Research on Lightweight Design of Inertia Vibrator

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Research on Lightweight Design of Inertia Vibrator

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Abstract. The lightweight structure design of the inertia vibrator is one the core tasks for subgrade vibration. This paper describes the relationship of the dynamic test parameters, including the vibrator weight, the vibration frequency, the vibration displacement, the landing time, and the impact force. By analysis and simulation, the influences of the static weight and the frequency on the vibrator performance are present, which is valuable for the optimal calculation of impact force.

1. Introduction

In the vibration process of the dynamic performance of inertia vibrator, it is difficult to determine the proper weight of the vibrator under certain frequency. In order to design a lightweight inertia vibrator which can be used in heavy load situation, the influence of the vibration frequency on the vibrator performance was studied. Based on it, the relationship between the impact force and the static weight is analyzed. According to the simulation of the dynamic response model, the proper weight under different frequency is present.

2. Influence of the Vibration Frequency on the Vibrator Performance

When the static weight of the vibrator is 400 kg, vibrator keeps contact with subgrade surface. Vibrator can hardly move downward due to the large vibration plate area. Ignore the subgrade deformation, leave out the low frequency vibration amplitude, and only consider the impact force of the vibrator for the subgrade surface. Impact force is the sum of eccentric exciting force and the force of gravity. According to above analysis, when f < 12.73 Hz, the vibrator does not jump up from subgrade surface, and the impact force can be expressed as:

$$F(t) = -30.84 f^2 \sin 2\pi ft + 4000 \tag{1}$$

Therefore, the impact force becomes biggest, and equals to 7084 N, when f equals to 10 Hz. In the process of vibration, the vibrator movement condition including suspended state and ground state should be considered. Then vibrator movement displacement and impact force on subgrade should be analyzed. The static weight of the vibrator is 400 kg, vibration frequency f is in the range of 10 to 40 Hz. Therefore, displacement-time curves of the vibrator under six different frequencies according to Eq. (1) are shown in Fig. 1, while the vibration frequency f >12.73 Hz.

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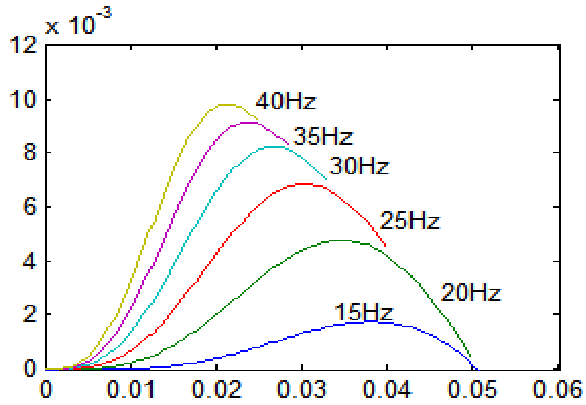

Figure 1. Displacement-time Curve Under Six Different Frequencies

When vibration frequency is 15 Hz, set the displacement equals to 0 as the land location. Then t = 0.0505 s is the landing time. The acceleration-time curve and the speed-time curve are drawn in Fig. 2 and Fig. 3. On the curves as shown, the point after the landing time is 0. According to the curves, the vibration of subgrade is stable when vibration frequency f is 15 Hz. the vibration amplitude is less than 2.5 mm and the impact velocity is 0.2981 m/s. Comparing impulse force with eccentric vibration force, the influence is small. To achieve high frequency and overload effect, the time around the maximum eccentric vibration force should be considered as appropriate landing time.

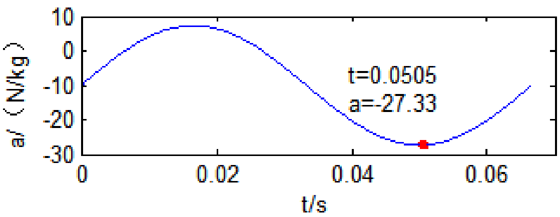

Figure 2. Acceleration-time Curve

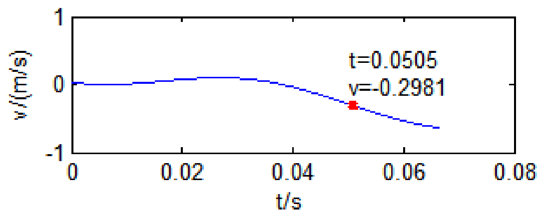

Figure 3. Speed-time Curve

3. Influence of the Static Weight on the Vibrator Performance

The problem that impact force loss caused by vibrator suspension is existed when the vibrator parameters are improper. So vibrator design should consider eccentric vibration force amplitude F_0 to coordinate with the static weight of vibrator M. The vibrator produces different impact force on subgrade under different vibration frequencies. Generally, the impact force on subgrade can be adjusted through the weight of vibration plate. When changing the static weight of vibrator M, whether or not the vibration can work normally under given frequency and the impact force loss should be considered.

To design a vibrator, first of all, a suitable parameter ξ should be chosen to obtain vibrator's normal vibration, and $\xi \geq 0.4$ is recommend. According to above analysis, velocity and acceleration at the landing time, and impact force on subgrade can be obtained. Then the static weight of vibrator is determined by the impact force. When f = 40 Hz, landing time under different ξ, in the range of 0.4 to 0.9, can be calculated. Fig. 4 shows the curve of landing time versus ξ. The curve shows that the landing time is linearly decreased with ξ. Fig. 4 shows acceleration trends under different ξ in a cycle. When vibrating with 40 Hz frequency, the impact force with different ξ in different landing time can be obtained, shown in Fig. 5.When ξ increases from 0.4 to 0.58, landing time is closer to 270°, and impact force gradually increases. However, when $\xi > 0.58$, with increasing of ξ, acceleration gets lower. The more the landing time closes to the left position in Fig. 6, the smaller the impact force becomes. Then increase ξ, impact force will loss.

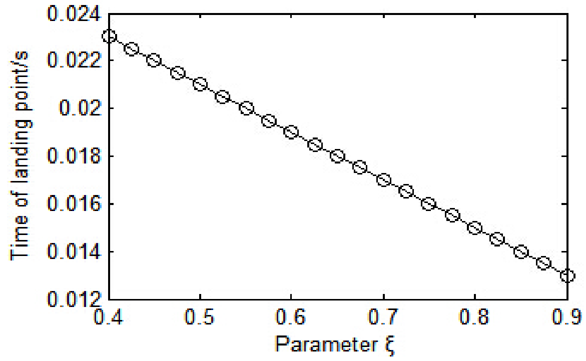

Figure 4. Landing Time Versus ξ

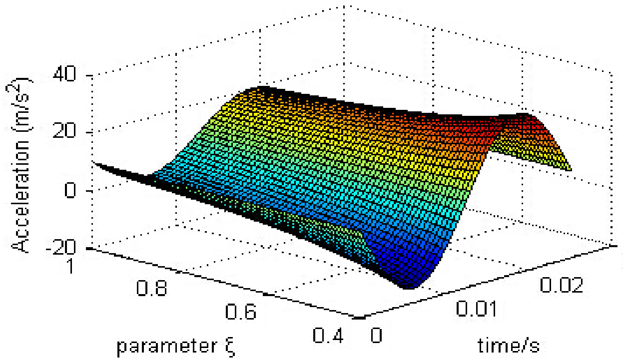

Figure 5. Acceleration Trend under Different ξ

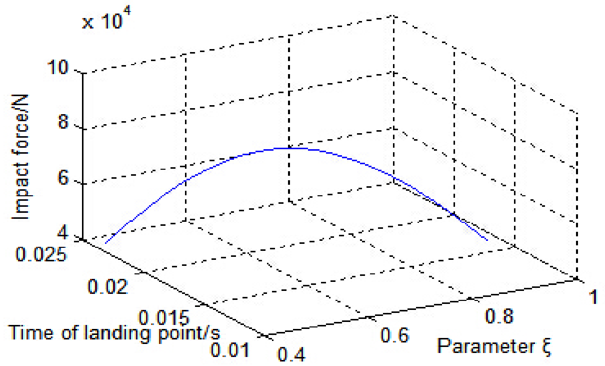

Figure 6. Impact Force and Reducing Loss Coefficient ξ

4. Experimental Results

In order to verify the parameters for the vibration, the experiments by changing the weights of the vibrator under 20 Hz excitation frequencies are designed to analyze the dynamic motion characteristics of the vibrator. Here the vibration displacements and the impact forces of the subgrade surface are tested by selecting the vibrator weight as 200kg and 900kg. The test values in 1s time are drawn as curves, as shown in Fig.7 and Fig.8. In Fig.7(a), it is found when the vibrator weight is 200kg, the vibration displacement waves irregularly from 0.05m to 0.075m, which indicates the vibration is unstable. In

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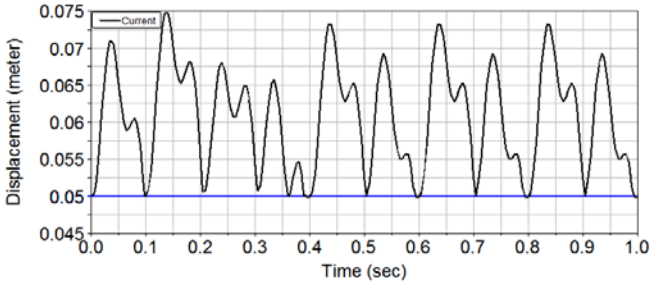
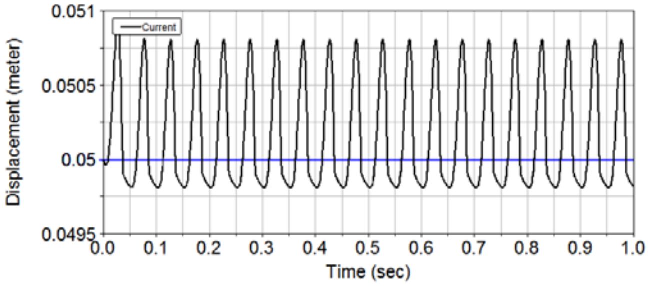
Fig.7(b), the vibrator weight is 900kg. In this case, the vibration displacement waveform is regular and waves from 0.05m to 0.051m, which indicates the vibration is stable with little fluctuation. In Fig.8(a), it is found when the vibrator weight is 200kg, the maximum output impact force is 18kN, far less than the expected value 25.66kN. Meanwhile, the impact force is 0 from 0.35s to 0.95s. It means the obvious empty vibration exists during working which would result in insufficient output impact force. In Fig.8(b), the vibrator weight is selected as 900kg recommended in Table 1. In this case, the output impact force wave is stable, and the value is about 25.7kN which agrees well with the calculated value in Table 1. Therefore, it can be concluded if the vibrator weight is improper under the given vibration frequency, the vibrator cannot output the specified impact force to meet the requirements of dynamic subgrade test.

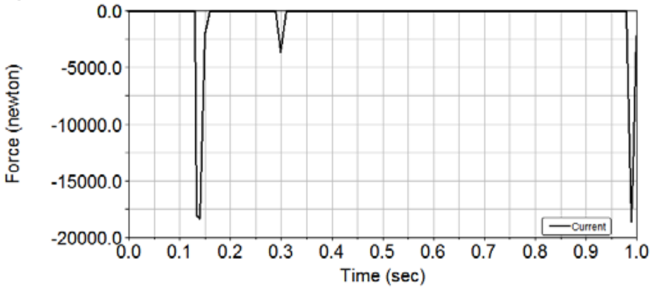


(a) Vibration weight = 200kg

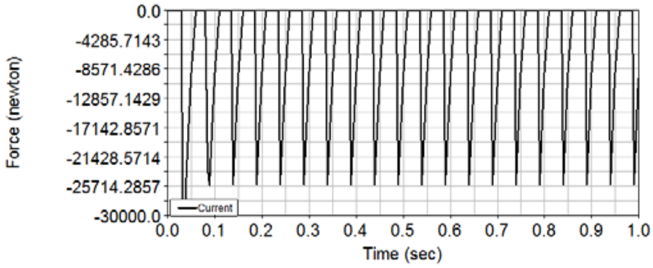


(b) Vibration weight = 900kg

Figure 7. Vibration Displacement under Different Weight



(a) Vibration weight = 200kg



(b) Vibration weight = 900kg

Figure 8. Impact Force under Different Weight

5. Conclusion

Based on the analysis and the simulation, the proper parameters range is given in this paper. According to target impact force, suitable static weight should be chose to realize better impact force with lighter weight. The method can be used to provide reference for lightweight design of inertia vibrator. The experimental results show the recommended value is suitable for the design of inertial vibration device that as railway subgrade dynamic response testing equipment.

6. References

[1] Luo Chun-lei, Han Qing-kai. Synchronization Characteristics Research of Eccentric Gyration System Controlled by Hydraulic Driving[J]. Journal of Mechanical Engineering, 46(6): 176-181, 2010.
[2] Evarts, Kingsley S. Eccentric vibration system with resonance control[J]. Journal of the Acoustical Society of America, 122(1): 24, 2007.
[3] Qiu Ming, Liao Zhen-qiang,FAN Li-xia. Dynamic modeling and finite element analysis of square plansifter[C]. Proceeding of ICMEM2007 International Conference on Mechanical Engineering and Mechanics, 993-997, 2007.
[4] Ou Zhu-guang. Engineering Vibration[M]. Wuhan: Wuhan University Press, 2010.
[5] Kawahara S, Muro T. Effects of Dry Density and Thickness of Sandy Soil on Impact Response Due to Rockfall[J]. Journal of Terramechanics, 43(3): 329-340, 2006.