Journal of Metallurgical and Materials Engineering, Vol.27, No.2, 2016.

The Effect of Second Hot Rolling on the Hot Ductility Behavior of IMI834 Alloy

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1- Introduction

IMI834 alloy is the most recently developed near-alpha type titanium alloy. High ultimate tensile strength at room temperature, i.e. 1030 MPa, operating temperatures up to 600 °C, and a good combination of creep and fatigue resistance at elevated temperatures promoted its application in discs and blades in the high pressure parts of compressors and advanced jet engines. Titanium alloy components are more difficult to fabricate as compared to other traditional metallic materials due to their poor formability at room temperature, high flow stress at elevated temperatures and high sensitivity of flow stress to temperature. Thermomechanical processing (TMP) is an effective method for forming and improving the microstructure and mechanical properties of titanium components. Thermomechanical processing of these alloys involves a primary β processing (ingot breakdown) stage, to convert the cast ingot to a worked billet, and secondary α+β processing to prepare the final product. A number of studies have indicated that alpha–beta and near-alpha titanium alloys show poor hot ductility around the beta to alpha phase transformation temperature. Fugii and Suzuki have reported a hot ductility trough in Ti-6Al-4V between 750 ˚C and 930 ˚C. Ushkov found that the ductility drop is associated with the presence of 5–6 wt.% aluminum and more than 2 wt.% β-stabilizer elements. Damkroger demonstrated that the ductility loss and the effect of alloy composition on the hot ductility can be related to the beta to alpha transformation kinetics and the presence of a specific microstructure, i.e. either coarse, lamellar alpha–beta or lenticular α’ in Nb containing alloys. Rath reported that microstructures consisting of equiaxed alpha, present good hot ductility at all temperatures. However, Widmanstatten alpha or duplex martensite plus alpha microstructures reduce the hot ductility in Ti alloys. Hence, investigation of the hot ductility behavior in this alloy to determine proper and improper conditions is very important.

2- Experimental procedure

In this research hot ductility of near-alpha Ti alloy IMI834 is investigated. The chemical composition of this alloy is listed in Table 1.

Table. 1 The chemical composition of IMI834 alloy (mass %)

Al	Sn	Zr	Nb	Mo
5.30	2.90	3.00	0.65	0.500
Si	O	H	N	Ti
0.20	0.06	0.004	0.005	Bal

Hot tensile tests were performed on two strips of the alloy under two conditions: first hot rolling in the single phase beta region and second hot rolling in the two phase alpha-beta region. For this reason, the ingot underwent the first hot rolling after two melting steps in a vacuum arc remelting furnace (VAR) and homogenization in the single beta phase region. Hot tensile test samples were then prepared in the rolling direct according to ASTM-E8. The specimens were deformed at temperatures of 800, 850, 900 and 1000 °C and strain rates of 0.1s-1. The specimens were held at the deformation temperature for 10 minutes to allow for thermal homogenization. The second hot rolling was performed in the two phase alpha-beta region to evaluate the effect of secondary hot rolling on the hot ductility of the alloy. Samples were then prepared from the second hot rolling strip and were tested at 800, 850, 900 and 1000 °C and a strain rate of $0.1s^{-1}$. All the samples were water quenched immediately after the deformation for metallographic evaluations.

3- Results and discussion

Fig. 1 shows the microstructure of IMI834 after the first hot rolling in the single beta phase region. The microstructure is completely beta with Widmanstatten morphology.

Fig. 2 shows the microstructure of IMI834 after the second hot rolling in the two phase alpha- beta region. The microstructure consists of transformed beta and primary alpha.

Fig. 3 shows the reduction of area and elongation of the hot tensile specimens tested at 800, 850, 900 and 1000 °C and a strain rate of $0.1s^{-1}$, under two conditions of prior to and after the second hot rolling.

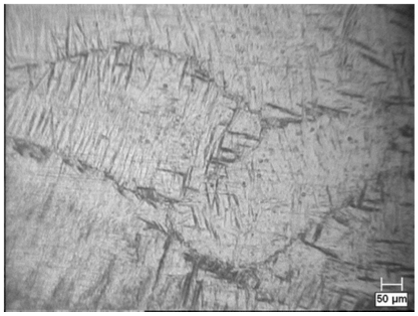

Fig. 1 The microstructure of IMI834 alloy after the first hot rolling

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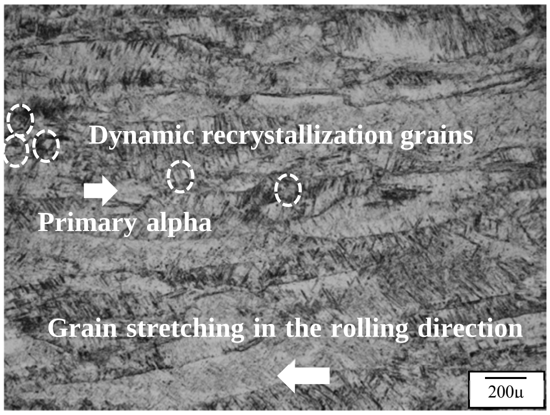

Fig. 2 The microstructure of IMI834 alloy after the second hot rolling

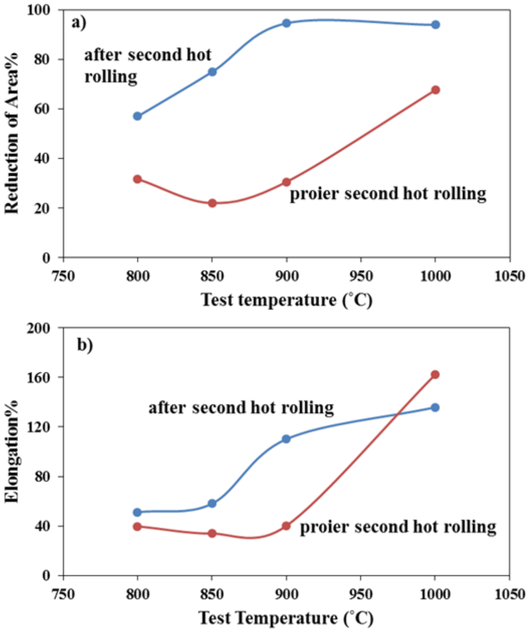

Fig. 3 a) reduction of area and b) elongation of IMI834 at 0.1 s^{-1} under two conditions of prior to and after the second hot rolling

Hot ductility increased significantly after the second hot rolling stage. The reduction of area at 900 °C increased significantly from 31% (before the second hot rolling) to 95% (after the second hot rolling). Furthermore, the hot ductility trough at 850°C was not observed after the second hot rolling stage. Ductility improvement in the lower two phase alpha-beta region (800-900°C), can be attributed to grain refining. The ductility trough observed in the first rolling condition can be attributed to the contraction of the crystal lattice due to the formation of the beta phase and localization of strain at the intersection of alpha and beta phases. After the second hot rolling stage and grain refinement i.e. increase in grain boundary area, the sensitivity of grain boundary at the intersection of alpha and beta phases decreased. As a result, local strain at the intersection of alpha and beta phases, which in the first hot rolling condition caused the ductility trough at 850 °C, did not exist in the second hot rolling condition and the ductility continuously increased with increasing temperature. The observed increase in ductility in the two phase alpha-beta region (1000 °C) can only be attributed to the grain refinement due to the second hot rolling.

4- Conclusions

After first hot rolling, the hot ductility of IMI834 alloy is low. The minimum value of hot ductility is seen at 850 ˚C. The hot ductility increased after the second hot rolling stage and ductility loss did not occur. Hot ductility improvement after the second hot rolling can be attributed to grain refinement and decrease of grain boundary sensitivity and strain localization. Workability is increased after the second hot rolling stage and hot tensile tests at 800-900 ˚C is redounded to dynamic kinking and dynamic globularization of alpha lamellae. These phenomena contribute to the decrease of UTS and increase of hot ductility. Acceptable hot ductility values are obtained at 1000 ˚C under two conditions of prior to and after second hot rolling.