Characterization of porosity in Al-12Si specimens by ultrasonic velocity measurement

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Abstract
The conventional processing methods to build Al-alloy component is by casting with or without heat treatment, while the typical SLM processing methods to build the components is either by checkerboard (CB) or single-melt (SM) scan strategy. In this work, ultrasonic testing were employed to determine the porosity of Al-12Si specimens. Consequently, relationship between porosity % (area) and Al-12Si specimens with different processing methods was obtained.

1. Introduction
Additive manufactured (AM) metal alloys has enabled the fabrication of lightweight and high complexity components. Similar to traditional processing methods, porosity is a common concern in AM metal alloys. X-Ray Computed Tomography (CT) scanning is the “ultimate” tool for porosity measurement in metal alloys. However, the equipment is costly, bulky and the data requires large storage size and long processing time. Therefore, there is a need to develop alternative non-destructive testing (NDT) techniques that are reliable yet less costly and impose lesser demand on post-measurement processing.

2. Experiment & Results
2.1 Metal specimen
The Al-12Si specimens measure 10mmx10mmx20mm and their details were depicted in Figure 1. With reference to Figure 1, “conventional (cast)” refers to that made by conventional manufacturing process in graphite mold and “heat treatment (HT)” refers to the conventional Al-alloys that were treated at 300°C for 6hr in Ar-atmosphere. The scanning patterns of the SLM Al-alloys are “single melt (SM)” and “checkerboard (CB)” – SM pattern is where each layer is built with one direction of scan, while CB pattern looks like that of a checkerboard pattern. The SLM Al-alloys were produced in room temperature using spherical gas-atomized powder [1, 2]. Image analysis method was employed to quantify the porosity % area of the specimens. In this method, the specimens were polished and etched before capturing 10 micrographs at fixed magnification of 25x. The porosity % area was then expressed as the ratio of cross-section area of pores to that of the micrograph [3]. There are at least 2 sources of uncertainty present, namely the cross-section might not cut through the pore centre and the pores might not be uniformly distributed in the specimens.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sample Description</th>
<th>Porosity % (area) based on image analysis method</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI_Cast</td>
<td>Conventional</td>
<td>~0%</td>
</tr>
<tr>
<td>AISI_HT</td>
<td>Heat Treatment</td>
<td>~1%</td>
</tr>
<tr>
<td>AISI.SM(12% content)</td>
<td>Single Melt</td>
<td>~1%</td>
</tr>
<tr>
<td>AISI_CB</td>
<td>Checker Board</td>
<td>~1%</td>
</tr>
</tbody>
</table>

Figure 1. Description of the four Al-12Si specimens with different processing methods. Estimated values of the porosity % (area) based on image analysis method were also included.
2.2 Ultrasonic Results
Ultrasonic testing was performed on the four Al-12Si specimens, and the left of Figure 2 depicts the schematic of the configuration. In this test, A-scan was performed on the sample, i.e. amplitude scan, magnitude vs. time. The center frequency of the transducer is 20MHz and the ultrasound is a longitudinal wave, with ultrasound gel acting as the coupling medium.

The ultrasound velocities were depicted in the right of Figure 2. It was reported elsewhere that the velocity of the ultrasound decreases with increasing porosity [4]. One can thus infer the degree of porosity among the four Al-12Si specimens from the ultrasound velocities, i.e. with “apparent” decrease in porosity % from AlSi_Cast, AlSi_CB, AlSi_SM to AlSi_HT. However, note that this trend does not agree with the porosity % values obtained from the image analysis method. We believe that the observed discrepancy is due to the abovementioned sources of uncertainty, and will validate our results with X-Ray CT scan or Archimedes’ Principle method in future.

![Figure 2. Schematic of the configuration (left) and ultrasound velocities of the four Al-12Si specimens (right), where the specimens were arranged in decreasing ultrasound velocity.](image)

3. Conclusions
Preliminary ultrasonic testing was performed on four Al-12Si specimens with different processing methods. From the ultrasound velocity, one can infer the porosity content among the Al-12Si specimens. This method is faster and less costly than conventional methods, and will be beneficial to those working on the NDI of AM metal alloys.

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References