3-AXIS FORGING OF NIOBIUM (Nb) TO IMPROVE MECHANICAL PROPERTIES

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ABSTRACT

The mechanical properties of high purity (R.R.R.) Niobium as a function of plastic strain were investigated. Nb samples were forged to strains using the 3 axis deformation technique. Grain size & Hardness depend strongly on the amount of straining. Plastically straining a material can decrease its grain size and increase its hardness. Hence forging can significantly increase strength and toughness of a material through the alteration of grain size during the 3-axis forging process.

Introduction:

Niobium is a rare, soft, malleable, ductile, gray-white transition metal. It has a body-centered cubic crystalline structure. Niobium resists corrosion due to an oxide film on its surface. Niobium was mined chiefly as columbite.

Applications

- Pure niobium has excellent superconducting properties
- Production of high-temperature-resistant alloys & stainless steels
- Nb carbide used in cutting tools
- Nb - tin & Nb -Ti alloys are used as wires for superconducting magnets
- Nb imparts greater strength to metals at low temperatures
- Used in stainless steel alloys for nuclear reactors, jets, missiles, cutting tools, pipelines, super magnets and welding rods
- Alloys are used in surgical implants - they do not react with human tissue.

Physical & Mechanical Properties of Niobium

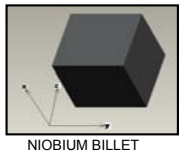
Atomic Mass Average	92.91
Density	8.55 g/cc @ 20ºC
Hardness Scale: Vickers	60-100
Physical State (at 20 ºC & 1atm)	Solid
Modulus of Elasticity	105 GPa
Yield Stress	103 MPa

Forging

Metal forging is a centuries old metal working technique but it is still employed today. The process involves using a load to plastically deform a material to alter its bulk shape. This causes microstructural changes that can improve strength.

MATERIALS & METHODS

Pure Nb billets (15mm cubes) were forged to strains of (Є) 20%, 40%, 60%, 130% using the 3-axis forging method . (Successive forging along 3 major axes with approximately 20% each forging). The final formed samples were sectioned, mounted, polished and etched to reveal the microstructure. A Vickers hardness tester was used to test samples for hardness. LEICA Inverted Microscope was used for microanalysis.



NIOBIUM BILLET

3 – Axis Forging

FORGING PRESS

Cutting, Mounting, Grinding & Polishing

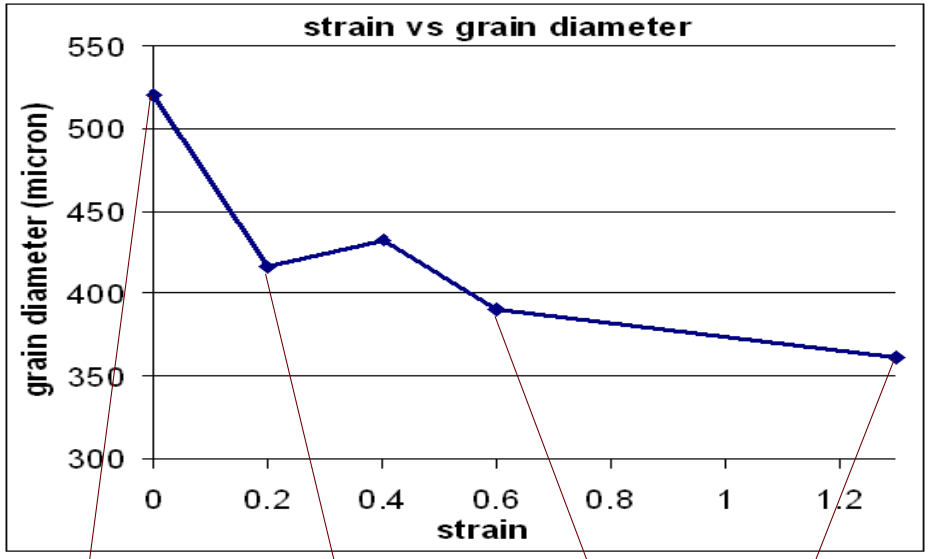
LIGHT MICROSOPE

Vickers Hardness Test

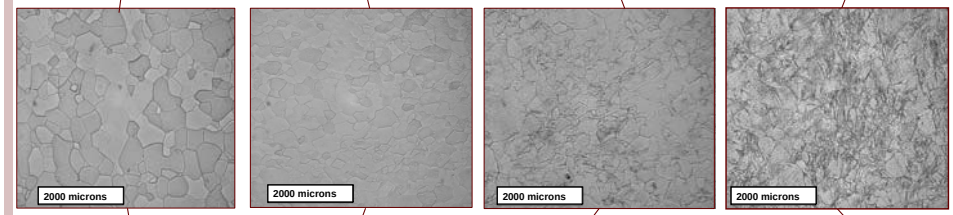
Microscopy of Grain Structure

VICKERS HARDNESS TESTER

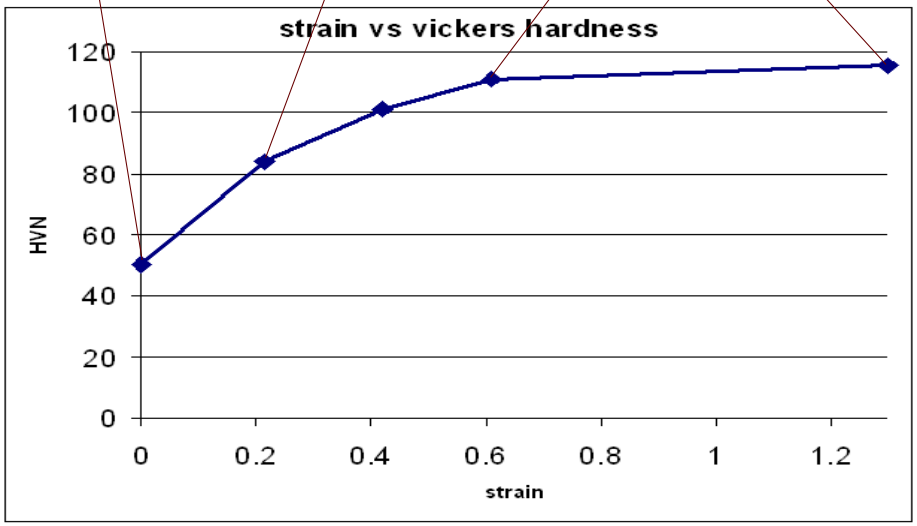
RESULTS & DISCUSSION



Evaluation of the strain vs. grain diameter data
- Increasing strain noticeably decreases the grain size of the niobium.
- Grain size determined using simple line intercept method.



Microscopy of the grain structure of the different sample strain under optical microscope. The grain size appears to decrease as the strain increases



Evaluation of the strain vs. the Vickers hardness of the samples
- The Vickers hardness shows a significant increase as the Nb strain is increased.
- e20=1 pass
- e40=2 passes
- e60=1 cycle
- e130=2 cycle

CONCLUSIONS

- 3 axis forging of Niobium is particularly beneficial in increasing strength and toughness through controlling grain size.
- Grain refinement increases strength and toughness.
- 3 axis forging is therefore an effective method of improving mechanical properties while not drastically altering bulk shape. (unlike conventional deformation techniques such as rolling and drawing etc).

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