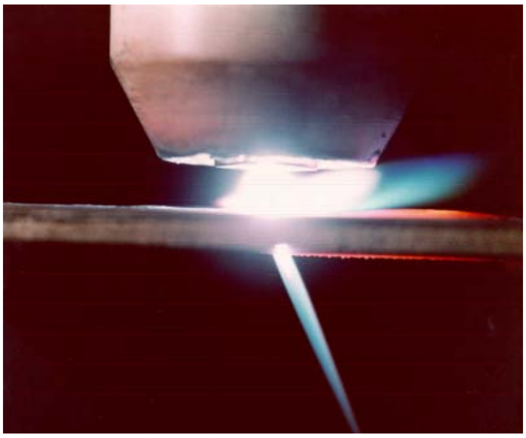
PR10569 **APRIL 2006**

HIGH PRODUCTIVITY ARC AND LASER WELDING OF TITANIUM AND TITANIUM ALLOYS

For: A Group of Sponsors



Keyhole plasma welding

Surface appearance of MIG butt weld made using G-coat wire

Summary:
Recent advances in welding processes and equipment offer potential productivity advantages for the welding of titanium and titanium alloys. These include:

- Advanced TIG and plasma welding.
- Pulsed MIG welding with novel filler wire.
- High power laser and hybrid laser /arc welding.

The objective of the proposed programme of work is to demonstrate the high productivity benefits achievable with the advanced arc and laser processes, whilst maintaining high weld quality levels. It will also establish practical guidelines to facilitate the industrial implementation of these processes for a range of applications. Additionally, alternative methods of excluding the atmosphere from the weldment area, with the aim of reducing weld joint set-up time, will also be investigated.

BACKGROUND

The advantageous properties of titanium alloys in terms of low density, high strength and corrosion resistance in many environments are well recognised. In particular titanium alloys have found widespread exploitation for aerospace use. Furthermore titanium alloys are increasingly attractive for a range of other applications including process piping and structural fabrication in the offshore, defence and chemical industries. However, a significant factor in the choice of metals is the ease and cost of fabrication, as well as the technical merits of any alternative material. Although it is the favoured process, TIG welding is relatively slow making the fabrication costs too high for some applications. A further consideration which affects fabrication costs is the requirement to encapsulate the Ti weldments in an inert environment to prevent contamination during welding. Thus, there is a demand for higher productivity fabrication methods in which weld quality is not compromised.

Recent advances in welding processes and equipment offer potential productivity advantages for the welding of titanium and titanium alloys as follows:

- **High frequency pulsed TIG welding**

The high frequency pulsed TIG welding technique, developed by VBC, produces a constricted, deeply penetrating arc which can be used to reduce heat input. This makes it possible to weld titanium without the need for a trailing gas shield.

- **TopTIG™ welding**

This TIG process technique, developed by Air Liquide, utilises filler wire fed directly through the welding torch nozzle directly into the arc. This is claimed to improve the weld deposition efficiency which can exploited to improve the welding speeds attainable with the mechanised TIG process.

- **Keyhole plasma welding**

Modern plasma equipments provide precise control of the welding parameters, thus giving better process repeatability. Using the keyhole mode, single pass welding of up to 16mm thick titanium alloy is possible using a square edge close butt joint preparation.

- **Pulsed MIG welding**

Recently a novel titanium wire has been produced that is claimed to result in improved arc stability and reduced spatter. This has been achieved by the use of a novel wire production process that modifies the wire surface, together with the use of optimised pulse parameters. Significantly higher metal deposition rates are possible compared with TIG welding.

- **Keyhole and hybrid laser welding**

The latest addition to the high power laser family is the Yb fibre laser, which combines high powers, good beam quality and the flexibility of optical fibre delivery. Both Nd:YAG and Yb fibre laser sources have been shown to weld titanium at appreciable speeds, at thickness up to 10mm. Additional benefits, primarily related to gap bridging capability and productivity, may be realised by using the hybrid laser/arc welding process.

Benefits

- Up to ten-fold increase in welding productivity compared to manual TIG welding.
- Reduced susceptibility to weld metal porosity in the case of keyhole plasma welding.
- Simplification of joint preparation in the case of keyhole plasma and laser welding.
- Decreased consumption of filler wire in the case of keyhole plasma and laser welding.
- Significant increase in metal deposition rates in the case of pulsed MIG welding.
- Lower distortion levels and improved manufacturing accuracy and flexibility, particularly in the case of laser welding.
- Shorter arc times leading to decreased operator exposure to welding fume and ozone emission.
- Reduced joint set-up times by using more flexible and efficient trailing gas shield systems.

OBJECTIVES

- To determine the productivity benefits achievable for the welding of titanium alloys in plate and pipe form using advanced arc and laser welding processes.
- To assess the integrity of titanium alloy welds made using high productivity welding procedures.
- To develop more efficient and flexible trailing gas shielding systems.
- To establish practical guidelines to facilitate the industrial application of high productivity welding techniques.

Work Programme

Materials

The suggested base materials will include commercial purity and Ti-6Al-4V grades in both plate and pipe form and in thicknesses ranging between 3 and 15mm. TIG and plasma welding will be carried out using matching filler wires, i.e. AWS ERTi-2 and ERTi-6Al-4V (or ELI grade). The novel wire in matching base material composition, i.e. G-coat supplied by Daido Steel, will be used for MIG and hybrid laser/arc welding.

Welding Equipment

Arc welding will be performed using the following equipments:

- Interpulse 150 MK2 welding system.
- TopTIG™ welding system.
- Polysoude 600PC plasma welding system.
- Daihen Inverter 350 MIG power source.

For the laser experiments, two laser sources could be used, depending on the thickness range of interest:

- 7kW IPG Yb fibre laser.
- 4kW Trumpf lamp-pumped Nd:YAG laser.

Welding Trials

The following processes will be evaluated:

- High frequency TIG welding.
- TopTIG™ welding.
- Keyhole plasma welding.
- Pulsed MIG welding.
- Keyhole fibre delivered solid state laser welding.
- Hybrid laser/arc welding

For each process, butt welding procedures will be developed for both plate and pipe, in both material types and in a range of thicknesses. All welding will be carried out in the PA position. Both manual and mechanised modes of operation will be used as appropriate. For MIG welding, fillet welds in the PB position will also be performed.

The welding characteristics of the alternative welding processes will be assessed in terms of:

- Joint preparation requirements (fit up tolerances etc).
- Joint cleanliness requirements.
- Shielding requirements to avoid atmospheric contamination.
- Welding process stability (spatter, arc stability, wire feeding etc).
- Welding speed and productivity.

Weld Assessment

The completed welds, both faces, will be subject to a visual assessment, including temper colour, and a radiographic examination.

Mechanical testing will be carried out in generally accordance with ASME IX or EN15614-5. Selected welds will be subject to a detailed metallographic examination and metallurgical characterisation.

Trailing gas shield methods

Alternative methods of eliminating the atmosphere from the immediate vicinity of the weldment (surrounding and following the molten weld pool) will be developed and assessed. The following approaches will be investigated:

- The use of flexible and conformable trailing gas shield systems
- The use of focussed delivery of liquid argon to achieve atmospheric displacement in the environment surrounding and following the molten weld pool.

Application Guidelines

Based on the results obtained detailed practical guidelines will be developed which will facilitate industrial exploitation of the advanced arc and laser processes for a range of applications.

DELIVERABLES

- Qualified welding procedures based on the use of advanced welding processes.
- Detailed assessment of welding process performance.
- Database of qualification test results.
- Guidelines to assist the application of advanced welding processes.
- Improved methods for trailing shields and guidance on their implementation.

PROJECT PRICE AND DURATION

The proposed programme of work is estimated to cost £240,000. Eight Sponsors are sought, each providing a contribution of £15,000 per annum. This project will take two years to complete.

TWI will initiate the project when four Sponsors have agreed to support the project, although the scope of work will be reduced if the planned number of Sponsors are not found.

LAUNCH INFORMATION

Date: **Wednesday 28 June 2006**
Time: **To be confirmed**
Venue: **TWI Ltd, Granta Park, Great Abington, Cambridge CB1 6AL**

FURTHER INFORMATION

Interested parties are requested to contact TWI staff as listed below:

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