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Study the Effect of Build Orientation on Tensile Properties LPBF Processed Al10SiMg Super Alloy for Aerospace Applications

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ABSTRACT: We investigated the effects of building orientation and heat treatment temperature on the anisotropy of SLM- formed AlSi10Mg specimens. Three different deposition orientations of 0°, 45° and 90° and heat treatment temperatures of 270 °C, 300 °C and 330 °C were used to hold the specimens for 2 h, followed by furnace cooling. Al10SiMg is renowned for its lightweight, high-strength properties, making it ideal for aerospace structures. LPBF offers the ability to produce complex geometries with reduced material waste compared to traditional methods. However, mechanical properties of LPBF-produced parts can vary based on build orientation due to microstructural differences induced during printing. Samples were fabricated in vertical, horizontal, and inclined orientations, and tensile tests were conducted to evaluate properties such as ultimate tensile strength, yield strength, and elongation at failure. Preliminary results indicate significant variations in mechanical properties depending on build orientation, with parts built vertically demonstrating superior strength. These findings offer insights for optimizing build orientation in LPBF-produced Al10SiMg components for aerospace, aiding in enhanced performance and reliability while minimizing material usage and production time.

KEYWORDS: selective laser melting; AlSi10Mg alloy; Heat treatment; Tensile test; LPBF

I. INTRODUCTION

The aerospace industry is continually driven by the demand for lightweight yet high-strength materials to enhance the performance and efficiency of aircraft structures. Among the materials utilized for aerospace applications, aluminum alloys have garnered significant attention due to their favorable combination of low density, excellent mechanical properties, and corrosion resistance. Al10SiMg has emerged as a promising super alloy for aerospace components owing to its exceptional strength-to-weight ratio and suitability for complex geometries. With the advent of additive manufacturing technologies, such as Laser Powder Bed Fusion (LPBF), new opportunities have emerged for fabricating aerospace components with intricate designs and optimized material usage. LPBF enables the layer-by-layer deposition of metal powders, fused together by a high-powered laser, to create parts with reduced waste and enhanced design freedom compared to conventional manufacturing methods. However, the mechanical properties of LPBF-produced parts can be influenced by various factors, including build orientation. During the printing process, the solidification and cooling rates vary depending on the orientation of the part relative to the build plate, leading to differences in microstructure and resulting mechanical properties. Understanding how build orientation affects the tensile properties of LPBF-produced Al10SiMg super alloy is essential for optimizing component design and ensuring performance requirements are met in aerospace applications. This study aims to investigate the effect of build orientation on the tensile properties of LPBF-processed Al10SiMg super alloy, providing valuable insights into how orientation impacts mechanical performance. By systematically evaluating tensile properties such as ultimate tensile strength, yield strength, and elongation at failure for parts fabricated in different orientations, this research seeks to elucidate the relationship between build orientation and mechanical behavior. Ultimately, the findings of this study will inform the development of optimized manufacturing strategies for LPBF-produced Al10SiMg components in aerospace applications, facilitating the advancement of lightweight, high-performance structures for next-generation aircraft.

II. RELATED WORK

Solution Heat Treatment (T6 Heat Treatment): Solution heat treatment involves heating the alloy to a temperature where the soluble alloying elements dissolve into the aluminum matrix. For AlSi10Mg, this temperature is typically between 520°C to 560°C (970°F to 1040°F). Hold the alloy at this temperature for a sufficient period to ensure complete dissolution of the alloying elements. The duration of the soak time depends on the thickness and size of the part. After soaking, quench the alloy rapidly in a suitable quenching medium, such as water or polymer solution, to "freeze" the microstructure in a supersaturated solid solution state.

Artificial Aging (T6 Heat Treatment): After solution heat treatment and quenching, the alloy is in a supersaturated state, which is unstable and prone to aging over time at room temperature. However, to expedite the aging process and achieve desired mechanical properties, artificial aging is performed.

Artificial aging involves reheating the quenched alloy to a lower temperature, typically around 150°C to 200°C (300°F to 390°F), and holding it at this temperature for several hours.

The purpose of artificial aging is to allow the alloying elements to diffuse within the aluminum matrix, forming precipitates (such as Mg₂Si) that strengthen the material. This process improves the alloy's hardness, strength, and other mechanical properties.

Performing a tensile test on AlSi10Mg involves securing a sample of the material in a testing machine, often with specialized grips, and applying a gradually increasing tensile force until the sample fractures. During the test, various parameters such as load, deformation, and strain are measured.

The results of a tensile test provide valuable information about the material's mechanical properties, including its ultimate tensile strength (UTS), yield strength, elongation at break, and modulus of elasticity. These properties are crucial for understanding how a material will behave under tensile stress in real-world applications, helping engineers and designers make informed decisions about material selection and structural design.

III. METHODOLOGY

- ✓ **Sample Preparation:** Design and fabrication of test samples with varying build orientations relative to the build plate.
- ✓ **LPBF Processing Parameters:** Ensuring consistency in LPBF parameters (e.g., laser power, scanning speed, hatch spacing) throughout the printing process.
- ✓ **Microstructural Analysis:** Employing microscopy techniques (optical, electron microscopy) to analyse the microstructure and grain orientation in samples printed at different orientations.
- ✓ **Tensile Testing:** Conducting tensile tests on the printed samples along different orientations to measure mechanical properties.
- ✓ **Build Orientation Selection:**
 - Define and justify the selection of different build orientations (e.g., horizontal, vertical, inclined).
 - Consider the application-specific requirements and potential impact on anisotropy.
 - Ensure that the chosen orientations cover a comprehensive range
- ✓ **Specimen Design:**
 - Design tensile test specimens using computer-aided design (CAD) software.
 - Follow relevant standards (e.g., ASTM E8) for specimen dimensions and geometry.
 - Include replicates for each build orientation to ensure statistical significance.
- ✓ **Statistical Analysis:**
 - Perform statistical analyses, such as analysis of variance (ANOVA), to determine the significance of differences between build orientations.
 - Use statistical tools to validate the reliability of the results
- ✓ **Optimization Recommendations:**
 - Based on the findings, provide recommendations for optimizing build orientation and LPBF process parameters to achieve desired tensile properties.
 - Consider the implications for specific applications or industries

IV. EXPERIMENTAL RESULTS

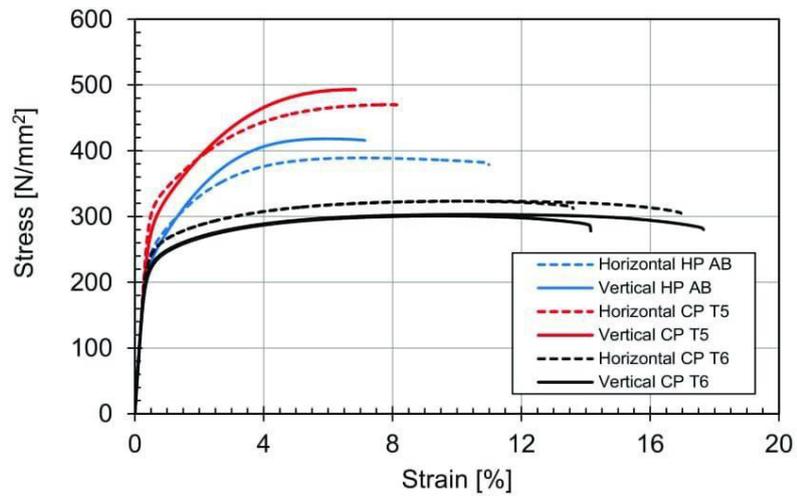


Figure 1: Tensile test result



Figure 1.1: Tensile Tested Specimens

Sample code	Sample Orientation	UTS (N/mm ²)	0.2 YS(N/mm ²)	Strain at Fracture (%)
CP T5	horizontal	471(0.8)	321(1.8)	8.6(0.5)
	Vertical	493(0.6)	292(0.6)	6.0(0.6)
CP T6	horizontal	323(0.0)	243(0.0)	15.3(2.4)
	Vertical	302(1.4)	223(2.8)	16.0(2.5)
HP AB	horizontal	386(2.6)	248(1.7)	8.6(1.4)
	Vertical	412(5.5)	228(4.1)	7.0(0.1)

Tensile tests were performed on the investigated alloy to evaluate the influence of the different tempers. In addition, the effect of sample orientation was considered by testing samples machined from both horizontal and vertical bars, namely, specimens with longitudinal axis normal and parallel to the building direction, respectively. Table summarizes the main tensile properties achieved, while Figure shows the recorded tensile curves.

The collected data clearly show that the best strength is achieved by optimally aging the cold platform as-built samples (CP T5), thus preserving the ultrafine cellular structure, and inducing the expected precipitation of strengthening phases. Despite its large aging potential, highlighted by the DSC analyses, the solution-treated samples (CP T6) attained the lowest strength, but took benefit from a remarkable improvement in fracture elongation. Finally, the performance of samples built on hot platform (HP AB) showed an intermediate condition in terms of strength and ductility. It is suggested that, in this temper, the material could benefit from the fine cellular structure, but could not fully exploit its strengthening potential, due to the lack of a tailored aging stage.

Finally, as far as the effect of specimen orientation is concerned, there is evidence from tensile data that CP T5 and HP AB samples tested in the horizontal direction always feature higher yield strength and fracture elongation, but lower ultimate tensile strength. On the contrary, solution annealing and aging (CP T6) led to the best yield and ultimate strength values in the horizontal samples, but comparable ductility for the two directions.

V. CONCLUSION

- ✓ Summarizing the impact of build orientation on the tensile properties of LPBF-produced Al10SiMg alloy.
- ✓ Implications for optimizing part orientation in additive manufacturing processes to achieve desired mechanical performance.
- ✓ Suggestions for further research or process optimization based on the outcomes of the study.
- ✓ This synopsis outlines the potential structure and focal points of a study investigating the influence of build orientation on the tensile properties of Al10SiMg alloy processed via LPBF, providing insights that can aid in optimizing additive manufacturing processes for improved mechanical performance of aluminium alloy components.

REFERENCES

1. D. Herzog, V. Seyda, E. Wykes, C. Emmelmann, "Additive manufacturing of metals", Acta Materially, vol. 117, pp. 371-392, 2016.
2. E. Olakanmi, R. Cochrane, K. Dalgarno, "A review on selective laser sintering/melting (SLS/SLM) of aluminium alloy powders: Processing microstructure, and properties", Progress in Materials Science, vol. 74, p. 401-477, 2015
3. X. Wang, S. Xu, S. Zhou, W. Xu, M. Leary, P. Choong, M. Qian, M. Brandt, Y. Xie, "Topological design and additive manufacturing of porous metals for bone scaffolds and orthopedic implants: A review", Biomaterials, vol. 83, pp. 127-141, 2016.
4. L.E. Murr, "Frontiers of 3D Printing /Additive Manufacturing: from Human Organs to Aircraft Fabrication", Journal of Material Science & Technology, vol. 32, pp. 987-995, 2016.
5. S. Sing, J. An, W. Yeong, F. Wiria, "Laser and electron-beam powder-bed additive manufacturing of metallic implants: A review on processes, materials and designs", Journal of Orthopedic Research, vol. 34, n. 3, pp. 369-385, 2016.
6. C. Yap, C. Chua, Z. Dong, Z. Liu, D. Zhang, L. Loh, S. Sing, "Review of selective laser melting: Materials and applications", Applied Physics Reviews, vol. 2-4, p. 041101, 2015.

9. S. Tofail, E. Koumoulos, A. Bandyopadhyay, S. Bose, L. O'Donoghue, C. Charites's, "Additive manufacturing: scientific and technological challenges, market uptake and opportunities", *Materials Today*, vol. 21, n. 1, pp. 22-37, 2018.
10. E. Atzeni, A. Salmi, "Economics of additive manufacturing for end-usable metal parts", *The International Journal of Advanced Manufacturing Technology*, vol. 62, n. 9-12, pp. 1147-1155, 2012.
11. T. Debroy, H. Wei, J. Zuback, T. Mukherjee, J. Elmer, J. Milewski, A. Beese, A. Wilson-Heid, A. De, W. Zhang, "Additive manufacturing of metallic components - Process, structure and properties", *Progress in Materials Science*, vol. 92, pp. 112-224, 2018.
12. I. Tolosa, F. Garcíandía, F. Zubiri, "Study of mechanical properties of AISI 316 stainless steel processed by "selective laser melting", following different manufacturing strategies", *The International Journal of Advanced Manufacturing Technology*, vol. 51, n. 5-9, p. 639-647, 2010.
13. K. Guan, Z. Wang, M. Gao, X. Li, X. Zeng, "Effects of processing parameters on tensile properties of selective laser melted 304 stainless steels", *Materials and Design*, vol. 50, pp. 581-586, 2013.
14. B. Vrancken, L. Thijs, J.-P. Kruth, J. Van Humbeeck, "Heat treatment of Ti6Al4V produced by Selective Laser Melting: Microstructure and mechanical properties", *Journal of Alloys and Compounds*, vol. 541, n. 15, pp. 177-185, 2012.
15. X. Gong, T. Anderson, K. Chou, "A study of the microstructural evolution during selective laser melting of Ti-6Al-4V", in *ASME/ISCIE 2012 International Symposium on Flexible Automation*, Louis, MO; United States, 2012.
16. Q. Jia, D. Gu, "Selective laser melting additive manufacturing of Inconel 718 superalloy parts: Densification, microstructure, and properties", *Journal of Alloys and Compounds*, vol. 585, pp. 713-721, 2014.
17. P. Kanagarajah, F. Brenne, T. Niendorf, H. Maier, "Inconel 939 processed by selective laser melting: Effect of microstructure and temperature on the mechanical properties under static and cyclic loading" *Materials Science and Engineering A*, vol. 588, pp. 188-195, 213.
18. E. Louis, P. Fox, C. Sutcliffe, "Selective laser melting of aluminium components", *Journal of Materials Processing Technology*, vol. 211, n. 2, pp. 275-284, 2011.
19. L. Thijs, K. Kempen, J.-P. Kruth, J. V. Humbeeck, "Fine-structured aluminium products with controllable texture by selective laser melting of pre-alloyed AlSi10Mg powder", *Acta Materialia*, vol. 61, p. 1809-1819, 2013.
20. N.T. Aboulkhair, N. Everitt, I. Ashcroft, C. Tuck, "Reducing porosity in AlSi10Mg parts processed by selective laser melting", *Additive Manufacturing*, vol. 1, pp. 77-86, 2014.
21. T. Kimura, T. Nakamoto, M. Mizuno, H. Araki, "Effect of silicon content on densification, mechanical and thermal properties of Al-xSi binary alloys fabricated using selective laser melting", *Materials Science and Engineering A*, vol. 682, pp. 593-602, 2017.
22. A. Aversa, M. Lorusso, G. Cattano, D. Manfredi, F. Calignano, E. Ambrosio, S. Biamino, P. Fino, M. Lombardi, P. Pavese, "A study of the microstructure and the mechanical properties of an Al-Si-Ni alloy produced via selective laser melting", *Journal of Alloys and Compounds*, vol. 695, pp. 1470-1478, 2017.



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