda},r^*=\frac{r}{R_0},\psi^*=\frac{\psi}{8R_0},t^*=\frac{8t}{\lambda R_0},R^*=\frac{R}{R_0} \tag{7}$$

Thus

$$\propto\left[\frac{\partial}{\partial t}+\frac{1}{r}\frac{\partial\psi}{\partial z}\frac{\partial}{\partial r}-\frac{1}{r}\frac{\partial\psi}{\partial r}\frac{\partial}{\partial z}-\frac{2}{r^2}\frac{\partial\psi}{\partial z}\right]E^2\psi=E^4\psi \tag{8}$$

where $E^2=\propto^2\frac{\partial^2}{\partial z^2}+\frac{\partial^2}{\partial r^2}-\frac{1}{r}\frac{\partial}{\partial r}$

$\propto=\frac{R_0}{\lambda}<1$

Boundary conditions are

$$\frac{\partial\psi}{\partial r}=0=\frac{\partial\psi}{\partial z}\text{ at } r=\pm R \tag{9}$$

$$\psi=\text{constant at } r=R \tag{10}$$

III. Analysis

In the present analysis the road traffic noise effect is assumed to be the computational physiological parameter. The effects on human health are unbearable when any individual is exposed for a longer period at noise level greater than 67 dB. The vibrations produced by the noise show the variations on the arterial pressure. As a result the characteristics of fluid conveying vessels are associated with the system of flow. These characteristics stimulate the sympathetic nerve fibers in blood flow through the vessels.

Stream function for various time intervals for the analysis of physiological flow parameters, we have,

$$\psi=a_0\psi_0+a_1\psi(t)+a_2\big(\psi(t)\big)^2+a_3\big(\psi(t)\big)^3+\cdots \tag{11}$$

Axial velocity

$$u=-\frac{4}{R^2}\left(1-{R_1}^2\right)e^{i\omega t}+\propto\left(\frac{i\omega}{8}\left(1-2{R_1}^4\right)e^{i\omega t}-\frac{1}{9R^3}\frac{\partial R}{\partial z}\left(16{R_1}^2-18{R_1}^4+2{R_1}^6\right)e^{2i\omega t}\right) \tag{12}$$

$$\text{Flux } Q=\int_0^R 2\pi r u(r)dr \tag{13}$$

$$Q=2\pi\left(-\cos\omega t-\frac{\propto\omega R^2}{48}\sin\omega t-\frac{5\propto}{36R}\frac{\partial R}{\partial z}\cos 2\omega t\right) \tag{14}$$

Wall shear stress τ is,

$$\tau=\frac{4\mu Q}{\pi R^3} \tag{15}$$

$$=\frac{4\mu}{\pi R^3}\left\{2\pi\left(-\cos\omega t-\frac{\propto\omega R^2}{48}\sin\omega t-\frac{5\propto}{36R}\frac{\partial R}{\partial z}\cos 2\omega t\right)\right\} \tag{16}$$

$$=\left(\frac{-8\mu}{R^3}\right)\cos\omega t+\left(\frac{-\propto\omega\mu}{6R}\right)\sin\omega t+\left(\frac{-10\mu\propto}{9R^4}\frac{\partial R}{\partial z}\right)\cos 2\omega t \tag{17}$$

Pressure gradient is given by,

$$\frac{\partial p}{\partial z} = \frac{8\mu Q}{\pi R^4} \tag{18}$$

$$\frac{\partial p}{\partial z} = \left(\frac{-16\mu}{R^4}\right)\cos\omega t + \left(\frac{-\propto\omega\mu}{3R^2}\right)\sin\omega t + \left(\frac{-20\mu\propto}{9R^5}\frac{\partial R}{\partial z}\right)\cos 2\omega t \tag{19}$$

IV. Results And Discussion

As the height of the road traffic noise level changes the effect of noise decreases when the noise measurements done with 5 feet, 10 feet and 15 feet in downward direction. Noise effect increases during the measurement 5 feet, 10 feet an 15 feet upwards. This causes the temporary onset increase in diastolic blood pressure (as in the given table). If this type of exposure of the individuals is prolonged for longer period, then there exists the threshold shift in diastolic blood pressure with 5 mm Hg. The axial velocity, flux, wall shear stress and pressure gradient are estimated for three different heart rates 80, 100 and 120.

Table 1: Noise measurements at (Location-1).

Heights	**L_{max}**	**L_{min}**	**LF (dB)**
h_1	112.8	68.4	117.6
	111.9	68.9	117
	111.2	69.6	116.2
	110.2	69.9	116.4
	110.8	70.8	116.2
h_2	111.8	70.6	116.8
	111.2	70.3	116.2
	110.8	71.8	116.1
	110.2	69.8	115.8
	110	71	116.1
h_3	112.8	71.4	116.2
	110.9	72.3	116.1
	110.1	72.1	116
	110	70.4	115.8
	109.2	70.6	115.1

Table 1:Measurements of blood pressure and heart rate of the noise exposed person on National Highway (NH-4), Pune - Bangaluru road, Davangere, Karnataka, India at (L-1).

Name	**Age**	**Systolic blood pressure mm Hg**			**Diastolic blood pressure mm Hg**			**Heart rate Beats/min**		
		M	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**
A_1	45	135	143	161	121	126	130	71	79	90
A_2	39	111	125	140	70	79	92	94	101	125
A_3	47	127	135	160	111	96	90	87	73	85
A_4	38	138	139	145	88	95	100	78	90	105
A_5	35	114	130	150	70	92	95	77	85	98
A_6	46	150	123	149	79	73	88	78	81	70
A_7	48	150	134	145	125	107	112	95	94	98
A_8	50	107	132	148	69	78	90	106	100	85
A_9	45	153	132	146	90	87	80	94	94	100
A_{10}	39	119	116	135	76	66	95	77	80	91
A_{11}	37	150	139	153	104	94	100	91	81	85

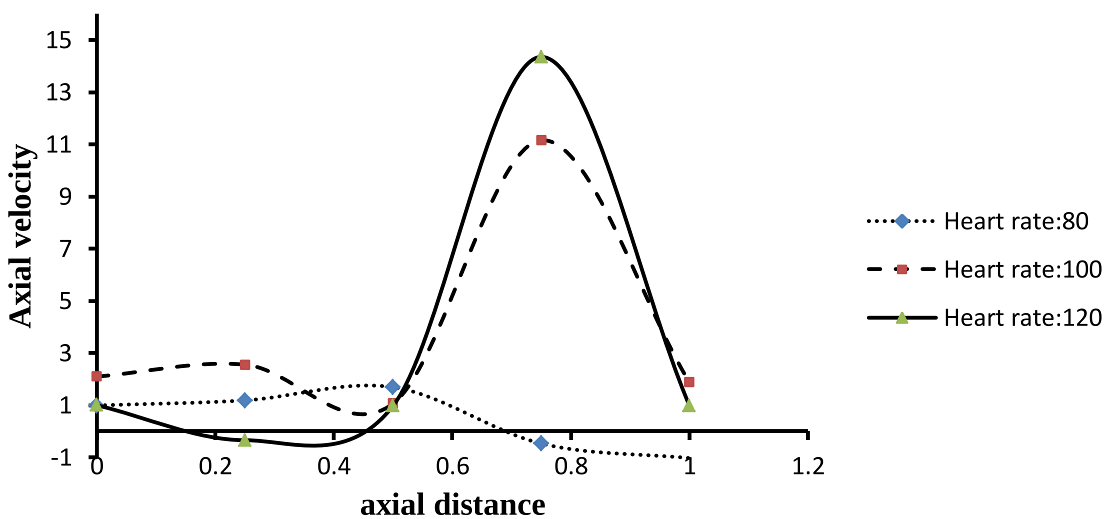

Fig 1: Axial distance v/s axial velocity (for heart rate 80, 100, 120)

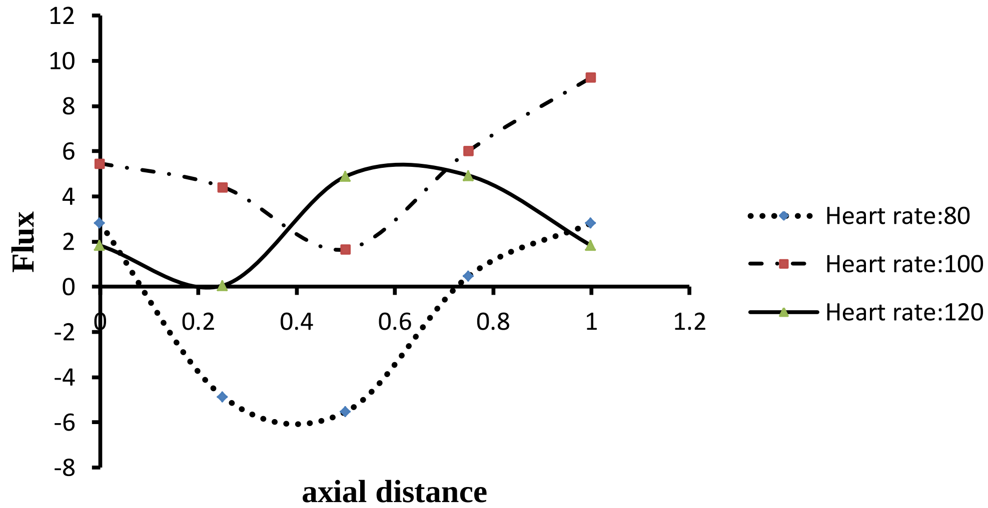

Fig 2: axial distance v/s flux (for heart rate 80, 100, 120)

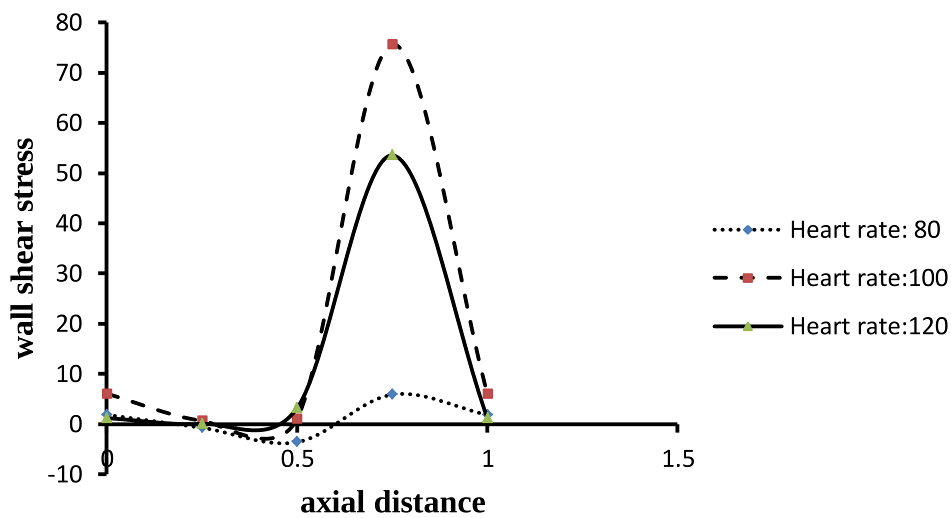

Fig 3: Axial Distance V/S Wall Shear Stress (For Heart Rate 80, 100, 120)

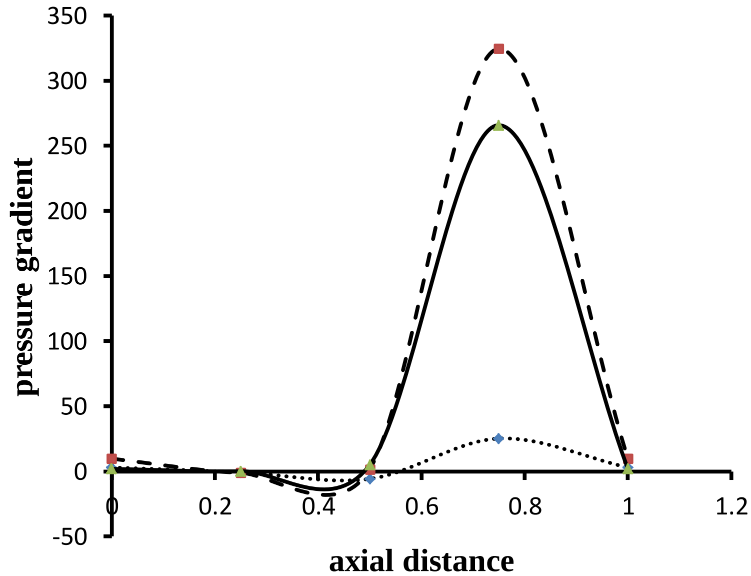

Fig 4: Axial distance v/s Pressure gradient (for heart rate 80, 100, 120)

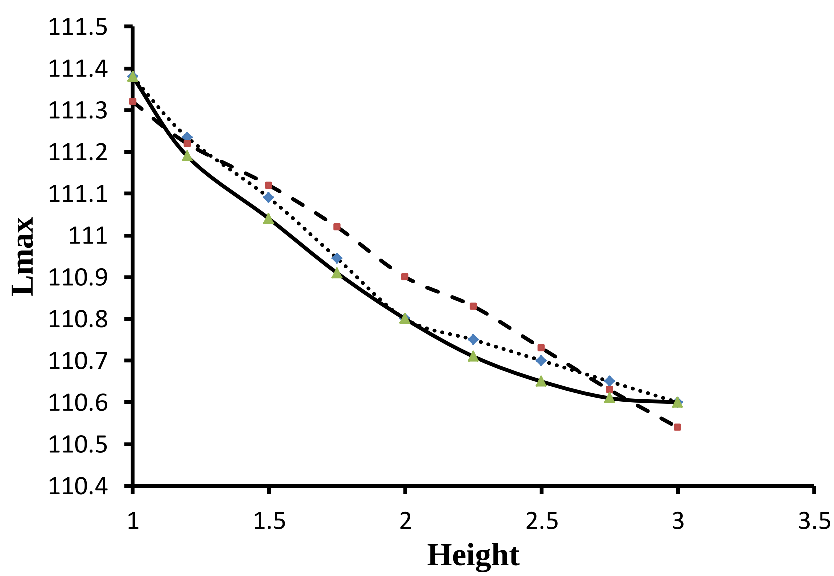

Fig 5: height v/s L_{max}(for L-1)

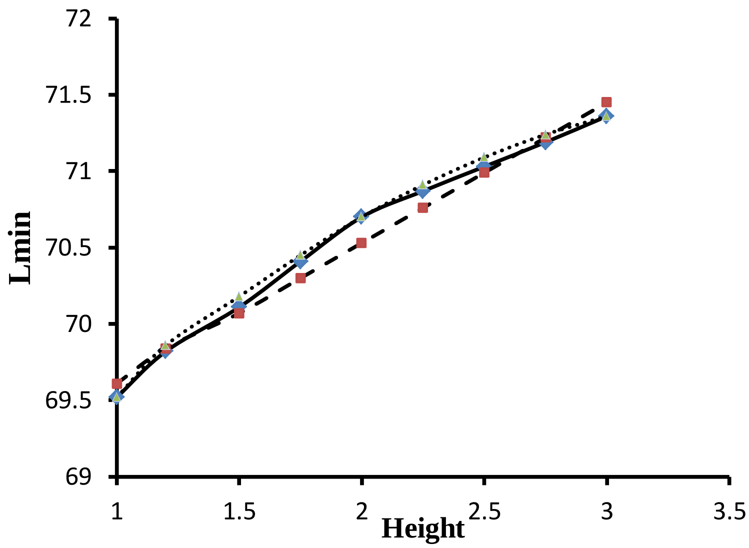

Fig 6: height v/s L_{min}(for L-1)

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