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On the evaluation of thin AlSi10Mg hollow-strut lattice structures using X-ray computed tomography

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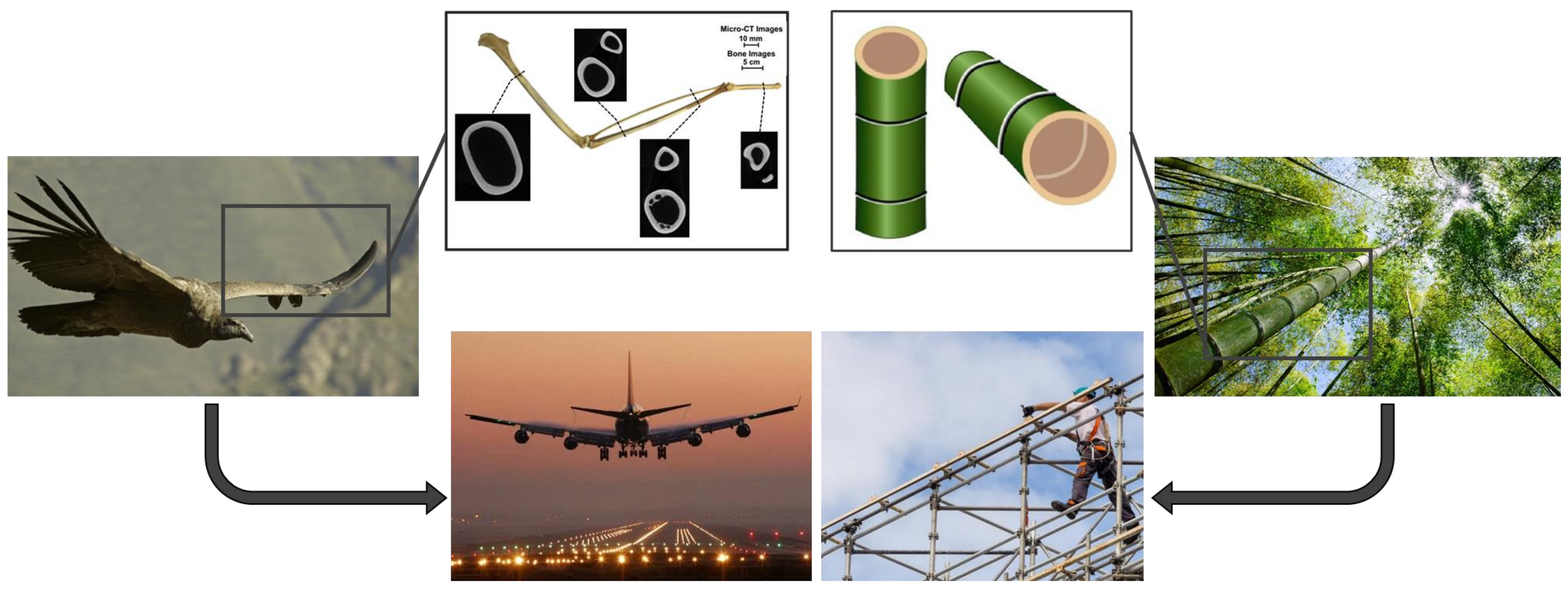
Introduction

Hollow structures, such as **avian feathers and bones**, enhance flight efficiency by reducing weight and improving aerodynamics. These **biological designs** demonstrate **exceptional stiffness-to-mass ratios**, outperforming the dense-walled bones found in rodents. Similar **hollow architectures** are seen in plant stems, such as **bamboo**, which combine fluid transport with mechanical strength. Inspired by nature, industries have integrated **hollow structures** into engineering, utilizing them, for example in **load-bearing columns**.

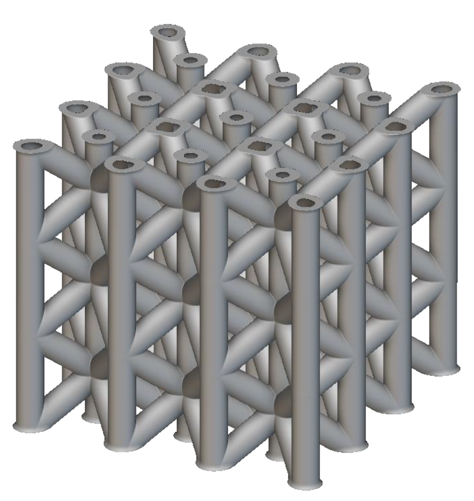


Lattice structures, known for their energy-absorbing and lightweight properties, are also prevalent in nature. However, the combined use of **hollow tubes and lattice frameworks** remains limited by **manufacturing constraints.**

Additive Manufacturing (AM), particularly **Laser Powder Bed Fusion (LPBF)**, enables the production of **complex hollow lattice structures**, especially for **lightweight aerospace components**. However, producing **defect-free thin-walled hollow struts** in **AlSi10Mg alloy** using LPBF is challenging, particularly at **submillimeter scales**. Variations in **laser energy density** to produce thin walls can cause defects like **through-holes**, leading to **leakage** and reduced **mechanical performance**. **Non-destructive testing techniques**, such as **X-ray computed tomography (XCT)**, are promising for detecting such defects, but there is a need for **systematic methods**. This study evaluates **the relationship between produced wall thickness** and **the presence of through-holes using single laser track pathways by varying laser energy density** in LPBF and proposes an **automated XCT post-processing method** for defect detection.

Materials and Methods

BCCz + column repeated unit cell



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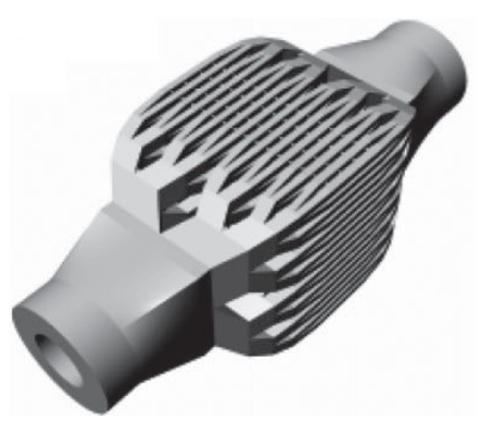
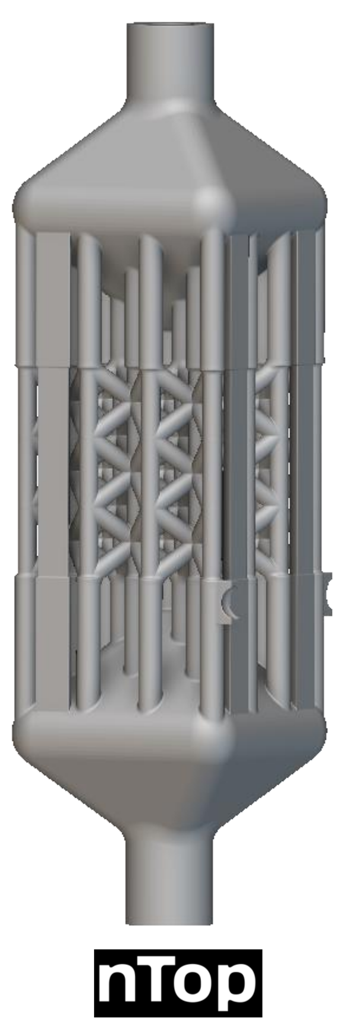
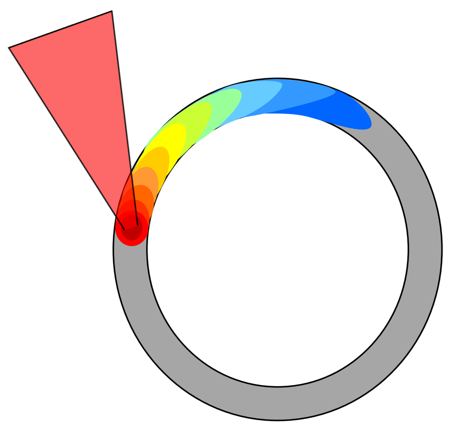
Model of a simplified network structure





Single laser track



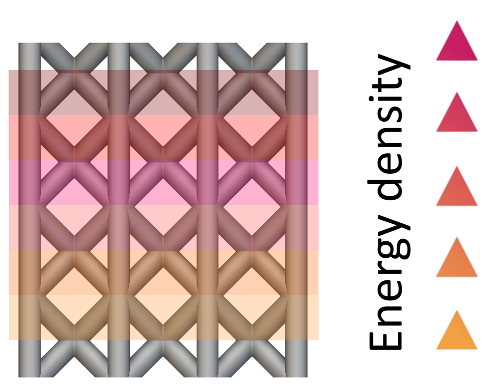


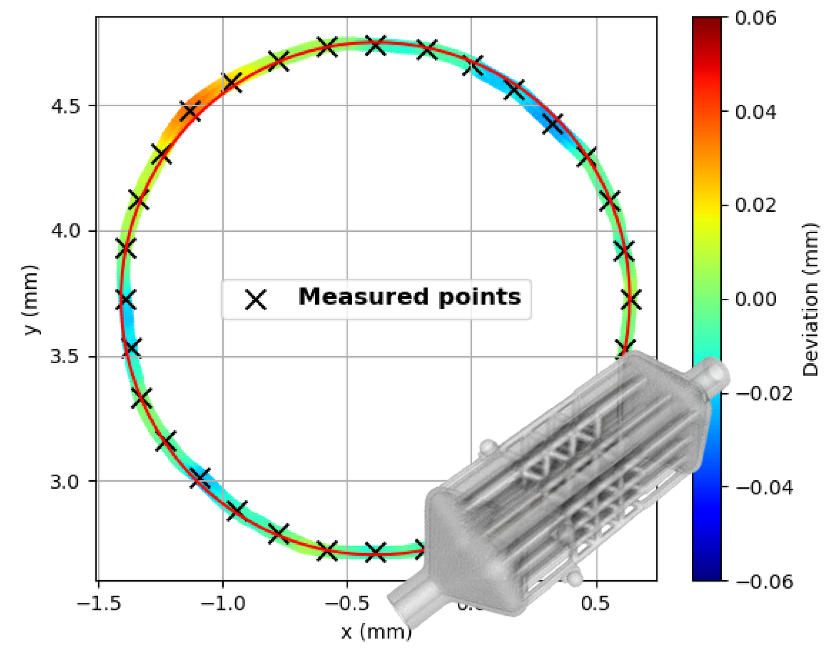
Table 1. DoE. Linear energies applied (J/mm)

Lack of fusion domain			Keyhole domain		
0.056	0.140	0.224	0.336	0.420	0.504

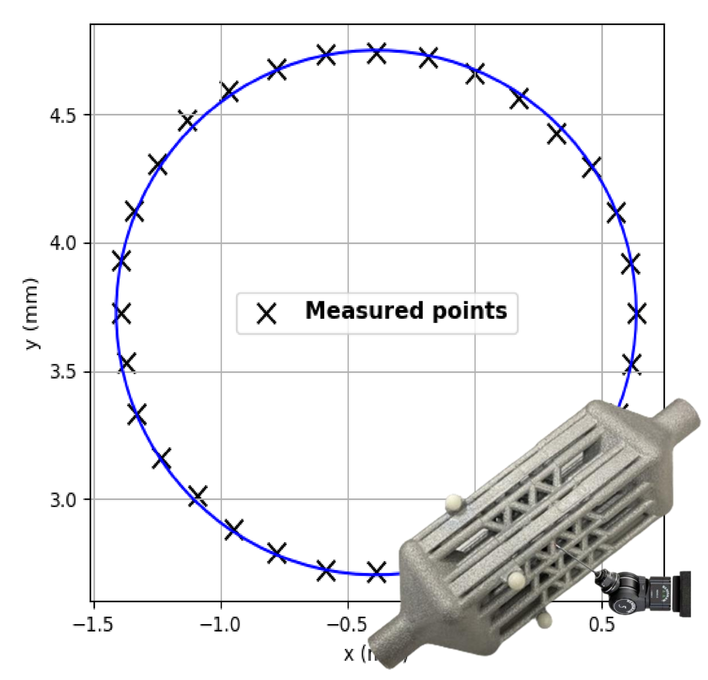
Experimental Procedure

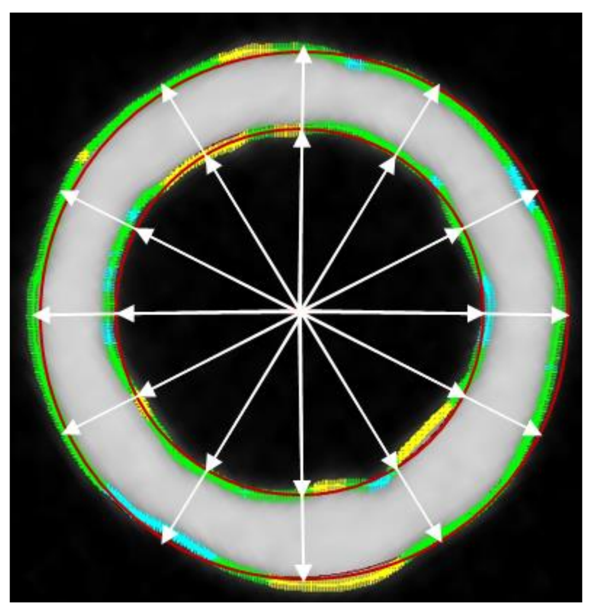
Hollow lattice thickness measurement workflow

CT measurements



CMM measurements





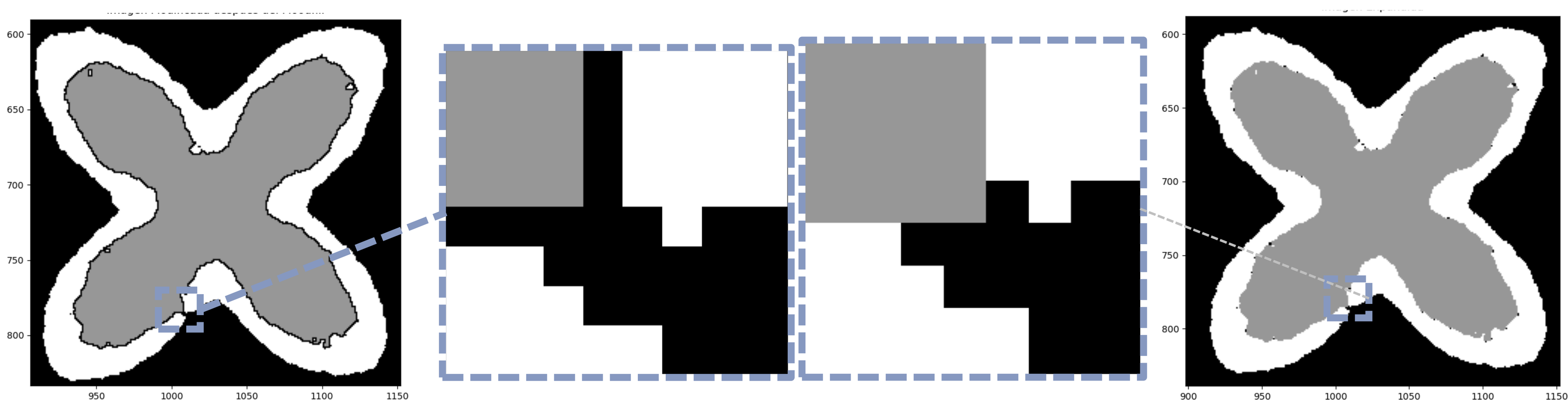
$$U_{MP} = k \cdot \sqrt{u_{cal}^2+u_p^2+u_b^2}$$

$$b = \overline{y} - y_{cal}$$

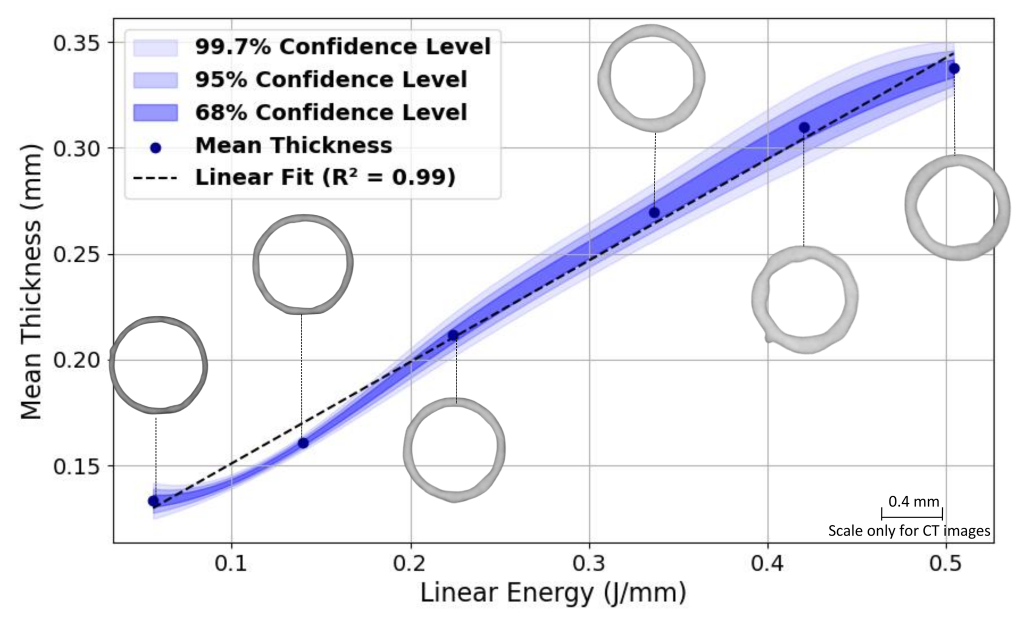
Outer diameter calibration uncertainty is propagated to the inner diameter. Five repeated measurements estimate repeatability. Thickness is calculated as the distance between outer and inner Gauss-fitted circumferences, measured every 15º to assess variation around the 360º.

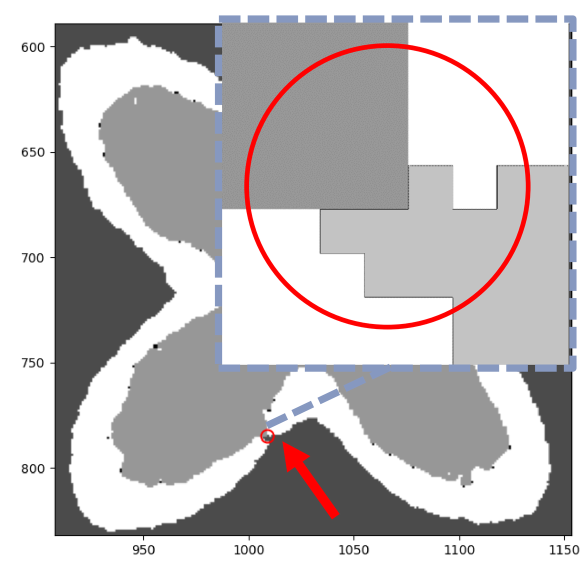
Hollow lattice through holes detection workflow

Step 1: A 3D flood fill starts from a specific coordinate, expanding in 26 directions. If values >250 are found within the '*check_size*', the fill stops; otherwise, the current point is assigned a new value. **Step 2:** The '*check_size*' expands, stopping if values >250 are found. **Step 3:** A final flood fill is performed, detecting the intersection between both fills.



Results and Discussion





In conclusion, **wall thickness is more stable at lower energy values**, but the likelihood of **through-hole defects increases as energy density decreases. Energy density is proportional to the produced wall thickness** within the evaluated range.

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