Evaluation of Load and Load Point Displacement Through Three Point Bend Set Up for Dynamic Loading

Sanjay Kumar*, Anoop Kumar Pandouria, Vikrant Tiwari
Department of Applied Mechanics, Indian Institute of Technology, Hauz Khas, New Delhi, 110016, India

Article Info
Article history:
Received 25 January 2016
Received in revised form
20 February 2016
Accepted 28 February 2016
Available online 15 March 2016

Keywords
Modified Hopkinson Pressure Bar,
Two points strain measurement methods,
one dimensional wave theory and striker.

Three point bend set up is used to evaluate load and load point displacement on specimen during dynamic condition. Here, experiments have been conducted on Al 6063 alloys on Modified Hopkinson Pressure Bar (MHPB) in dynamic condition. The cylinder pressure and striker velocity was measured during experiments and it was 3.1 bar and 24m/s respectively. The strain gauges, data acquisition & computer were used to measure strain at two points at Hopkinson bar. The load point displacement and load are obtained by the two point strain measurement methods and one dimensional wave theory in terms of strains measured experimentally at two points.

1. Introduction

Aluminum alloys are generally used as structural materials in vehicle for outer portion of bodies and generally it encounters with collision, crash etc. So scientists and researchers are interested to study dynamic fracture behavior at different loadings. Three point bend set up has been designed and fabricated for three point bend test at different loading rate. This set up is also known as Modified Hopkinson Pressure Bar for three point bend test. It mainly consists of compressor, pressure cylinder, control panel, striker, barrel, Hopkinson bar and three point bend fixture. The strain gauges are pasted at two different location of Hopkinson bar for the measurement of incident and reflected pulse with the help of Data Acquisition System and personal computer. This set up is used to obtain the load point force and load point displacement [1].Ming-zhiet et al. [2] found the crack initiation toughness, crack propagation toughness ofAl2024-T4 and Al7075-T6,
Raman PSingh [3] investigated crack propagation in a brittle material reinforced with a ductile layer.L.Rubioet.al[4]obtained stress intensity factor in terms of crack mouth opening displacement (CMOD), input load and load point displacement. Also he has used Digital Image Correlation (DIC) and fracture gauge to obtain crack mouth opening displacement (CMOD) and time of initiation of fracture. In this paper only load point displacement and load applied on specimen is measured, further for evaluation of fracture initiation toughness, time of initiation of fracture is required, it can be obtained either use of Digital Image Correlation(DIC) or fracture gauge or strain gauge.

Corresponding Author,
E-mail address: sanjaydce2008@gmail.com;
Phone No--+91-9968558596

2. Experimental Set Up and Sample Preparation

Schematic of Modified Hopkinson Pressure Bar is shown in figure 1.This set up mainly consists of compressor, air cylinder, pressure cylinder, control panel, striker, barrel, Hopkinson bar and three point bend fixture. The compressed air is used to run the experiment.
Initially, compressed air is filled in the air cylinder through the compressor. This compressed air is supplied at desired pressure in the pressure cylinder through control panel. The striker of length 300mm and diameter 20mm made of stainless steel (same material of incident bar) is pushed toward incident bar through the compressed air stored in pressure cylinder. The compressed air in the pressure cylinder suddenly released on striker by solenoid valve. The striker starts motion from one end of barrel near pressure cylinder and strikes at incident bar near other end of barrel. The velocity of striker is measured through velocity probes mounted on outside diameter of barrel, these are used to measure the velocity of the projectile before strike the incident bar. The velocity probes are connected to a high-speed data acquisition system on the digital channel. When striker strikes the incident bar of length 1500 mm length and 20mm diameter, the compressive pulse is generated in the rod and travels towards other side where specimens are placed on roller support of three point bend fixture. The compressive pulse at end of incident bar changes to tensile pulse due to change in impedance of bar and specimen. The strain gauges are placed at two different locations on incident bar measure incident and reflected pulse by use of analog channel of data acquisition system and personal computer. The incident strains at two different locations is used to evaluate load point force and load point displacement by use of two point strain methods[1] which is further used to evaluate stress intensity factor (SIF).The actual photographs of this set up is shown in figure(2).

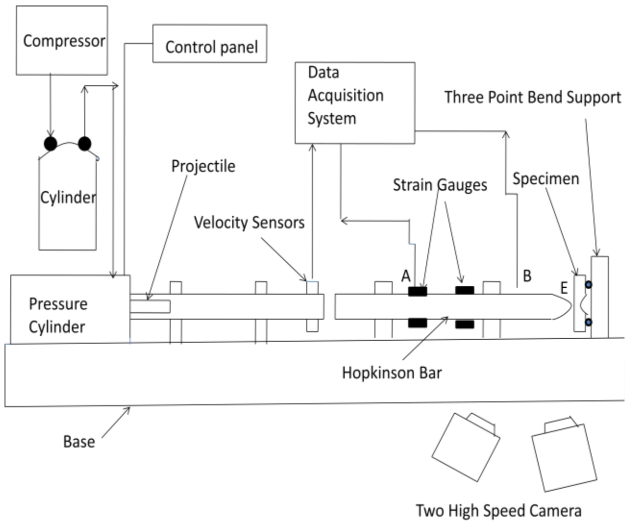


Fig. 1 Schematic of Modified Hopkinson Pressure Bar

The Al 6063, aluminum alloy is used in experiment at different loading rates. The size of specimen is 100mmX20mmX10mm as shown in figure 3.A notch is made of 1.5mm of uniform width and depth up to 7mm from one side of specimen on milling machine. The cutter of high speed steel is used for machining of uniform width notch. A v-notch of depth 1.5mm after uniform width was made by incline teeth cutter and finally fatigue crack of length 1.5mm is made by use of MTS machine .Therefore total length of notch in specimen was 10mm.The specimen photographs before and after experiment are shown in figure(3).

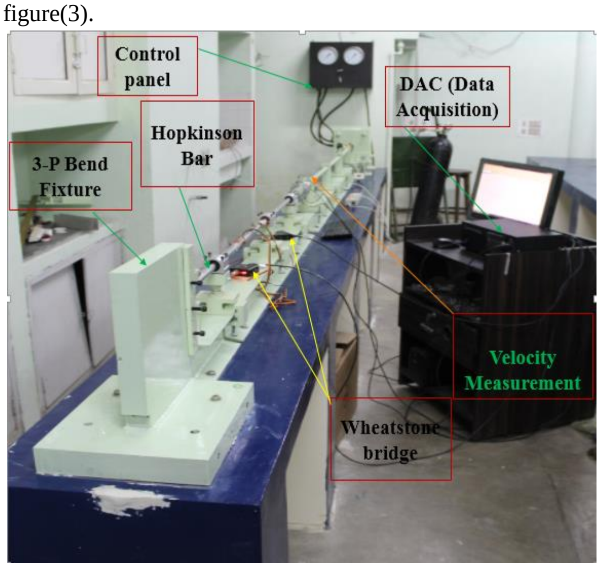
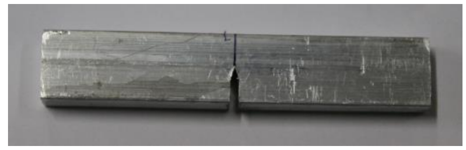


Fig.2 Actual photograph of three points bend setup for Modified Hopkinson Bar



(A) Before experiment

(A) After experiment

Fig.3. Three Point Bend Specimen (Al6063)

2.1Evaluation of Load-Point Displacement and Applied Load by Two Point Strain Measurement Method [1, 3]

Strain at points A and B (ε_A (t) and ε_B (t) at distance X_A and X_B is measured through stain gauges.

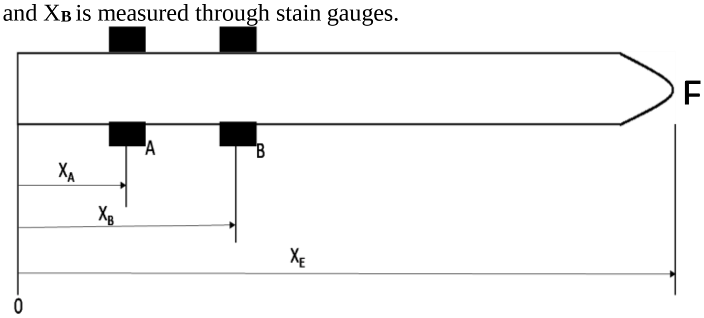


Fig.4.Modified Hopkinson Pressure Bar

E=Young's Modulus of Elasticity, ρ = Density, A=Cross-sectional area, Characteristic impedance,

$$Z=\rho AC_o$$

Normal force at position'x_A'and 'x_B'are

$$N_A(t)=EA\,\varepsilon_A(t) \text{ and } N_B(t)=EA\,\varepsilon_B(t) \quad (1)$$

The particle velocity, $V_A(t)$ at position x_A is given by

$$V_A(t)=V_A(t_p)+\frac{1}{Z}[-N_A(t)-N_A(t_p)+2N_B(t-T_{AB})] \quad (2)$$

Where t_p=t-2T_{AB} and $T_{AB}=\frac{X_B-X_A}{C_o}$

Force N_E (t) and Velocity V_E (t) at distance X_E can be expressed in term

$N_E(t)=$

$$\frac{1}{2}\left[N_A(t+T_{EA})+N_A(t-T_{EA})\right]+\frac{Z}{2}\left[V_A(t+T_{EA})-V_A(t-T_{EA})\right] \quad (3)$$

$V_E(t)=$

$$\frac{1}{2}\left[V_A(t+T_{EA})+V_A(t-T_{EA})\right]+\frac{1}{2Z}\left[N_A(t+T_{EA})-N_A(t-T_{EA})\right] \quad (4)$$

Where, $T_{EA}=\dfrac{X_E-X_A}{C_o}$ The load point displacement u(t) and applied force F(t) can be expressed as

$$u(t)=\int_0^t V_E(\tau)d\tau \quad (5)$$

$$F(t)=-N_E(t) \quad (6)$$

3. Results and Discussion

The strain data extracted from experiment at two points ‘A’ and ‘B’on Hopkinson bar is graphically shown in figure(4). The experiment was conducted at pressure 3.1 bar and striker velocity measured corresponding this pressure was 24 m/s. The force at point ‘A’ and ‘B’is obtained by relation mentioned in equation (1) and shown in figure (5).The maximum load on bar is recorded as 125kN .The Load point force and load point displacement at point ‘E’ are obtained by use of equation (1) to (6)by use of MATLAB code. Force at point ‘E’ obtained from two point strain measurement method [1] is shown in figure (6).Force at point ‘E’ is also obtained by use of one dimensional wave theory and shown in figure (7) and it validates that load at point ‘E’ obtained from both methods two point strain measurement methods and one dimensional wave theory. Also load point displacement at point (E) is shown in figure (8) and load at point ‘E’ is separately shown in figure (9).From load point displacement vs. time diagram, it is observed that load point displacement always increases with time. Moreover, from load vs. time diagram it is observed that initially load increases but after some time it decreases due to crack initiation in the specimen.

From figure(4), it can be seen that the load at point ‘A’ is started from zero time, so time required to reach pulse at the end of rod should be 150 micro second. Figure (8) and (9) depicts that load and displacement at point E is increased after 150 microseconds after pulse reached at point (E).

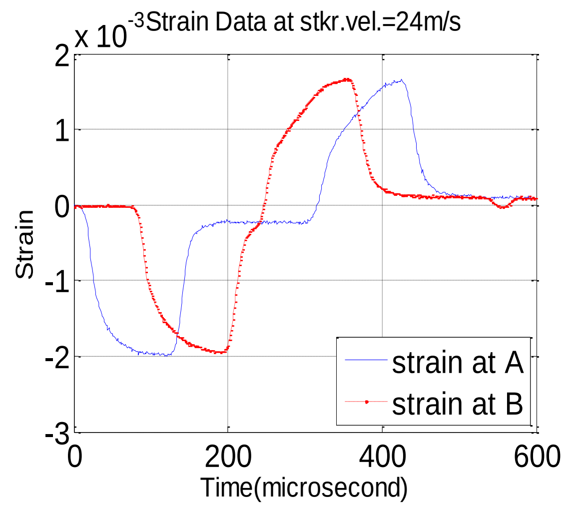


Fig. 4 Micro strain at point ‘A’&’B’ versus Time (μs)

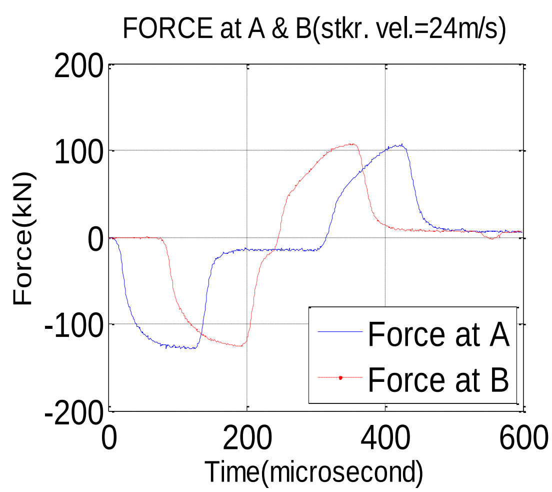


Fig.5 Force at point A, B versus Time (μs)

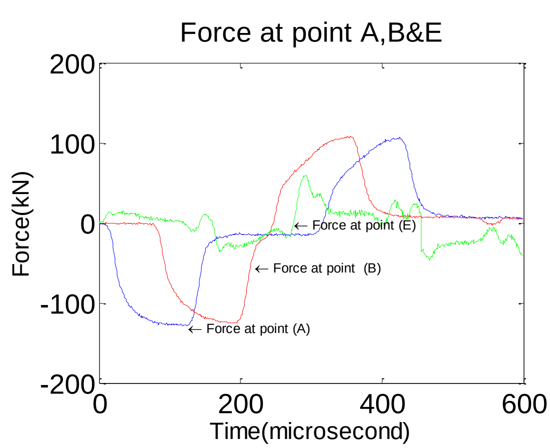


Fig. 6 Force at point ‘A’,’B’ &’ Versus Time (μs)

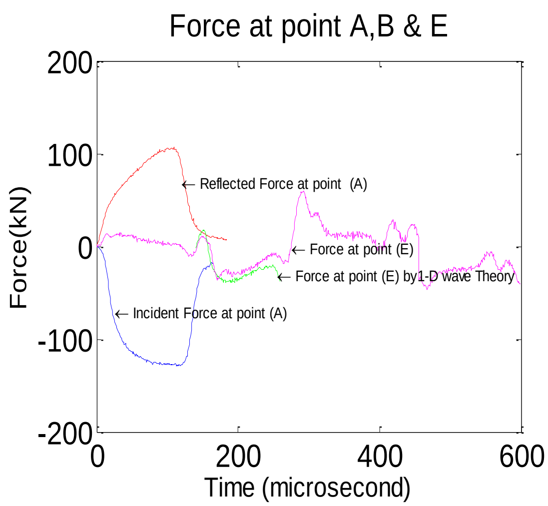


Fig. 7 Force at point ‘A’,’B’ &’E’ versus Time (µs)

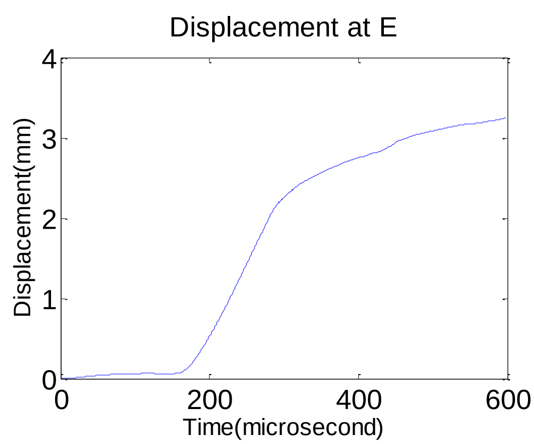


Fig.8 Displacement at point ‘E’ versus Time (µs)

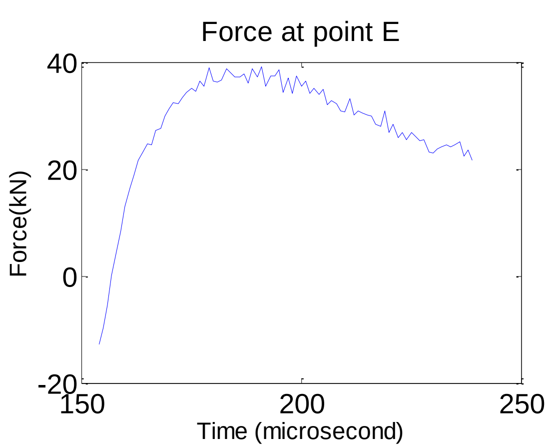


Fig.9. Force at point ‘A’&’B’ versus Time (µs)

4. Conclusions

1. Force and displacement are measured at load point (E) on the specimen by use of two point strain methods.
2. Force at load point (E) is also measured by use of incident pulse and reflected pulse according to one dimensional wave theory.
3. Force measurement at point ‘E’ by two point strain method and one dimensional wave theory coincides.
4. During loading, initially load increases after that decreases it indicates crack is initiated in the specimen.

5. References

[1.] C.Bacon,J.Farm, and J.LLataillade “Dynamic fracture determined from load-point Displacement ”, Experimental Mechanics 34 (1994) 217-222.

[2.] Ming-zhi.Xing,Yong-gang,JiangdWangandZhao-xiuynamic, “ Fracture Behaviors of Selected Aluminum Alloys Under Three-point Bending”ScienceDirectDefence Technology 9 (2013) 193-200.

[3.] RamanP.Singh,VenkitaanarayananParameswaram “An experimental investigation of dynamic crack prorogation in a brittle material reinforced with a ductile layer ”, Optics and Lasers in Engineering 40 (2003) 289-306.

[4.] L.Rubio, J.Fernandez-Saez and C.Navarro” Determination of Dynamic Fracture-initiation Toughness using three -point Bending Tests in aa Modified Hopkinson Pressure Bar.”Experimental Mechanics 43(2003) 379-386.