Microstructure evolution and creep performance of LPBFed near α, and near β - Ti alloys

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Ti alloys are used as jet engine compressor components due to their lightweight and excellent mechanical properties at high temperatures. There are two categories of alloys for jet engine applications, such as near α (hcp) -Ti alloys and near β alloys. In near α -Ti alloys, the β phase volume fraction is controlled to less than 10%. In near β (bcc) -Ti alloys, the stability of α phase decreases, but they form during aging treatment. Near α -Ti alloys are used as compressor blades, and near β -Ti alloys are used as compressor disks.

3D Additive Manufacturing (AM) is a promising processing method that enables the fabrication of complex shapes by melting and solidifying one layer at a time using a laser or electron beam. Additionally, in the AM process, rapid heating and cooling have a significant impact on the microstructure of metallic materials. In this study, the laser beam was chosen due to its rapid cooling rate. The microstructure evolution produced by the laser powder bed fusion and subsequent heat treatment of near α (Ti-6Al-4Nb-4Zr, wt%) and near β -Ti alloys (Ti-6Al-2Sn-4Zr-6Mo) was investigated. Creep behavior of near α and near β -Ti alloys was also investigated, and the potential of LBPFed Ti alloys as jet engine materials is discussed.

In both alloys, the microstructure of as-bult samples clearly showed the melting pool boundaries that are formed by cyclic heating due to cyclic scanning of the laser beam. In near α -Ti alloys, the crystallographic orientation of the β phase was random 1, 2). While in near β -Ti alloys, depending on the processing condition, columnar microstructures with crystallographic lamellar-like microstructure (CLM), a near single crystal-like microstructure (SCM), and polycrystalline structures (PCM) were formed 3, 4). Furthermore, during rapid cooling, the α phase undergoes martensitic transformation, forming a fine α phase inside the melting pool. In near α Ti-Alloy, a fine α phase formed with decrease of energy density, VED, as shown by P/vdt, where P is laser power, v is scan speed, d is powder layer thickness, t is hatch distance 1, 2), while in near β -Ti alloy, the opposite behavior was observed; that is, a fine α phase formed at higher VED 3, 4).

Creep behavior of near α -Ti alloy and near β -Ti alloy was investigated. The creep deformation mechanism is dislocation creep, which depends on the microstructure in the molten pool rather than the grain size in both alloys. Even so, grain size dependence of creep life was observed in near α -Ti alloy 1, 2). Creep lives of LPBFed near α -Ti alloy (100~300 μm in melting pool size) were between those of the forged sample with bimodal structure (10 μm in grain size) and with lamellar structure (550 μm in grain size) 1, 2). It was also found that the Hot Isostatic Press (HIP) is helpful for improving creep life by eliminating micro-defects 1). In near β -Ti alloy, the creep strain was larger at low stress in the LPBFed samples, but the creep life was slightly longer in the LPBFed samples than in the forged sample. There is no significant difference in creep deformation between SCM, CLM, and PCM. In addition, a creep rupture surface was observed at the melt-pool boundary, suggesting that the α phase, which continuously forms on the melt-pool boundary in near β -Ti alloy, is the crack formation site.

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