Pulsed laser welding – case study

Background

In applications where energy input has to be strictly controlled, such as in welding of sensitive electronic components or medical devices, pulsed laser welding often provides the best option. In laser welding the total energy input and its spatial distribution can be controlled independently. This means that a certain amount of energy can be focused to a small spot size of the order of tens of microns, which due to high power density can induce local vaporisation or ablation of the material. Conversely the same energy can be spread across a larger area, resulting in low power density, which is used in conduction welding. Additionally in pulsed laser welding the energy input can be also controlled temporally. In this case the emission on-time is applied periodically in short pulses, which results in very little lateral thermal conduction of the heat to the component. The length of pulses can vary from 10^{-2}-10^{-15} of a second, depending on the application and laser source.

This opens a broad range of applications where pulsed lasers enable fast processing, high accuracy and reliability. In Figs.1-4 some examples of using pulsed laser processing for high precision composite machining, extremely highly productive drilling or low heat input spot welding are shown.

Fig.1: *Pulsed laser machining of carbon fibre reinforced composite*

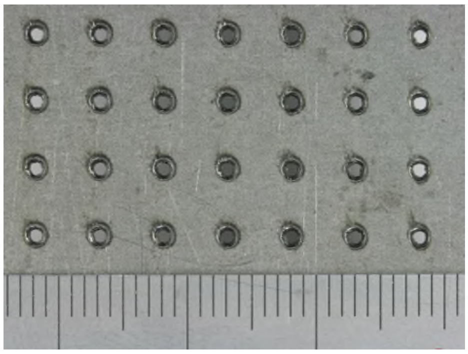

Fig.2: *Series of pulsed laser drilled holes in 0.8 mm thick steel sheet*

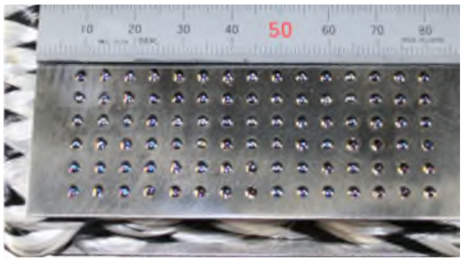

Fig.3: *Series of spot welds in Ti – composite joint*

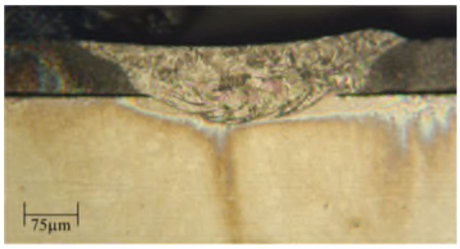

Fig.4: *Cross section of micro-spot lap joint in stainless steel*

Project scope

In this project the feasibility of joining elements of a medical device was investigated. As is often the case in medical industry, here the main challenge was to weld different materials with dissimilar properties and on top of that the process should ensure minimum energy input and maximum reliability. There were also certain quality requirements and mechanical performance that the joint had to satisfy.

Two different configurations of materials were studied:

- Oxygen-free copper wire coated with silver welded to oxygen-free copper tube coated with gold
- Oxygen-free copper wire coated with silver welded to stainless steel ring

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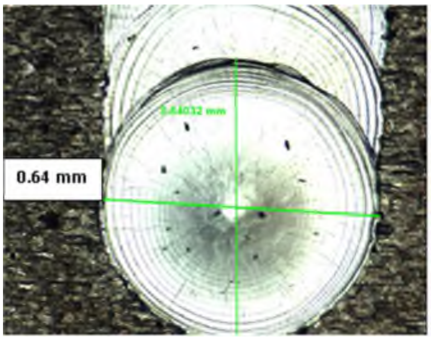

Fig.5: *Weld profile at 75% overlap*

The main objective was to apply a precise amount of laser energy required to join the components in order to ensure sufficient strength, but without excessive heating, which could have a detrimental effect on the substrate and could also promote formation of intermetallic compounds. To facilitate these requirements a careful selection of welding parameters was investigated. In pulsed laser welding the melting characteristics can be controlled by tailoring the pulse parameters, as well as spot size, frequency of pulsing and a rate of overlap of subsequent spots. In Fig.5 the effect of overlap rate on weld profile is shown.

Both material configurations required extremely different welding conditions, due to differences in thermal properties. The highly conductive and heat-dissipating copper tube, in the first case, required a rapid thermal cycle and therefore application of laser energy in order to weld the two materials. In the second case, on the other hand, the stainless steel ring, having a thickness of 300 µm, required much less energy before its degradation occurred than in case of the copper wire. However, a precise control of the energy input, spot size and laser position, enabled the development of conditions suitable for successful joints in both cases as shown in Fig.6 and Fig.7.

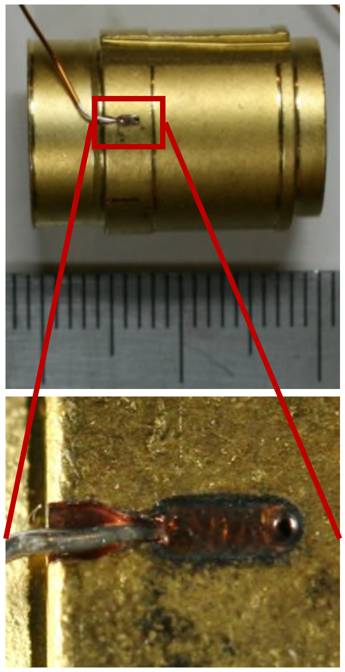

Fig.6: *Silver-coated copper wire welded to gold-coated copper tube*

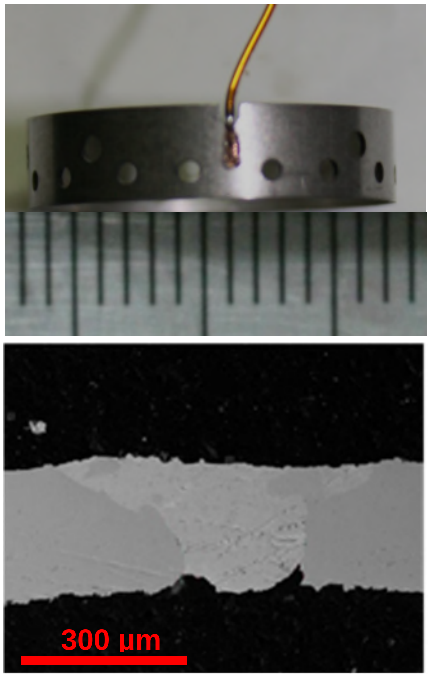

Fig.7: *Silver-coated copper wire welded to stainless steel ring*

Summary

In this study a pulsed laser was used to weld delicate components of a medical device. Precise control of the heat and rapid heating and cooling, which is characteristic for pulsed operation of laser, ensured suitable welding conditions for both material configurations. The achieved joints exhibited satisfactory mechanical properties and robustness, as well as good aesthetic appearance.

Acknowledgement

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