Role of Microstructure on Small Fatigue Crack Initiation and Propagation behavior of Rolled and Forged Ti-6Al-4V Alloy

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Abstract: Fatigue life is determined by microscopic fatigue crack initiation and growth. Since fatigue crack is generally initiated on the slip plane of microstructure and propagated by slip deformation of the crack tip, fatigue life should depends on microstructure. To computationally simulate the effect of microstructure on fatigue property, it is necessary to understand microstructural small fatigue crack initiation and growth behavior. Although Ti-6Al-4V alloy has superior fatigue strength, fatigue strength of forged pancake, used for such as airplane engine, is normally lower than that of rolled alloy. It is possibly comes from microstructural difference, such as micro-texture. However, it is not enough clarified yet. In this study, to clarify the effect of microstructure on fatigue strength, forged or rolled Ti-6Al-4V alloy with two deferent heat treatments were prepared. Those totally four different microstructures has almost same mechanical properties and bimodal microstructure of two levels of primary α-phase volume fraction. After that, fatigue crack initiation behaviors were investigated with replication method and digital microscope system. As a result, even though tensile and cyclic yielding strength were almost same, fatigue strength of forged samples were obviously lower than that of rolled one. On the other hand, effect of primary α-phase volume fraction was not clear in this case. Based on small fatigue crack observation, since fatigue crack growth life that fatigue crack is larger than 0.1 mm was comparable between forged and rolled sample, the difference in fatigue life was caused from microstructural fatigue crack initiation. In the forged material, since fatigue crack was initiated linearly across multiple grains, initial fatigue crack size were larger than that of rolled one. Therefore, remained fatigue crack growth life of forged material became shorter than rolled material. It was considered that plurality of grains with close crystal orientations were lining-up due to the micro-texture. In addition, Schmid's factor related to crack initiated plane of micro-texture of forged material was maybe higher than that of rolled material. Therefore, in other words, effective grain size related to fatigue strength of forged sample was considered to be larger than that of rolled material.

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