INVESTIGATION OF THE A AND B TEXTURE EVOLUTION OF HOT FORGED TITANIUM ALLOY PRODUCTS

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Forged Ti17 titanium alloy is used in the aircraft industry for its superior mechanical properties. In order to understand fatigue life discrepancy in titanium alloy, previous studies were performed. They have emphasised the role of a crystallographic macro-structure, constituted by clusters of millimetre and centimetre sizes, on micro-cracks initiation on TA6V [1]. The macro-structure of the alloys was assumed to be correlated with the ex-β grains. Moreover, according to other authors, specific texture of the β phase improves fatigue toughness on Ti17 [2].
In order to understand the role of the as-received material initial microstructure and texture and the effects of the forging process in β phase ($T>T_\beta$) on macro-zones formation, a numerical simulation of the process has been undertaken, allowing us to follow the evolution of the crystallographic texture and morphology for different deformation rates. The evolution of β texture and grains morphology during the forging treatment is predicted by a crystalline approach implemented in the finite element code Abaqus.

Material and Thermomechanical process

At room temperature, Ti17 is a quasi β titanium alloy presenting 70% of α phase (hcp) and 30% of β phase (bcc). Above the transus temperature (T_β= 890°C), a 100% bcc structure is obtained. In pure titanium, the hcp α phase generally transforms into the bcc β phase according to the Burgers relation (with sometimes orientation variant selections): $(110)_\beta//(00.2)_\alpha$ & $[-11-1]_\beta //[2-1.0]_\alpha$

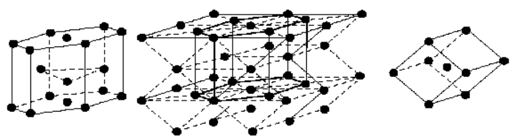

Figure 1. Burgers relation

The thermomechanical process used for Ti17 is given on figure 2: OA represents the heating stage where α→β phase transformation occurs, AB corresponds to the deformation and BB'/BB'' to the cooling where transformation of 70% of β phase into α phase occurs.

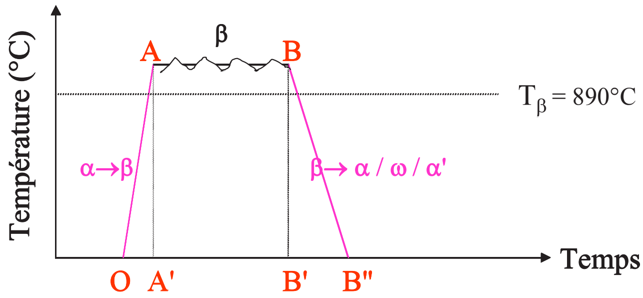

Figure 2. Thermomechanical treatment

The characterization of the texture of the β phase before forging was performed assuming that the texture and grain size in A is similar to the characteristics of A' (there is no effect of the β→α transformation on the β texture [3]). The same process is used to obtain the final texture corresponding to B.
The as-received material, supplied by TIMET Savoie, presents a morphology constituted by ellipsoidal β grains up to 5mm with nodular α phase of about 1µm as pointed out by OIM analyses and tensile tests.

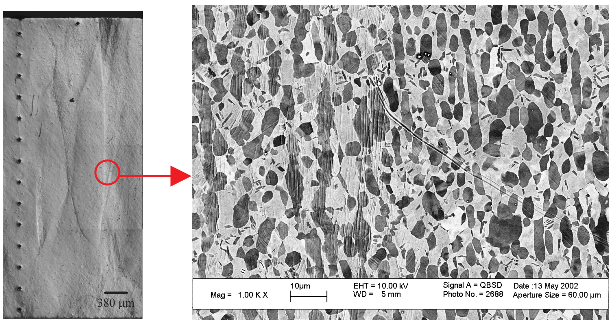

Figure 3. macro/micro-structure of the as received material

The **A' material** *(solution treated for 20 min at $T>T_\beta$ then water quenched)* presents well-defined grains (the average size is about 300µm) scattered by clusters of about one millimetre composed of grains slightly misoriented (Fig. 4). The **B' material** *(solution treated for 20 min at $T>T_\beta$ before applying a specific plastic deformation (ε=0,7) and then water quenched)* presents large grains up to 800µm (Fig. 4).

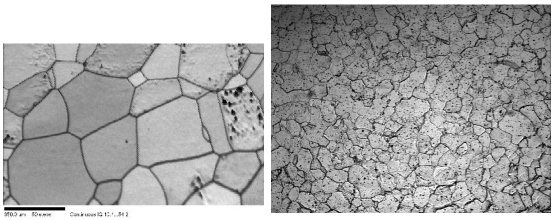

Figure 4. microstructure of A' and B' materials

Consequently, neutrons diffraction technique was necessary to obtain a quantitative description of the texture. Crystallographic textures at points O, A', B' were characterized at Léon Brillouin Laboratory (CEA-Saclay) on the 6T1 diffractometer.
The experimental poles figures are presented on figure 5, the normal direction corresponding to the forging axe.

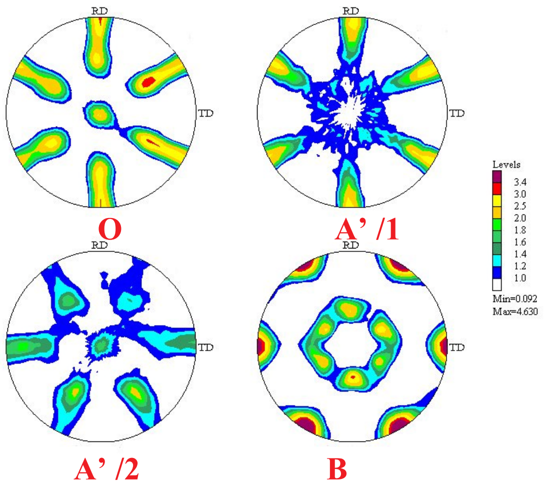

Figure 5: Experimental $(110)_{\beta}$ poles figures obtained by neutron diffraction.

Texture analysis of (α+β) materials in O and B' were relevant with some qualitative results of EBSD and DRX. The β phase texture of the as-received sample (O) is dominated by a (110)<112> orientation. After forging (B), we observe a very strong (111)<-1-12> component, also than the orientations (001)<100> and (001)<110> which are pronounced.
Concerning A' material, several analyses were conducted. In all the cases, the (110) orientation disappeared whereas a weak (111) orientation appeared, compared to the texture of the supplied material. But in the A’ materials, the components are not precisely identical (see figure 5) and these differences seem to come from a non homogeneity of the heat treatment.
EBSD analyses (Figure 6) have clearly shown that the microstructure in the A’/2 sample was heterogeneous with different grain size compared with the results from the A’/1 which presented a well defined microstructure. The heat treatment applied to the A’/2 is not considered as valid.

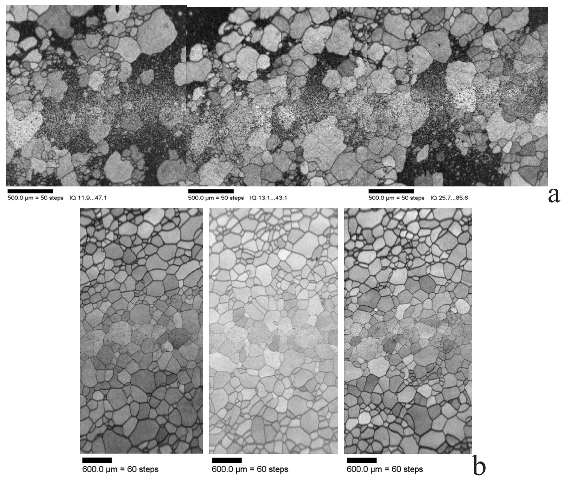

Figure 6. EBSD characterization of a)A’/2 and b)A’/1 samples.

The result of the forged materials was used to valid a plasticity modelling, presented elsewhere [4], developed in our laboratory to simulate the deformation of the β phase at high temperature. The numerical and experimental results are in good agreement and allow to go further in prediction of formation of large crystallographic entities after forging.
The study of the texture evolution during phase transformation in forged material, would gain with being carried out in-situ because only one axe is known. The in situ measurements are in progress, a furnace has been adapted to the diffractometer. They will contribute to understand the texture evolution during the phase transformation respecting the Burgers relation or from the pre-existing β nuclei in the matrix [5].

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References

1. K. Le Biavant, étude de l’amorçage de fissures de fatigue dans le TA6V, PhD, ECP, 2000.
2. O. Gourbesville, Caractérisation par DRX de la microstructure d’alliages à base de nickel et de titane forgés et traités, PhD, ENSAM, 2000.
3. Quesne *et al.* Proceedings of Titanium 99, 1711-1717
4. J. Delfosse *et al.* Proceedings of Titanium 03, 1315-1322
5. Wenk et al. Acta Mat. 52 (2004), 1899-1907