3D printing of TiAl turbine blades for aircraft engine applications

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Abstract

Metal-based 3D printing (3DP) has attracted much attention since the process can build 3D objects by adding layer on layer of materials. In the present study, we carried out systematic studies on the fabrication of TiAl low-pressure turbine blades for aircraft engines by electron beam powder bed fusion (EB-PBF). As a result, it was found that the microstructure of TiAl alloys depends strongly on the process parameters such as beam current and scanning speed. Furthermore, the mechanical properties of TiAl alloys are closely related to the microstructure. In particular, at lower beam currents and higher scanning speeds, the cooling rate is so fast that microstructure evolution through massive transformation occurs, resulting in excellent high temperature strength, compared with conventional TiAl alloys.

Background & Results

In general, 3DP has been used as a tool for shape control. However, the microstructure and mechanical properties of TiAl alloys can be freely controlled by changing the process conditions of 3DP. Furthermore, we also succeeded in establishing a manufacturing process for TiAl turbine blades with 20 cm in long. The simultaneous control of shape and microstructure by 3DP is expected to lead to new trend in the development of new turbine blades.

Significance of the research and Future perspective

TiAl intermetallic compounds has been used as low-pressure turbine blades of aircraft engines due to their lightweight, high-strength, and excellent oxidation resistance. In general, TiAl turbine blade is manufactured by a precision investment casting. However, TiAl is so active that contamination from crucible and oxidation are big concerns. Metal 3D printing (additive manufacturing) has attracted much attention since the process can build 3D objects with arbitrary shape by repeated powder feed-fusion-solidification cycles. In particular, electron beam powder bed fusion (EB-PBF) is an optimal process for fabrication of TiAl blades, since the process is mold-free and done in vacuum. Anisotropic Design & Additive Manufacturing Research Center at Graduate School of Engineering, Osaka University was established in December 2014, and has been working on the development of EB-PBF process for TiAl turbine blades. As a result, it is possible to control the microstructure of TiAl by changing the process parameters such as beam current and scanning speed of EB-PBF. For example, at higher beam currents and lower scanning speeds, the microstructure of EB-PBFed specimens is similar to that fabricated by casting. In contrast, at lower beam currents and higher scanning speeds, the cooling rate is high, so that a "massive transformation" and subsequent formation of nano-lamellar structure occurs, resulting in excellent high temperature strength, compared with conventional TiAl alloys. Therefore, EB-PBF not only can reproduce complex shapes of turbine blades, but also control the microstructure. Recently, we also succeeded in prototyping TiAl turbine blades with 20 cm in long and its microstructure control.

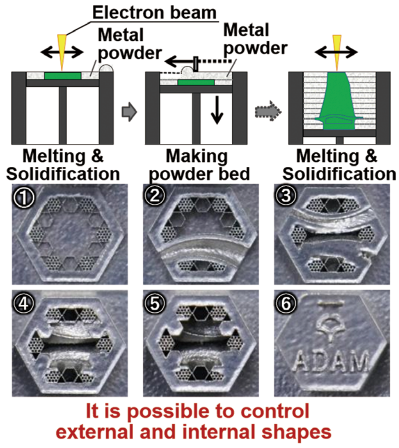

Fig. 1 A schematic drawing of EB-PBF process. It is possible to control internal shape of 3D products by adding layer-on-layer of material.

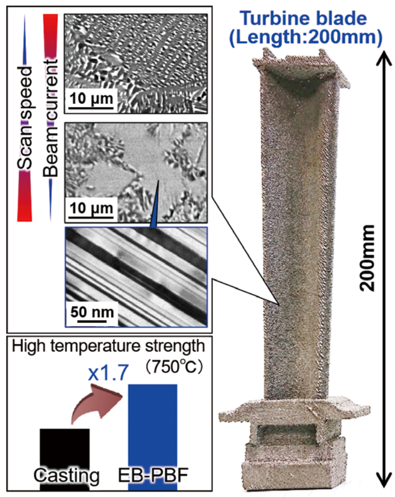

Fig. 2 It is possible to control microstructure of TiAl alloys by EB-PBF. A nano-scaled layered microstructure can be obtained through a unique phase transformation. The strength of the alloys with the nano-scaled layered microstructure is 1.7 times higher than that of casting alloys.

Patent	Japanese Patent No. 6792837
Treatise	Cho, Ken; Yasuda, Hiroyuki; Nakano, Takayoshi et al. Peculiar microstructural evolution and tensile properties of β-containing γ-TiAl alloys fabricated by electron beam melting. Additive Manufacturing. 2021, 46: 102091. doi: 10.1016/j.addma.2021.102091 Cho, Ken; Yasuda, Hiroyuki; Nakano, Takayoshi et al. Improving the tensile properties of additively manufactured β-Containing TiAl alloys via microstructure control focusing on cellular precipitation reaction, Crystals, 2021, 11 (7), p.1-13. doi: 10.3390/cryst11070809
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