Ain Shams University

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MICROSTRUCTURE AND PROPERTIES OF TIG-WELDED JOINTS OF FULL-AUSTENITIC STEEL USING IMPULSE TRANSISTOR TECHNIQUE

BY

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STATEMENT

This dissertation is submitted to Ain-Shams University for the degree of Doctor of Philosphy in Mechanical Engineering.

The work included in this thesis was carried out by the auther in the " Institut für Füge/SchweiB Technik, Technische Universität West Berlin,from September 1983 to March 1986.

No Part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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- SUMMARY -

The aim of this work was dictated from the lack of knowledge existing among the previous literatures about the newly originated pulsed GTAW process, specialy its use as cracking eliminator.

The research is therefore aiming at studying the effect of variables of this process when applied to fully austenitic stainless steel on its cracking susceptibility. The pulse form variables (frequency, time ratio, pulse current, rest current, and current ratio with constant welding power) construct the core of this study.

The research starts with a study of the functional coherence between these variables, and their effects on the welding electrical work, power, and heat energy.

Considering the shape, size, and structure of the resulted welded bead, they are studied in this work at the three orthogonal reference planes of the bead, for different conditions of the pulse form varaibles.

The effects of these variables on the material cracking susceptibility are obtianed using the Fan-shape specimen as cracking test specimen, and are interpreted using their effects on the bead shape,size, and structure. The optimum conditions of the pulse form variables are determined on the basis of the maximum crack length.

The weld beads mechanical properties, e.g. microhardness, transverse tensile strength, longitudinal tensile strength, and impact energy absorption are determined and related to their macro - as well as micro-structures.

The high speed photography technique is used to obtain a cronograph for the solidification process of the pulsed GTAW, which helped in establishing a proposed mechanism for the crack formation when applying the pulsed GTAW for the Fan-shape specimen.

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- NOMENCLATURE -

Symbol		Unit		Definition
Ap	:	(mm^2)	:	Elevational sectional area of a pulse puddle.
Ar	:	(mm^2)	:	Elevational sectional area of a rest puddle.
c	:	(mm)	:	Maximum crack length.
Dp	:	(mm)	:	Pulse puddle depth.
Dr	:	(mm)	:	Rest puddle depth.
E	:	(mm)	:	Shift between weld bead centre line and cracking specimen centre line.
e	:	(mm)	:	Shift between weld bead centre line and the crack centre line.
F	:	------	:	Puddle form factor.
f	:	(Hz)	:	Pulse frequency.
G	:	(μm)	:	Grain size.
Har	:	(J/mm)	:	Arithmatic mean value of heat energy input per millimeter of specimen.
Hp	:	(J/mm)	:	Heat energy input during the pulse current duration per millimeter of specimen.
Hr	:	(J/mm)	:	Heat energy input during the rest current duration per millimeter of specimen.
Ht	:	(J/mm)	:	Total heat energy input during one complete cycle per millimeter of specimen.
HV	:	(N/mm^2)	:	Vickers micro-hardness values.
I	:	(A)	:	Steady (unpulsated) current.
Iar	:	(A)	:	Arithmatic mean value of pulsated current.

Ip	:	(A)	: Pulse current.
Ir	:	(A)	: Rest current.
i	:	(A)	: Instantaneous value of current.
L	:	(mm)	: Length of cracking test specimen.
lc	:	(mm)	: Instantaneous crack length.
lo	:	(mm)	: Overlapping length.
lp	:	(mm)	: Pulse puddle length.
lr	:	(mm)	: Rest puddle length.
ls	:	(mm)	: Progress of solidification front.
lw	:	(mm)	: Welding length.
Par	:	(watt)	: Arithmatic mean value of power.
Peff	:	(watt)	: Effective value of power.
Pp	:	(watt)	: Power of the pulse interval.
Pr	:	(watt)	: Power of the rest interval.
Pt	:	(watt)	: Total power per pulse cycle.
Rinter	:	(N/mm^2)	: Strength of solidification fronts interface.
Rul	:	(N/mm^2)	: Longitudinal ultimate tensile strength.
Rut	:	(N/mm^2)	: Transverse ultimate tensile strength.
r	:	(°)	: Grain orientation angle.
S	:	(mm/min)	: Welding speed.
$\overleftarrow{S}$	:	--------	: Sense of welding speed direction.
Sacc	:	(N/mm^2)	: Accumulated internal stresses of solidified part.
T	:	(s)	: Pulse periodic time.
t	:	(s)	: Time .
tp	:	(s)	: Pulse current duration.
tr	:	(s)	: Rest current duration.
t.S	:	(mm)	: Distance travelled by the electrode during a time (t).
tp.S	:	(mm)	: Distance travelled by the electrode during the pulse interval.
tr.S	:	(mm)	: Distance travelled by the electrode during the rest interval.

UL	:	(N.mm)	: Area under the curve of longitudinal tensile load-elongation.
UT	:	(N.mm)	: Area under the curve of transverse tensile load-elongation.
u	:	(N.mm)	: Impact absorped energy.
Var	:	(V)	: Arithmatic mean value of voltage.
Veff	:	(V)	: Effective value of voltage.
W	:	(J)	: Instantaneous value of work.
War	:	(J)	: Arithmatic mean value of work.
Wp	:	(J)	: Work done during pulse interval.
Wr	:	(J)	: Work done during rest interval.
Wt	:	(J)	: Total work done in a complete cycle.
wp	:	(mm)	: Pulse puddle width.
wr	:	(mm)	: Rest puddle width.
θ	:	(^{o})	: Puddles diversion angle.
θc	:	(%)	: Columnarity ratio.
θd	:	(%)	: Diameter ratio.
θi	:	(%)	: Current ratio.
θo	:	(%)	: Overlapping ratio.
θp	:	(%)	: Penetration ratio.
$(\theta p)p$	:	(%)	: Penetration ratio at a pulse puddle section.
$(\theta p)pH$	:	(%)	: Penetration ratio at a pulse puddle section with higher time ratio.
$(\theta p)pL$	:	(%)	: Penetration ratio at a pulse puddle section with lower time ratio.
$(\theta p)r$	:	(%)	: Penetration ratio at a rest puddle section.
$(\theta p)rH$	:	(%)	: Penetration ratio at a rest puddle section with higher time ratio.
$(\theta p)rL$	:	(%)	: Penetration ratio at a rest puddle section with lower time ratio.
θt	:	(%)	: Time ratio.
λ	:	(mm)	: Pulse pitch.
δ_L	:	(%)	: Longitudinal maximum strain.
δ_T	:	(%)	: Transverse maximum strain.
ϕ_L	:	(N/mm^2)	: Longitudinal static toughness.

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- ABBREVIATIONS -

Symbole:		Definition:
AFS	:	American Foundrymen's Society.
AIME	:	American Institute for Mechanical Engineers.
ASM	:	American Society for metals.
Auto.W	:	Automatic Welding.
Aust.WJ	:	Austeralian Welding Journal.
B.M.	:	Heat unaffected zone of the Base Metal.
BWJ	:	British Welding Journal.
C.L.	:	Centre Line.
CMES	:	Chinese Mechanical Engineering Society.
EDS	:	Energy Dispersive System.
EPMA	:	Electron-Probe Micro-Analyser.
G.B.	:	Grain Boundary.
GTAW	:	Gas Tungsten Arc Welding.
H.A.Z.	:	The Heat Affected Zone of Base Metal, is distinguished by relatively coarse grains.
H.S. Camera	:	High speed camera.
Int.Conf.	:	International Conference.
IIW	:	International Institute of Welding.
JWRI	:	Japanese Welding Research Institute.
MC	:	Metal Construction.
Metall.S	:	Metallurgical Society.
Metall.Trans.A	:	Metallurgical Transactions (Series A).
p.p.	:	Pulse puddle.
p.p.s	:	Pulse puddles.
Procd.	:	Proceedings.
R.H.S.	:	Right Hand Side.
r.p.	:	Rest puddle.
r.p.s	:	Rest puddles.
Scand.J Metall.	:	Scandinavian Journal of Metallurgy.