DEVELOPMENT OF A NOVEL MINIATURE IMPACT TEST SYSTEM

Zhanwei Liu [1], Xintao Lv [1], Ximin Chen [1], Huimin Xie [2]

1. School of Aerospace engineering, Beijing Institute of Technology, Beijing 100081, China

2. AML, Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China

Summary A miniature impact test system with a length of 1m based on a mini split Hopkinson bar and the new driving principle of multi-stage electromagnetic pulse was developed for researching the dynamic properties of materials in small and micro dimensions. Effective validation tests on 2024 aluminum alloy for the impact compression and tests on Polyimide (PI) film for the impact tension were carried out.

INTRODUCTION

Studying dynamic mechanical properties of film materials such as piezoelectric film is becoming a hot spot. The Split Hopkinson Pressure Bar (SHPB) technology is widely recognized as the typical experiment technology of studying dynamic mechanical properties of materials. However, the current available SHPB device mostly adopts the pneumatic launch to obtain shock loading on specimens. The technique makes the SHPB device very huge, bringing energy conversion with low efficiency and large noise pollution when launching. It's difficult to miniaturize the diameter of tensile bar. Besides, it is impossible to study the dynamic mechanical properties of micro-specimens. This paper develops a novel miniature impact test system in which the striker bar is driven by multi-stage electromagnetic pulse.

The miniature impact test system developed in this paper mainly includes mini Split Hopkinson bar (SHB) components, multi-stage electromagnetic pulse launcher and strain test device as well as high speed digital image correlation (DIC) system. SHB components include: two different strikers, two different incident bars and a transmit bar.

MINIATURE IMPACT COMPRESSION TEST SYSTEM

The schematic of the system is shown in Figure 1and the schematic of multi-stage launcher is shown in Figure 2.

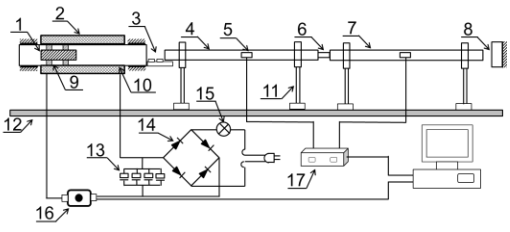

Fig. 1 Schematic of miniature SHPB device system

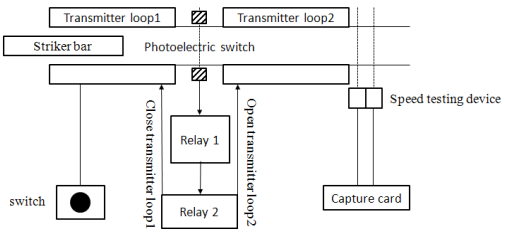

Fig. 2 schematic of multi-stage launcher

In Figure1: 1.Striker bar 2.Transmitter loop 3.Speed testing device 4.Incident bar 5.strain gauge 6.specimen 7.Transmit bar 8.Buffer 9.Bracket 10.Launching tube 11.Surport 12.Guide rail 13.Capacitor group 14.Diodes rectifying circuit 15.Charging indicator 16.Switch 17.Ultrahigh dynamic strain tester.

As shown in Figure 1and Figure 2, the multi-stage electromagnetic pulse launcher developed here consists of two magnetic transmitter loops, diode rectifying circuit, capacitor group, charging indicator and switch. At the press of the switch, the ferromagnetic cylindrical striker bar can be launched quickly by the pulsed force produced by the instantaneous discharging pulse electromagnetic field of the capacitor group. The speed range of striker bar is 5m/s ~ 20m/s, adjustable. Launching speed is calibrated through a pair of photoelectric sensor.

In order to validate the reliability of the new miniature impact compression system, the dynamic compression experiments are presented with two different dimensions of 2024 aluminum: $\varnothing 2\times 1$ mm and $\varnothing 2\times 2$ mm; Figure 3 shows the typical incident, reflect and transmit wave signals originally obtained from the strain gauge for dynamic compression. Then the stress-strain curve can be determined based on the one-dimensional stress wave theory. Results are displayed in Figure 4-5.

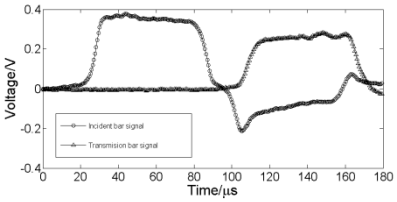

Fig. 3 Typical incident, reflected and transmitted wave

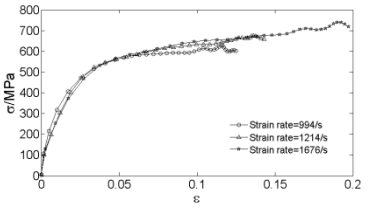

Fig. 4 Stress-strain curve of Φ2×1 of different strain rate

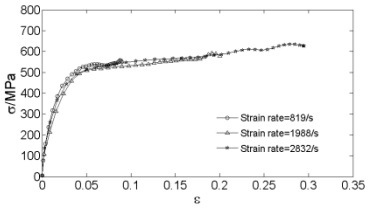

Fig. 5 Stress-strain curve of Φ2×2 of different strain rate

Figure 4-5 shows that the two different dimensions specimen have very close dynamic yield stress, which exhibits stable dynamic mechanical properties in a limited change of dimension. The test result demonstrates the effectiveness of the miniature impact compression system.

MINIATURE IMPACT TENSION TEST SYSTEM

The miniature impact tension test system is almost the same as the compression test system except for the SHTB components. Here the SHTB components include: a tube striker, an incident bar with flange and the same transmit bar with compression. The transmit bar, with one flat side for compression and one grooved side for tension. The grooved side is machined a 0.3mm-width groove, as shown in Figure 6.

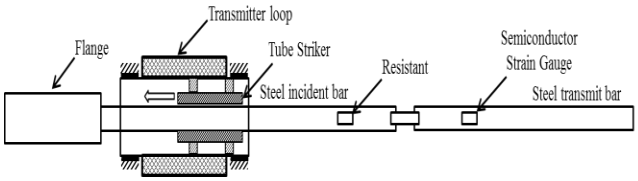

Fig. 6 Schematic of SHTB device after transformation

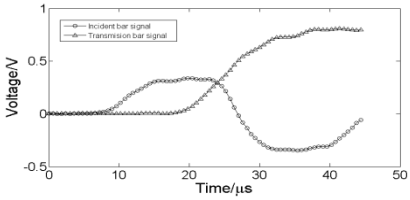

Fig. 7 Typical incident, reflected and transmitted wave

In order to verify the feasibility of the impact tension test system, the dynamic mechanic property of 250-μm thick PI film is measured. Typical tensile signal is obtained during an experiment from the miniature SHTB device developed, as shown in Figure 7. Figure 8 shows the strain-stress curves of the film in two different high strain rates and a reference in quasi-static strain rate.

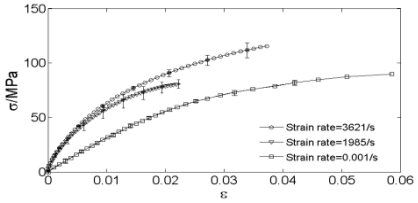

Fig. 8 Tensile Strain-Stress curves

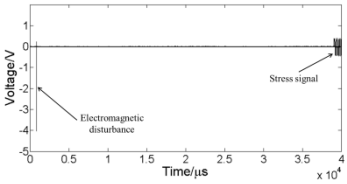

Fig. 9 The whole signal recorded

The repeatability of the stress-strain response demonstrates the reliability of the SHTB device for dynamic tensile test of micro-film. The Polyetherimide film is significant strain rate relative and exhibits non-linear behavior. The static tensile curve was linear at the first stage and became non-linear when the stain is larger than 3%, which is obviously different from the dynamic tests.

Because of the use of electromagnetic field to produce energy, the disturbance brought by magnetic field has to be faced. Figure 9 is part of the signal containing electromagnetic disturbance and strain signal captured in test. From the time axis, the electromagnetic disturbance appears far earlier than the stress wave signal and only last less than 5μs; this is due to both the spread speed and attenuation degree of electromagnetic pulse are far larger than that of the stress wave. The above analysis has fully demonstrated the disturbance brought by the electromagnetic field doesn't have any effect on the strain data recorded although the amplitude of electromagnetic disturbance is larger than that of the strain signal.

CONCLUSION

Compared with the traditional split Hopkinson bar system, a smaller, simple, compact and more promising system was established, which is especially suitable for dynamic properties investigation of small and micro sample.