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Study the Effect of Pulse Shaper on Dynamic Compressive Behavior of AL2014-T6 and AL7075-T6

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Abstract

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

The purpose of the present work is to study mechanical characterization of aluminum alloys, at dynamic loading because aluminum alloys are widely used as structural material in aerospace industry due to their high stiffness/weight and strength/weight ratio [1] .The two aluminum alloys Al2014-T6 and Al7075-T6 were procured from vendor at Mumbai and tested at high strain rates. The Split Hopkinson Pressure Bar (HSPB) is conventional technique used by many researchers to find material properties at high strain rates. Singh et al.[2] investigated mechanical properties of mild steel at different strain rates on Split Hopkinson Pressure Bar(HSPB).They also studied the effect of pulse shaper on mechanical properties of structural materials. For Hopkinson pressure bar, engineering stress ($\sigma_s(t)$),engineering strain (ϵ_s(t)) are expressed in terms of modulus of elasticity of bar (E_b), cross sectional area of bar (A_b), cross sectional area of specimen(A_s), wave velocity (c_o),specimen length(l_s),reflected strain($\epsilon_R(t)$) and transmitted strain($\epsilon_T(t)$) are shown in equation 1.

$$\sigma_s(t) = \frac{A_b}{A_s} E_b \epsilon_T(t), \quad \epsilon_{s(t)} = 2\frac{C_o}{l_s}\int_0^t \epsilon_R(t)dt \text{ ----------- (1)}$$

The true stress (σ_t) and true strain (ϵ_t) on specimen are related as:

,$\sigma_t = \sigma_s(1 + \epsilon_s)$ and $\epsilon_t = \ln(1+\epsilon_s)$ --------(2)

2. Materials and Experimental Technique

The chemical composition in terms of weight percent of aluminum alloy Al2014-T6 is shown in table1.It is compared with standard value as per ASM Aerospace specification Metals. The chemical composition of another aluminum alloy, Al7075-T6 is shown in table 2.It is also compared with standard value from ASM Aerospace specification Metals.

The Split Hopkinson Pressure Bar (SHPB) (available in Applied Mechanics Department at Indian Institute of Technology, Delhi) was used for dynamic compressive test at high strain rates .It consists mainly pressure cylinder, striker, incident bar and transmission bar. The diameter of striker, incident bar and transmission bar was same and striker's length was 300mm and incident and transmission bar lengths were 1500mm each. During experiments specimens were sandwiched between incident and transmitted bar and striker was impacted on incident bar, so incident pulse is generated in incident bar, travel towards specimen. Some part of incident pulse (ε_i) is absorbed by specimen and remaining part is returned to incident bar as reflected pulse (ε_r). The incident and reflected pulse are recorded by strain gauges pasted on incident bar with the help of data acquisition system and personal computer.

The complete set up of Split Hopkinson Pressure Bar is shown in figure Fig.1(a) and specimen sandwhiched between Hopkinson bars is shown in Fig.1(b).

2. Results and Discussion

The dynamic compression tests on aluminum alloys (Al2014-T6 and Al7075-T6) without and with pulse shaper have been done on Split Hopkinson Pressure Bar (HSPB). The yield stress has been evaluated at the different strain rates. The compression tests have been performed with and without use of pulse shaper. Here, dynamic compression tests have been performed on Al2014 and Al7075. The length to diameter ratio of each specimen was 0.75. The length and diameter are 10mm and 13.5mm for each specimen. Here, experiments were conducted without with use of aluminum pulse shaper at one bar pressure. The velocities of striker was measured by using of velocity sensors and were found to be 8.61m/s and 8.67m/s without and with use of pulse shaper at 1bar pressure.

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Table1. Chemical composition of Al2014-T6 [3]

	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Sn	Pb	Other each	Othert otal
Present alloy composition (wt. %)	93.76	0.001	4.1054	0.1651	0.625	0.4910	0.6812	0.0578	0.0679	0.0029	0.0064	-	-
Standard alloy composition (wt. %)	90.4-95	Max 0.1	3.9-5	Max 0.7	0.2-0.8	0.4-1.2	0.5-1.2	Max 0.15	Max 0.25	-	-	Max 0.05	Max 0.15

Table 2 Chemical composition of Al7075-T6 [4]

Elements	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Sn	Pb	V	Bi
Present alloy composition (wt. %)	90.28	0.2312	1.3733	0.117	2.3359	0.032	0.0697	0.0607	5.473	0.001	0.0024	0.0076	0.0014
Standard alloy composition (wt. %)	87.1-91.4	0.18-0.28	1.2-2	Max 0.5	2.1-2.9.	Max 0.3	Max 0.4	Max 0.2	5.1-6.1	-	-	-	-

Elements	Other each	Other total
Present alloy composition (wt. %)	-	-
Standard alloy composition (wt. %)	Max 0.05	Max 0.15

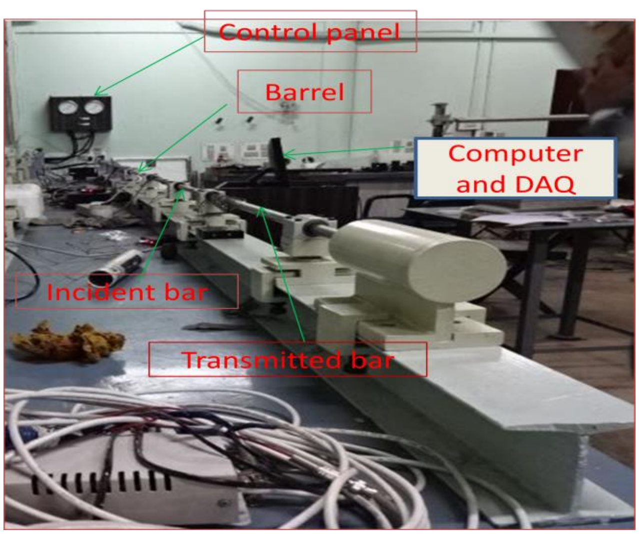

Fig.1 (a) Split Hopkinson Pressure Bar (SHPB)

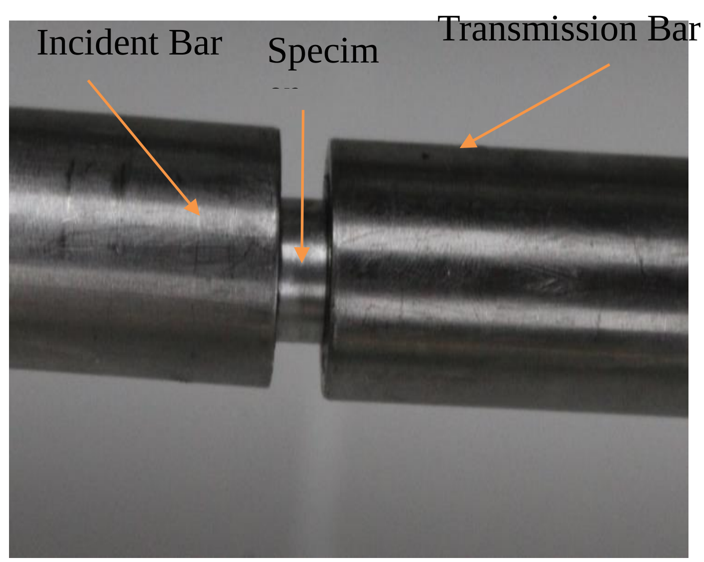

Fig.1(b) Specimen between Hopkinson Bar

First set of experiments were performed on Al2014 and Al7075 without use of pulse shaper and results are shown between engineering stress and time is shown in figure 2. From this curve, it is observed that maximum stress developed in Al2014 is nearly 350MPa, while Second set of experiments were performed on Al2014 and Al7075 with use of pulse shaper and graph between engineering stress and time is shown in figure 3. From this figure it is observed that maximum stress obtained for Al2014 and Al7075 are 200MPa and 300MPa respectively. Due to use of pulse shaper maximum load decreases from 350MPa to 200MPa for Al2014 and 350MPa to 300MPa for Al2014.

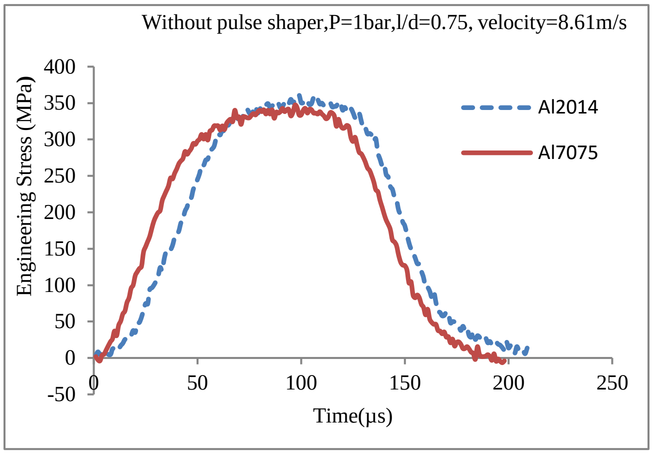

Fig.2 Engineering Stress Vs time without pulse shaper

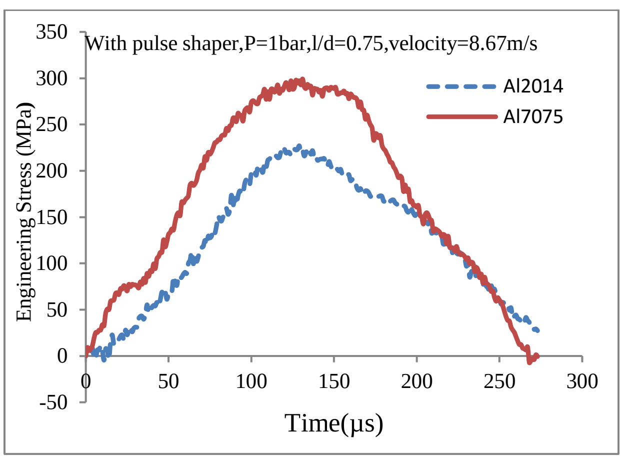

Fig.3.Engineering stress Vs time with pulse shaper

Figure 4 shows the plot of engineering stress vs engineering strain for Al2014 and Al7075 without use of pulse shaper. For Al7075 maximum stress attained is reached at 0.2% strain after that it becomes almost constant up to 1.5% of strain. For Al2014 maximum stress is attained at 0.6% strain after that it becomes almost constant up to 1.5% of strain.

Figure 5 shows the plot of engineering stress vs engineering strain for Al2014 and Al7075 with use of pulse shaper. For Al7075 stress increases sharply up to 250MPa at strain 0.3% and after that its increases slowly to 300MPa at strain 1.1% and then decreases sharply. Similar pattern is observed for Al2014 though the maximum stress attained for Al2014 is 200 Mpa which is lower than 350MPa.

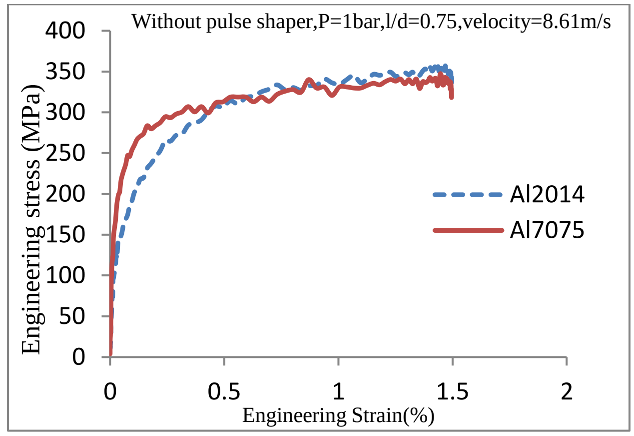

Fig.4 Engineering stress Vs engineering strain withoutpulse shaper

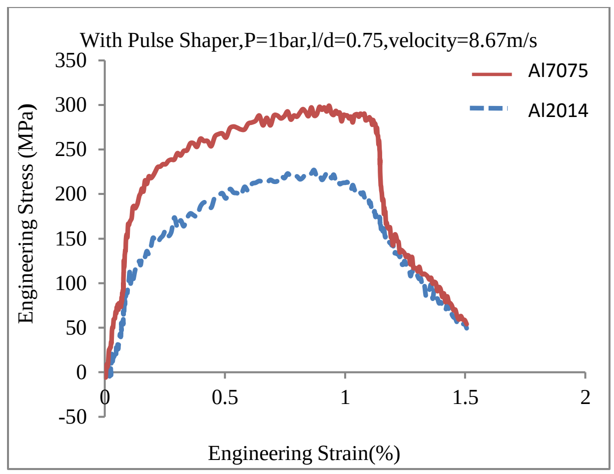

Fig.5.Engineering stress Vs engineering strain with pulse shaper

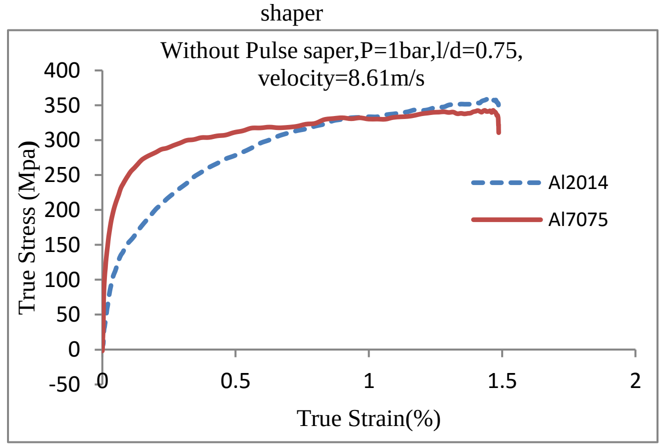

Fig.6.True stress Vs true Strain without pulse shaper

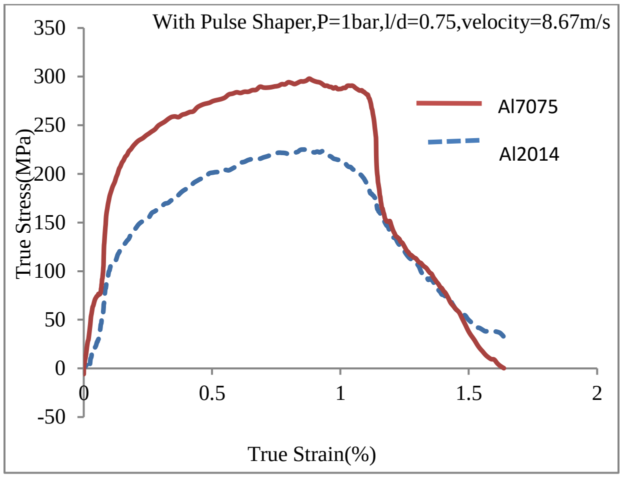

Fig.7.True stress Vs true strain with pulse shaper

Figure 6 shows the plot of true stress vs true strain for Al2014 and Al7075 without use of pulse shaper. For Al7075 initially true stress rises steeply after that it becomes nearly constant to 350MPa. Although for Al2014 stress does not rise as sharply but it attains maximum value of 350MPa at strain 1.4%.

Figure 7shows the plot of true stress vs true strain for Al2014 and Al7075 with use of pulse shaper. For Al7075 the stress increases sharply up to 250MPa to strain 0.2% and afterthat, it increases slowly to 300MPa at 1.1% strain and then decreases sharply. For Al2024 the stress increases slowly than Al7075 and attained maximum value 200MPa.

From above figures 4 and6, it is observed that true stress and engineering stress are approximately same because % change in strain due to compression is very less. Similar type of observation was obtained for Al2014 and Al7075 when pulse shaper was used.

4. Conclusions

1. The composition of elements obtained from spectro analysis matched with composition provided by ASM Aerospace specification Metals.
2. The dynamic stress developed without pulse shaper in Al7075 is earlier but slightly lower than Al2014.
3. With pulse shaper stress developed in both materials are decreases but, this reduction is appreciably more in Al2014 than Al7075.
4. Initially the engineering stress and true stress are slightly differ for Al2014 and Al7075, but after 0.6% of strain both are matching.

5. References

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[3] ASM Material data sheet's Aerospace specification metal Inc. Aluminum 2014-T6.

[4] ASM Material data sheet's Aerospace specification metal Inc. Aluminum 7075-T6.