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MEASUREMENTS OF VIBRATION AMPLITUDE AND IMPACT FORCE IN 2M SHOCK TUNNEL

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ABSTRACT

This paper describes the primary study of impact vibration measurement of the shock tunnel with the tunnel test section fixed or unfixed to the ground. A piezoelectric ceramic glued to the nozzle is used to measure the impact force of the shock tunnel in above two modes. The vibration amplitude of the test section and the shock tube are recorded separately when the bolts unlocked to the ground. A color pen fixed to the driven section is used to record the displacement of the shock tube, and white powder is used to record the displacement of the test section. The vibration amplitude test results show that the shock tunnel test section moved little in a fixed operating mode, and moved a big distance in a sliding run mode. The impact force influences the shock tunnel vibration mode complexly. The test section has a trend to move to the direction of the driver section first, and then trend to move to the direction of the vacuum tank. Using piezoelectric ceramic can measure the impact force of the shock tunnel in the axis direction. During test, the impact force changed to-and-fro. When the bolts are fixed, the orientation of the force changed faster than that of the blots are unfixed. But, when the shock tunnel operated in a sliding mode, the impact force is larger.

Key Words: shock tunnel; vibration; impact force; sliding run

INTRODUCTION

In the range of hypersonic wind tunnels, the shock tunnel have the characteristics of wide rang of test parameters, better simulating capability, and low test costs. The shock tunnel has great importance in the research of weapon. In the past, the base of test part of 2m shock tunnel is direct fixed to the ground. When the tunnel is running, the impact force of the tunnel body affects the ground directly. As the tunnel operate for years, the ground split obviously, that will affect the safe of the tunnel running and it's buildings significantly, so the experiment carry out only in low Reynolds number state, but it is need to research of aerodynamics of missile in high Reynolds number. Some researchers think that it is better to adopt the sliding running method to change this status. However, how much is the vibration amplitude of the test section during the shock tunnel is running? And how much is the impact force during this period? These problems determine how to design the sliding run methods, model supporting system, and its connecting

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mode to the tunnel. So before change the state, impact character of the tunnel must be researched. When the shock tunnel in a full sliding run mode, that is to say, unfixed all the bolts of the test section and the ground, the tunnel body will be slipped freely. In this research, two states are compared: one with the fixed blots, and the other with the unfixed blots.

1 AMPLITUDE MEASUREMENT

When the shock tunnel is fixed to the ground, the amplitude is small, so we use one simple optical method to magnify the test signal to resolve the vibration amplitude. We take photograph about the amplitude of a fixed point on the shock tunnel, and use a geometry method to confirm the amplitude of the tunnel body. Figure 1 and Figure 2 show the sketch map of the test principle. In this test, the vibration of the cameral pedestal must be insulated; otherwise, the exposal wobble caused by the cameral pedestal vibration will cause a large disturbance. Thereby, we fixed a laser pen on the shock tunnel test section, and the laser can emit to the screen with a graph paper in a long distance, and the camera can take photographs continually in a stable state. At last, read the signal photo and get the amplitude of the test section when the shock tunnel running with a fixed mode. But some states, for example, when the shock tunnel's driver press is 10MPa, 32MPa, and 50MPa, there is no observable movement of the light spot. That is to say the vibration amplitude of the shock tunnel body is less than the resolution of this measurement.

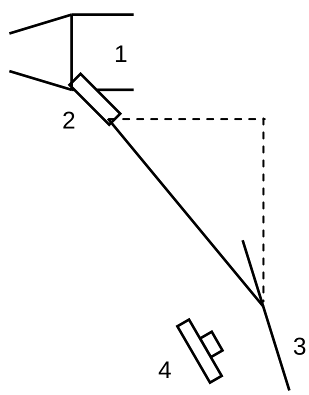

Fig.1 The sketch map of amplitude measurement when tunnel fixed
1-test section, 2-laser pen, 3-screen with plotting paper, 4-camera

Fig.2 Laser pen fixed on the test section

When the blots between the test section of the shock tunnel and the ground are unlocked, the vibration amplitude is much larger than that of the blots is locked. In this case, it can be use a relatively simple and direct method to measure the vibration amplitude. The method to test the shock tube vibration amplitude is showed in Figure 3. The color pen is fixed to a steel bar, and the other tip is fixed to driven section of the shock tube. Adjusting the position of the pen to touch the graph paper on the ground exactly, the vibration amplitude of the shock tunnel is recorded. But the test result is not satisfactory. It is maybe the steel bar fixed by the iron wire, and this measurement system stiffness is not enough. The fine white powder on the basement of the shock tunnel test section is used to record the vibration amplitude, we can not get detail trace by this way but it can clearly indicate the shock tunnel test section position. So it can record the maximum vibration amplitude of the test section. The results are showed in Table 1.

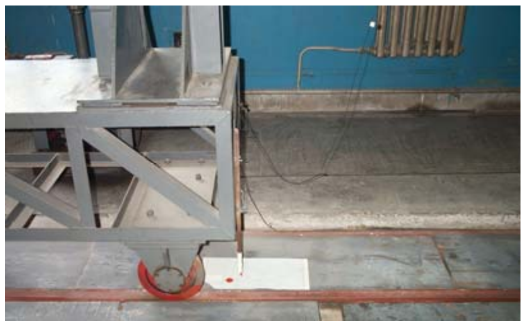

Fig.3 Amplitude measurement with pen fixed on the ground

Table 1 Measurement results

Measurement content	Bolts state	Driving pressure P_4(MPa)	Results
Amplitude	Unlocked	50	-4.3mm
			3.3mm
Impact force	Locked	10	-156.8kN
			196.0kN
		50	-747.7kN
			880.0kN
	unlocked	50	-788.9kN
			1050.6kN

Note: - represent the orientation to the driver section of the shock tube, and +represent to the vacuum tank orientation

2 IMPACT FORCE MEASUREMENT

According to the former research, when the drive press reached to 80MPa, the impact load on the test section can achieved as large as 1400KN. When the shock tunnel running, the wave in the shock tube is complex, there is expansion wave and reflect shock wave after the incident shock wave, so the impact force to-and-fro acted on the test section. It is very interest in the impact force act on the basement, but it is difficult to measure directly. Considering the impact force is caused by the shock tube, the test position is on the nozzle near the shock tube end, and the location is show in Figure 4. In order to avoid the effect during structure change of the shock tunnel, two $5 \times 10 \times 0.3\text{mm}^3$ piezoelectric ceramic are used as the sensitive gauge to measure the strain caused by the impact force. The test curve is showed in Figure 5 and Figure 6, and the result is showed in table 1.

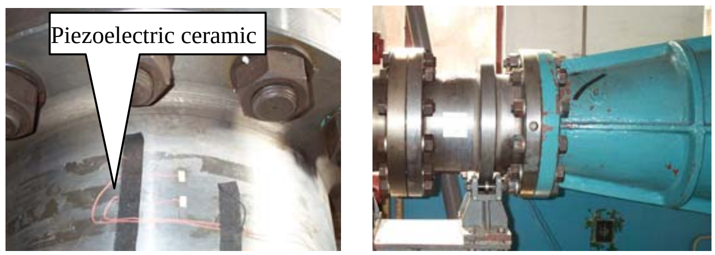

Fig.4 The photo of impact force measurement location

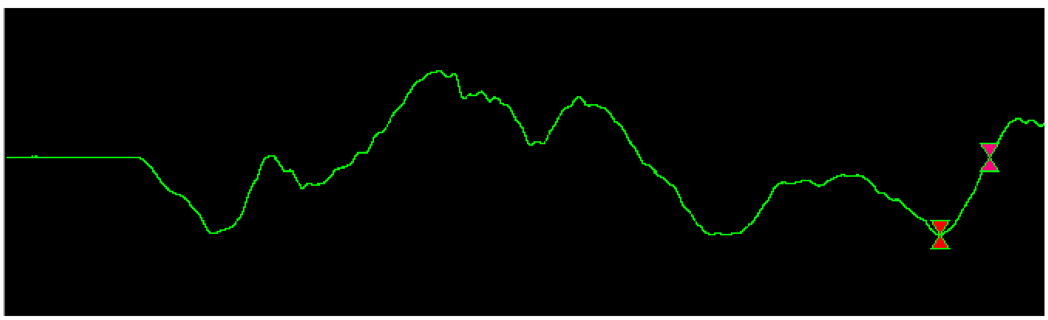

Fig.5 The impact force curve when bolts unlocked at P_5=50MPa

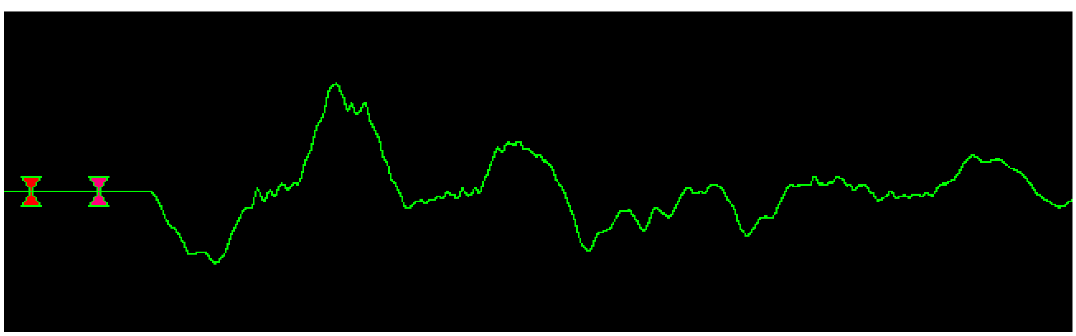

Fig.6 The impact force curve when bolts locked at P_5=50MPa

3 RESULTS AND DISCUSSION

When the driving press was at 10MPa, 17MPa, 32MPa, there was unobvious movement caused by the shock tunnel vibration impact force. It is showed that the impact force is smaller than the friction between the test section and the basement. We can see from table 1, when the P_4=50MPa, the test section (including the vacuum tank) move to the driver direction for 4.3mm firstly, and then to the vacuum tank direction for 7.6mm. When the shock tunnel running was finished, the test section stopped at the location of 3.3mm backward. Which indicate that, under the impact force, the shock tunnel body is not simple oscillation, and the impact force orientation is first to the upwards and then to the backward. According to the impact force measurement, when the P_4=50MPa, and the blots are unlocked, the orientation of the impact force pointed to the driving section with the maximum force of 788.9kN, and then pointed to the vacuum tank with the maximum force of 1050.6kN. The results of impact force measurement coincided with the amplitude measurement.

From the amplitude test, we found that the results near the nozzle exit are different from the results of vacuum tank. Can we say that the impact amplitude of the test section and the vacuum is not in the same value? Or the section is distortion in the experiment? By analyzed, we think that it is caused by the difference of the structure between the vacuum tank and the base. There is a wedge iron besides the normal connect structure in the vacuum tank. When the tank moved, the wedge iron moved also, that is to say, there is more freedom in this section, so the distance is different.

We can see from table 1, when the driving press is 50MPa, the impact force have a great different when the blots is locked or unlocked. It is caused by some reasons. Firstly, the driving gas is 80% hydrogen and 20% nitrogen with the blots locked and pure nitrogen with the blots unlocked. Secondly, when the blots are unlocked, the main purpose of the test is to measure the displacement of the test section in the floating mode, consider for the safety, the vacuum and the pump pipe is separated completely (including the bolts), at the same time, the driven section of the tube tip is blocked, the tunnel operated in a shock tube mode. Table 1 showed that, the impact force and the amplitude test coincide with each other. When the impact force acted to the downwards, the test section moved through the counterpoise first and then moved to the downwards, it is obviously that, the work of the impact force overcome the friction is larger than the impact force acted to upwards. The momentum also confirmed this conclusion. We can see from Figure 5, Figure 6 and table 1 that, when the blots is unlocked, the impact force in the second direction is larger than the first direction in the peak value, and the momentum is also much larger. By integral, the momentum is 1517.69N.s to the driver section in the first wave, and the momentum is 2567.82N.s to the driver section in the second wave. That caused the test section stopped downward other than return to the former location. So when the shock tunnel operated in the sliding mode, it is necessary to consider how to control the displacement of the tunnel, or how to reset the tunnel after every time test running or after some tests running, which is necessary to insure the shock tunnel on the safe mode. Figure 6 indicate that, it is more complex when the blots are locked. In the same interval time with the blots unlocked, the impact force orientation changed faster, the momentum is 992.18N.s to the driver section in the first wave, and the momentum is 1788.84N.s to the test section in the second wave, then the momentum is 2063.95N.s to the driver section in the third wave. That is to say, the impact force orientation changed once more when the blots locked than that of the blots unlocked. The momentum is much larger to the base of tunnel test section, so the destruction is much stronger.

4 CONCLUSIONS

From the measurement of the impact character of the 2m shock tunnel, we can get below some conclusions:

a. The vibration mode is complex by the effect of impact force, the shock tunnel test section trend to move to the shock tube driving section and then trend to move the vacuum tank. When the base bolts locked, there is no movement of the tunnel body, and the vibration of the shock tunnel transmitted all to the base. When the blots unlocked, there is no movement of the shock tunnel at the driving pressure less than 32MPa also, and moved downwards at the driving pressure larger than 50MPa, and the vibration of the base is smaller.

b. The axis vibration impact force of the shock tunnel can be measured by the piezoelectric ceramic. The orientation of the impact force moved up-and-fro during running time. The impact force orientation changes fast when the blots locked, and the momentum is larger and larger, and the damage to the base is stronger. When the blots unlocked, the momentum is larger, and the peak value of the impact force is also larger.

c. When the shock tunnel operated in the sliding mode, the replacement of the shock tunnel must to be considered.

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