Forging Operations

Billet

C

Reheat

Annealing Process

Experimental Procedure

In the billetizing process, as-cast titanium is mechanically worked and thermally treated to form billets. Each supplier has a different billetizing process which results in various microstructures and properties. Alcoa’s billetizing process is seen in the flow diagram above. Therefore, microstructure and mechanical properties will be analyzed for each billet. The microstructure portion of the test plan is to analyze morphology, grain size, and structure. Mechanical tests will include tensile, fracture toughness, and fatigue crack growth rate tests.

Processing

Ti-6Al-4V is considered to be alpha-beta titanium, meaning both the alpha and beta phase are present in the alloy. In the annealing process, the alpha phase is formed by cooling the beta phase titanium. Plates of alpha phase titanium begin to form at the beta-grain boundaries. The alpha plates then nucleate into colonies. Plate formation is shown in the schematic.

The annealing process continues when the alpha plates form a basket-weave structure upon cooling. The thickness of each alpha plate is dependent on the cooling rate. The part is heated to just below the beta transus temperature where the individual plates fuse together to form equiaxed alpha grains.

Alcoa’s annealing process is seen to the right. The process begins with the beta anneal, heated above the beta transus temperature, to give only a beta phase microstructure. After an air quench, the recrystallization anneal begins. As it cools, the alpha plates nucleate to form the basket-weave structure. After the last reheat, the alpha grains fuse to become equiaxed.

Microstructure Results

3D microstructures for A Center (1), A 1 cm from Surface (2), B 1 cm from Surface (3), C Center, (4), and C 1 cm from Surface (5). Each supplier has a different billetizing process, leading to different resulting microstructures at the center and surface of each billet.

Mechanical Properties Results

Conclusion

Due to different processing methods of each supplier, the billets have varying microstructures. Billet B exhibits a plate-like alpha microstructure which, theoretically, should display lower mechanical properties compared to the equiaxed fine alpha grains in transformed beta matrix. Although there is no statistically strong correlation between these mechanical tests and microstructure, there is a decrease in the mechanical properties in Billet B. The results can be useful to Alcoa based on their specific customers’ needs. An increase in sample size per test would further help determine this microstructure to property correlation.

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Alcoa, Inc. has asked our team at Purdue to analyze and compare Ti-6Al-4V billet forging stock of three titanium suppliers. Alcoa wants their forged final product made of Ti-6Al-4V to match their customers’ needs. Our senior design team needs to characterize the billets from three different suppliers in order to ensure the best suited product Alcoa will supply. Our goal is to rank billet quality based on the results of a quantitative comparative analysis of the three titanium suppliers that compares the mechanical properties and microstructure of each supplier’s billets. In order to achieve the goal, we will analyze and compare microstructure and mechanical properties of each billet supplier to determine what causes the property differences.