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A technique for hi-speed indentation experiment based on Hopkinson bar

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Abstract

A new technique for hi-speed indentation experiment based on Hopkinson bar is presented. The ball projectile is accelerated with high pressure air gun and the Hopkinson bar is used for impact force measurement. The whole indentation displacement and force history can be obtained with this new technique. For accurately measuring the force pulse with several microseconds duration, a finite element simulation is carried out using ABAQUS for determining the transfer function of the bar. Then, the transformation function is used for reproducing the fore pulse. It gives much better results compared to traditional method base on 1-D or quasi 1-D stress wave theory. It is possible that the new technique holds feasibility and accuracy.

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Keywords: Dynamic indentation; Hopkinson bar; Transfer function

Nomenclature

C_0	velocity of one-dimensional stress wave in the bar
A_0	cross-sectional area of the bar
E_0	Young's modulus of the bar material
$\dot{u}_0$	velocity of the ball projectile
m_b	mass of the ball projectile
$\varepsilon_t(x_I, t)$	axial strain at the position of ball-specimen interface
$\varepsilon_t(x_{II}, t)$	axial strain at the position of specimen-bar interface

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h	height of the specimen
x_1	distance between strain gage and the input end of the bar
C_s	velocity of one-dimensional stress wave in the specimen
ε_m	measured strain
φ	transfer function
f_c	force pulse

1. Introduction

Instrumented indentation experiment is widely used to test static mechanical properties of materials. The similar technique is also used in the dynamic properties test. The earlier dynamic indentation test (dynamic hardness test) has been introduced by Tabor[1] and the indentation experiment devices based on Hopkinson bar are more used in dynamic property test of materials. One of these devices is suggested by Subhash et al. In his device, the pressure bar worked as a loading component and the indent force is measured with a force sensor [2]. Another similar device is suggested by Nilsson and the force and displacement are all measured with the Hopkinson pressure bar [3]. It is known that the loading velocity of Hopkinson bar is limited by the material yield stress, so the maximum indentation velocity can only be 50m/s or slightly higher in practice. The dynamic indentation experiment with higher speed can be achieved by the ball impact experiment [4][5]. However, only the initial velocity of the ball projectile and the final indentation can be measured in the present experiment arrangement. So, it is not enough to derive the dynamic mechanical properties of the tested material. In this paper, a new technique for hi-speed indentation experiment base on Hopkinson bar is presented. Combined with the stress wave inversion technique base on the transfer function, the whole indentation displacement and force history can be obtained with this new technique.

2. A technique for hi-speed indentation experiment base on Hopkinson bar

2.1. The device of hi-speed indentation experiment

The device of hi-speed indentation experiment is shown as Fig.1, which is different from earlier experiment device. The waveguide rod is used to support the specimen like to the transmission bar in SHPB. In this way, if the waveguide rod is assumed as ideal pressure bar, the whole indentation force history can be calculated by stress wave signal.

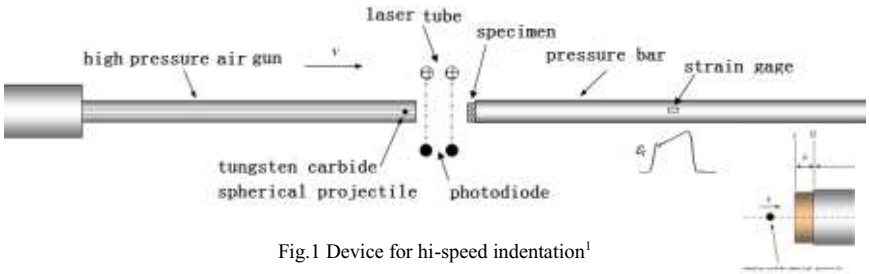

Fig.1 Device for hi-speed indentation[1]

2.2. Measurement of the indentation

The initial velocity of the ball projectile can be measured though the photoelectric trigger or other ways. The stress wave signal in pressure bar can be easily obtained by the strain gage. Under the assume that pressure bar is ideal one-dimension rod, the whole indentation displacement and force history can be conveniently obtained with the calculation method of waveguide rod stress and particle velocity.