

# **STUDIES ON UNDERWATER HYPERBARIC PULSED GAS METAL ARC WELDING**

by  
**V. R. KRISHNAN**

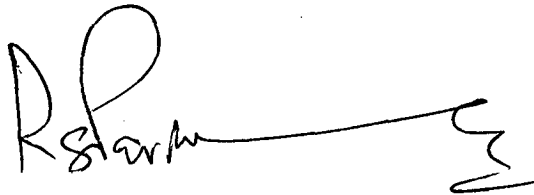
*A THESIS SUBMITTED  
IN FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
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## CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON UNDERWATER HYPERBARIC PULSED GAS METAL ARC WELDING", being submitted by Mr.V.R.Krishnan to the Indian Institute of Technology, Delhi, for the award of the degree of "Doctor of Philosophy" in Mechanical Engineering, is a record of the bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis which has reached the requisite standard. The results contained in this thesis have not been submitted, either in full or in part, to any other University or Institute for the award of any degree or diploma.



(Dr. R. S. Parmar),

Professor,

Department of Mechanical Engineering,

Indian Institute of Technology, Delhi,

Hauz Khas, New Delhi -110 016, INDIA.

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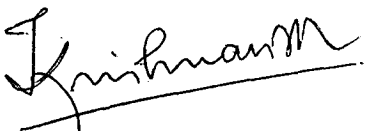
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## ABSTRACT

Dry underwater welding had been recognized as the possible technique for obtaining satisfactory weldments under water, as it avoided the presence of water completely. Of the various welding processes, gas shielded processes were preferred due to the absence of troublesome flux and slag that tended to reintroduce the problem of hydrogen absorption and slag inclusions. Among the two gas shielded arc welding processes, Gas Metal Arc Welding process (GMAW) was considered preferable due to its high productivity and due to some typical problems associated with Gas Tungsten Arc Welding process at elevated pressures. However, GMAW was not popular as it was thought to pose a number of technological problems related to arc stability and metal transfer. Though at pressures higher than 10 bar GMAW with current electrode negative polarity had been successfully demonstrated, the range of 2-10 bars was left unstudied as it was found to be difficult to hold a steady arc. The present investigation attempts to understand the reported difficulties in using GMAW in this pressure range of 2-10 bars, and to establish the suitable optimal operational envelopes so that the process could be proven to be employable for hyperbaric welding application. Since much information on the control of metal

transfer had been gained in recent times with pulsed GMAW, it was decided to use this knowledge to the present investigation also.

The experiments were carried out in two phases. In the first phase, diagnostic studies on the reported problems in the range of 2-10 bar were taken up. It was recognized that the occurrence of opposing plasma jets emanating from the weld pool resisted the droplet detachment leading to the instabilities in arc and metal transfer and that this problem could be overcome by maintaining a minimum arc length. Also, it was found that commercial grade argon gave broader operational envelope compared to the one offered by argon-CO<sub>2</sub> mixture and that DCEP was more suitable due to its better <sup>2</sup> control over the arc and transfer characteristics. Therefore, the second phase of the experiments were conducted with argon in order to gain comprehensive knowledge of the limits of critical parameters associated with pulsed GMAW with DCEP polarity.

Detailed investigations were carried out using V-I transients, high speed cinematography, profile projection, micro- and macrography, hardness survey and chemical analysis. The results of the investigations are presented in this thesis. It was found that, once the reason for the instability was eliminated, it was possible to obtain excellent spray or dropspray type of metal transfer with DCEP P-GMAW. There was no change in the preferred polarity as reported earlier. The burn-

off characteristics, the fusion characteristics, the bead characteristics, metallurgical/mechanical integrity of the weld deposits etc. were found to be satisfactory.

Based upon the results, it was concluded that pulsed GMAW could be considered as a viable and suitable welding process for use in hyperbaric welding applications, in the pressure range of 1-10 bars.

## LIST OF ABBREVIATIONS USED

### WELDING PARAMETERS

GMAM	:	Gas Metal Arc Welding
P-GMAW	:	Pulsed Gas Metal Arc Welding
DCEP	:	Direct Current Electrode Positive
I <sub>p</sub>	:	Peak Current, Ampere
I <sub>b</sub>	:	Base Current, Ampere
T <sub>p</sub>	:	Peak Time, milli second
T <sub>b</sub>	:	Base Time, milli second
T <sub>d</sub>	:	Total Time for droplet detachment, milli second
T <sub>pc</sub>	:	Critical Time for the detachment of the droplet during the peak pulse time
SCC	:	Short Circuit Current, Ampere
SCD	:	Short Circuit Detect Voltage, Volt
I <sub>mean</sub>	:	Mean Current, Ampere
Wfs, Vfs	:	Wire feed speed, metres/min.
V	:	Voltage, Volts
S	:	Stand off, mm
ms	:	milli seconds
mm/s	:	milli metres/second

### VISUAL OBSERVATIONS :

S	:	Short circuiting
T	:	Metal Transfer
A	:	Arc appearance

B : Bead appearance  
 F : Fume level

RELATIVE GRADATION :

1 : Very Bad  
 2 : Bad  
 3 : O.K.  
 4 : Very Good  
 5 : Excellent

BEAD CHARACTERISTICS :

P : Penetration, mm  
 W : Bead width, mm  
 R : Reinforcement, mm  
 A : Area of plate melted, mm<sup>2</sup>  
 A<sub>p</sub> : Area of deposited bead, mm<sup>2</sup>  
 b

% Dilution :  $\frac{A_p}{A + A_p} \times 100$

DF : Dilution Factor = % Dilution / (I X V)

Hv<sub>10</sub> : Hardness, Vicker's with 10 kg load

HAZ : Heat Affected Zone

T No : Trace Number

R No : Run Number

FPS : Frames Per Second in high speed cinematography

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