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ANALYSIS OF ADDITIVELY MANUFACTURED AlSi10Mg ALLOY USING X-RAY DIFFRACTION

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ABSTRACT

This research deals with the study of additively manufactured AlSi10Mg alloy samples by X-ray diffraction. The effect of sample orientation during 3D printing by Selective Laser Melting on the values of macroscopic residual stresses and microstructural parameters and their possible inhomogeneities of the cylindrical sample was investigated. Phase analysis identified the intermetallic phase Mg_2Si in addition to the major phases (solid solutions of Al and Si). Tensile residual stresses weredetected in the surface layer for all samples. Inhomogeneities of the investigated parameters of all samples were observed along the circumference of the shank. These effects may be related to the direction of the layers relative to the axis of the sample. These inhomogeneities form so-called microstructural notches or weak spots that are prone to the formation of fatigue cracks, which have a major influence on the fatigue life.

1. INTRODUCTION

Additive Manufacturing (AM), more specifically Selective Laser Melting (SLM) technology, is a promising method of metal powder consolidation and offers excellent part production possibilities. It is based on selectively melting parts of a thin flat powder bed in layers using a scanning energy source to produce 3D parts [1].

AM enables the creation of functional and complex parts, the production of which would be very difficult, if not impossible, using standard processes.Parts made of metal powders using AM can be further modified by conventional methods such as machining, grinding, polishing, welding, and/or heat treatment.However, for complex structures, post-processing is not always possible, so it is essential to investigate the effect of the as-built surface on the mechanical properties of the part, e.g., fatigue.The initiation and propagation of fatigue cracks play an important role in fatigue properties with a strong dependence on roughness,sub/surface microstructure parameters (dislocation density, crystallite size, microcracks), and residual stresses (RS) [2, 3].Microstructural parameters can non-destructively be investigatedonly by diffraction methods, either X-ray (surface analysis) or neutron (bulk analysis).Therefore, it is possible to optimize 3D printing based on the results of diffraction methods.

2. METHODS AND RESULTS

For the fabrication of five AlSi10Mg tubular samples (marked 0–40°: slope related to the Z axis) with 12.5 mm outer diameter and 10 mm inner diameter from a recycled powder, Renishaw AM400 was used with the printing parameters: laser power 350 W, spot size 80 µm, layer thickness 30 µm, laser speed 1150 mm/s, and Meander printing strategy. No heat treatment was performed on the printed samples to maintain a fine-grained microstructure using SLM technology.

Residual stresses were determined by X-ray diffraction using the $\sin^2\psi$ method when the *{311}* diffraction line of the aluminum phase was measured using chromium radiation in the direction parallel to the rotation axis of the sample.

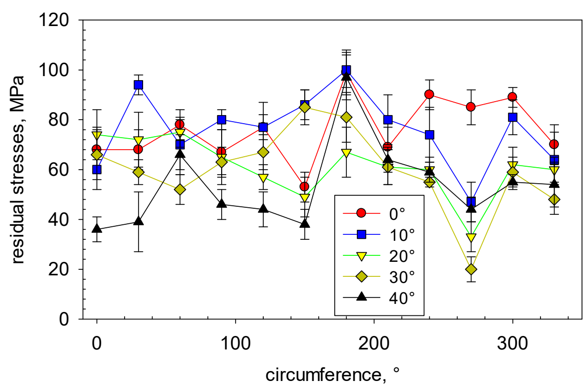

Fig. 1. Circuit surface distribution of residual stresses of aluminum phase depending on the printing slope (related to Z axis)

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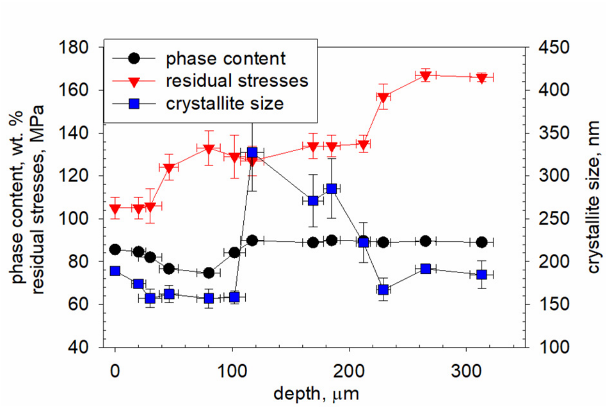

Fig. 2. Depth distribution of phase content, residual stresses, and crystallite size of aluminum phase

3. CONCLUSION

Using X-ray diffraction, the major phases (solid solutions of Al and Si) and the intermetallic phase Mg_2Si were identified in the irradiated volume. In the case of the selected samples, inhomogeneities of the RSof the Al phase were observed around the outer circumference of the tubular; see Fig. 1. These effects may be related to the direction of the layers relative to the axis of the sample.

In Fig. 2, the depth distributions of the selected microstructure parameters of Al phase up to approx. 300 μm show the increasing values of tensile residual stresses. Moreover, the clear inhomogeneities of the phase content and the crystallite size were observed.

These inhomogeneities and tensile RS form the so-called microstructure notches prone to fatigue crack formation, which has a major influence on fatigue life.

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REFERENCES

[1] Bartlett J.L., Li X., An overview of residual stresses in metal powder bed fusion, Additive Manufacturing, 27 (2019) 131–149

[2] Schneller W., Leitner M., Pomberger S., Springer S., Beter F. Grün F., Effect of post treatment on the microstructure, surface roughness and residual stress regarding the fatigue strength of selectively laser melted AlSi10Mg structures, Journal of Manufacturing and Materials Processing, 3(4) (2019) p. 89

[3] Černý I., Čapek J., Kec J., Trojan K., Ganev N., Němeček S., Fatigue of Laser-Welded Structures: Role of Residual Stress, in Comprehensive Structural Integrity, ed. Elsevier Science, (2023), ISBN 9780128229446