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Tohoku University

The Boeing Company

Improvement of fatigue strength of additive manufactured metal by 1.6 times

～Introducing of compressive residual stress by impact at bubble collapse with smoothing by abrasive～

【Point】

- As additive manufactured (AM) metals have a weak point that the fatigue strength was extremely small due to the surface roughness caused by the metal particles, a novel surface modification technique was developed and it was proofed that the fatigue strength was improved by 1.6 times by using the surface modification technique.
- The developed surface modification technique can introduce compressive residuals stress into AM metals using cavitation impact with smoothing by abrasive impact at the same time.
- The proposed surface modification technique can treat curved and complex surface, as the technique is using a submerged water jet with abrasive.
- As cavitation is generated using hydrodynamic cavitation not ultrasonic cavitation, cavitation can be generated efficiently.

【Summary】

Additive manufactured (AM) metals, which can be applied to aviation parts and biomedical implants, have weak point that the fatigue strength is extremely small as compared with that of the bulk material, as AM metals have remarkably large surface roughness due to un-melted particles. In order to use AM metals for practical applications, a novel surface modification technique, which can reduce surface roughness, improve fatigue strength and treat complex surface, is required.

Prof. H. Soyama, Department of Finemechanics, Tohoku University and Dr. D. Sanders, Boeing Research & Technology, The Boeing Company developed a surface modification technique using a submerged water jet with abrasive, and they demonstrated that the fatigue strength of AM metal was improved by 1.6 times by using the developed surface modification technique. The proposed technique can introduce compressive residuals stress into AM metal using cavitation impact with smoothing by abrasive impact at the same time.

This result is presented at 30th Advanced Aerospace Materials and Processes (AeroMat) Conference and Exposition (2019 May 6th-8th, Reno, USA) organized by ASM International (American Society for Metals). This work was partly supported by JSPS KAKENHI Grant Number 17H03138.

https://asm.confex.com/asm/aero19/webprogram/Paper47973.html

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【Contents】

[Background]

Additive manufactured (AM) metals are attractive materials for the aerospace and biomedical industries, as complex shapes can be produced directly using computer aided design systems, and material waste can be reduced. However, the fatigue strength of AM metals have a weak point that the fatigue strength was extremely small, as AM metals have remarkably large surface roughness due to un-melted particles. When the surface of AM metals are smoothed by milling and/or machining, the fatigue strength of AM metals can be improved, however, the advantages of additive manufacturing are not effective. Thus, in order to use AM metals for practical applications, a novel surface modification technique, which can improve fatigue strength with reducing surface roughness and treat complex surface, is required.

Prof. Soyama has been developed a mechanical surface modification technique, which improves fatigue strength of metallic materials by introducing compressive residual stress and work-hardening by using cavitation impacts induced by a submerged water jet. Prof. Soyama and Dr. Sanders et al. developed a novel mechanical surface modification technique to improve fatigue strength of AM metals using cavitation impacts.

[Results]

In order to demonstrate a novel mechanical surface modification technique for the improvement of fatigue strength of AM metals, titanium alloy manufactured by electron beam melting (EBM) was treated. In the proposed surface modification technique, a submerged water jet with abrasive was used to introduce compressive residual stress into AM metals with smoothing the surface roughness by abrasive at the same time (see Fig. 1). It was proofed that the fatigue strength of titanium alloy manufactured by EBM at 10^7 cycles was improved by 1.6 times by using the proposed surface modification technique (see Fig. 2).

[Social significance]

In the present research, it was revealed that the surface modification technique using the submerged water jet with abrasive could improve fatigue strength of AM metals. The proposed surface modification technique is safe as water and abrasive are used without chemicals.

【Presentation conference】

Conference : 30th Advanced Aerospace Materials and Processes (AeroMat) Conference and Exposition (2019 May 6th-8th, Reno, USA)

Title of presentation : Use of an Abrasive Water Cavitating Jet and Peening Process to Improve the Fatigue Strength of Titanium Alloy 6A-l4V Manufactured by the Electron Beam Powder Bed Melting (EBPB) Additive Manufacturing (AM) Method

URL : https://www.asminternational.org/web/aeromat-2019/home

https://asm.confex.com/asm/aero19/webprogram/Paper47973.html

【Presenters】

Daniel Sanders (Boeing Research & Technology, The Boeing Company, Senior Technical Fellow)

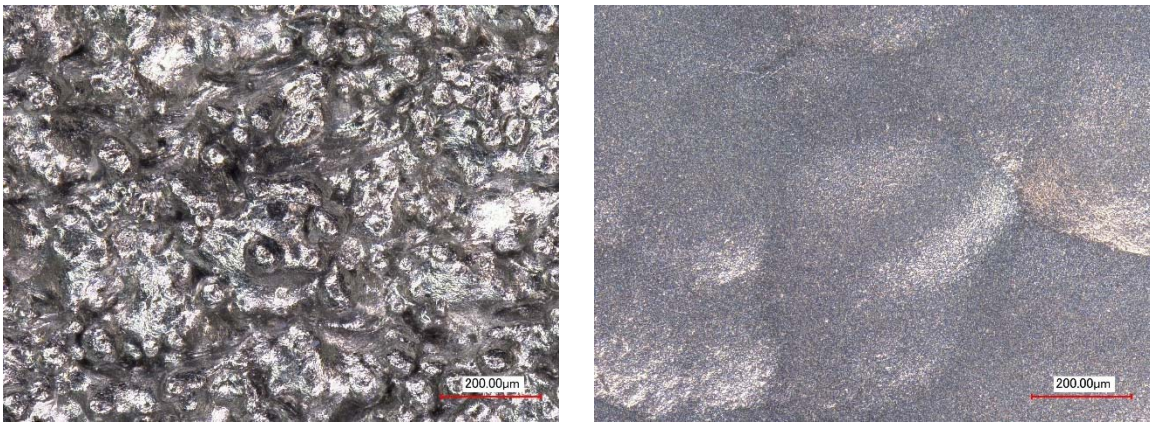
Hitoshi Soyama (Department of Finemechanics, Tohoku University, Professor)

【Glossary】

Cavitation

Phase change phenomenon from liquid phase to gas phase, i.e., bubble by decreasing pressure with increasing fluid velocity. At bubble collapse from gas phase to liquid phase by decreasing fluid velocity, the impact is produced.

【Appendix】



(a) Without treatment **(b) With treatment**

Fig. 1 Aspect of surface of titanium alloy manufactured by electron beam melting EBM

The surface modification using the submerged water jet with abrasive reduced the surface roughness.

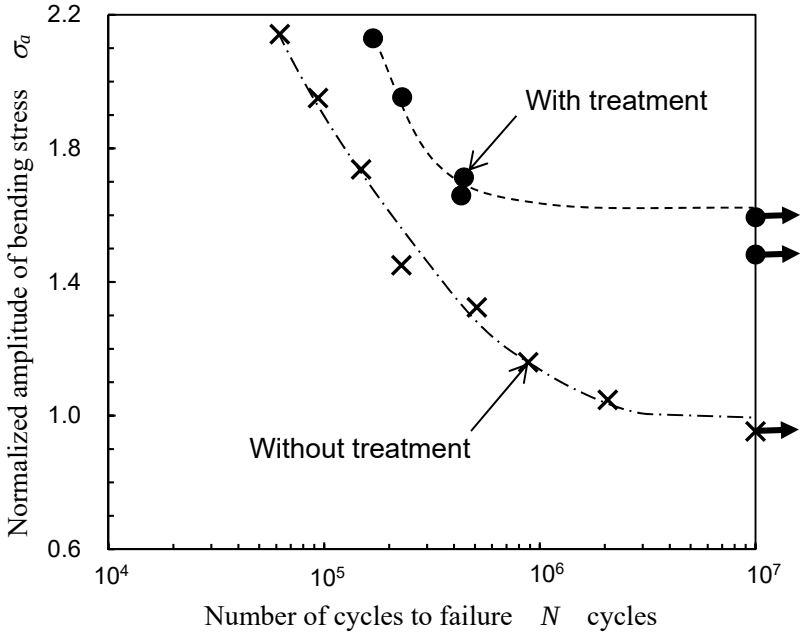


Fig. 2 Improvement of fatigue strength of titanium alloy manufactured by EBM

The surface modification technique using the submerged water jet with abrasive improved the fatigue strength of titanium alloy manufactured by EBM by 1.6 times.