ARC WELDING CURRENT WAVEFORM CONTROL FOR AUTOMATIC AND ROBOTIC APPLICATION

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Features of digital inverter type GMAW machine

1. Arc stabilization in non-pulse GMAW
2. Spatter reduction technology
3. Pulsed GMAW process
4. Low frequency pulsed GMAW process
5. AC pulsed GMAW process
6. Cold tandem pulsed GMAW
7. Arc ignition control
**Sheet metal welding – Low current range –**

Work piece: Mild Steel, 1.6 mm
Wire: ER70S-G, 1.2 mm
Welding Current: 150 A
Arc Voltage: 23 V
Welding Speed: 100 cm/min

<table>
<thead>
<tr>
<th>Before Welding</th>
<th>After Welding</th>
<th>Cross Section</th>
</tr>
</thead>
</table>

High frequency of short circuiting is required for getting good arc stability under low current range.

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**Heavy section welding – High current range –**

Wire: C-Mn steel solid wire, size: 1.4 mm
Shield gas: 80% Ar + 20% CO₂, 20 l/min
Welding current: 400 A
Arc voltage: 32 V
Welding speed: 50 cm/min

Small current change rate is required for getting soft and good arc stability under high current range.
**Electronic reactance control**

Thyristor type

Digital inverter type

**Bicycle frame welding**
1. Arc stabilization in non-pulse GMAW
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Spatter generation by re-ignition of arc

Controlled Bridge Transfer (CBT) process

In non-pulsed GMA welding process under short-circuit transfer current range, spatter generates mostly at the moment of re-arching right after the short circuit. Therefore, the spatter generation at the re-arching can be suppressed by the rapid decreasing of the welding current right before re-arching.

Arc current is maintained the optimum value for ensuring periodical short circuit transfer cycle.
**Spatter reduction by CPT process**

**CBT-ExpandedProcess**

In order to obtain periodical short circuit under globular transfer current range, a pulse current superimposed by a triangular waveform decrease repelled force and forms a stable droplet at the tip of the wire fed in high speed.
Comparison of spatter level

CBT Expanded process achieves that the spatter level is 0.5g/min or less, only minutes spatter particle is observed.

Spatter reduction by CPT process
Bead and Penetration Profile of CBT-EX process

Welding current: 230 A, Arc voltage: 18.5 V
Welding speed: 100 cm/min, Wire feed rate: 7 m/min
Wire diameter: 1.2 mm φ (YGW-12)
Shielding gas: 100% CO₂, Extension: 15 mm
Base metal: SPCC, Joint gap: 1.0 mm
Thickness: Upper 1.6 mm, Lower 3.2 mm

Deep penetration in the thicker lower plate is obtained with no burn-through on the thinner upper plate. Good bead appearance with no undercut is also achieved.

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**Pulsed GMAW process—one dropper pulse**

Wire: A4043 (1.2 mm), Iav: 23 A, Vav: 16.5 V

**Shielded gas for pulsed GMA welding**

In general, the mixture gas of argon (Ar) gas and 18-20% carbon dioxide gas used as the shielded gas in pulsed GMAW of C-Mn steel.

**Japan**
- CO₂ mixture ratio is wanted increased up to 30% for saving gas cost
- CO₂ mixture ratio often fluctuates due to gas mixture in factory

**USA**
- 25%CO₂+75%Ar mixture is a popular as shielded gas for GMAW

It is hard to obtain one droplet per pulse with high CO₂ mixture ratios!!
**Pulsed current waveform for C-Mn steel**

**Pulsed welding process for Mild steel**
- Stable metal transfer under the CO₂ mixture ratio up to 30%

**Comparison of bead appearance**

<table>
<thead>
<tr>
<th>Mixture ratio</th>
<th>Developed pulse waveform</th>
<th>Conventional pulse waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% Ar + 20% CO₂</td>
<td><img src="image1" alt="Developed waveform" /></td>
<td><img src="image2" alt="Conventional waveform" /></td>
</tr>
<tr>
<td>74% Ar + 26% CO₂</td>
<td><img src="image3" alt="Developed waveform" /></td>
<td><img src="image4" alt="Conventional waveform" /></td>
</tr>
<tr>
<td>70% Ar + 30% CO₂</td>
<td><img src="image5" alt="Developed waveform" /></td>
<td><img src="image6" alt="Conventional waveform" /></td>
</tr>
</tbody>
</table>
Due to excellent puddle control achieved with the optimum pulse parameters for overhead position welding, the bead appearance is much like that of flat position.

<table>
<thead>
<tr>
<th>Welding current</th>
<th>250 A</th>
<th>Arc voltage</th>
<th>27 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding speed</td>
<td>60 cm/min</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bead appearance | Cross Section

Torch SW Current Adjuster

Pulsed welding process for Stainless steel
- Metal transfer is improved, ferrite and duplex stainless steel etc.
Comparison of welding result for stainless steel

Conventional pulsed waveform for aluminium alloy

Pulsed welding process for Stainless steel
- Metal transfer is improved, Small spatter was reduced.
**New pulsed current waveform proposal**

![Diagram of pulsed current waveform]

**Aluminium train car body welding**

![Images of aluminium train car body welding]
Welding application of non-ferrous materials

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The previous generation low frequency modulated pulse employs a pulsed current waveform that switches over into two preset unit pulse conditions (pulse peak current and its duration) alternate with a constant wire feed rate.
Benefits of low frequency modulated pulsed GMAW

1. Improvement of bead appearance.
2. Improvement of gas tolerance and wire misalignments.
3. Grain refinement of the weld metal.
4. Improvement of solidification susceptibility.
5. Blowhole reduction.

Clear ripple pattern bead appearance

Developed modulated pulse

Base metal: A5052, Thickness: 3 mm, wire: A5356, 1.2 mm,
Welding current: 100 A, Arc voltage, 20 V, Welding speed: 40 cm/min,
Modulated pulse frequency: 3 Hz,
Aluminium motor cycle frame welding

Grain refinement and inhibit of hot cracking

DJK@D Corporation
Porosity reduction

Base metal: Zinc coated steel, 9 mm (Zn: 25 mm), Wire: VGW-15, 1.2 mm,
Shielding gas: 80%Ar+20%CO₂, Modulated pulse frequency: 3 Hz,
Welding current: 200 A, Arc voltage: 25 V, Welding speed: 30 cm/min

**Bead appearance**

<table>
<thead>
<tr>
<th>Without modulated pulse</th>
<th>With modulated pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Bead appearance" /></td>
<td><img src="image2" alt="Bead appearance" /></td>
</tr>
</tbody>
</table>

**Cross section**

![Cross-section](image3)

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5. **AC pulsed GMAW process**
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"DESIGN, PRODUCTION AND SERVICE OF WELDED CONSTRUCTIONS AND PRODUCTS"

(a) Flanged joint (b) Flanged joint

) Joggled lap joint

Wire feed rate

Current

AC pulse GMA welding process

DC pulse

EP

EP: electrode positive

0

Time

AC pulse

EP

EN: electrode negative

Sep

0

Time

EN

EN ratio = \frac{Sen}{Sen + Sep}

EN ratio defines the ratio of the average current of electrode negative polarity in a cycle of AC pulse.
**AC pulsed GMA welding process**

- **Aluminium alloy wire**
  - Wire: ER5356 (ALMGO), Size: 1.2 mm

- **C-Mn Steel wire**
  - Wire: ER70S-G, Size: 1.2 mm, 0.04 mm

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**Effect of EN ratio on bead formation**

<table>
<thead>
<tr>
<th>EN: 0%</th>
<th>EN: 15%</th>
<th>EN: 30%</th>
<th>EN: 60%</th>
<th>EN: 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage: 28 V</td>
<td>Voltage: 26.5 V</td>
<td>Voltage: 26 V</td>
<td>Voltage: 24.5 V</td>
<td>Voltage: 24.5 V</td>
</tr>
</tbody>
</table>

- Wire feed rate: 700 cm/min, Welding speed: 80 cm/min, Wire: ER70S-G, Size: 1.2 mm
- Shielded gas: 80%Ar + 20%CO₂, 20 l/min, Base metal: SPCC (JIS), Thickness: 3.2 mm
## Lap joint welding result

<table>
<thead>
<tr>
<th>EN ratio</th>
<th>Wire feed rate</th>
<th>Bead appearance</th>
<th>Cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 %</td>
<td>2.8 m/min</td>
<td><img src="image" alt="Bead 0%" /></td>
<td><img src="image" alt="Cross section 0%" /></td>
</tr>
<tr>
<td>10 %</td>
<td>3.2 m/min</td>
<td><img src="image" alt="Bead 10%" /></td>
<td><img src="image" alt="Cross section 10%" /></td>
</tr>
<tr>
<td>20 %</td>
<td>3.6 m/min</td>
<td><img src="image" alt="Bead 20%" /></td>
<td><img src="image" alt="Cross section 20%" /></td>
</tr>
</tbody>
</table>

Welding current: 80 A, Welding speed: 80 cm/min
Base metal: A5052, 1.5 mm thickness, Wire: A5356, 1.6 mm dia.

## Crushable bumper welding application

150A, 21V, 10%EN
Welding speed: 45 cm/min
Low frequency: 3.5 Hz
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Lap joint welded without and with adaptive control

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DULIN Corporation
### Cold Tandem GMA Process

- **Welding direction**
- **Pulsed spray arc**
- **Cold filler wire**

![Diagram](image_url)

- **Base metal**
- **Molten pool**
- **Weld metal**

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### Inhibiting Effect of the Humped Bead Formation

<table>
<thead>
<tr>
<th>Currents 260 A, Voltages 32 V</th>
<th>Welding speed 200 cm/min</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Cold Tandem GMAW</th>
<th>Pulsed GMAW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Welding direction</strong></td>
<td></td>
</tr>
</tbody>
</table>

- **Filler wire feed rate:** 80 cm/min

![Diagram](image_url)

**3mm**

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Beneficial effect of Cold Tandem GMAW

Tire wheel welding application – Result –

Bead appearance

Welding condition

- Welding current: 480A
- Arc voltage: 38V
- Welding speed: 1.4m/min
- Wire feed rate: 17–3m/min
- Wire size: φ1.4mm
- Wire Ext.: 20mm
- Shielding gas: 80%Ar+20%CO₂, 25L/min
Truck frame application

- Thickness: 4.5~
- Setting

Bead appearance

Torque converter application

Welding condition
- Welding current: 300A
- Arc voltage: 29V
- Welding speed: 1m/min
- Wire feed rate: 10 + 1.7m/min
- Wire size: φ1.2mm
- Wire Ext.: 20mm
- Shielding gas: 80%Ar+20%CO₂, 25L/min
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Arc ignition control

Case 1

Case 2

Conventional arc ignition

RS control

RS control
Hvala Lepa

ご清聴有難うございました

Thank you for kind attention