inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 46.2

VIBRATION ANALYSIS OF A FORKLIFT TRUCK WITH A HALF-FLOATED POWER TRAIN

H K Jang (1), D S Kim (1), S H Lee (2) & K B Park (2)

(1) Laboratory of Automotive Technology, Institute for Advanced Engineering, Yongin PO Box 25, Kyonggi, Korea, (2) Industrial Engineering Department, Daewoo Heavy Industries Ltd, 6 Manseok-dong, Dong-gu, Incheon,Korea

1. INTRODUCTION

Two kinds of configurations are used in mounting the power-train of a forklift truck. One is the conventional way of engine mounting, in which the power-train is floated by three or four flexible mounts. In this case the objective function for selecting mount postion and/or stiffness may be the minimization of transmitted forces through the mounts. However, in small class(less than 5 ton) forklift trucks, a peculiar way of mounting is often used because of the limited engine room space[1]. The dimension of the power-train of these forklifts, which consists of an engine block, a clutch, a transmission, and a trans-axle, is over a half of the whole vehicle size. In this way of mounting, as shown in Fig.1, a part of the power-train is directly connected to the body frame by a pin joint, and the other part mounted by flexible mounts. Unlike the conventional cases, considerable amount of force generated from the engine may be transmitted through the connection point, and only the remains through the mounts. So, the conventional methodology to select mounts is no longer valid. Moreover, there are few articles on vibration analysis of the 'half-floating' method.

In this work, the vibration characteristics of the forklift truck with the half-floated power train were analyzed by simulations and experiments. By changing the mount stiffness, the vibration at the driver's site was reduced. Through the vibration analysis and the modification of mounts, the guideline to select better mounting configuration was presented.

2. MODELING AND EXPERIMENTS ON FORKLIFT TRUCK

The forklift truck was modeled by using the design parameters. The whole structure is almost symmetric about the center line(z-axis), so inertia properties (Ixz, Iyz) are assumed zero. The body frame was assumed to move vertically(y-axis) and to have both a pitch and a roll. The power-train can rotate about trans-axle(front wheel axis) in the body frame. As the forklift truck has a 6 cylinder in-line engine, it is assumed that there exist only a torque with respect to the crank shaft as an excitation[2]. The minimum speed of engine rotation was 750rpm, and the corresponding fundamental excitation frequency was 37.5Hz.

The important natural frequency of the model related to the resonance of engine-mount system was 35Hz. The same resonance in the real structure from an experiment was 33Hz, which shows good approximation.

3. REDUCTION OF VIBRATION BY CHAINING MOUNT STIFFNESS

Quantification of Vibration for Human

In this work the vibration was quantified in the view point of human response[3]. As the vertical vibration on the floor of driver's site was comparatively large, it was selected as a representative value for human response. In accordance with the regulation(prEN 1031), measured vibrations were band-passed and multiplied by the weighting function in the frequency domain. The band-pass filter and the weighting function for the vertical direction were shown in Fig.2

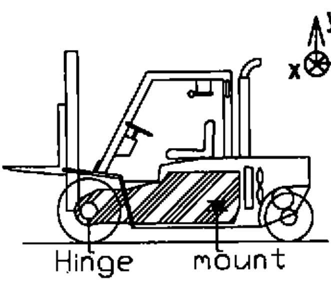


Fig.1 Configuration of engine mounting in forklift truck

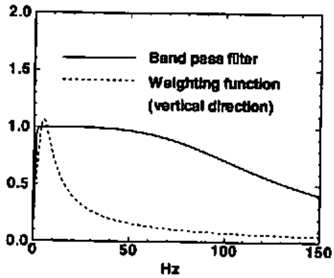


Fig.2 Band-pass filter and weighting function for human response

Guideline to Select Mount Properties

Mount stiffness and the locations of mounts are of the most importance in the engine mounting, which are the design factors also in this application. Modification of the other parameters such as tire stiffness/locations and the inertial properties of the body frame or the power-train are not allowed because of the other requirements.

The stiffness of the mount should be selected so as to meet the following conditions; i) resonance of the engine-mount system should avoid the excitation frequency, ii) mount stiffness should be bounded so as to restrict the strain of the elastomeric materials. The recommended maximum strain for a rubber mount was 15% in tension-compression[4].

Reduction of Vibration by Changing Mount Properties

In Fig.3 are shown the excitation frequencies and the resonance frequencies of the structure, which shows closeness between the excitation frequency and the natural frequency of the engine-mount system. In order to push down the structure resonance, the mount stiffness should be reduced by at least 30%. In this work, the mount with the stiffness of one third of the original was selected.

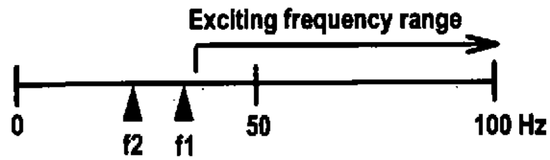
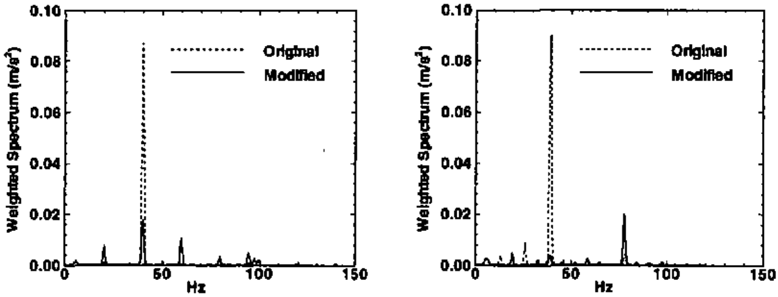


Fig.3 Resonance frequency and excitation frequency range
(f1, f2 : original and modified natural frequency)

The weighted vibration spectra at idling (750 rpm and 2400 rpm) were shown in Fig.4. The vibration at the fundamental excitation frequency was considerably reduced but at the harmonic frequency increased slightly, which are summarized in Table 1. Although the vibration level at 750rpm was increased(2nd column), human vibrations were reduced(3rd column), and so, it can be concluded that human factors should be introduced in the application. From the last column of the table, the vibration was reduced by about 30% after the mount change.

Table 1 Comparison of overall vibrations(up to 150Hz) on the floor (m/s^2)

rotation speed (unloaded)		not weighted		weighted	
750 rpm :	original	2.705		0.0435	
	modified	2.952	(9.13% ⇑)	0.0288	(33.8% ⇓)
2400 rpm :	original	3.259		0.0410	
	modified	2.819	(13.5% ⇓)	0.0294	(28.3% ⇓)



(a) 750 rpm (b) 2400 rpm

Fig.4 Comparison of weighted vibration spectra at the floor of driver's site in case of minimum and maximum idling speed

4. CONCLUSION

The vibration analysis of the forklift truck by using the dynamic model gives the guideline to select mount stiffness. By reducing the mount stiffness, the human vibration at the floor of driver's site was reduced by 28~33%.

REFERENCES

[1] D. S. Kim and H. K. Jang, "Reduction of Noise and Vibration of Daewoo Forklift Truck," Technical Report, Institute for Advanced Engineering, 1995.

[2] C. F. Taylor, The Internal Combustion Engine in Theory and Practice, Vol.2, MIT Press, 1980.

[3] M. J. Griffin, Handbook of Human Vibration, Academic Press, 1990.

[4] H. Kowara, Rubber for Vibration Isolation, Japanese Railroad Industry, 1975.