

**Erick Alejandro Gonzalez Olivares**

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**Hybridization between Plasma and MIG  
Processes in a Tandem Configuration  
for Aluminum Joints**

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Herausgeber: Prof. Dr.-Ing. U. Reisgen

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**Hybridisierung zwischen Plasma- und MSG-  
Prozessen in einer Tandemkonfiguration für  
Aluminiumverbindungen**

Von der Fakultät für Maschinenwesen der Rheinisch-Westfälischen Technischen Hochschule Aachen zur Erlangung des akademischen Grades eines Doktors der Ingenieurwissenschaften genehmigte Dissertation

vorgelegt von

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### **III. List of abbreviations**

AC	Alternating Current
ASTM	American Society for Testing and Materials
BM	Base Metal
CTWD	Contact Tip-to-Workpiece Distance
DC	Direct Current
DCEN	Direct Current Electrode Negative
DCEP	Direct Current Electrode Positive
DIN	Deutsches Institut für Normung
EN	Europäische Norm
HAZ	Heat Affected Zone
MIG	Metal Inert Gas
PMZ	Partial Melted Zone
SSC	Static Source Characteristic
SAC	Static Arc Characteristic
TIG	Tungsten Inert Gas
VPPA	Variable Polarity Plasma Arc
WM	Weld Metal

**IV. List of symbols**

$L_{el}$	Wire-electrode extension.....	[mm]
$L_a$	Arc extension.....	[mm]
$R^2$	Coefficient of determination.....	[-]
$a$	MIG arc length.....	[mm]
$V_M$	MIG voltage .....	[V]
$I_M$	MIG current .....	[A]
$I_P$	Plasma current .....	[A]

## V. Abstract

Welding is one of the key manufacturing processes in the metal mechanic industry, for this reason, any improvement in quality and efficiency leads to enhanced overall productivity. On the other hand, aluminum alloys are increasingly becoming a fundamental part of the task of reducing the weight of metal structures in means of transport, as a means of reducing CO<sub>2</sub> emissions. The union or hybridization between two welding processes as a means of increasing productivity in joint applications is a widely used and studied technique. An alternative hybrid process that is being studied in recent years is the Plasma-MIG process in a tandem configuration. This process is characterized by having a torch arrangement on the same axis (paraxial) with a distance between them. With this configuration it is guaranteed that each one of its processes maintains its unique properties. However, problems and phenomena such as current transfer between the welding arcs which affects the measurement of electrical signals have been vaguely commented on in the scarce literature on the subject.

In this investigation the Plasma-MIG in tandem configuration is characterized by gradually bringing their torches closer together in order to observe the behavior of their electrical signals as the arcs are coupled. In addition, the Plasma process is configured with direct and alternating current, in order to observe the need for cathodic cleaning when the hybrid process is used in aluminum alloys. Once the phenomena that occur when hybridizing the processes are known, the interaction between the welding processes is studied, from an energy point of view. The objective is to observe if there is an exchange of current between the welding processes and, if it exists, how this affects the welding processes. The results showed that it is possible to couple the Plasma and MIG processes in a paraxial (tandem) configuration to make aluminum joints, with a stable arc and greater penetration than the single processes. The establishment of a "current path" between the MIG and plasma arcs was noticed, which allows the current flow between the welding process, influencing directly the MIG arc length behavior. Moreover, it was concluded that it is not necessary to configure alternating current in the Plasma process to weld aluminum, because the MIG process does the cathodic cleaning. It was also concluded that an external magnetic field is not necessary to stabilize the behavior of the welding arcs. The joints of 10 and 15 mm

thickness presented good surface appearance, although the hybrid process demonstrated superiority only for the 15 mm thick joints.

## Kurzfassung

Schweißen ist einer der wichtigsten Herstellungsprozesse in der Metallmechanik. Aus diesem Grund führt jede Verbesserung der Qualität und Effizienz zu einer Steigerung der Gesamtproduktivität. Auf der anderen Seite werden Aluminiumlegierungen immer mehr zu einem grundlegenden Bestandteil der Aufgabe, das Gewicht von Metallstrukturen in Transportmitteln zu reduzieren, um so die CO<sub>2</sub>-Emissionen zu verringern. Die Vereinigung oder Hybridisierung zwischen zwei Schweißprozessen als Mittel zur Produktivitätssteigerung bei Verbindungsanwendungen ist eine weit verbreitete und untersuchte Technik. Ein alternativer Hybridprozess, der in den letzten Jahren untersucht wird, ist der Plasma-MIG-Prozess in einer Tandemkonfiguration. Dieses Verfahren zeichnet sich dadurch aus, dass die Brenner auf derselben Achse (paraxial) mit einem Abstand zueinander angeordnet sind. Mit dieser Konfiguration ist gewährleistet, dass jeder seiner Prozesse seine einzigartigen Eigenschaften beibehält. Probleme und Phänomene, wie z.B. die Stromübertragung zwischen den Schweißlichtbögen, die die Messung der elektrischen Signale beeinträchtigt, sind jedoch in der spärlichen Literatur zu diesem Thema nur vage kommentiert worden.

In dieser Untersuchung wird das Plasma-MIG in Tandemkonfiguration dadurch charakterisiert, dass sich ihre Brenner allmählich einander annähern, um das Verhalten ihrer elektrischen Signale bei der Kopplung der Lichtbögen zu beobachten. Darüber hinaus wird der Plasmaprozess mit Gleich- und Wechselstrom konfiguriert, um die Notwendigkeit einer kathodischen Reinigung zu beobachten, wenn der Hybridprozess bei Aluminiumlegierungen eingesetzt wird. Sobald die bei der Hybridisierung der Prozesse auftretenden Phänomene bekannt sind, wird die Wechselwirkung zwischen den Schweißprozessen unter energetischen Gesichtspunkten untersucht. Ziel ist es, zu beobachten, ob es einen Stromtausch zwischen den Schweißprozessen gibt und, falls vorhanden, wie sich dieser auf die Schweißprozesse auswirkt. Die Ergebnisse zeigten, dass es möglich ist, die Plasma- und MIG-Prozesse in einer paraxialen (Tandem-)Konfiguration zu koppeln, um Aluminiumverbindungen mit einem stabilen Lichtbogen und einer größeren Eindringtiefe als die Einzelprozesse herzustellen. Es wurde die Etablierung eines "Strompfades" zwischen dem MIG- und dem Plasmalichtbogen festgestellt, der den Stromfluss zwischen den Schweißprozessen

ermöglicht, was sich direkt auf das Längenverhalten des MIG-Lichtbogens auswirkt. Darüber hinaus wurde der Schluss gezogen, dass es nicht notwendig ist, Wechselstrom im Plasmaprozess zu konfigurieren, um Aluminium zu schweißen, da der MIG-Prozess die kathodische Reinigung übernimmt. Man kam auch zu dem Schluss, dass ein externes Magnetfeld nicht notwendig ist, um das Verhalten der Schweißlichtbögen zu stabilisieren. Die Verbindungen von 10 und 15 mm Dicke wiesen ein gutes Oberflächenaussehen auf, obwohl der Hybridprozess nur für die 15 mm dicken Verbindungen eine Überlegenheit zeigte.