# Mechanical proprieties and fatigue behaviour of the Ti10Ta alloy


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## 1- INTRODUCTION

Knowledge about the mechanical properties of the various types of Ti-Ta alloys is scarce ([1], [2], [3]), and does not cover the fatigue behaviour of the material. The documented information is insufficient, particularly for the specific case of Ti-Ta containing 10% (wt% - weight percentage) tantalum. The scarcity of information is even more striking when the Ti10Ta alloy is produced by the emerging process of LASER cladding. One of the few studies approaching Ti-Ta alloys produced by LASER cladding, is the one by Morgado *et al.* [4], in which an experimental study is developed to evaluate the wear behaviour of the Ti-30%Ta and Ti-52%Ta (wt%) alloys.

Concerning the production method used to fabricate the alloy studied in the present work, LASER cladding is a technique that, besides its additional application in the manufacturing of 3D components, finds an important use in the improvement of the mechanical properties of a material's surface through the addition of thin layers of different materials [5]. LASER cladding uses a LASER beam as the heat source to melt and deposit a thin layer of a specified material with the desired properties onto a substrate [6], [7].

## 2- OBJECTIVE

The objective of the present work is to study the mechanical behaviour of the Ti10Ta alloy produced by the LASER cladding process, including its fatigue behaviour through the determination of the S-N curves. This study also includes the manufacturing process, research the selected process parameters to the Ti10Ta alloy manufacturing process.

## 3 – MATERIAL AND MANUFACTURING PROCESS

To manufacture the Ti10Ta alloy that corresponded to the cladding material, titanium and tantalum powders were mixed in a weight percentage of 90% to 10%, respectively. These powders were supplied by *NewMet Ltd. – New Metals and Chemicals Ltd* in a range of 45-90 µm and a purity of 99.9%. Both powders were produced by the so-called hydrogenation-dehydrogenation (HDH) process, presenting a crushed particle shape. The powders were premixed and kept in an oven at 100ºC for 20 hours before putting them in the powder hopper. The mixture was then kept for two hours in the hopper of the powder feeder, shaking it by an internal mixer. Titanium grade 2 plates of 15x160x160 mm were used as the substrate onto which the powdered cladding/coating material was deposited by a 2.2kW diode pumped Nd:YAG LASER LASER cladding (Figure 1). It was used the cross strategy for layers deposition [8].

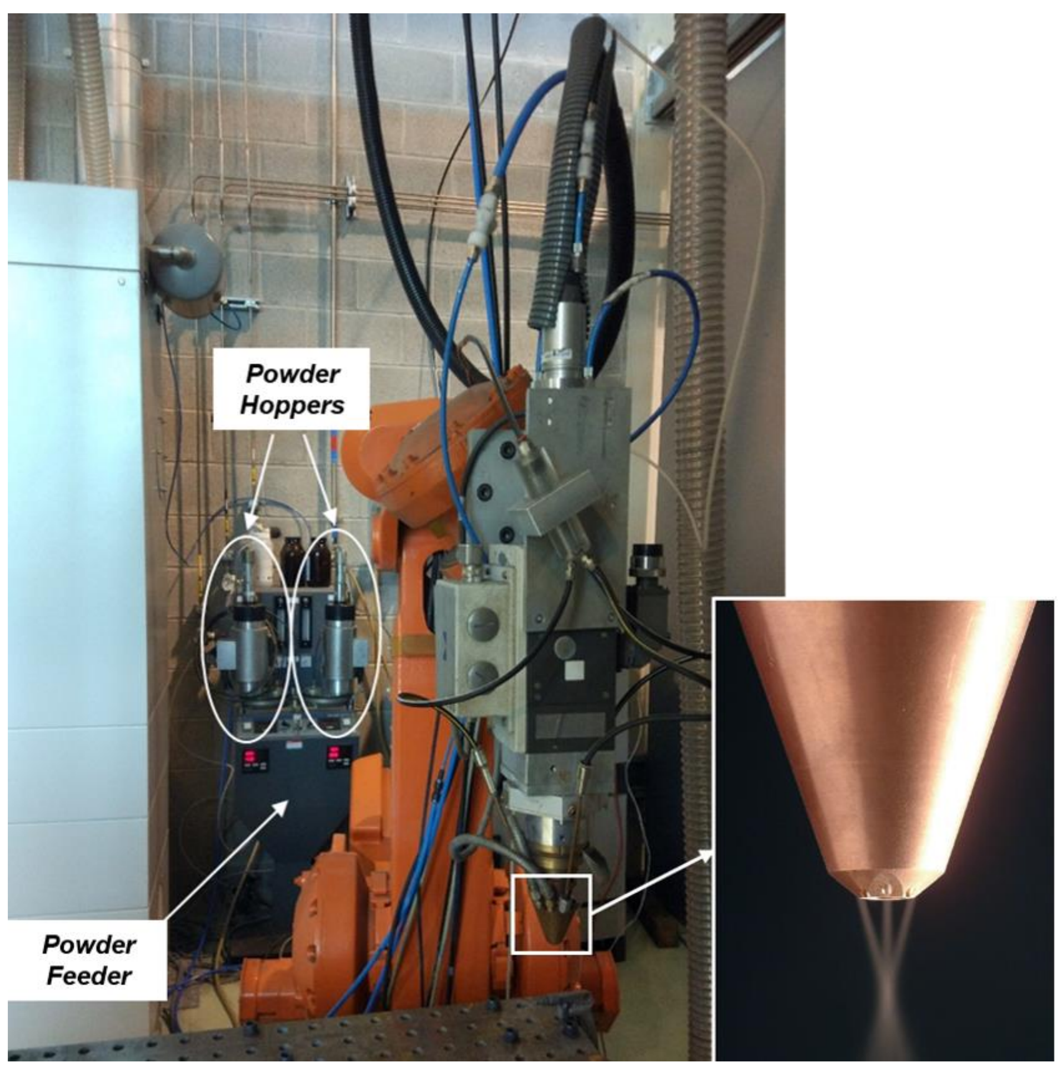


Figure 1– LASER cladding, with a three orificies coaxial nozzle. Equipment available in IK4-TEKNINKER Spain used to manufacturing the test specimens of Ti10Ta alloy.

From the two Ti10Ta blocks manufactured by LASER cladding shown in Figure 2, the 18 tensile specimens were extracted with their geometry normalized in accordance with *ASTM E8/E8M-09* [9]. The geometric dimensions of the mechanical test specimens are shown in Figure 3. Blocks cutting was performed by wire-EDM, with a brass wire, using an *ONA PRIMA E-400 + AWF* machine [8].

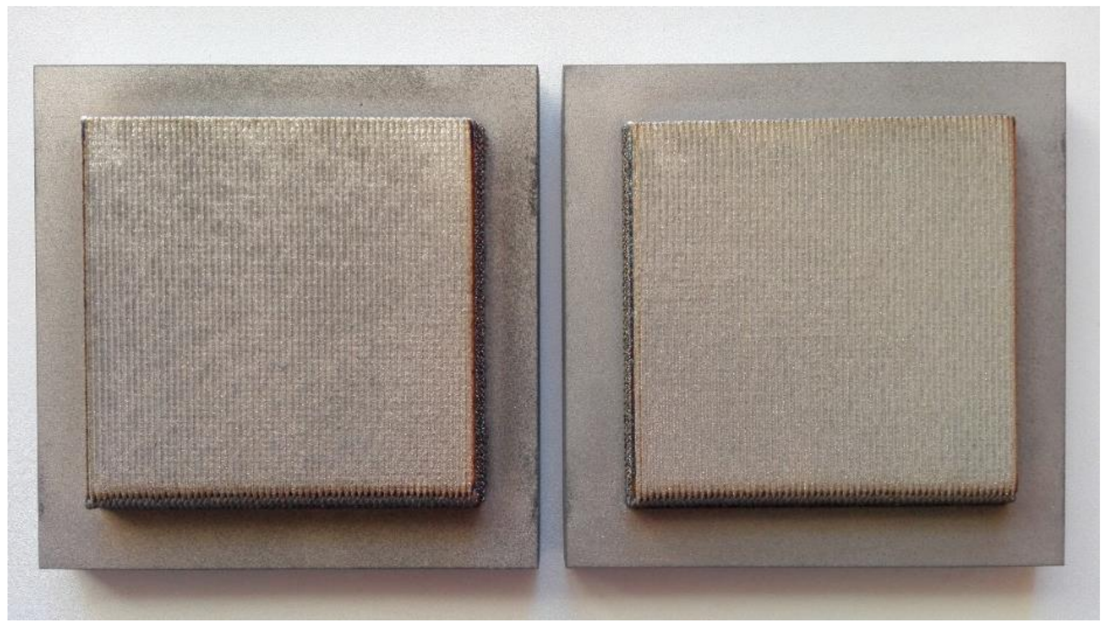

Figure 2- Ti10Ta blocks manufactured by LASER cladding, with 10x120x120 mm each.

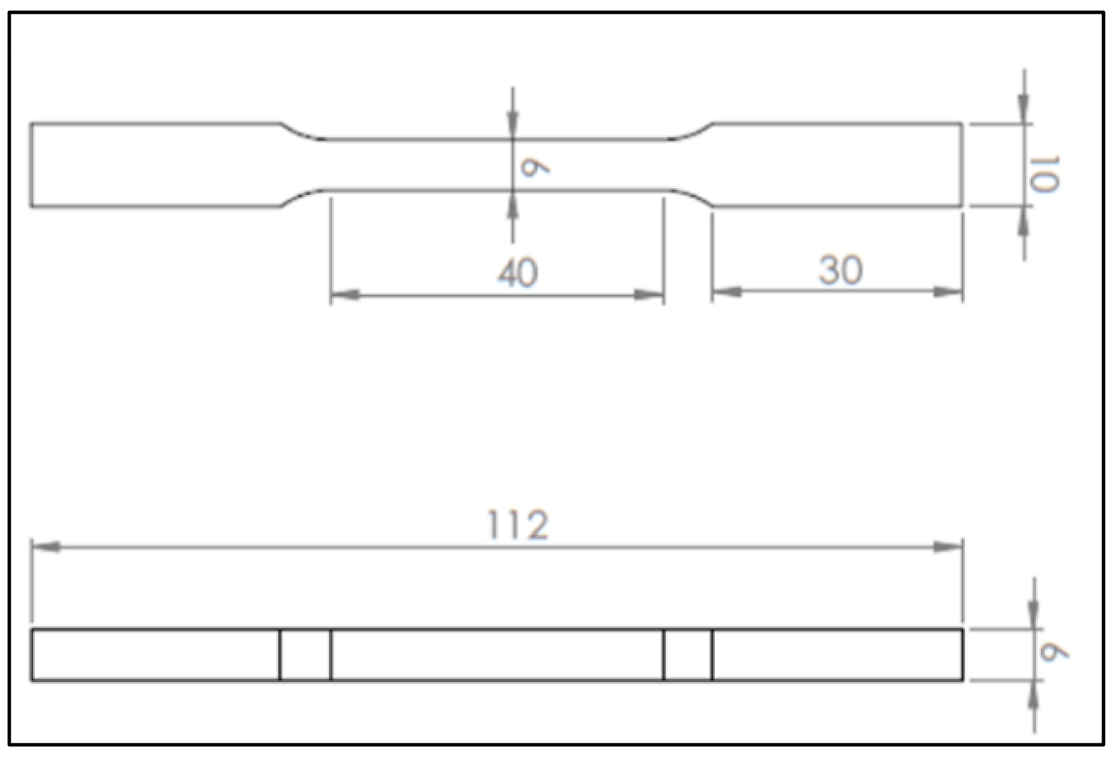


Figure 3- Geometric dimensions in millimeters of tests specimens for tensile and fatigue tests.

## 4 – EXPERIMENTAL PROCEEDING

After a grinding and polishing treatment as prescribed in the *ASTM E3-95* standard [10], Vickers micro hardness tests were performed on 3 samples of Ti10Ta, in accordance with *ASTM E384-16* [11]. These tests were executed in *Mitutoyo HM-112* Micro hardness 6 indentations being made on each sample.
Uniaxial tensile tests were performed over 6 specimens at room temperature, with a stroke rate of 3 mm/min, as prescribed by *ASTM E8/E8M-09* [9], using a *Shimadzu AG-50kNG* universal testing machine. The tests were also conducted at room temperature.
Additionally, fatigue tests were performed on the 12 remaining specimens, using an *Instron 1342* universal testing machine. The tests were also conducted at room temperature [9]. One of 3 levels of maximum stress (650 MPa, 550 MPa and 450 MPa) was used for each group of 4 specimens. The stress cycle applied was sinusoidal, a stress ratio of 0.5 being selected.

## 5 – RESULTS AND DISCUSSION

The results of the Ti10Ta tensile tests also provided data to represent in a bilogarithmic graphic that translates the true stress - true strain ($\bar{\sigma}$-$\bar{\varepsilon}$) relationship of the material in the uniform plastic deformation regime (Figure 4).

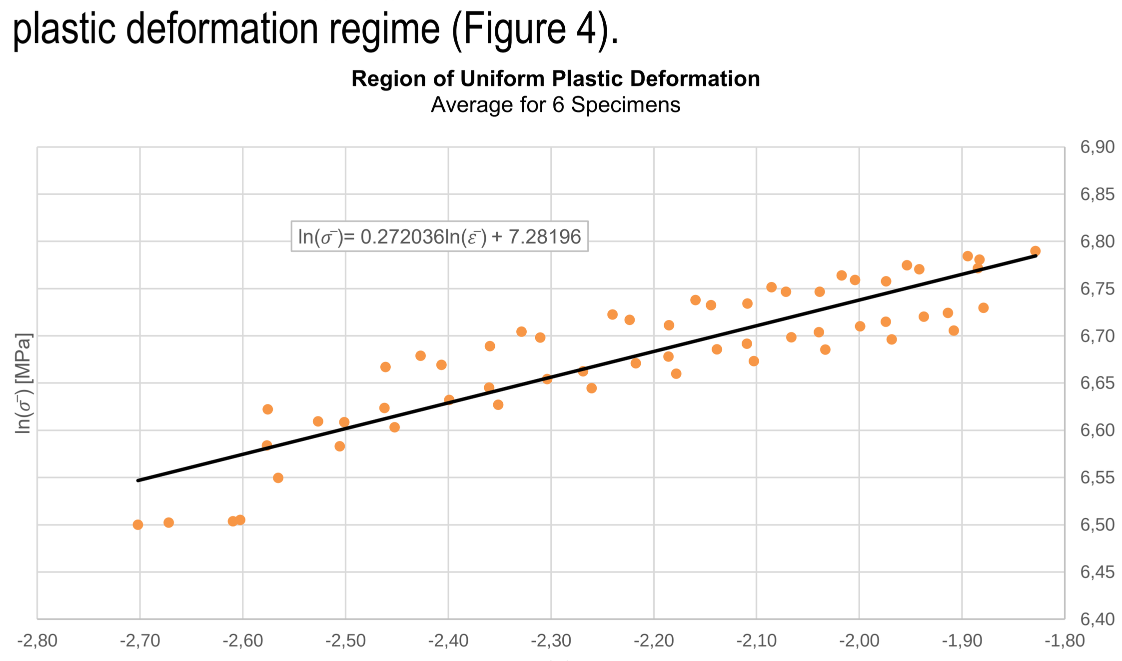


Figure 4– Bi-logarithmic representation of the uniform plastic deformation regime, as recorded by the true stress - true strain ($\bar{\sigma}$-$\bar{\varepsilon}$) curve, for determination of $n$ and $K$.

The analysis of the data (Figure 4) led to estimate the following values of **hardening and resistance coefficients,** respectively: $\boldsymbol{n \cong 0.272; K \cong 1454}$ **MPa**.
The small value measured for the Young's modulus (9.77 GPa in terms of true value) for the Ti10Ta alloy is similar to that exhibited by the human bone (5 to 30 GPa) [12].
The $S$-$N$ curve was determined from the tests performed, the relationship between the applied stress in MPa and the number of cycles during which fatigue fracture may be hoped to be averted may be translated by equation $\sigma_{max}N^{0.181} = 3369$.

## Conclusions

It was possible to conclude that the **Vickers hardness** of the Ti10Ta alloy, determined through the realization of micro indentation tests, presents the value of $\mathbf{255.2^{+4.4}_{-3.7}}$ **HV0.5**.
From the tensile curves (stress-strain curves), it was possible to verify that the material shows a ductile behaviour, with the following values being determined for some of its mechanical properties: **E= 9.77 GPa; $S_Y$: 642 MPa; Engineering yield strain: 0.0771 (7.71%); $S_t$= 735 MPa; Engineering uniform strain: 0.164 (16.4%); Strain after fracture: 0.168 (16.8%); Cross sectional area reduction: 0.228 (22.8%).**

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