RESPONSE OF A SEMI-INFINITE ELASTIC BEAM TO A MOVING PULSE

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Summary Dynamic response of a semi-infinite elastic beam to a moving single sinusoidal pulse was investigated by using a finite element method with the ABAQUS/Explicit code. Results show that the average of the maximum Mises stress in the beam reaches its maximum when the velocity of the pulse is closed to a critical velocity due to the coupling between the moving pulse and the flexural wave in the beam.

INTRODUCTION

The structure of a railway carriage may be damaged when subjected to intense dynamic loads. A positive-negative pressure variation appears when two trains pass each other, as shown in Fig.1 [1]. The pulse travels on the side bodies of trains. In the experiment of real trains passing each other, it was found that the amplitude of pressure increases as the speeds of trains grow [2]. So, the stable of the structure of railway carriage may become a serious problem when the train runs faster and faster. The influence of the pressure variation on the train's running safety has been studied by numerical method of multi-body systems dynamics [3]. On the other hand, the response of a prestressed elastic plate strip to a moving pressure load has been investigated and it was found that the deflection becomes unbounded when the velocity of the moving load is close to a critical velocity, which depends only on the magnitude of the prestress and the property of the plate [4]. However, the problem of the dynamic response of structures to a moving positive-negative pulse has not attracted much attention.

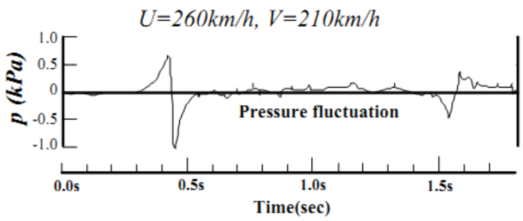

Fig. 1. Pressure variations occurring when two trains pass each other measured on the middle of each train [1].

FINITE ELEMENT MODEL

In the present study, the dynamic response of a beam to a moving positive-negative pulse is investigated by using ABAQUS/Explicit code. A beam with length 1000 m is modelled and its one end is clamped. There are 5001 nodes along the beam and the distance of any two adjacent nodes is ΔL = 0.2 m. The cross section of the beam is square with edges equal to 0.05 m. Since the transverse shear deformation is important, the Timoshenko (quadratic) beam element B32 is selected. The density, Young modulus and Poisson's ratio of the beam are 2700 kg/m^3, 70 GPa and 0.3, respectively. A single sinusoidal pulse travels from the free end to the clamped end of the beam, as schematically represented in Fig. 2. The period of the pulse is 0.4 sec and the amplitude is 0.01 MPa. Different moving velocities of the pulse are applied. The maximum Mises stress and displacement along the beam are calculated. To approximate a semi-infinite model, namely, to neglect the influence of the reflected flexure wave, the calculation ends when the pulse moves to 500 m and only the Mises stresses and displacements within the first 190 m are considered.

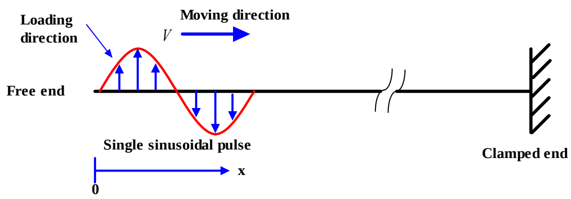

Fig. 2. The moving single sinusoidal pulse on the beam.

RESULTS AND DISCUSSION

The phase velocity of the flexural wave in the beam subjected to a concentrate force at its free end is firstly determined. The magnitude of the force changes as sine periodically. To compare the phase velocity and the critical velocity in the

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sinusoidal pulse condition, it is necessary to keep the pulse's periods identical. The phase velocity is about 29.4 m/s when the period is 0.4 sec.

As shown in Fig. 3a, at the beginning when the pulse travelling into the beam (stage I), the maximum Mises stress (σ_{max}) increases with the distance to the free end; after achieving its maximum at certain position, the maximum Mises stress in the beam ahead tends to be identical (stage II). It is interesting that the maximum Mises stress at stage II significantly depends on the moving velocity of the pulse, and the average ($\bar{\sigma}_{max}$) is calculated and shown in Fig. 3b. It is interesting to find that $\bar{\sigma}_{max}$ achieves its maximum at the critical velocity 32 m/s, which is close to the phase velocity 29.4 m/s.

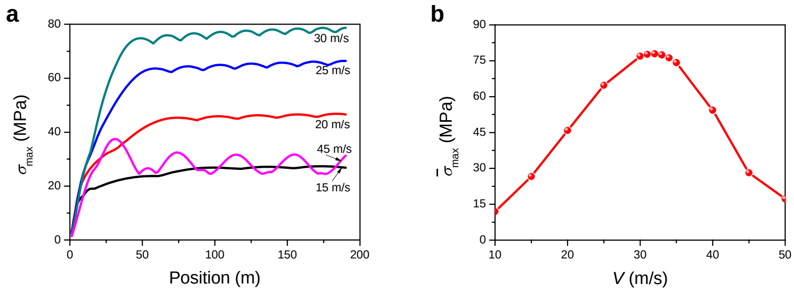

Fig.3. (a) Maximum Mises stress vs. position and (b) average of maximum Mises stress vs. the velocity of single sinusoidal pulse. Here, the period of single sinusoidal pulse is 0.4 sec.

These results may be caused by the interaction between the single sinusoidal pulse and the flexure wave. There are three cases of the relative velocity between the single sinusoidal pulse and the flexure wave: the former is slower than the latter, the former just catches the latter, and the former is faster than the latter, as shown in Fig. 4 where the displacement profile of the beam and the position of the pulse are plotted. Only in the second case, strong interaction takes place, leading to a higher level of bending. So, σ_{max} in the second case is much larger than in the other cases. In the third case, Fig. 4c, the flexural wave is suppressed by the positive-negative pulse and it can be seen that the amplitude of vibration is very small.

Since the phase velocity of a flexural wave is frequency dependent, the critical velocity of the single sinusoidal pulse also depends on its period.

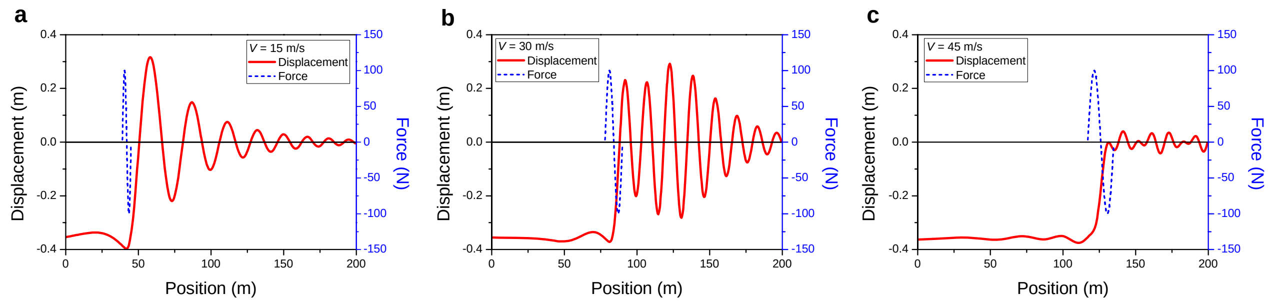

Fig. 4. The beam's displacement profile and the position of the single sinusoidal pulse at t = 3 sec for different velocities of the single sinusoidal pulse: (a) 15 m/s, (b) 30 m/s and (c) 45 m/s.

CONCLUSIONS

Dynamic response of a semi-infinite beam to a moving single sinusoidal pulse is studied numerically. The maximum Mises stress reached in the beam strongly depends on the moving velocity of the pulse and the critical velocity depends on the period of the pulse. This phenomenon is due to the coupling between the moving pulse and the flexural wave when their velocities are comparable.

Acknowledgements

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