THE EFFECT OF HALL-PETCH RELATIONSHIP ON MULTI-SCALE NUMERICAL SIMULATION OF MECHANICAL BEHAVIOUR OF TI-6AL-4V POLYCRYSTALLINE

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1- Context

Mechanical behaviour of an equiaxed polycrystalline alpha-beta Ti-6Al-4V alloy is investigated by an elasto-viscoplastic constitutive law developed based on crystal plasticity and finite element approach. Effects of the material parameters are investigated considering the Hall-Petch relationship.

2- Finite element modeling

The effect of grain size is investigated basing on local elasto-viscoplastic constitutive equations proposed by Méric-Cailletaud and Hall Petch relationship [1-3] with consideration of small strain assumption. The model parameters are founded in [4-5]. The microstructure features and crystallographic texture are modeled using Voronoi tessellations.

Four Representative Volume Element (RVE) with different Ti-6Al-4V microstructural features are reported in table 1. The role of five textures is studied (see table 2).

REV (120x120x120μm^3)	Microstructure	Average grain size μm	Number of grains within RVE
1	Homogenous	3	1900
2		14	700
3	Heterogeneous	3	1900
4		14	700

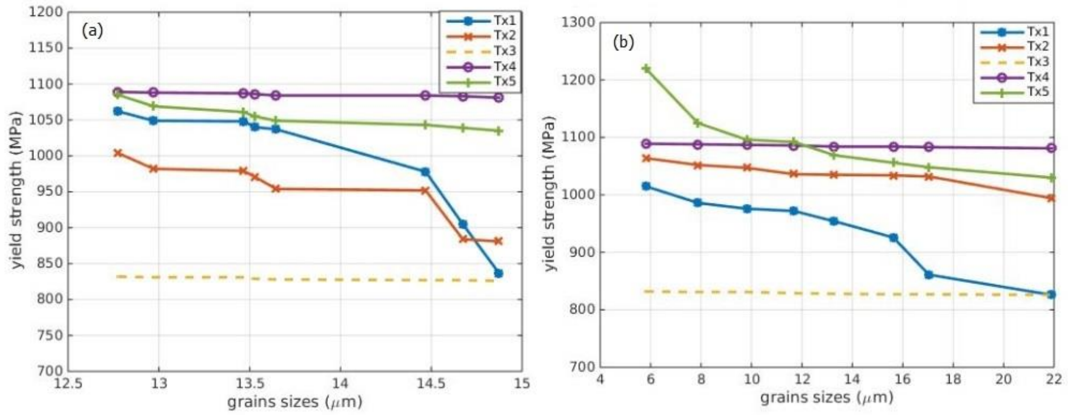
Table 1: REVs and microstructural aspects investigated

Texture	Tx1	Tx2	Tx3	Tx4	Tx5
Macrozone	No	Intermediate	Strong (0,0,0)	Strong (90,90,0)	Strong (45,45,45)

Table 2: Different textures investigated

3- Results

The evolutions of local yield stress and plastic strain are shown respectively in figures 1 and 2 as a function of the scattering of gain size. For heterogeneous morphology with no or intermediate macrozones, a strong heterogeneity of plastic strain is found. Coarse grains present more plastic straining compared to small grains. This is linked to the motion of dislocations, which is limited in the small grains since the grain boundaries limit the distance for free sliding of the mobile dislocations compared to the more coarsened grains. The interaction of the dislocation and grain boundaries induce in consequence more hardening of small grains and therefore enhance their yield strengths. This interaction is implicitly integrated through the Hall-Pech relationship that was added to the model of Meric-Cailletaud. However, when the Ti-6Al-4V grains are strongly textured along particular orientations (Tx3, Tx4 and Tx5), the plastic strain is more homogeneous Figure 2 and the yield stresses are comparable whatever their sizes. A very small variation is observed when the texture is Tx5, Figure 1. For this highly textured microstructure, the Hall-Petch relationship has no more a drastic effect.



Figure, 1: Evolution of local yield strength of a Ti-6Al-4V modelled with an average grain size of 14 µm and small grain size scattering morphology (homogeneous microstructure) in (a) and large grain size scattering (heterogeneous microstructure) in (b)

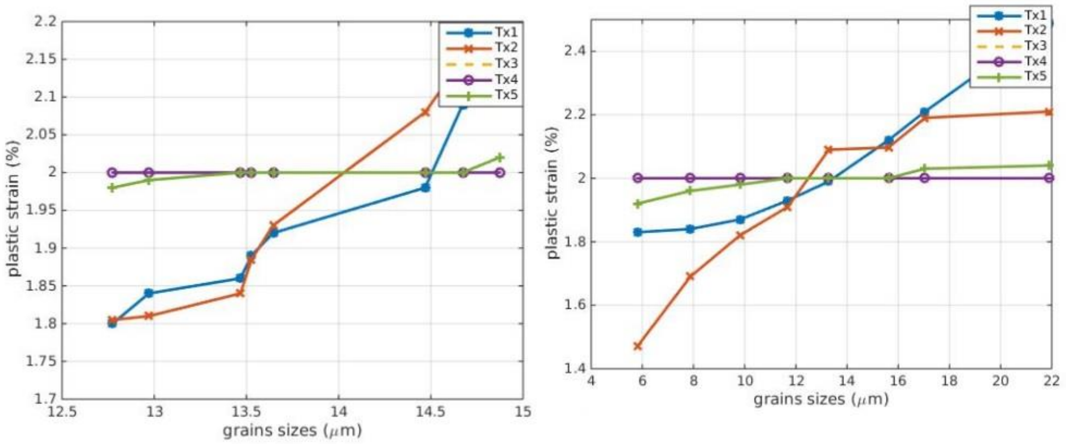


Figure 02: Evolution of local plastic strain of a Ti-6Al-4V modelled with average grain size of 14 µm and small grain size scattering morphology (homogeneous textured microstructure) in a and large grain size scattering heterogeneous textured microstructure in b

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