Effect of the contact angle between mass and finite rod in transverse vibration using Laminated Rubber-Metal Spring (LR-MS) Model for automotive absorber

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ABSTRACT – This paper presents the effect of the contact angle between mass and finite rod in transverse vibration using LR-MS model for automotive absorber. The mathematical model for transmissibility are developed by using two different approaches. The first approach using assumption of massless suspension absorber where the system are modelled by using spring and damper. The second approach employs the impedance technique that derived from wave propagation method. The contact angle will effect to the transmissibility graph either offset to upper or lower side. Furthermore, the parametric study also been discussed in this paper in order to get the transmissibility correlation.

1. INTRODUCTION

The suspension demonstrations in the axial direction as well as in the transverse direction. Since the transverse solidness is not unbounded, the system has a resonance in the transverse direction and the transverse movement at this frequency causes an undesired sensor yield and this blunder in the alignment. Then, by using the transverse vibration model, there need to consider the longitudinal excitation, orientation of moment and also wave effect. The equation of motion and the free-vibration solution of the system are found by assuming the mass, damping and stiffness of the system in harmonic motion. Additionally, the governing equation of automotive absorber in transverse direction had been developed using wave propagation method. In addition, the wave effect is proposed with the purpose of making comparison with previous model.

2. RESEARCH METHODOLOGY

This study is focused on the mathematical model technique that can be utilized for finding estimated answer for transverse vibration issues for the suspension system. This technique utilized for create suspension model and recreate the transmissibility performance in transverse vibration. Another working hypothesis brought up in this research is that the whole suspension system can be changed into finite rod system, by the end goal to get the contact angle relationship between mass and finite rod for LR-MS model. It was present a study on the effects of contact angle by changing its parameters where four important parameters are evaluated, which are mass density, young's modulus, length of suspension absorber and radius of finite rod. Figure 2.1 shows the partial displacement in finite rod model and Figure 2.2 shows the transmissibility comparison between lumped parameter and transverse model for single degree-of-freedom system, respectively.

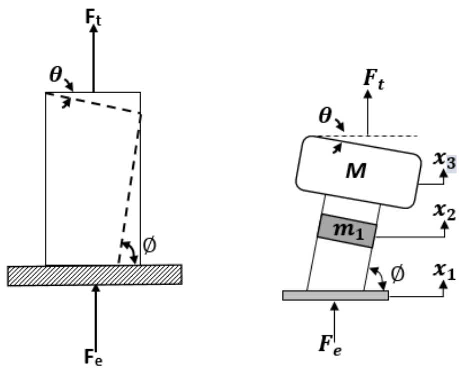

Figure 2.1: Partial displacement in finite rod model

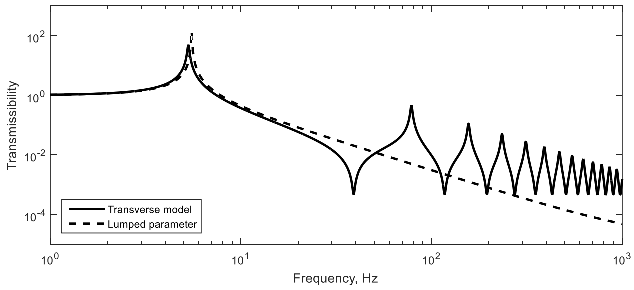

Figure 2.2: Transmissibility comparison between lumped parameter and transverse model for single-degree-of-freedom

The equation of motion of the mathematical model can be represented as

$$Z_{11} = \frac{2EIk_b^3 \cos(k_b L)\cosh(k_b L)}{j\omega(\sin(k_b L)\cosh(k_b L) - \cos(k_b L)\sinh(k_b L))} \quad (1)$$

$$Z_{22} = \frac{EIk_b^3 (1 + \cos(k_b L)\cosh(k_b L))}{j\omega(\sin(k_b L)\cosh(k_b L) - \cos(k_b L)\sinh(k_b L))} \quad (2)$$

$$Z_{12} = Z_{21} = \frac{EIk_b^3 (\cos(k_b L) + \cosh(k_b L))}{j\omega(\sin(k_b L)\cosh(k_b L) - \cos(k_b L)\sinh(k_b L))} \quad (3)$$

The transmissibility for the transverse vibration in the impedance equation:

$$T_\gamma = \left|\frac{F_t}{F_e}\right| = \left|\frac{-\omega^2(M)x_1 + j\omega(Z_{11}^{(1)}x_1) - j\omega(Z_{12}^{(1)}x_2)}{-j\omega Z_{21}^{(2)}x_2}\right| \quad (4)$$

The relationship of contact angle between mass and finite rod is

$$T_\gamma = \left|\frac{F_t \times \left(\frac{\theta\pi}{180}\right)}{F_e \times \left(\frac{\phi\pi}{180}\right)}\right| \quad (5)$$

For the rotation angle, there have two which are represented in Table 2.1 and 2.2.

Table 2.1: Fixed value of θ, variable value of ϕ

θ	$\frac{\theta\pi}{180}$ **(rad)**	ϕ	$\frac{\phi\pi}{180}$ **(rad)**
5°	0.08727	5°	0.08727
5°	0.08727	10°	0.17453
5°	0.08727	15°	0.26180
5°	0.08727	20°	0.34907
5°	0.08727	25°	0.43633
5°	0.08727	30°	0.52360

Table 2.2: Fixed value of ϕ, variable value of θ

θ	$\frac{\theta\pi}{180}$ **(rad)**	ϕ	$\frac{\phi\pi}{180}$ **(rad)**
5°	0.08727	5°	0.08727
10°	0.17453	5°	0.08727
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25°	0.43633	5°	0.08727
30°	0.52360	5°	0.08727

3. RESULTS AND DISCUSSION

The results for this study shows in Figures 3.1 and 3.2. According to these two figures, it shows that by increasing the frequency, the transmissibility going near to the unity, and by increasing the frequency, the anti-resonance peaks were appeared in small gap.

In addition, when the angle θ increase (ϕ fix at 5°) the transmitted force is greater than excitation force. In others word, the transmissibility is greater than 1. Next, if the angle ϕ increase (θ fix at 5°) the transmitted force is less than excitation force, indicate the effective isolation for the system. The value of natural frequency are same at any angle combination. That mean, the contact angle (θ,ϕ) only effect to the value of transmissibility which is offset to upper or lower side. Four parameters were taken into accounts which are density, young's modulus, length of suspension absorber and radius of finite rod. From the density analyses, there are show that the natural frequency still at same value (6.25Hz) even the value of density increased. The natural frequency will increased when the young's modulus increased. The resonance frequency shift right due to the effect of the elastic properties. The natural frequency will decreased when the length is increased. When the radius increased, the natural frequency had also increased

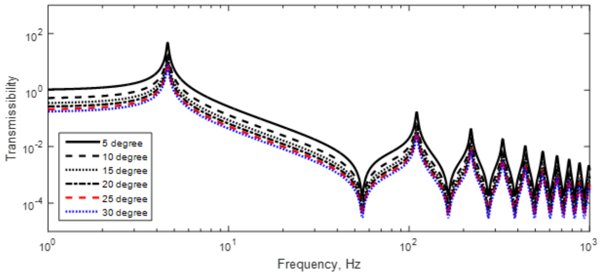

Figure 3.1: Transmissibility for variable value of ϕ

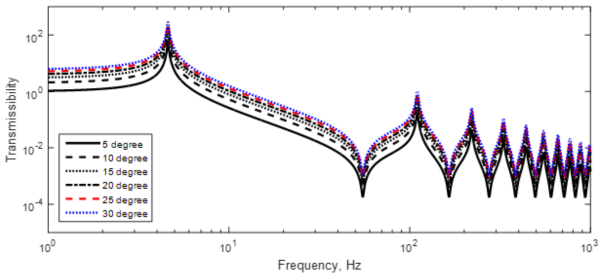

Figure 3.2: Transmissibility for variable value of θ

4. SUMMARY

At the end of this study, several conclusion were obtained. Generally, the study of transverse vibration model has provided some basic theory and understanding on how it influences the performance of the suspension absorber.

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