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investigating the affect of manufacturing technique of 3D printed AlSi10Mg alloy on the dynamic stress-strain behavior

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1. Abstract

An experimental research of the dynamic strain-stress of aluminum AlSi10Mg alloy manufactured by Additive Layer Manufacturing (ALM), better known as 3D printing, is presented. The system in which experiments were conducted is a Split Hopkinson pressure bar (SHPB). The goal of this study is to compare the between two manufacturers and draw conclusions regarding the effect of manufacturers technique on the dynamic characteristics.

Keywords: aluminum AlSi10Mg, SHPB, dynamic strain-stress

2. Introduction

In the past few years, there has been a considerable increase in interest in using AlSi10Mg alloy manufacture by ALM and it is has been extensively investigated in terms of its microstructure and quasi-static properties[1] [2]. Still, the dynamic properties of this alloy have yet to be explored over a wide range of strain rates. A better knowing of this alloy's properties will be a significant part in the integration of the ALM technology in the industrial field. In order to characterize the strength model of the alloy under a compressive load, a system of SHPB is used – one of the most common techniques to investigate material behavior at high strain rates. This work focuses on the affect the ALM technology on the dynamic behavior. In order to apply this goal two different manufacturers were selected, EOS and Concept Laser - both manufacturers used the same alloy, aluminum AlSi10Mg, but in a different ALM technique.

ALM is a layer-based additive manufacturing technology that is utilized to manufacture complex and customized structures from metal powder. A laser been induced thermal energy in to the powder layer and selectively melts the wanted area, the area in which the melting accord named the melt pool. In this process a thermal energy is large enough to remelt a few layers beneath and join them, as shown in Fig 1(a). There are a few scanning strategies which the path that the laser takes when melting the tracks that constitute each single layer of the component - EOS usde the bi-directional scannig fig 1(b) and C.L used a chessboard scanning fig 1(c) .

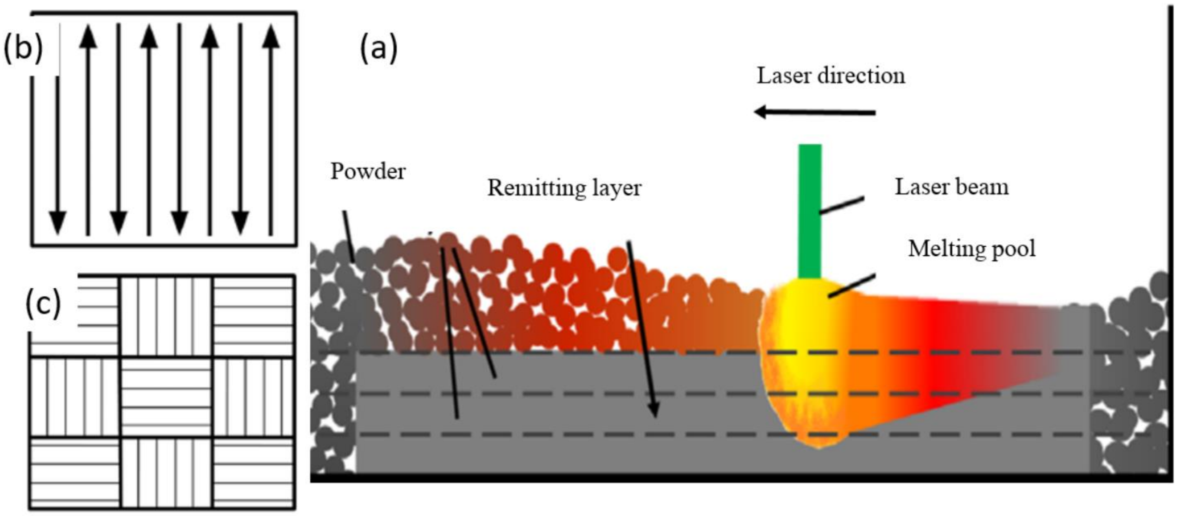

Figure 1. (a)- A Schematic Illustration of the ALM proses, (b)- bi-directional scanning, (c)- chessboard scanning.

For this research, the two manufacturers created two type of sample in rolls shape. One, Z oriented, built from the base up made from multiple disk shaped layers. The other, XY oriented, built as a horizontal rolls made from multiple rectangle layers. As shown in Fig 2.

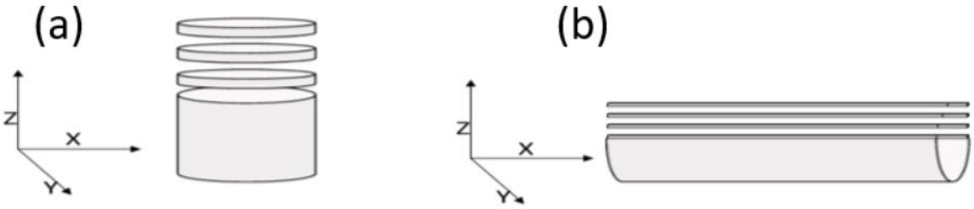

Figure 2. The scheme of samples Z oriented (a) and XY oriented (b)

The main purpose of these particular samples is to establish the way that the build orientation affects the dynamic strain-stress curve of the alloy.

3. Experimental

An experimental system of SHPB is used to form the dynamic strain-stress curve. It is built from two long bars, incident bar and a transmission bar, a striker (smaller bar). Fig 3 present a scheme of a SHPB system and a X-t curve showing the propagation of the compressive stress wave inside the SHPB's bars. When the striker hits the incident bar the impact generates a compression wave in the striker and the in incident bar. When the compression wave reaches the free end of the striker it unloads. The outcome is a compressive wave with a pulse width of two times the length of the striker. Due to the fact that the bars and the specimen are made from different materials, part of the wave is reflected back to the incident bar and the rest transmits into the transmission bar [3]. The bars withstand an elastic strain measured by strain gauges. Using the values of incident and transmitted strain, the strain rate, strain and stress in the specimen are calculated using equations 1-3.

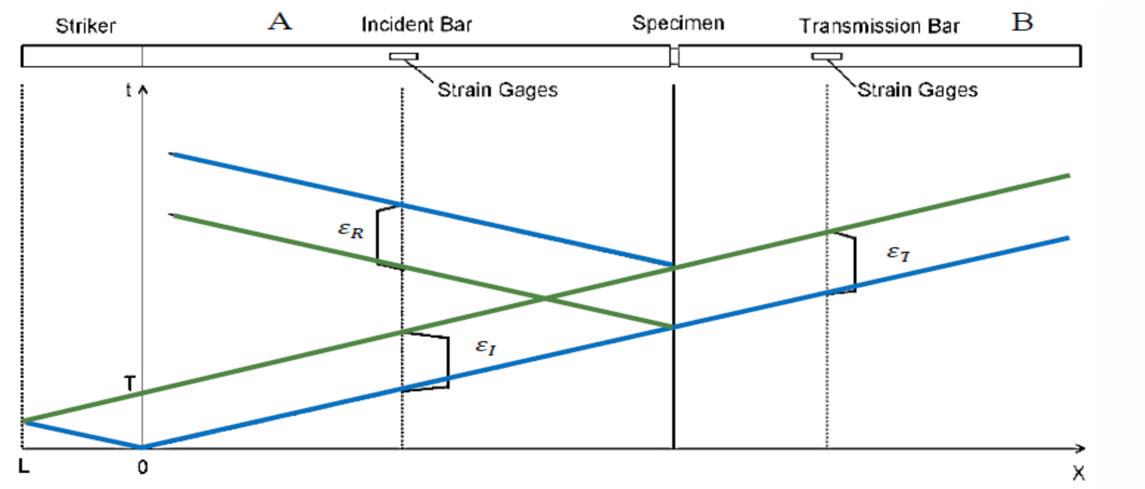

Figure 3 X-t diameter of stress wave propagation in a SHPB bar system [3]

$$\dot{\varepsilon}_s(t) = \frac{-2C_B\varepsilon_R(t)}{H_s} \tag{1}$$

$$\varepsilon_s(t) = -2\frac{C_B}{H_s}\int_0^t \varepsilon_R(t)dt \tag{2}$$

$$\sigma_s(t) = \frac{A_B}{A_s}E_B\varepsilon_T(t) \tag{3}$$

C is the bulk sound speed of the bar, H is the specimen length, ε is strain, σ is stress . A are cross-section areas. The indices R, T, S and B are for reflected, transmitted, specimen and bar correspondence.

4. Results

In order to compare the dynamic strain-stress curves of an alloy manufactured by EOS and C.L statistical analysis is required. Fig 4. shows the mean (solid line) of dynamic strain-stress in large variety of strain rates, followed by the standard deviation (dash line) of EOS manufacturer.

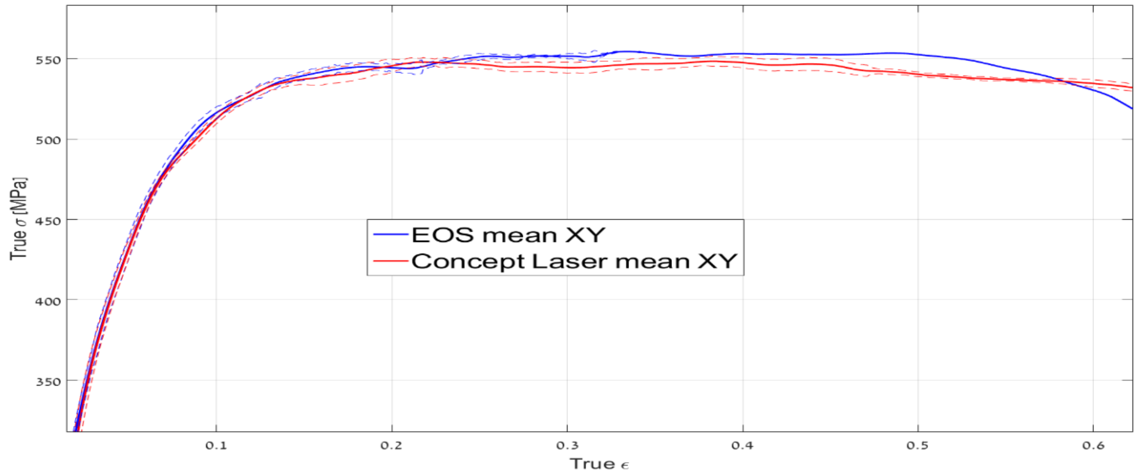

Figure 4 true stress vs true strain for XY oriented

It is noticeable that for all the range 0-60% of strain the dynamic curves behavior of the two manufactures are practically the same. Even the yield points of the two curves coalesce. The small range of standard deviation implying that the stain rate has no effect on dynamic stress strain behavior.

The result for Z oriented of the two manufactures present in Fig 5.

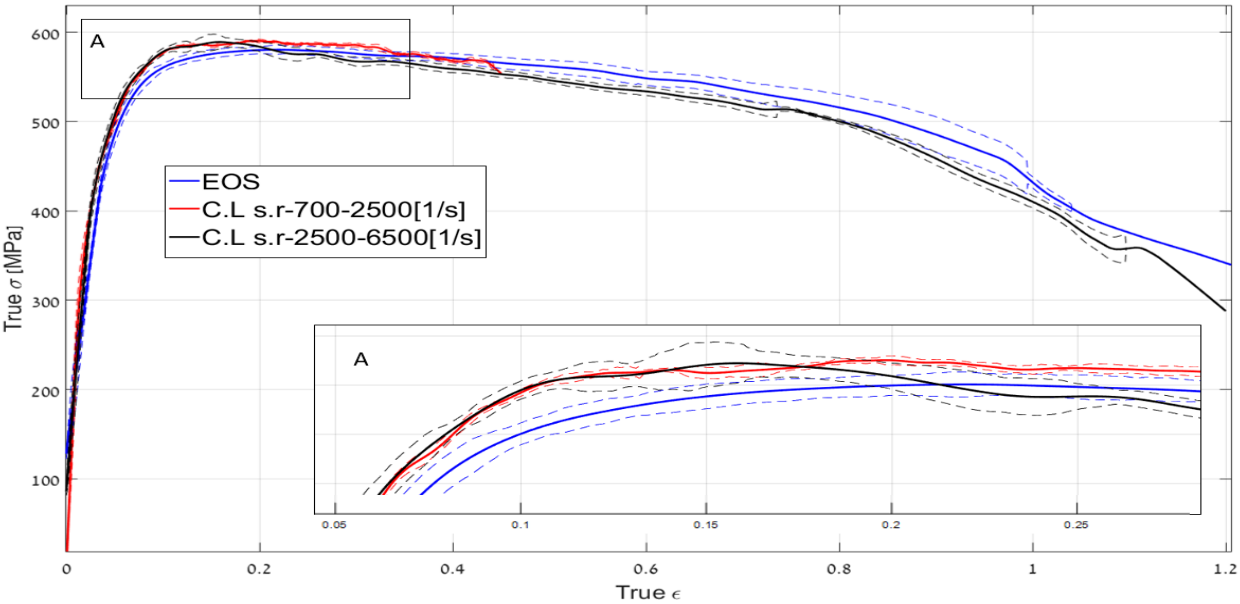

Figure 5 true stress vs true strain for Z oriented

It is noticeable that for the alloy manufactured by C.L at Z oriented there is a dependency of the strain rate in contrast to the alloy manufacture by EOS. It is shown that in the range of 0-20% strain no significant disparity is noticeable in the C.L curve, but beyond that strain C.L shows a sharp decline in high strain rate and more stable decline in lower strain rate. Moreover, the yield point of the C.L alloy is higher than EOS's yield point by 30 [Mpa]. Both alloys show a decrease in stress between 80-90% strain, probably due to cracking.

5. Conclusions

In this study, an experimental investigation of the dynamic strain-stress of aluminum AlSi10Mg alloy manufactured by Additive Layer Manufacturing (ALM) was conducted using a Split Hopkinson pressure bar. Two alloys with different printing directions were compared. The results showed there is no difference in the dynamic behavior in XY oriented alloy, but there is a small difference in Z oriented alloy. Moreover, the alloy manufactured by C.L shows a dependence of the dynamic behavior on the strain rate only in Z oriented printing.

6. References

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