A study on the effect of vehicle vibration on human brain by using human biodynamic and vehicle model

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ABSTRACT – Research on human biodynamic and vehicle model had been conducted over the years to study the vibration impact for both cases. In this study, five degree of freedom (5DOF) human biodynamic model is coupled with full car vehicle model to study the relationship on the impact of vibration on each tire towards the brain on the human biodynamic model. The model is analyzed by using MATLAB simulation under car speed of 10 km/h. From this model, it shows that the proposed model able to show the significant impact on skull and brain when the car is on the move or in cornering mode.

1. INTRODUCTION

Human driver and passenger are exposed to vibration which originate primarily from vehicle as the interaction between the road and the vehicle itself. This exposure of vibration cause bad effects towards human health such as back problem, effects on digestive system and decrease in alertness level which could leads to road accidents [1].

In recent studies, human biodynamic model focuses more only the human model without coupled with vehicle model. This model consists of lumped masses that are connected by springs and dampers which represent the human body muscles and joints. As for the input, certain vibration value is connected directly to the input of human biodynamic model [2]. Thus, in this paper, 5DOF model of human biodynamic model which were improved version of previous model consists of brain part is used to study the relationship of human biodynamic and vehicle model.

Vehicle model with the combination of lateral and longitudinal model is used since the weight shift is considered [3]. An electric car with maximum speed of 30 km/h is used to represent the vehicle model. This lateral and longitudinal force is calculated by using Dugoff's model as it considered the tire stiffness independent value for both lateral and longitudinal direction.

2. HUMAN BIODYNAMIC AND VEHICLE MODEL

The schematic of 5DOF of seated human biodynamic model is shown in Figure 2. This model consists of masses, m_i with dampers, c_i and springs, k_i which represents the muscles and joints of human body for each degree of freedom. Table 1 shows the biodynamic parameters for 5DOF model.

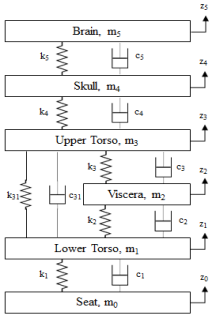

Figure 1 Schematic of 5DOF model [4-5]

Table 1 5DOF biodynamic model parameter [4-5]

Mass (kg)	Damping (Ns/m)	Stiffness (N/m)
m_1=36.0, m_2=5.5, m_3=15.0, m_4=3.5, m_5=1.5	c_1=2475.0, c_2=330.0, c_{31}=909.1, c_3=200.0, c_4=450.0, c_5=340.0	k_1=49340.0, k_2=20000.0, k_{31}=192000.0, k_3=10000.0, k_4=1800000.0, k_5=156000.0

Figure 2 shows the normal force, F_z that acting on the vehicle model. Total mass of vehicle is divided into two segments which are m_r for rear and m_f for front which shown in Figure 2(a). While Figure 2(b) shows the load transfer in lateral motion. Based on the figure, Equation (1)-(4) used to determine the vehicle mass shift in lateral and longitudinal acceleration of vehicle direction [3].

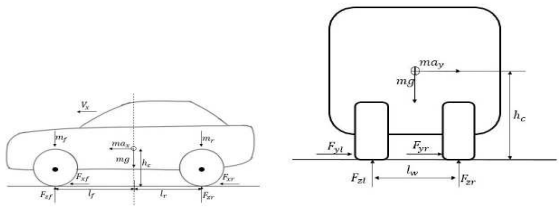

Figure 2 (a) Mass distribution and forces acting on vehicle, (b) Load transfer on vehicle [3]

$$F_{zfr} = mg\frac{l_r}{2l} + \frac{m_f a_y}{l_w} - ma_x\frac{h_c}{2l} \quad (1)$$

$$F_{zfl} = mg\frac{l_r}{2l} - \frac{m_f a_y}{l_w} - ma_x\frac{h_c}{2l} \quad (2)$$

$$F_{zrr} = mg\frac{l_f}{2l} + \frac{m_r a_y}{l_w} + ma_x\frac{h_c}{2l} \quad (3)$$

$$F_{zfl} = mg\frac{l_f}{2l} - \frac{m_r a_y}{l_w} + ma_x\frac{h_c}{2l} \quad (4)$$

where,

$l = l_f + l_r$, $l_f = l_r = 1.4\text{m}$, g=9.81m/s^2, $m_r = 980\text{kg}$, $m_f = 650\text{kg}$, $l_w = 0.9\text{m}$ and $h_c = 0.75\text{m}$

The simulation is done by using MATLAB Simulink based on Figure 3.

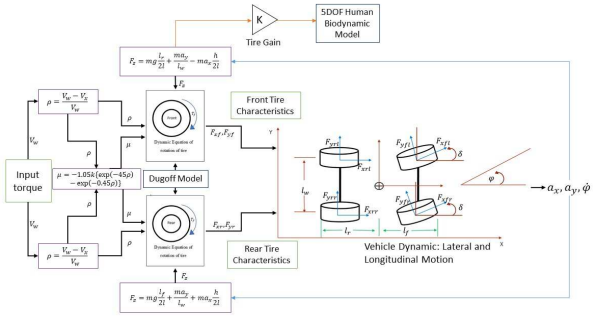

Figure 3 Schematic diagram of vehicle and human biodynamic model

3. RESULT AND DISCUSSION

Figure 4 shows the steering input that used in the coupled model. The sudden drop at 51 seconds indicate the vehicle in cornering mode before it moves forward.

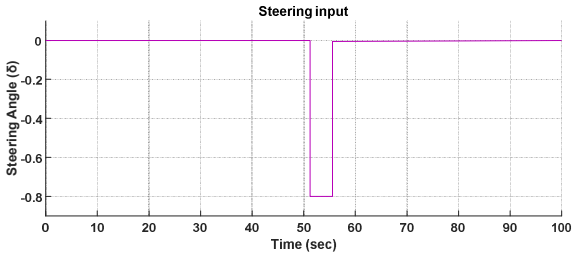

Figure 4 Steering Input

Figure 5 shows the normal force, F_z that acting on each tire at rear and front. When the cornering mode was happened, each tire shows different results as the forces moves based on the direction of the vehicle.

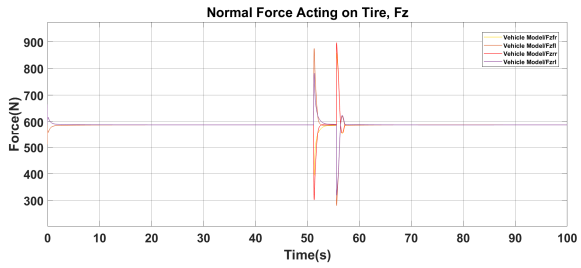

Figure 5 Normal force, F_z acting on tire

Figure 6 shows the result on the vibration response on skull and brain when the human biodynamic model were coupled with the vehicle model. Displacement output from F_{zfr} vehicle model were taken as the input for biodynamic model. The graph shows that there were an impact on skull and brain when the vehicle was cornered at 51.2 s.

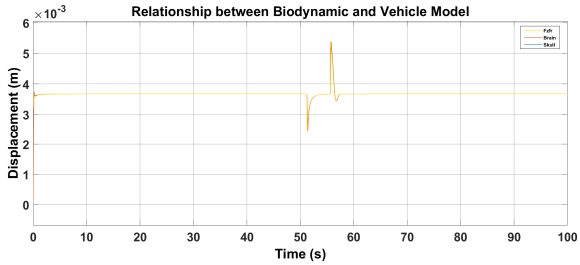

Figure 6 Relationship between human and vehicle model

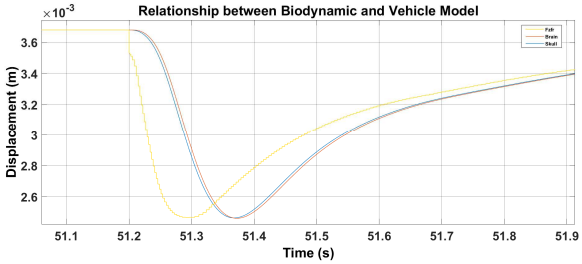

Figure 7 Relationship between human and vehicle model at 51.2 second

4. CONCLUSION

Impact of vibration on brain and skull can be observed clearly when vibration exerted on the vehicle when moving. As from the result, only one part of tire was considered as each tire gave out different result of forces when moving. Thus, further study on the impact of vibration on human brain towards the normal forces acting on different tire of vehicle is required.

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