Nd:YAG Pulsed Laser Welding of Thin Sheet of Tantalum

Arthur Maximo[1], Dr. Wagner de Rossi[2], Dr. Lincoln Silva Gomes[1], Mauricio Ogawa[1]

[1]**Centro de Tecnologia SENAI Solda** – Rua São Francisco Xavier, 601 – Maracanã – Rio de Janeiro; ZIP Code: 20550-011
[2]**Instituto de Pesquisas Energéticas Nucleares** – Av. Prof. Lineu Prestes, 2.242 – Butantã – São Paulo; ZIP Code: 05508-000

INTRODUCTION

Tantalum is known for its resistance to corrosion by acids. It's attacked only by hydrofluoric acid, containing the fluoride ion or by alkaline fusion. Tantalum is widely used in electronics, mechanical, optical and medicinal areas (AGULYANSKY, 2004).

Laser welding have been successfully applied in automotive, aerospace and mechanical industries (DAS NEVES et al., 2010; VENTRELLA et al., 2012). Thin sheet welding need a precise control of energy, due the low mass amount to melt and the difficult is increased in material with poorly thermal conductivity like tantalum. Pulsed laser welding is preferred for applications that need a very precise control of energy (DULEY, 1999; STEEN, 2005).

OBJECTIVE

In this work, the objective is to develop technology laser microwelding in thin sheets of tantalum to achieve a framework of technical and scientific knowledge about the process, understanding the metallurgy and weldability of advanced material tantalum in the shape of thin sheets using laser for applications in nuclear, chemical, aerospace and O&G industries.

METHODS AND MATERIALS

For the tests, Tantalum sheets with 100 µm of thickness were cut in size of 100 x 50 mm and welded in overlap joint configuration. The **Figure 01** show schematic diagram of machine configuration for that welding, which works with focal length of 200 mm.

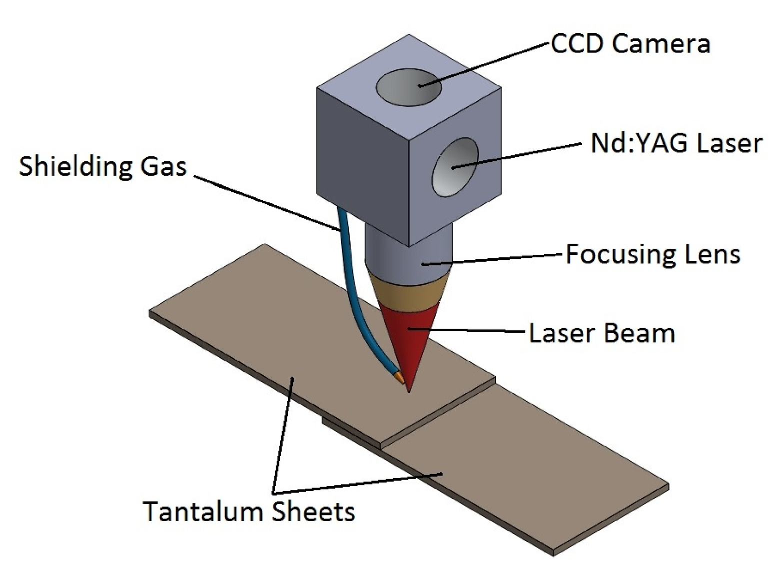

Figure 01: schematic diagram of Nd:YAG pulsed laser welding system.

Table 01 shows the results obtained in X-ray fluorescence analysis performed for obtain the chemical composition of the that material.

Table 01: chemical composition on tatalum (weight in %)

Element	Ta	Fe
%	99.9 ± 0,1	0.04 ± 0,02

In the welding of thin sheets is extremely important to use a device that fixes the sheets in the welding position. The samples were welded into a device to secure the attachment, avoiding lack of contact between the sheets and excessive distortion. The arrangement of plates in the device can be seen in **Figure 02**.

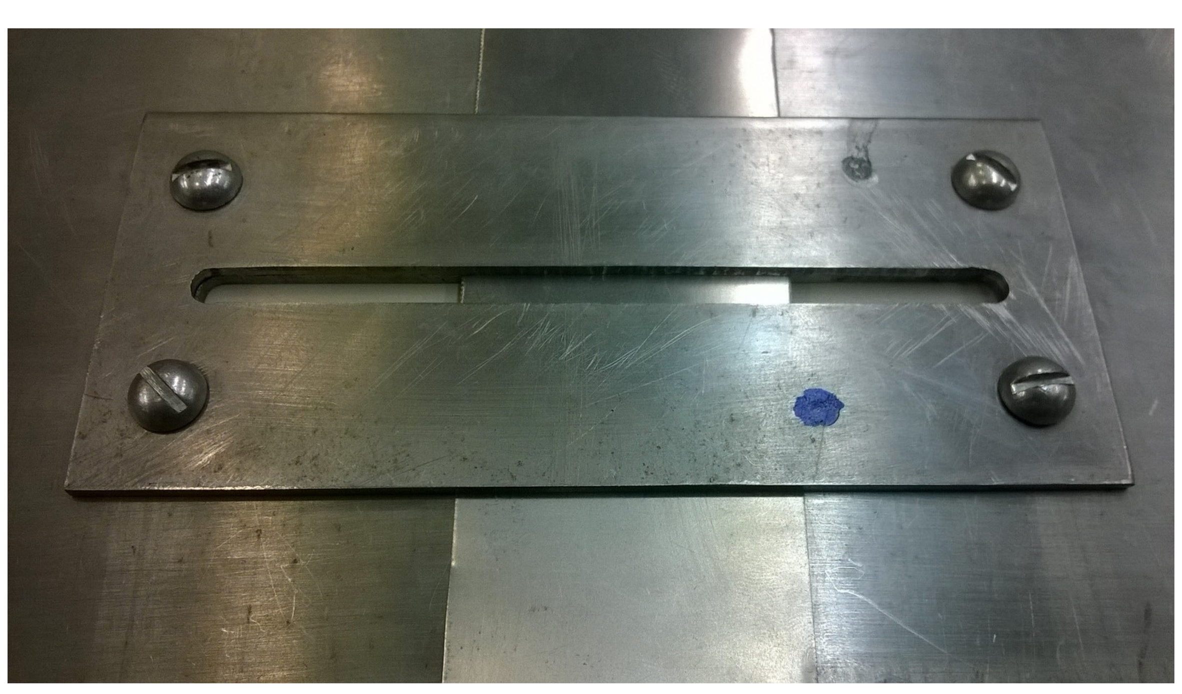

Figure 02: fixing system with the sheets positioned.

Were performed preliminary tests of weldment, based in another results presents in the literature, to determine an interval of power densities in order to avoid lose material using a higher power density or produce a fragile seam using a lower power density. Those test showed a better results in the interval of power densities between 24.2 and 35.7 MW/mm².

Some parameters shows less influence in the welding. Those parameters were fixed in this study and are showed in **Table 02**:

Table 02: parameters that were fixed to perform this study.

Parameter	Argon Flow Rate (l/min)	Welding Speed (mm/s)	Repetition Rate (Hz)	Incident Beam Diameter (µm)	Welding Angle (°)
Value	12	2,83	8	180	90

Table 03 shows the parameters that were varied for each sample, respecting the interval of power density encountered in the preliminary tests of weldment.

Some parameters are set direct in the machine control, for example, pulse energy and pulse duration. Other parameters are results of combination of other parameters, like power density and the overage heat input.

Table 03: parameters that were varied to perform this study.

Sample	Pulse Energy (J)	Pulse Duration (ms)	Power Density (MW/mm²)	Overage Heat Input (J/mm)
01	4	6.5	24.2	12
02	4.5	6.5	27.2	13.5
03	5	6.5	30.2	15
04	4	6	26.2	12
05	4.5	6	29.5	13.5
06	5	6	32.8	15

RESULTS AND DISCUSSION

The **Figure 03** shows the cross-section of the weld seams. That visual analysis was performed by optical microscopy with image analysis system.

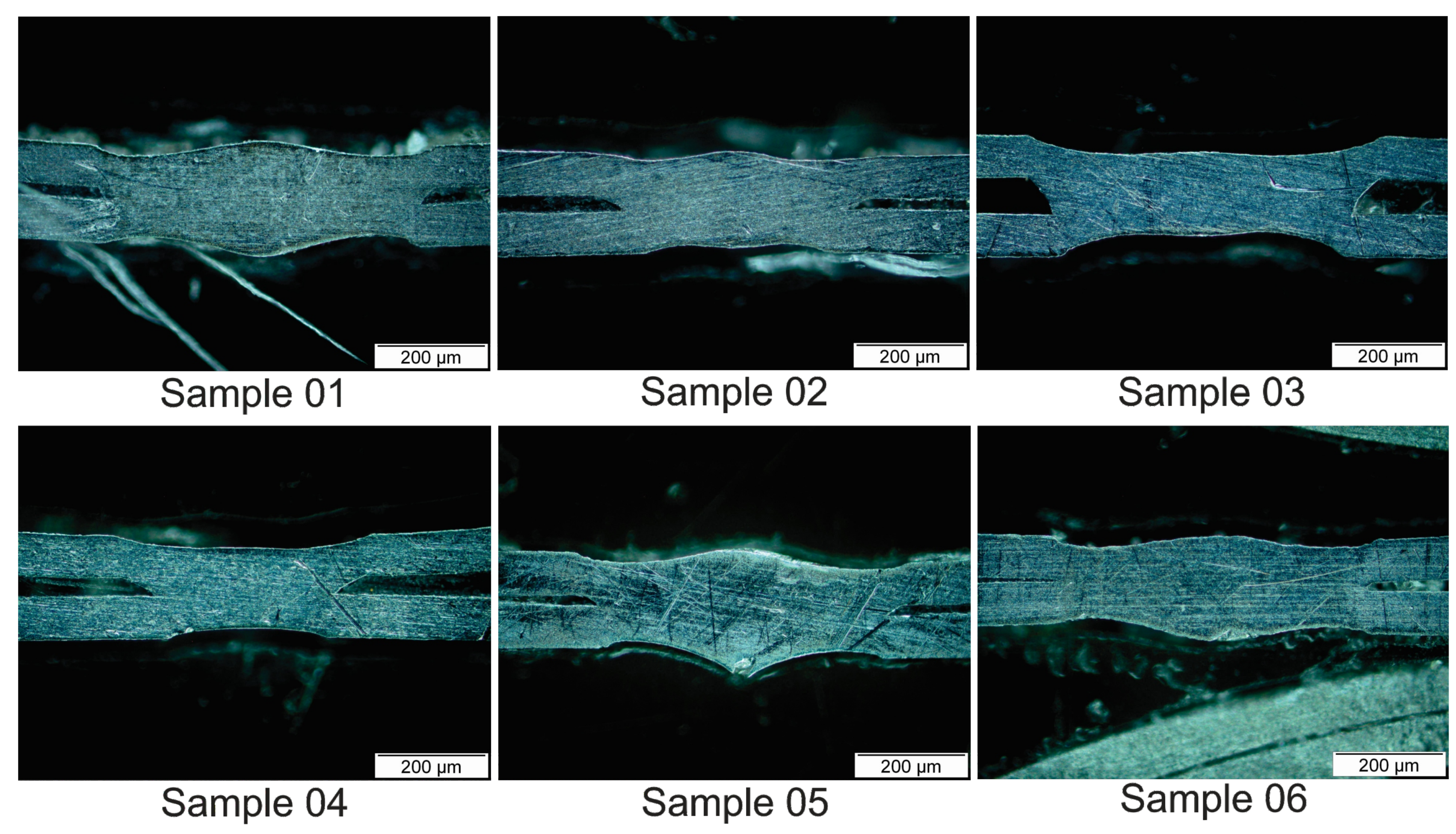

Figure 03: cross-section of weld seams.

All seams presented joining region, what is expected due a previous study performed to determine a better interval of power densities to work with that material.

All seams presented loss of material, probably by evaporation, in the surface and in the root. The loss of material is due a combination of high melting temperature and low thermal conductivity, if compared to another material that are welded for special applications, like aluminum and copper.

The samples that presented bigger gap between the sheets also presented bigger cavity in the surface and the root.

Is possible to note that the seams have approximately the same width in the surface and in the root. The Samples 03 and 04 due probably to distortion couldn't perform a good conduction of heat to the lower sheet and that resulted in a decreased thickness seam. Quantitative analyses of those facts are showed in the **Table 04**.

Table 04: overage width of weld seams.

Sample	01	02	03	04	05	06
Overage Width (µm)	644	437	591	394	569	637

CONCLUSIONS

As already observed in other studies laser welding of sheet with 100 µm of thickness is possible and often offers more benefits than other conventional processes due to their features like high power density and low heat input. Could be observed a very high sensitivity of the weld seam to the presence and size of the gap between the sheets, which had already been observed in another studies (KAWAHITO et al., 2007) that indicate that the larger the gap between the elements to be welded, the greater the concavity on the surface of the weld bead, since the molten metal has sufficient to fill the region of the gap, a fact which occurred at time these samples. This is due to the fact that the gap between the sheets can act as a stress concentrator in the connection line region.

This study shows how great the impact of the distortion in the welding of thin sheets is. Could be observed that for welding of thin sheets that is very important to use an efficient system to fix the sheet, in order to keep the sheets in the position and avoid the distortion.

Is possible to observe how is important perform preliminary tests for materials used in special applications, in order to determine what is the range of welding parameters that material will present the best results.

Due to the need for precise control of applied energy in the welding process for thin sheet, pulsed laser welding showed greater applicability to thin sheets of tantalum.

REFERENCES

- AGULYANSKY, A.; **"The Chemistry of Tantalum and Niobium Fluoride Compounds"**. Ed. Elsevier, 408 p., 2004.
- DAS NEVES, M. D. M.; LOTTO, A.; BERRETTA, J. R.; DE ROSSI, W.; JUNIOR, N. d.; **"Microstructure development in Nd:YAG laser welding of AISI 304 and Inconel 600"**. Welding International, v. 24, 2010, p. 739-748.
- VENTRELLA, V. A.; BERRETTA, J. R.; DE ROSSI, W.; **"Pulsed Nd:YAG Laser Welding of Ni-Alloy Hastelloy C-276 Foils"**. Physics Procedia, v. 39, 2012, p. 569-576.
- DULEY, W.W.; **"Laser Welding"**. Ed. John Wiley & Sons, Estados Unidos, p. 251, 1999.
- STEEN, W.M.; **"Laser Material Processing"**. Ed. Springer, Estados Unidos, p. 408, 2005.
- KAWAHITO, Y.; KITO, M.; KATAYAMA, S.; **"In-process Monitoring and Adaptive Control for gap in Micro butt Welding with Pulsed YAG Laser"**, Journal of Applied Physics, v.40, p. 183-190, 2007.