The Study of Honeycomb Material Dynamic Mechanical Properties which Under Out-plane Impact Load

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Abstract :The lightweight aluminum alloy honeycomb material has higher strength and stiffness, it can be used as sandwich board inner materials, so it is an ideal light structural material. In this paper, the SHPB technique is used for studying the dynamic mechanical response of lightweight alloy honeycomb panels whose diameter is 30mm under different high strain rate. The dynamic stress-strain curves of materials have been given, and the results and data of experiments have been analyzed. While the microscope is used for observing the cell figures which the specimens after tested to study the buffering and energy absorption ability of the material.
Keyword :Impact; SHPB; Aluminum alloy honeycomb materials; Strain rate

1.Introduction

Light weight Aluminum alloy honeycomb materials are ideal lightweight structure materials, which have higher specific strength and stiffness and could be as core materials of the sandwich panels. They are widely applied in aviation, aerospace, automobile and so on, and also is an ideal material for damping, buffering, heat insulation and energy absorption[1-2]. Nowadays the honeycomb materials impacting properties research mainly concentrate on numerical simulation[3-4] or drop hammer test[5]. In this paper, the SHPB technique which the aluminum alloy bar diameter is 37mm is used for studying the dynamic mechanics property of the lightweight aluminum alloy honeycomb materials which the diameter is 30mm. Study the strain rate dependency of the material by testing the stress-strain curves of the material under different high strain rate, and this work can provide a basis for engineering design and theoretic analysis.

2. Experimental facility and theory[6.7]

The Split Hopkinson Pressure Bar is simply called SHPB, and it is widely used for the study of material dynamic mechanics properties. It has simple structure, easy to operate ,and easy to control the wave shape, so this experiment technology is the mainly experimental method to test the constitutive relation of the material which the strain rate is 10^2~$10^4 s^{-1}$(one dimension stress-strain curve).The experimental facility as shown in figure 1.

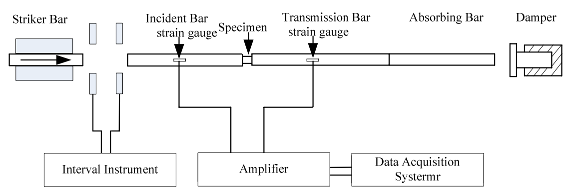

Fig.1 The experimental facility of SHPB

The experimental facility principle of SHPB is based on the one-dimensional elastic stress wave principle. And the stress as the strain change under the high strain rate is calculated by the incident wave and transmission wave which beside the specimen. The main theory as follows :

In the experiment, $\varepsilon_i, \varepsilon_r, \varepsilon_t$ respectively for the incident wave, reflect wave and transmit wave. C_0 is elastic wave velocity in the bars, l_s is the length of the specimen, E is the young's modulus of the bar, A is the section surface of the bar,A_s is the section surface area of the specimen.

Base on one-dimensional wave propagation in elastic bars, the displacement expression on the cross-sectional area of the elastic bars are :

$$u = C_0 \int_0^t \varepsilon dt \quad (1)$$

So applied equation(1) in the contact area of the specimen with the pressure bars. And the stress wave superimposition is considered , we can get:

$$u_1 = C_0 \int_0^t \varepsilon_i dt + (-C_0)\int_0^t \varepsilon_r dt = C_0 \int_0^t (\varepsilon_i - \varepsilon_r) dt \quad (2)$$

$$u_2 = C_0 \int_0^t \varepsilon_t dt \quad (3)$$

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and $$\varepsilon_r = \varepsilon_t - \varepsilon_i \quad (4)$$

So the average strain of the specimen ε_s is

$$\varepsilon_s = \frac{u_1 - u_2}{l_s} = \frac{C_0}{l_s}\int_0^t (\varepsilon_i - \varepsilon_r - \varepsilon_t)dt = \frac{-2C_0}{l_0}\int_0^t \varepsilon_r dt \quad (5)$$

The two side load of the specimen is:

$$F_1 = EA(\varepsilon_i + \varepsilon_r), \quad F_2 = EA\varepsilon_t \quad (6)$$

So obtain the average stress of the specimen :

$$\sigma_s = \frac{F_1 + F_2}{2A_s} = \frac{1}{2}E(\frac{A}{A_s})(\varepsilon_i + \varepsilon_r + \varepsilon_t) = \frac{AE}{A_s}\varepsilon_t \quad (7)$$

And the average strain rate of the specimen is

$$\dot{\varepsilon}_s = \frac{d\varepsilon_s}{dt} = -\frac{2C_0}{l_0}\varepsilon_r \quad (8)$$

Therefore we can get the stess, strain and strain rate of the specimen cross-sectional area in the high strain rate experiment are:

$$\begin{cases} \sigma_s = \dfrac{AE}{A_s}\varepsilon_t \\ \varepsilon_s = \dfrac{-2C_0}{l_s}\displaystyle\int_0^t \varepsilon_r dt \\ \dot{\varepsilon}_s = -\dfrac{2C_0}{l_s}\varepsilon_r \end{cases} \quad (9)$$

Therefore, through above formulas, we calculate the stress-strain data of the material by indirect test the strain of the bar. So from the SHPB equipment, it is easy to carry out the light weight aluminum alloy honeycomb material in high strain rate impact experiment, and then examine the material strain rate sensitivity and some other characteristics under impact load

3.Impact experiment and results analysis

3.1 Experiment parameter

In the test,there is 4 specimens , and the experiment parameters as the table1 shows:

Table 1 Experiment parameter

No.	Diameter (mm)	Height (mm)	Press (MPa)	Impact speed
1	30mm	3.66mm	0.1MPa	10m/s
2	30mm	3.66mm	0.15MPa	13m/s
3	30mm	3.66mm	0.2MPa	16m/s
4	30mm	3.66mm	0.25MPa	19m/s

And the figure 2 is the typical waveform of the experiments.

After data processing of the waveform, the stress - strain curve, the strain - time curve and the strain rate - time curve of the material is gained , as shown in figure 3 to figure 5.

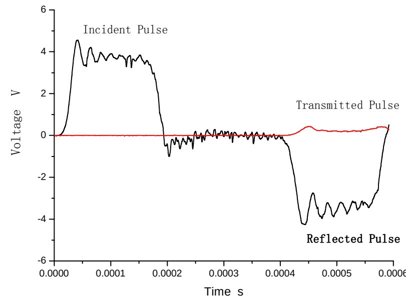


Fig.2 The typical waveform of testing(No.4)

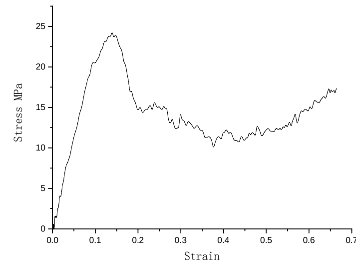


Fig.3 The stress - strain curve(No.4)

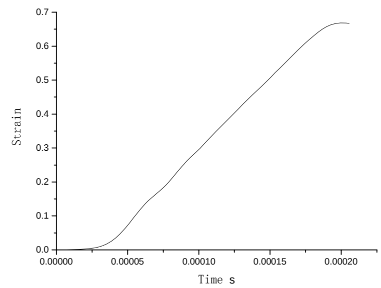


Fig.4 The strain - time curve(No.4)

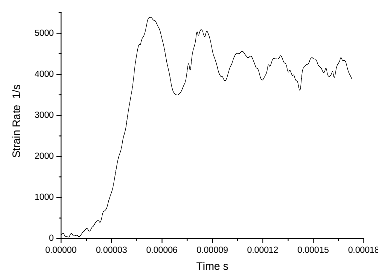


Fig.5 The strain rate - time curve (No.4)

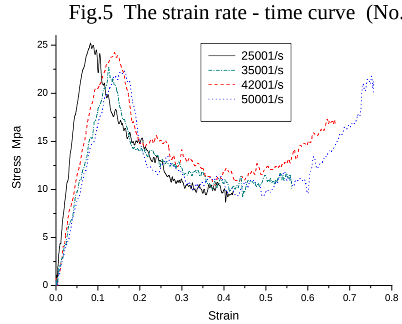


Figure.6 The stress-strain curves of different strain rate

Through calculating,the stress-strain curves of different samples is putting on the same coordinate system, as shown in figure 6.

Figure6 is the dynamic stress-strain curves of the strain rate is $2500s^{-1}$、$3500s^{-1}$、$4200s^{-1}$、$5000s^{-1}$. From the graph it can be seen that: (1) In the high-strain-rate case, the ultimate intensity of honeycomb material is 40 percent more than the static compression ultimate intensity, so the honeycomb material is rate related material. At the same time, in the high-strain-rate case, when the strain rate increased, the material ultimate intensity shows a downward trend. (2) From the testing curve can be found that the material impacting stress-strain curve can be divided into three phases, the first phase is the phase of elastic, and then has a considerable long stress platform, and third phase is the final period which the stress increased and the specimen is compacted fully. As the strain rate increased, the stress platform stretching, and the compaction phase of stress also significant growth. (3) From the stress-strain curves of figure 6, it can be see that, the first phase of material change is elastic deformation and then go into the plastic deformation, and also produce plastic hinge on the unit, and this played a role of energy-absorbing and cushion, when the load continue increased, the honeycomb unit will be gradually compacted. And the results is showed in Table 2.

Table2 The experiment results

No.	Max Stress MPa	Test Strain	Real Strain	Strain rate
1	25.5	0.45	0.68	$2500s^{-1}$
2	22.0	0.56	0.72	$3500s^{-1}$
3	23.9	0.66	0.73	$4200s^{-1}$
4	22.4	0.75	0.76	$5000s^{-1}$
5	17.5	-	-	$0.005\ s^{-1}$

Figure 7 is the strain rate-intensity curve of the material . From the curve it can seen that this kind of cellular material has obvious strain-rate dependent property.

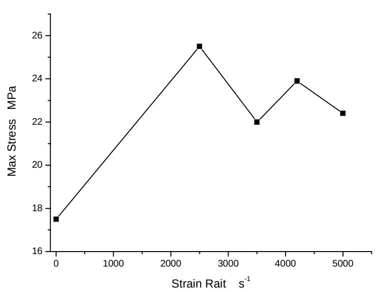


Figure 7 The strain rate-intensity curve of the material

Figure 8 is the strain rate - strain curve of the material, from the curve it can be seen that as the strain rate increasing , the strain value of the testing and the real strain value of specimen are getting more and more closer.

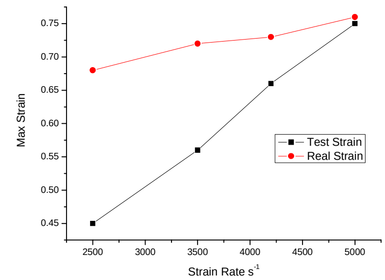
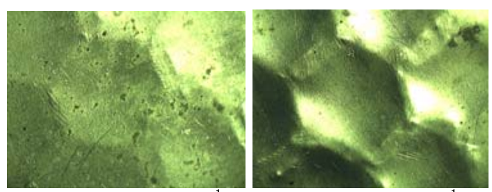
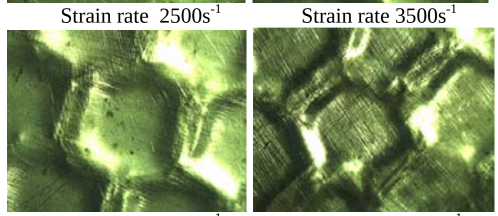


Figure 8 Strain rate - strain curves

Using the microscope to observe the cell figures which the specimen after tested, as the figure9 shows, from the figures it can be see that, as the strain rate increased, the compacted degree of the specimen is increased, and the six edge of the cell is projected more obvious, and this note that the role of material buffering and energy absorption ability is significantly



Strain rate $2500s^{-1}$ Strain rate $3500s^{-1}$



Strain rate $4200\ s^{-1}$ Strain rate $5000\ s^{-1}$

Fig 9. The specimen cell body photograph under the microscope which after tested

4、Conclusion

In this paper, the SHPB technology is used for testing mechanical properties of the light weight aluminum alloy honeycomb panel. And the stress-strain curves is given which the material under different high strain rate, and also the testing curves and the results are analyzed. From the testing results it can be seen that the material is typical strain rate dependent material, and the limit intensity under dynamic load is bigger about 7MPa than the static ，and the stress-strain curves is also the typical three-stage form. In the end, the microscope is also used for observing the specimen cell body deformation after tested, it can be seen that the buffer role and the energy absorption is distinctness.This study is good for the experimental analysis and engineering design of this materials in the dynamic load applications.

Reference:

[1]Fu Dingmei，Han Jingtao，Liu Jing，Fu Chenguang Progressive on Study of Honeycomb Sandwich Steel Panel.AVIATION PRECISION MANUFACTURING TECHNOLOGY40（3）(2004) 14-30

[2]Hua Yun-long,Yu Tong-xi. MECHANICAL BEHAVIOUR OF CELLULAR SOLIDS .ADVANCES IN MECHANICS21(4) (1991)457-469

[3]Lu Wen-hao ， Bao Rong-hao. The mechanical behavior of cellular material under dynamic load.JOURNAL OF VIBRATION AND SHOCK 24(1) (2005) 49-52

[4]Zhang Xin-jia,Liu Ying,Dynamic Deformation Mechanism of Cells with Different Shapes under In-plane Impact Loading, Science Technology and Engineering, (7)12(2007)2799-2802

[5]Cheng Xiao-quan, Kou Chang-he,Li Zheng-neng .Study on Damage of Composite Honeycomb Core Sandwich Panels Under Low Velocity Impact.ACTA MATERIAL COMPOSITAE SINICA 15 (3) (1998) 124-128

[6]Wang Li-li. The Progress of Impact Dynamics.Bei Jing：University of Science and Technology of China Publishing House ,1992

[7]Ma Xiao-qing . Impact Dynamics,Beijing College of Technology Publishing House1,Bei Jing,992