Influence of Processing and Alloying Method in Fracture Behaviour of Tungsten-Vanadium Alloys for ITER

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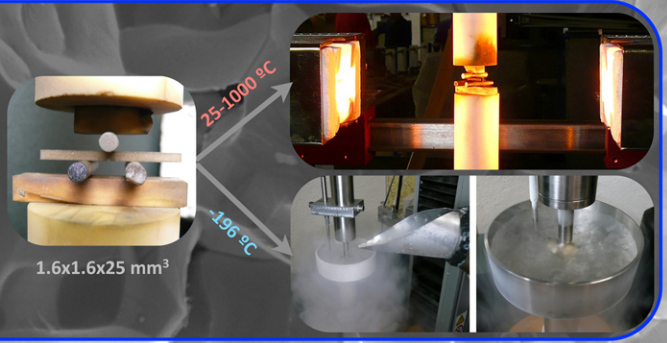
TARGET: evaluate the influence of processing and alloying (%V) in the mechanical behaviour of three tungsten alloys processing by HIP and compared them with a reference pure W

Table 1. Studied materials, processing methods and calculated relative density

material	processing	ρ_r (%)
pure W	blended + MA + HIP	91.64
W+2%wt V	blended + MA + HIP	96.32
W+2%wt V mix	blended + HIP	92.58
W+4%wt V	blended + MA + HIP	99.10

ρ_r = relative density; MA = Mechanical Alloying; HIP = Hot Isostatic Pressing

The mechanical characterisation was performed by three point bending tests in an oxidising atmosphere in a temperature range between -197 °C (immersion tests in liquid nitrogen) and 1000 °C



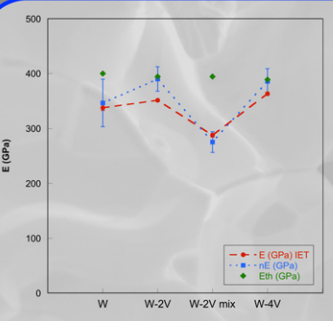


Fig.1. *Elastic modulus of each material. E is measured by the impulse excitation technique (IET); nE by nanoindentation and Eth is the calculated modulus*

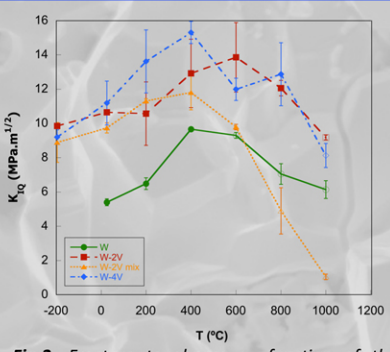


Fig.2. *Fracture toughness as function of the temperature of each material. The empty markers represent the apparent fracture toughness*

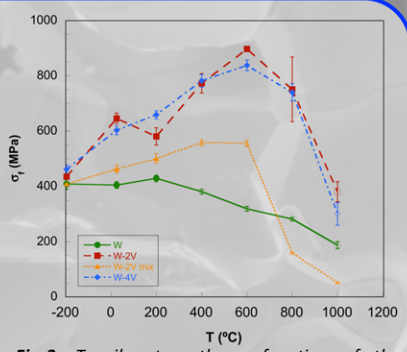


Fig.3. *Tensile strength as function of the temperature of each material. The empty markers represent the yield strength at 0.2%*

MECHANICAL PROPERTIES

Fig.1,2,3 show that the addition of 2 and 4 %V improve the mechanical properties, reaching maximum values of around 15 MPa·m$^{1/2}$ and 900 MPa. At temperatures above 600 ºC the degradation due to the oxidation process starts, so the properties are degraded but still the values are better than in pure W.

The step of MA is completely necessary because otherwise properties are lower.

In the material W-2V mix the elastic modulus is lower than the theoretical due to the porosity (see relative density in Table 1).

INTRODUCING THE NOTCH

Initially we make the notch with a refrigerate diamond disc because it is an easy an cheap alternative way to fatigue, but some problems arise like plastic damage (see Fig.4) or large notch tip radius around 200 µm. Then we developed a new experimental method that allow to create a notch similar to a crack with a notch tip radius around 5-7 µm (Fig.5 a) and no plastic damage (Fig.5 b).

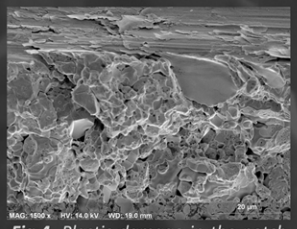


Fig.4. *Plastic damage in the notch tip radius*

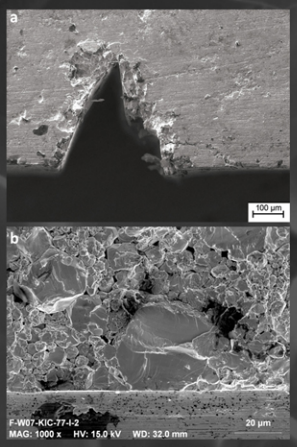


Fig.5. *View of the notch with the new experimental method, a) notch; b) notch tip*

MICROSTRUCTURE & FRACTURE SURFACES

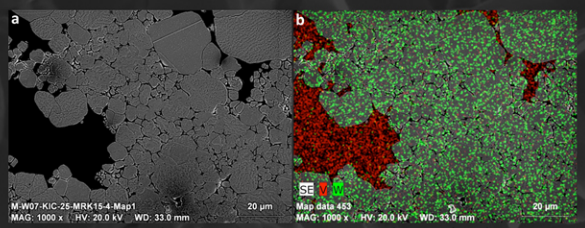


Fig.6. *Micrography, a) Granular structure and pore distribution in a zone of the W-2V mix alloy; b) mapping (W-V)*

Fig.6 shows the microstructure of the W-2V mix alloy, it can be seen the great porosity. There is no mixture of the alloying elements and therefore there is no solid solution formed that can give cohesion to the material.

In the analysis of the fracture toughness (Fig.7) it can be observed the porosity mainly in pure W and W-2V mix and that it is reduced with the addition of V as it shows in b). In the W-2V alloy appears a second phase that gives cohesion to the material so it is more resistant.

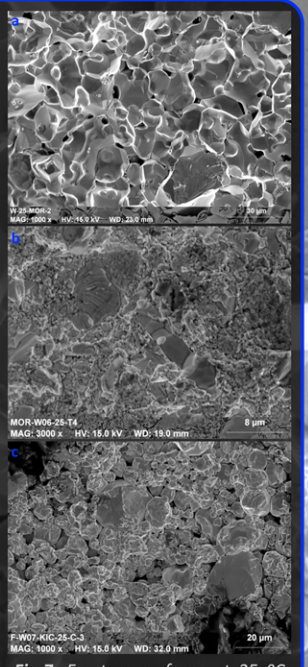


Fig.7. *Fracture surfaces at 25 ºC, a) pure W; b) W-2V; c) W-2V mix*

CONCLUSIONS:

- The addition of V increases the thermal degradation but the properties are still higher than the pure W reaching values of tensile strength of 900 MPa and very significative increase of fracture toughness with values around 15 MPa·m$^{1/2}$
- The new method to introduce the notch decreases the radius of the tip to values around 5-7 µm and do not introduce plastic damage around the notch tip
- The 2 %V mix alloy has a lower density and no cohesion between grains so all mechanical properties degrade at lower temperatures. The step of Mechanical Alloying (MA) during the processing is necessary

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