ARC WELDING CURRENT WAVEFORM CONTROL FOR AUTOMATIC AND ROBOTIC APPLICATION

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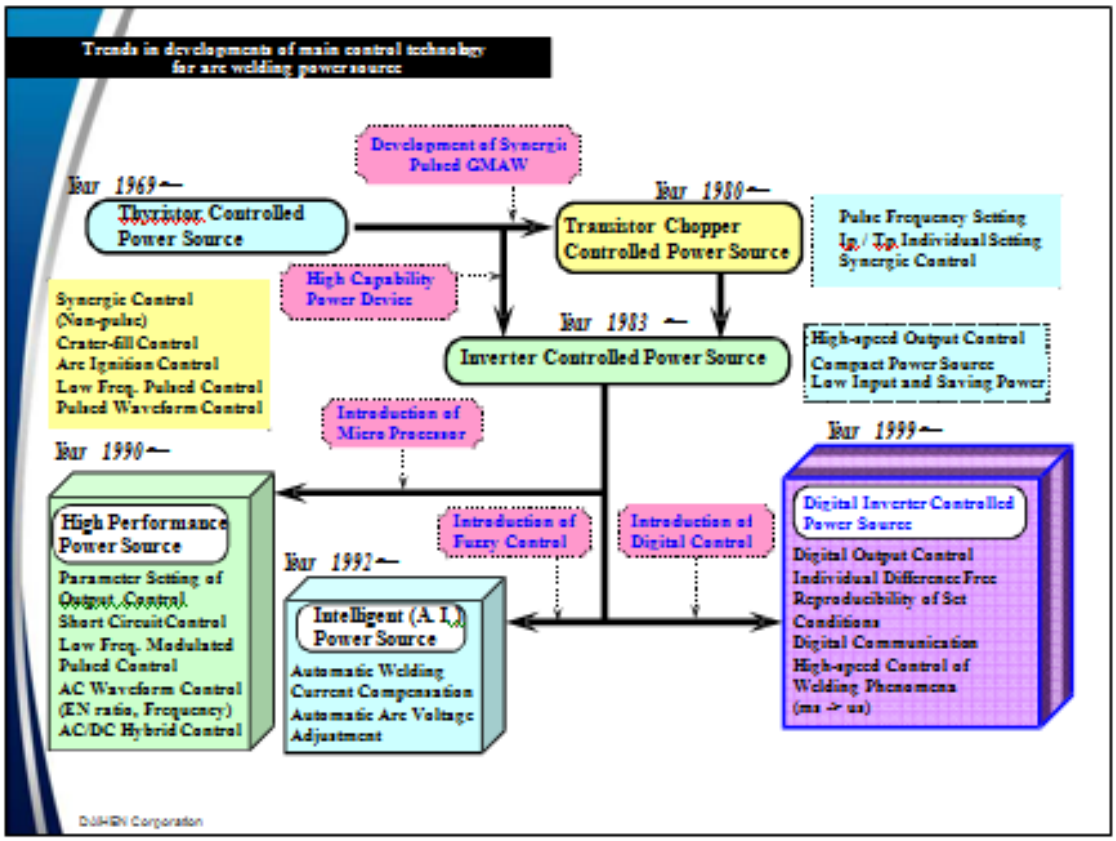

Shift and generation of power source

	The First Generation 1996 ~2000	The Second Generation 2001 ~	The Third Generation 2008 ~	The Fourth Generation 2010 ~
Power source			FPGA   FPGA ~ purpose LSI, in which signal DSP and CPU are assembled in 1 chip.	ASIC   ASIC LSI optimum for welding control, in which plural DSP, CPU and analog circuit are equipped in 1 chip.
Micro processor	16 bit	32bit / DSP	FPGA	ASIC
Processing cycle	100 μs	25 μs	1 μs	20 ns
Processing capability	1	4	16	64

DSP : Digital Signal Processor
FPGA: Field Programmable Gate Array
ASIC : Application Specific Integrated Circuit

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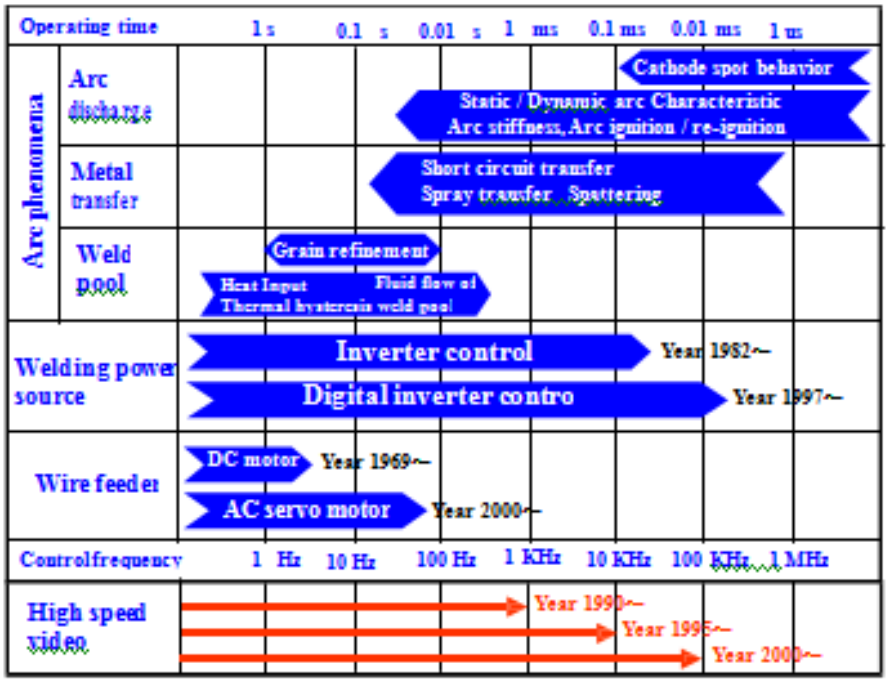
Operating time of welding phenomena



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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

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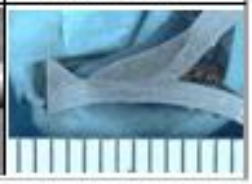
Sheet metal welding –Low current range–

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

Before Welding	After Welding	Cross Section
		

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

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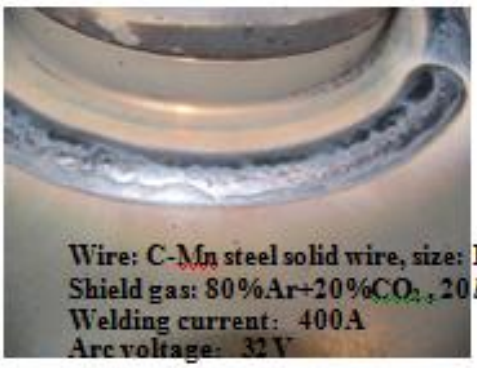
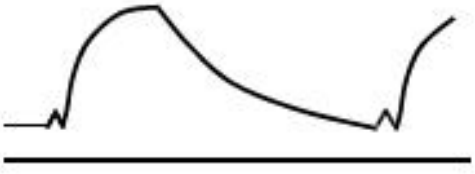
Heavy section welding –high current range–



Wire: C-Mn steel solid wire, size: 1.4 mm
Shield gas: 80%Ar+20%CO_2, 20 l/min
Welding current: 400A
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.

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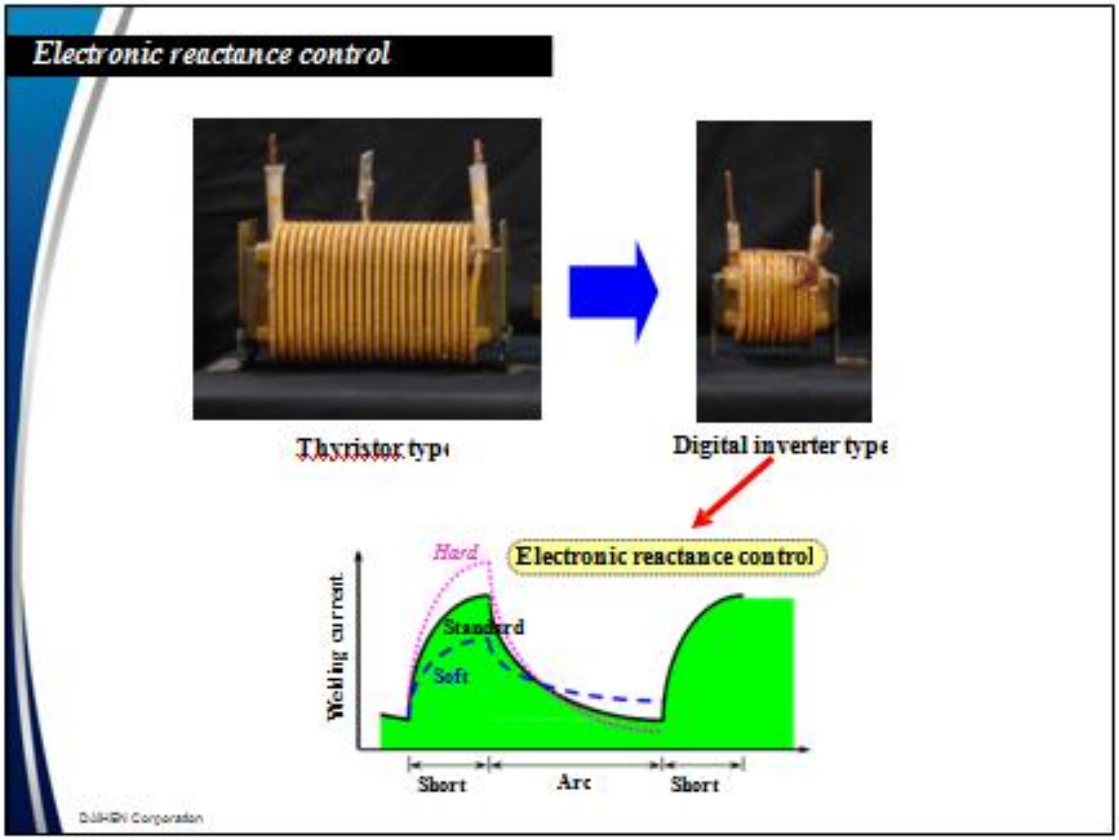
Electronic reactance control
Thyristor type
Digital inverter type
Hard
Electronic reactance control
Standard
Soft
Welding current
Short
Arc
Short
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Bicycle frame welding
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Earth moving equipment parts welding
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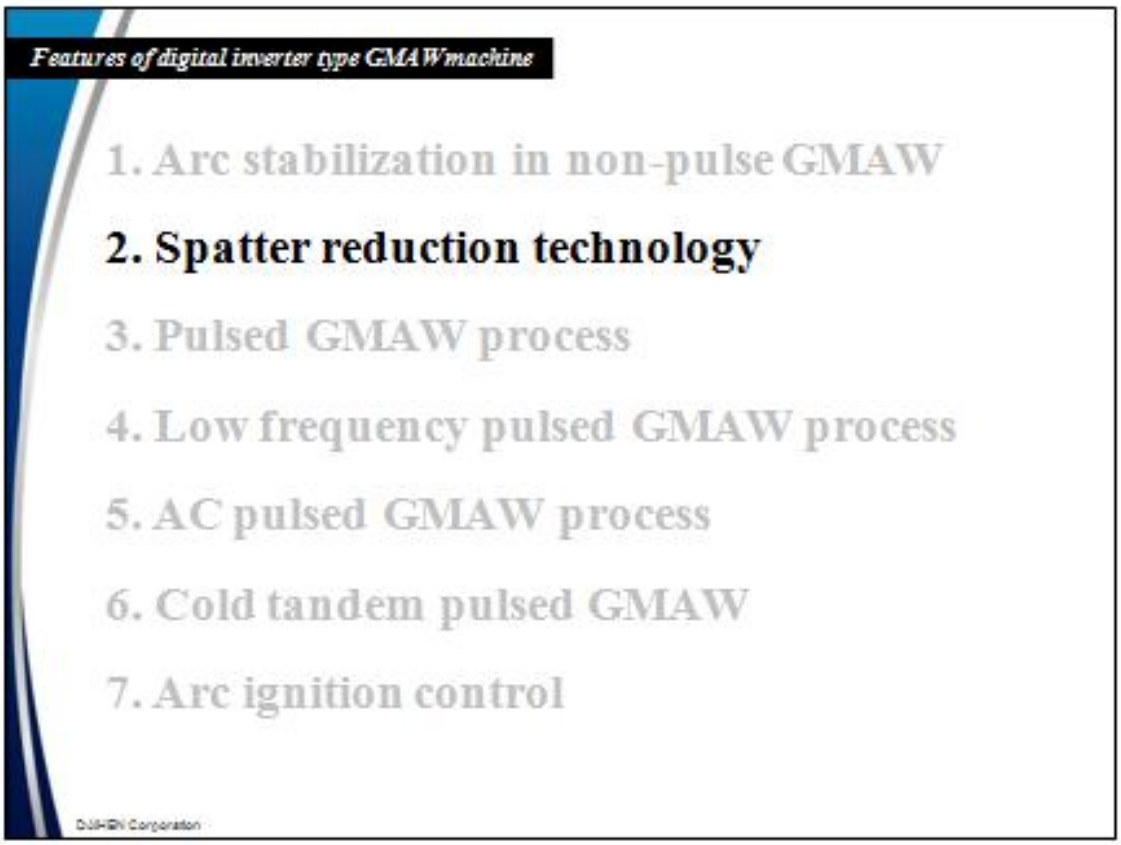
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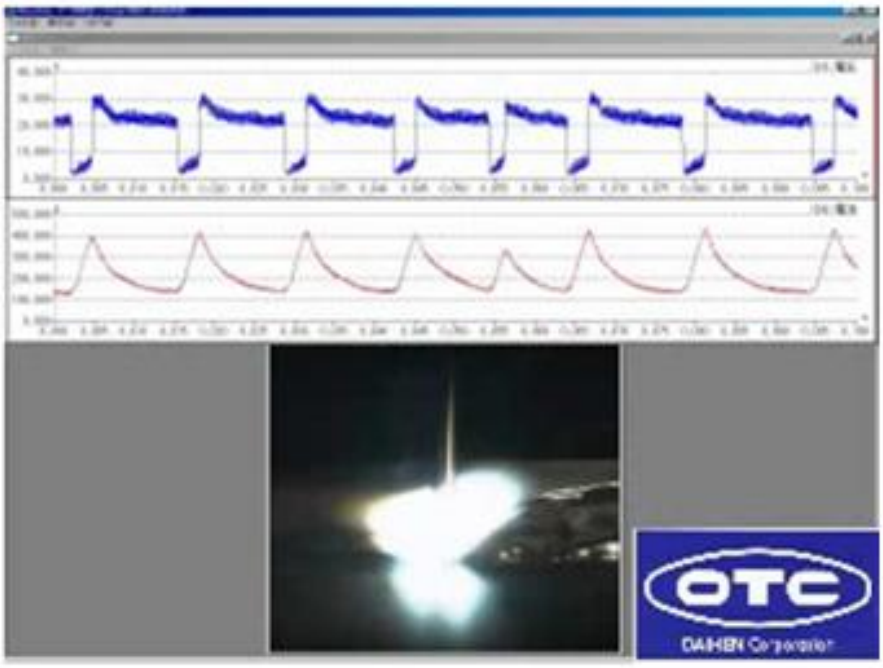
Spatter generation by re-ignition of arc



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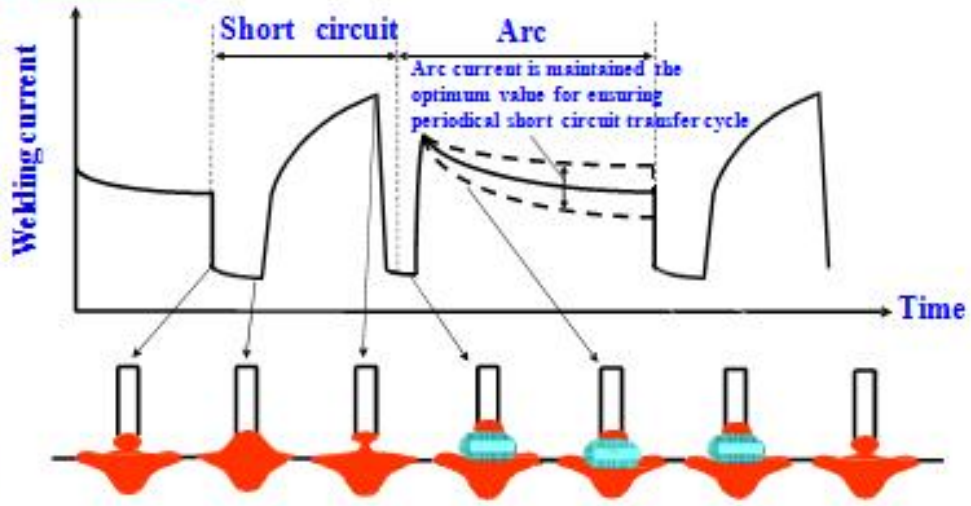
Controlled Bridge Transfer (CBT) process

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



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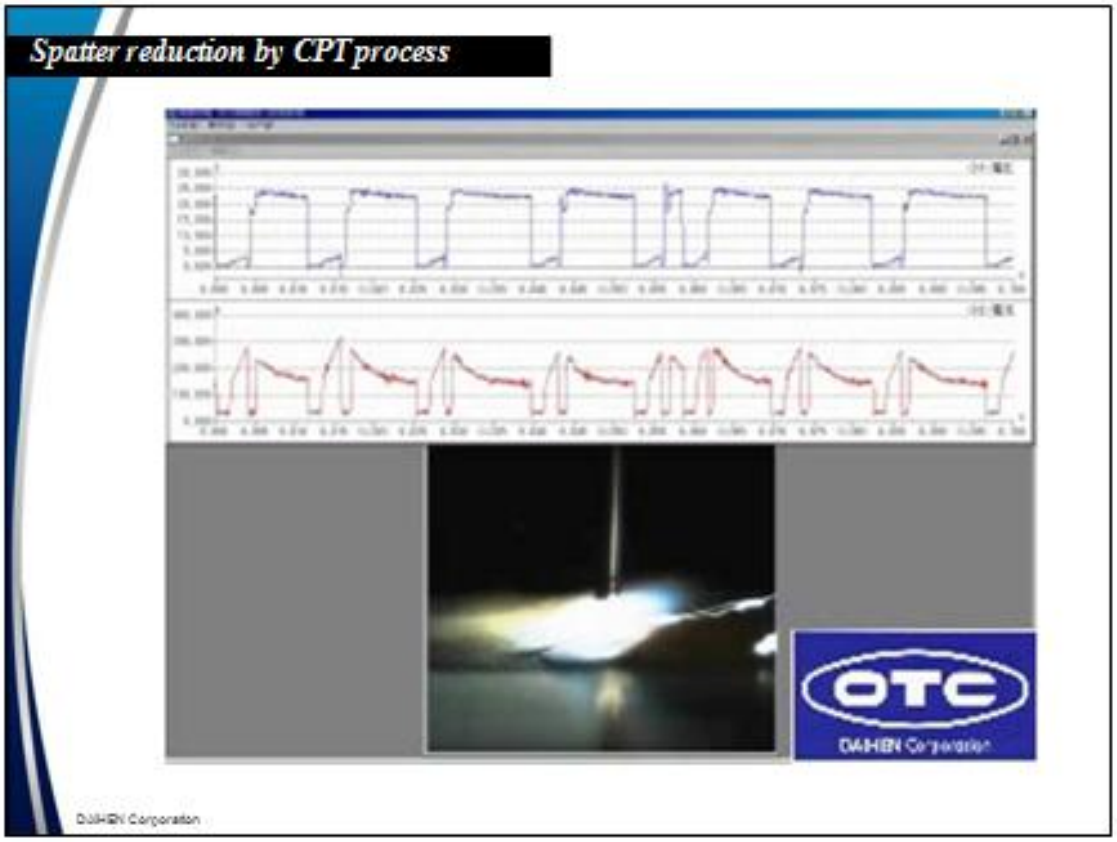
Spatter reduction by CPT process
OTC
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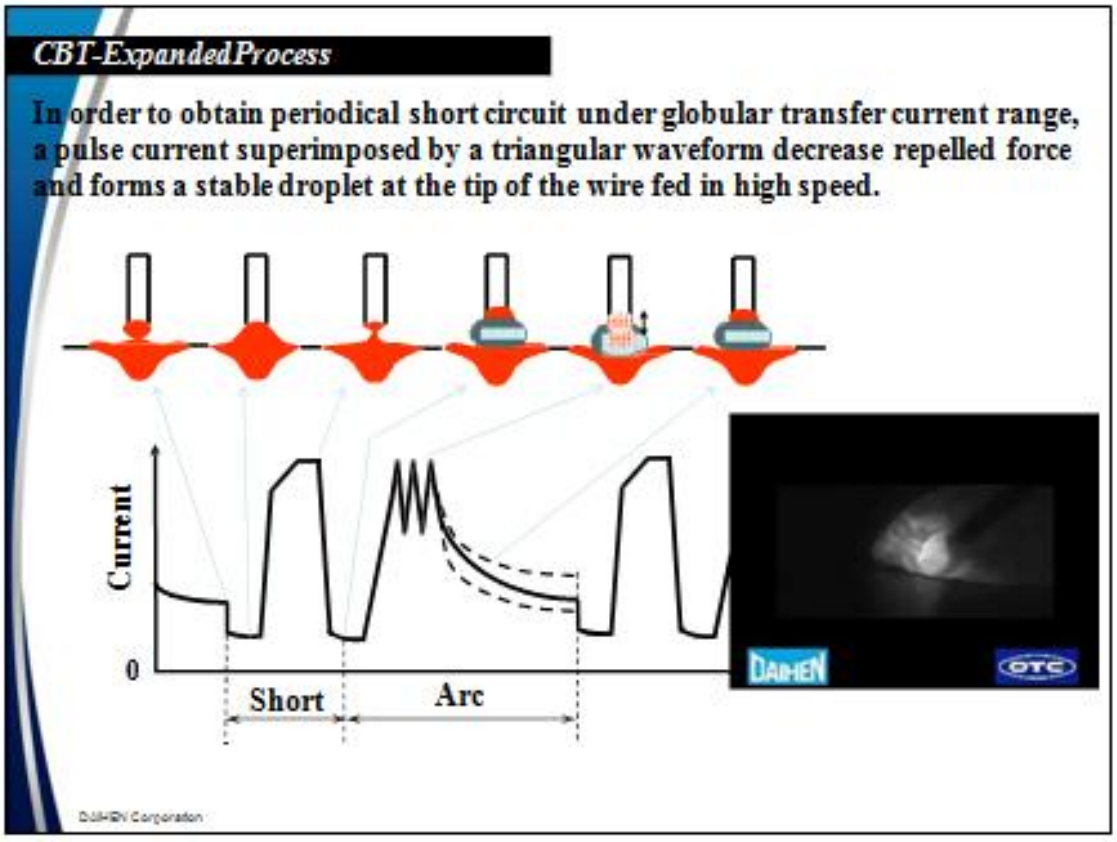
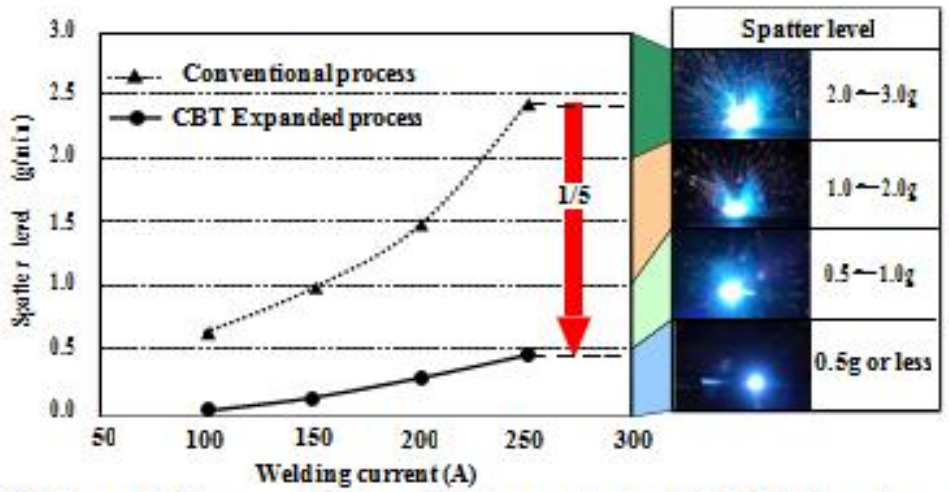

CBT-Expanded Process
In order to obtain periodical short circuit under globular transfer current range, a pulse current superimposed by a triangular waveform decrease repelled force and forms a stable droplet at the tip of the wire fed in high speed.
Current
0
Short
Arc
DAIHEN
OTC

Comparison of spatter level



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

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Spatter reduction by CPT process

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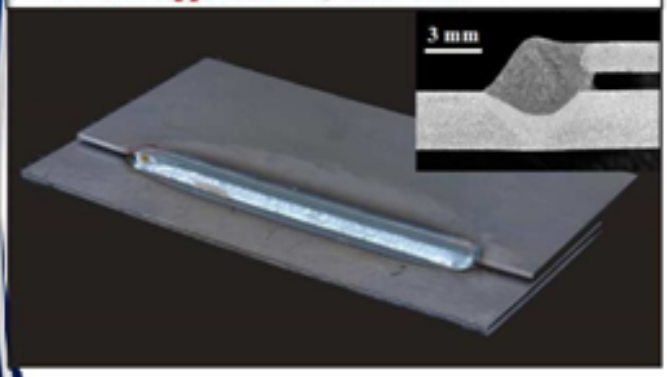
Bead and Penetration Profile of CBT-EXprocess

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 % CO_2 , 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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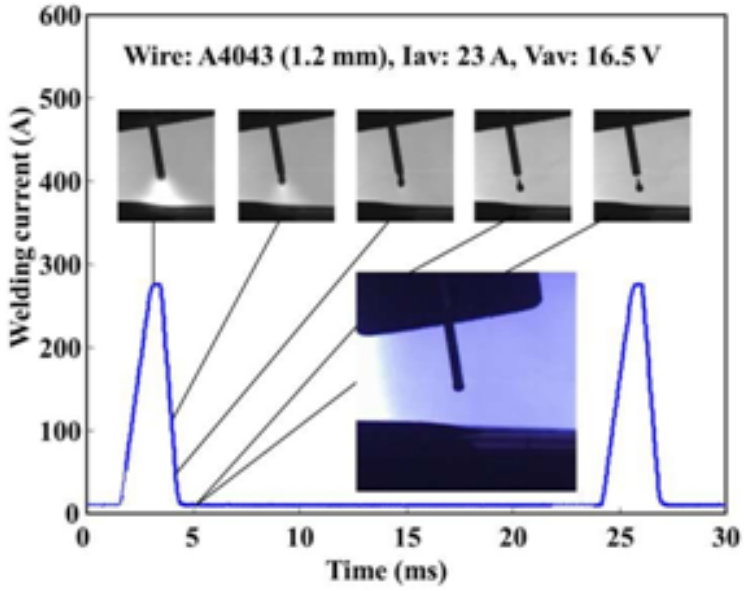
Pulsed GMAW process –one drop per pulse-



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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

CO_2 mixture ratio is wanted increased up to 30% for saving gas cost

CO_2 mixture ratio often fluctuates due to gas mixture in factory

USA

25%CO_2+75%Ar mixture is a popular as shielded gas for GMAW

It is hard to obtain one droplet per pulse with high CO_2 mixture ratios!!

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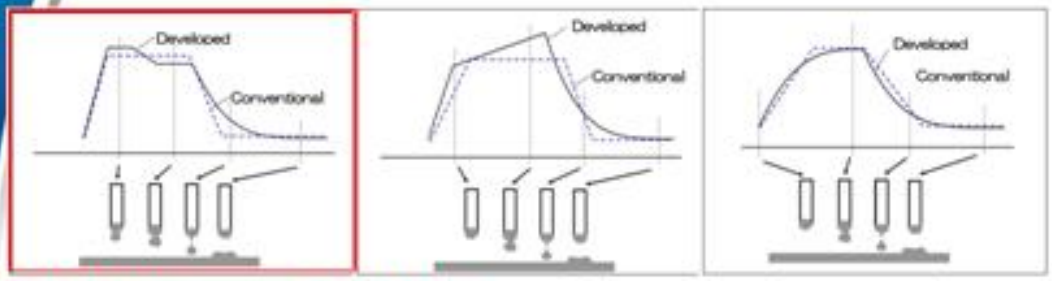
Pulsed current waveform for C-Mn steel



Pulsed welding process for Mild steel

- **Stable metal transfer under the CO_2 mixture ratio up to 30%**

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Comparison of bead appearance

Welding current: 150 A, Arc voltage: 24 V, Welding speed: 100 cm/min

Mixture ratio	Developed pulse waveform	Conventional pulse waveform
80%Ar + 20%CO_2		
74%Ar + 26%CO_2		
70%Ar + 30%CO_2		

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Boiler Tube Welding with Overhead Position

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.

Welding current : 250 A Arc voltage : 27 V
Welding speed : 60 cm/min

Bead appearance	Cross Section
	

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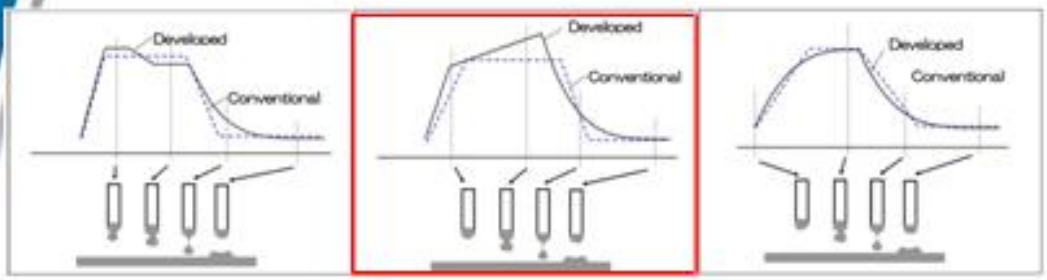
Torch SW Current Adjuster



Pulsed welding process for Stainless steel

- **Metal transfer is improved, ferrite and duplex stainless steel etc.**

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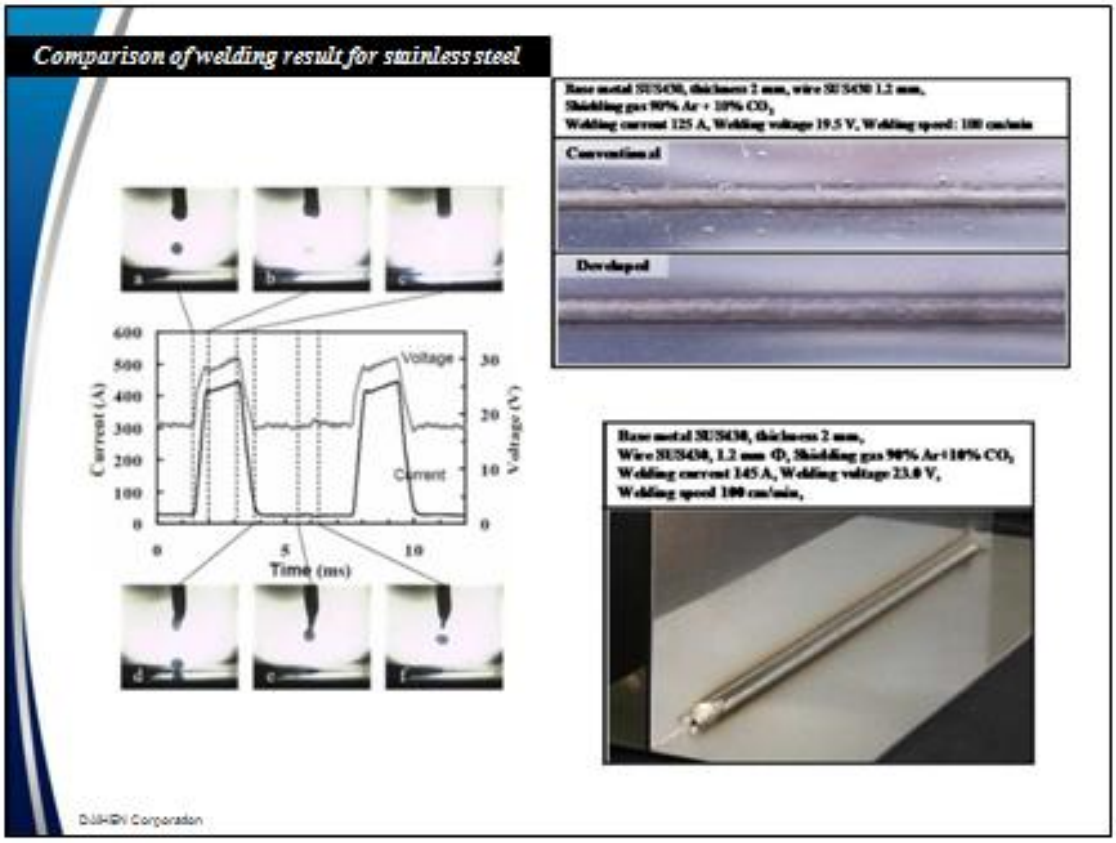
Comparison of welding result for stainless steel
Conventional
Developed
Voltage
Current
Current (A)
Voltage (V)
Time (ms)
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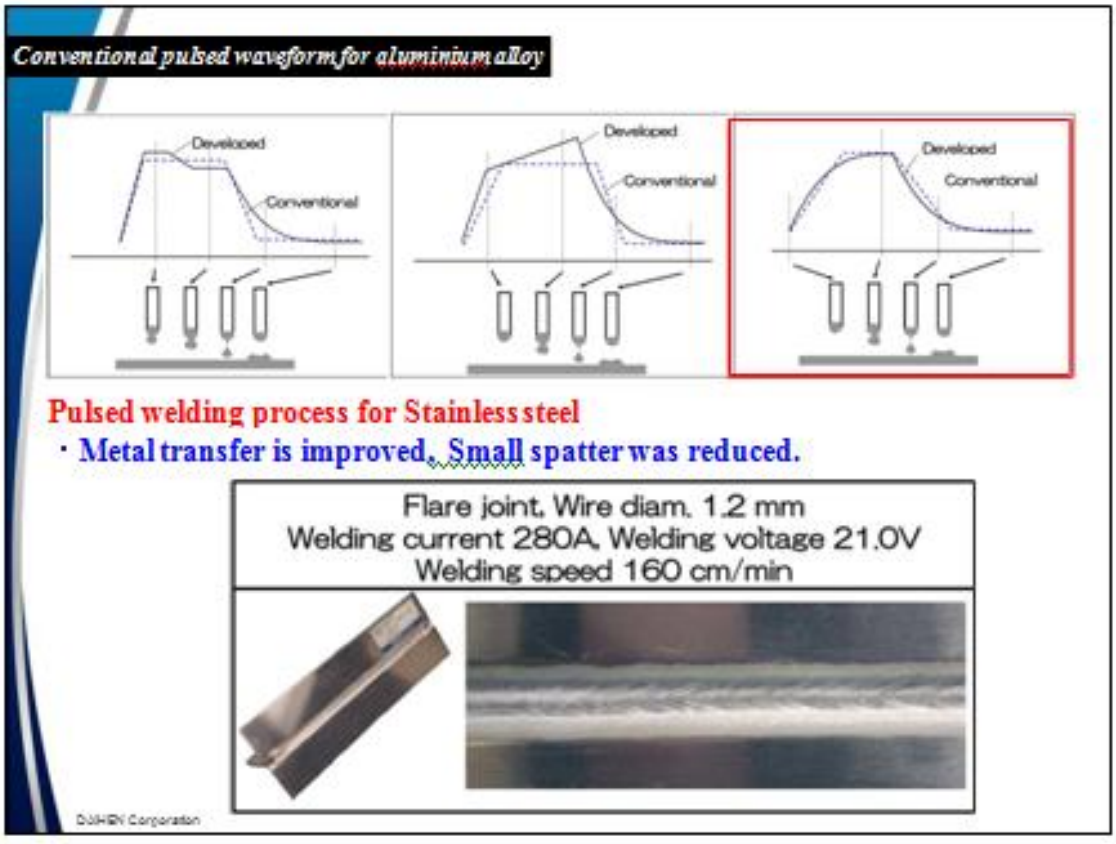
Conventional pulsed waveform for aluminium alloy
Developed
Conventional
Pulsed welding process for Stainless steel
・Metal transfer is improved, Small spatter was reduced.
Flare joint, Wire diam. 1.2 mm
Welding current 280A, Welding voltage 21.0V
Welding speed 160 cm/min
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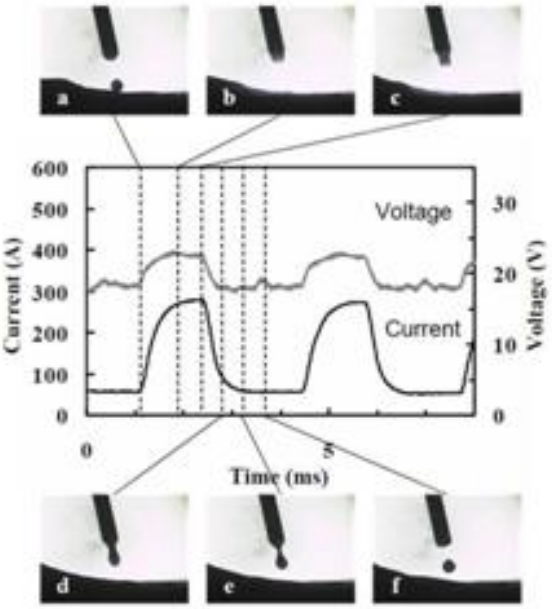
New pulsed current waveform proposal



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Aluminium train car body welding

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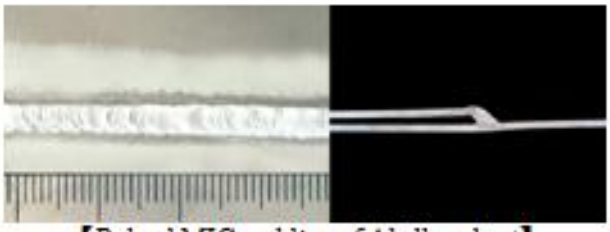
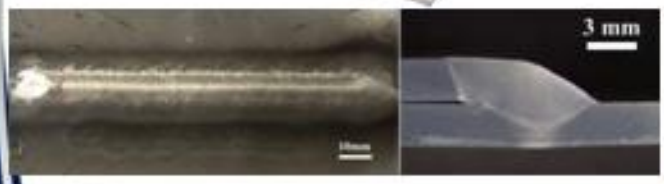
Welding application of non-ferrous material



【Pulsed MIG welding of Al alloy sheet】



【Pulsed MIG welding of Mg alloy】

【Pulsed MIG welding of Titanium】

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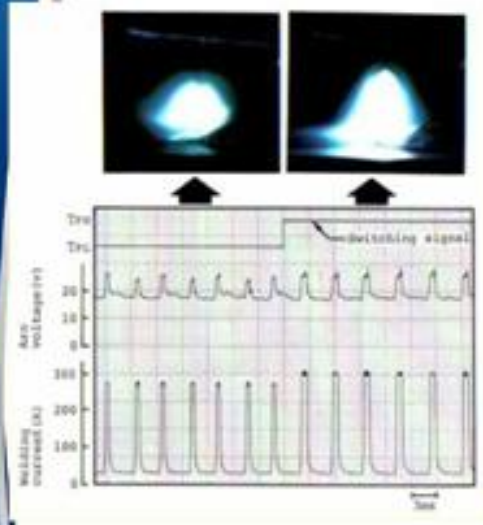
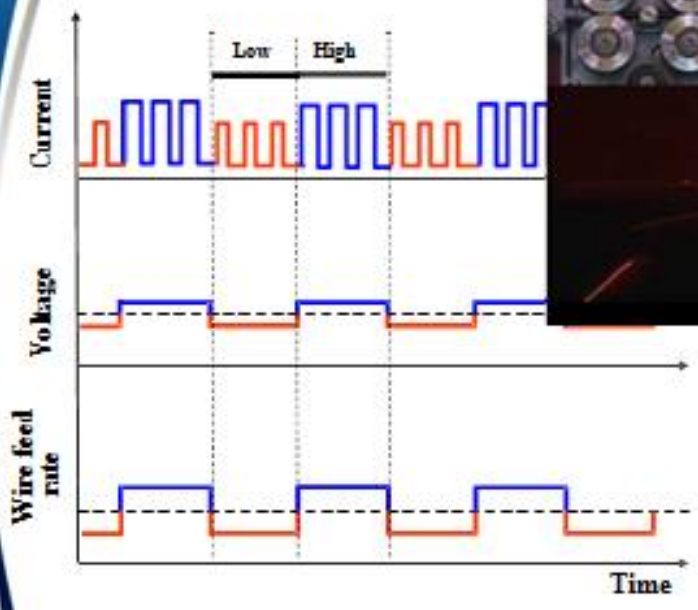
Low frequency moderated pulsed GMAW



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.

Low frequency modulated pulse process



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.

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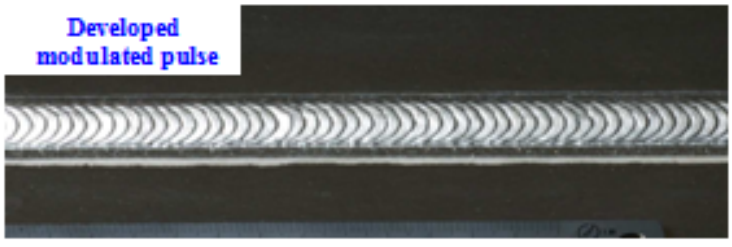
Clear ripple pattern bead appearance



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,

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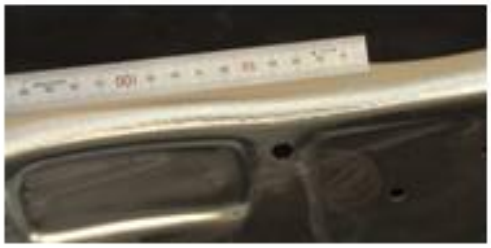
Aluminium motor cycle frame welding



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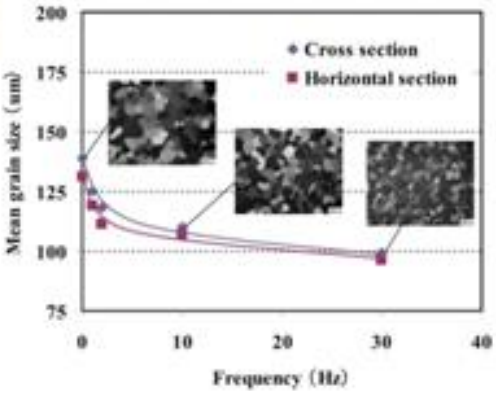
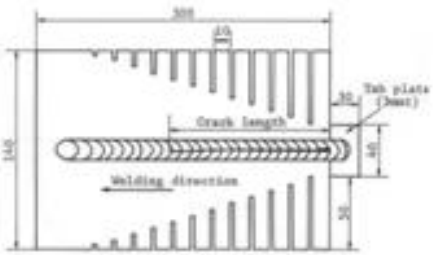
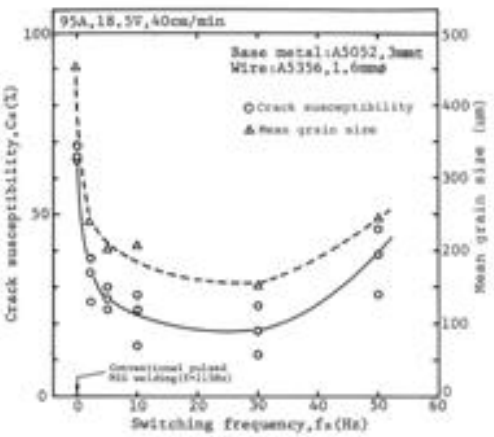
Grain refinement and inhibit of hot cracking







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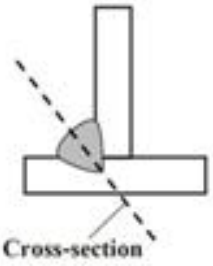
Porosity reduction

Base metal: Zinc coated steel, 9 mm (Zn: 28 mm), Wire: YGW-15, 1.2 mm,
Shielding gas: 80%Ar+20%CO_2, Modulated pulse frequency: 3 Hz,
Welding current: 200 A, Arc voltage: 25 V, Welding speed: 30 cm/min

	Bead appearance	Cross section
Without Modulated pulse		
With modulated pulse		



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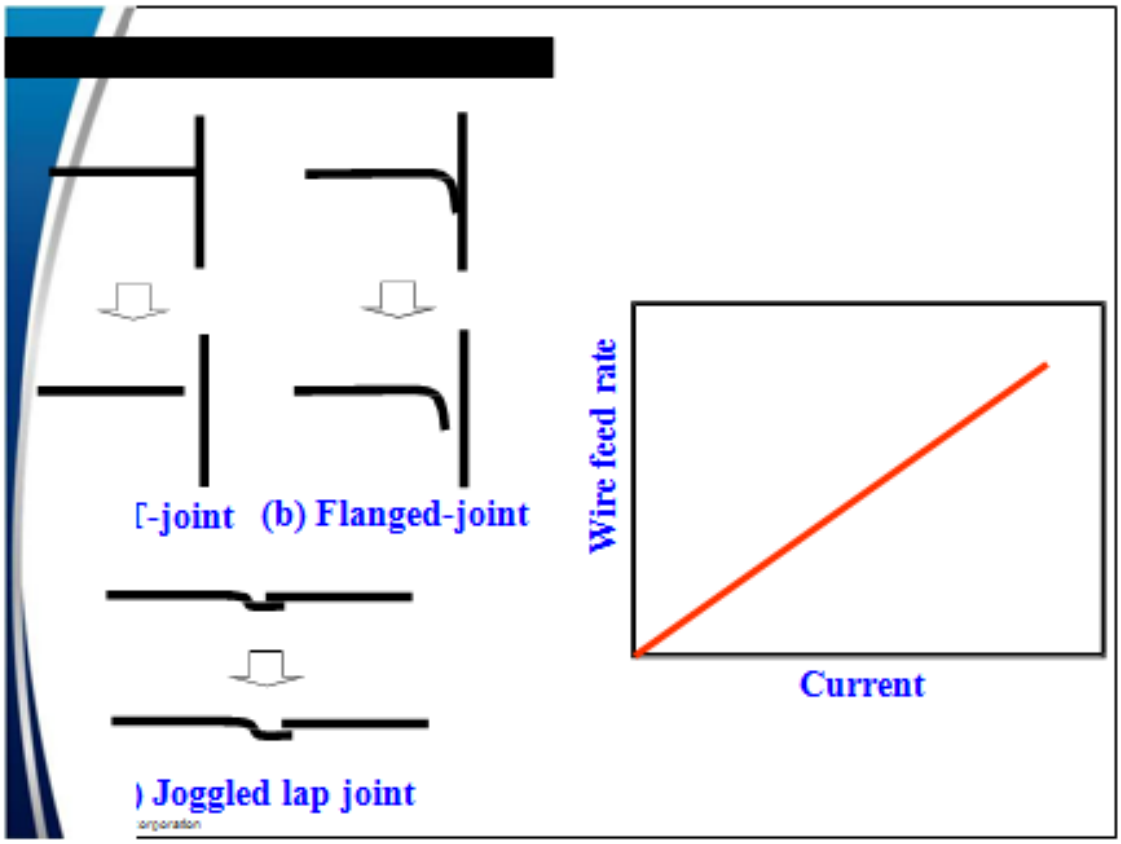
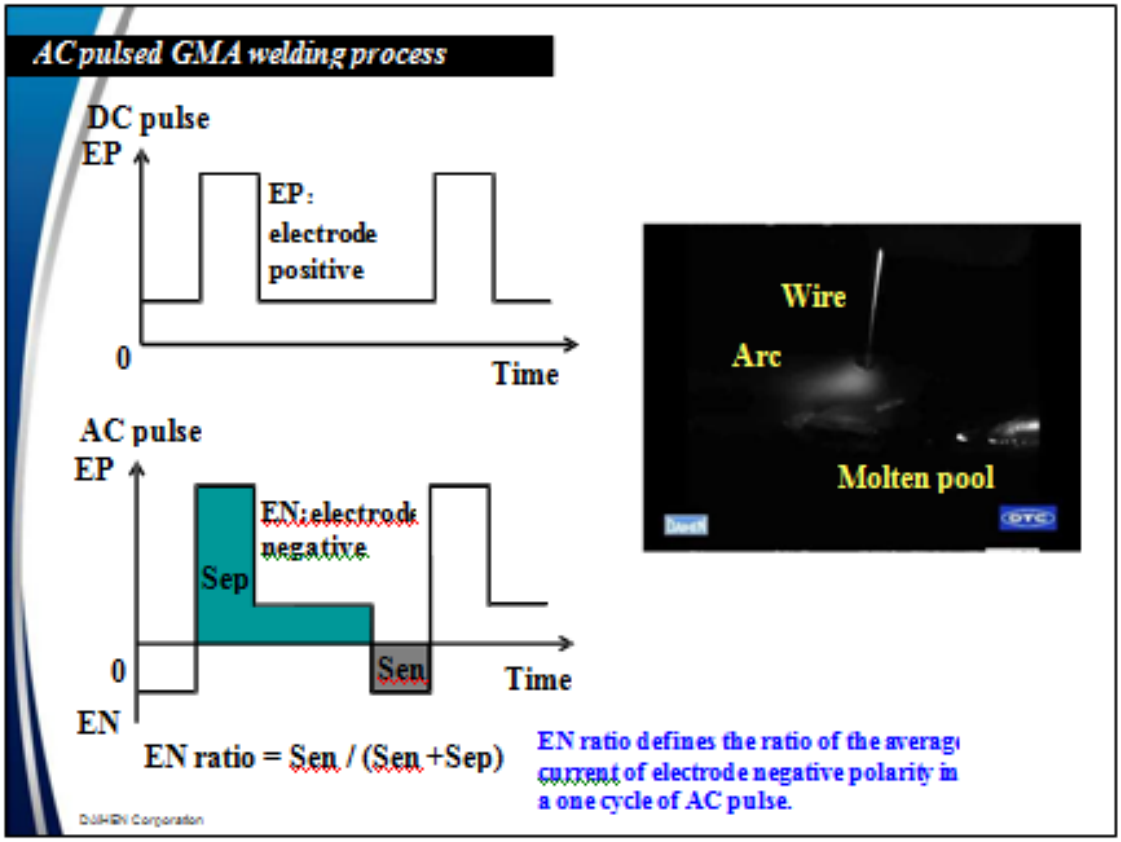
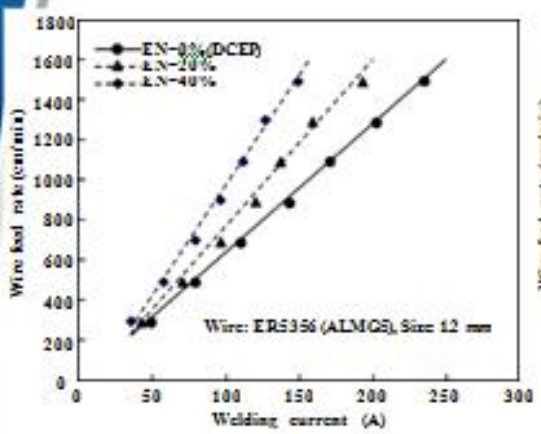
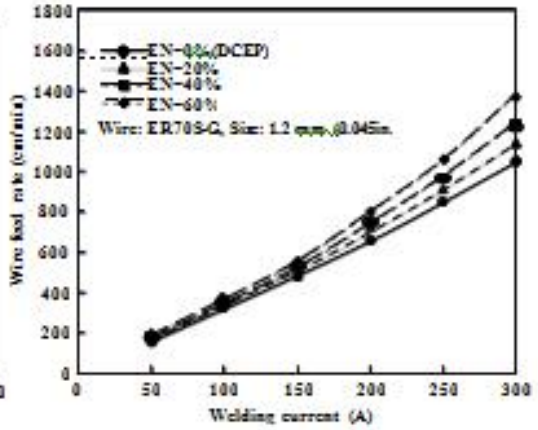

[-joint (b) Flanged-joint
) Joggled lap joint
Wire feed rate
Current


AC pulsed GMA welding process
DC pulse
EP
EP: electrode positive
0
Time
AC pulse
EP
EN:electrode negative
Sep
Sen
0
Time
EN
EN ratio = Sen / (Sen +Sep)
EN ratio defines the ratio of the averag current of electrode negative polarity in a one cycle of AC pulse.
Wire
Arc
Molten pool

AC pulsed GMA welding process



Aluminium alloy wire



C-Mn Steel wire

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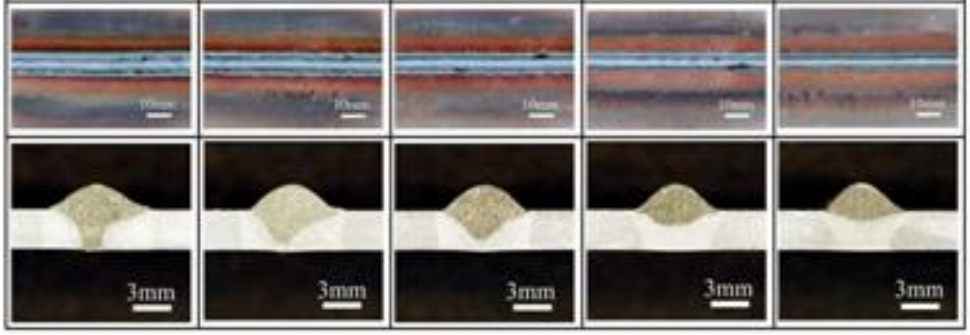
Effect of EN ratio on bead formation

Wire feed rate : 700 cm/min, Welding speed : 80 cm/min, Wire : ER70S-G, Size: 1.2 mm
Shielded gas : 80%Ar + 20%CO_2, 20 ℓ/min, Base metal : SPCC (JIS), Thickness: 3.2 mm

EN: 0%	EN: 15%	EN: 30%	EN: 60%	EN: 75%
Current: 210 A	Current: 205 A	Current: 200 A	Current: 170 A	Current: 165 A
Voltage: 28 V	Voltage: 26.5 V	Voltage: 26 V	Voltage: 24.5 V	Voltage: 24.5 V



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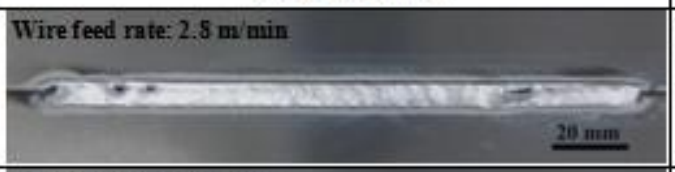
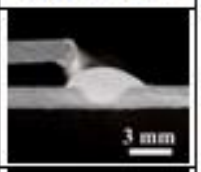
Lap joint welding result

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

EN ratio	Bead appearance	Cross section
0 %	Wire feed rate: 2.8 m/min 	
10 %	Wire feed rate: 3.2 m/min 	
20 %	Wire feed rate: 3.6 m/min 	

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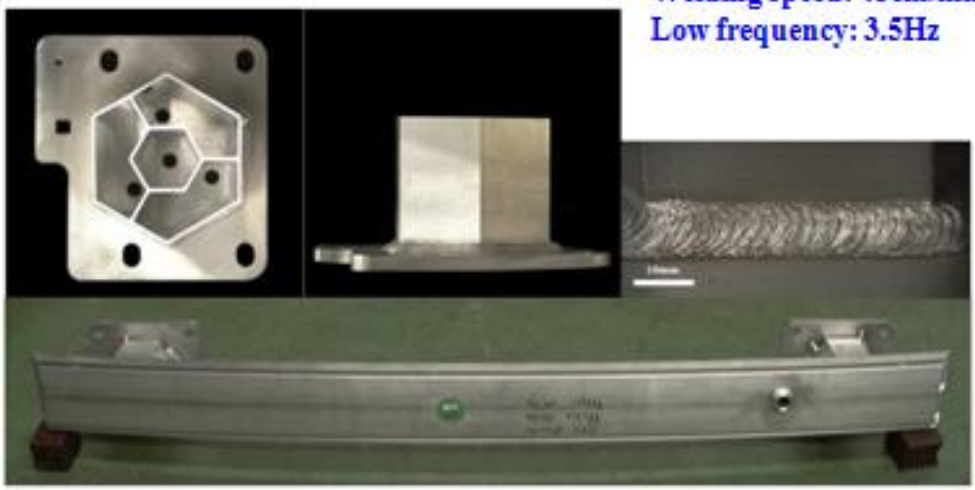
Crushable bumper welding application

150A, 21V, 10%EN
Welding speed: 45cm/min
Low frequency: 3.5Hz



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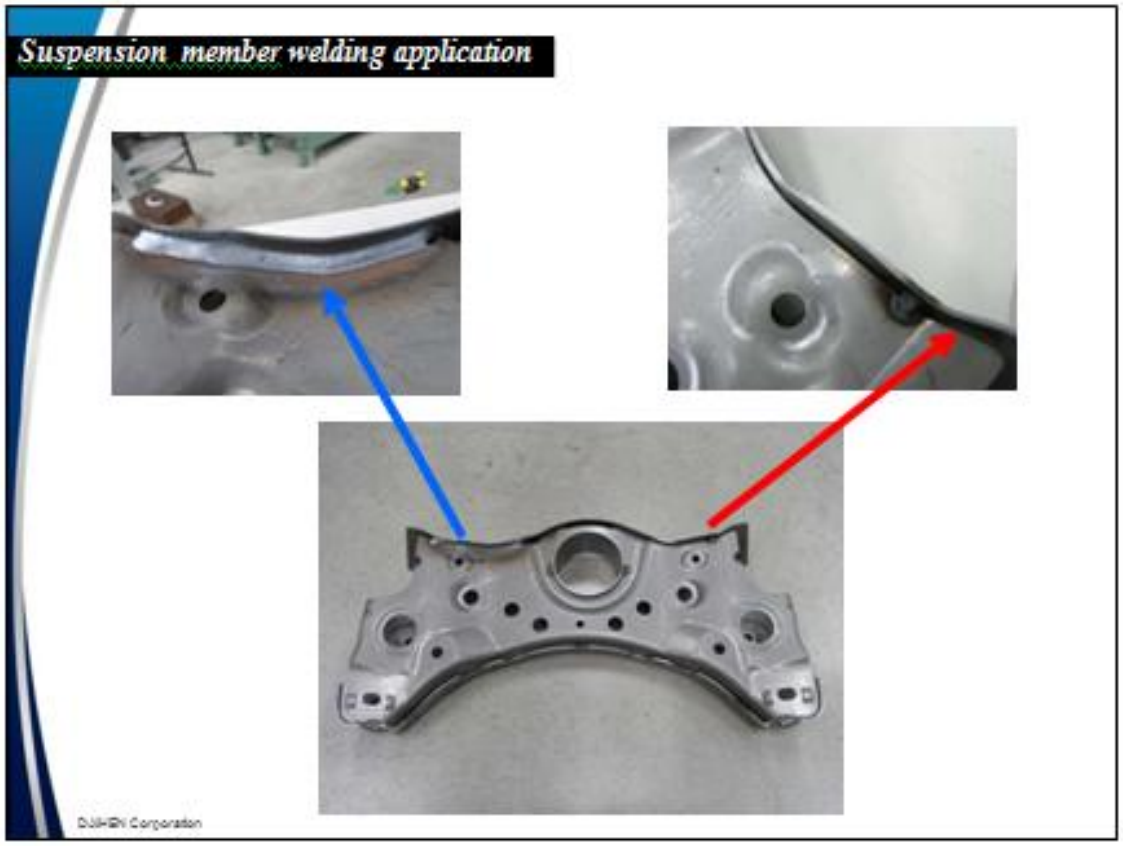
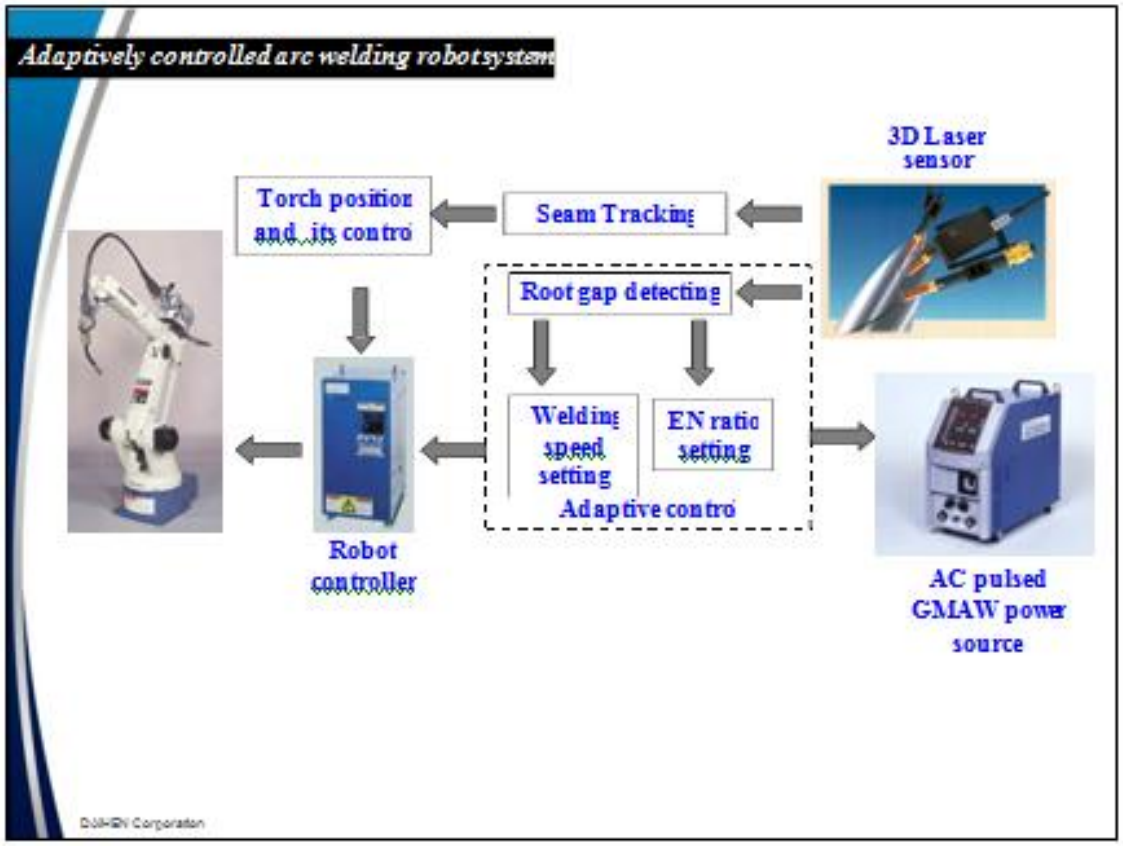
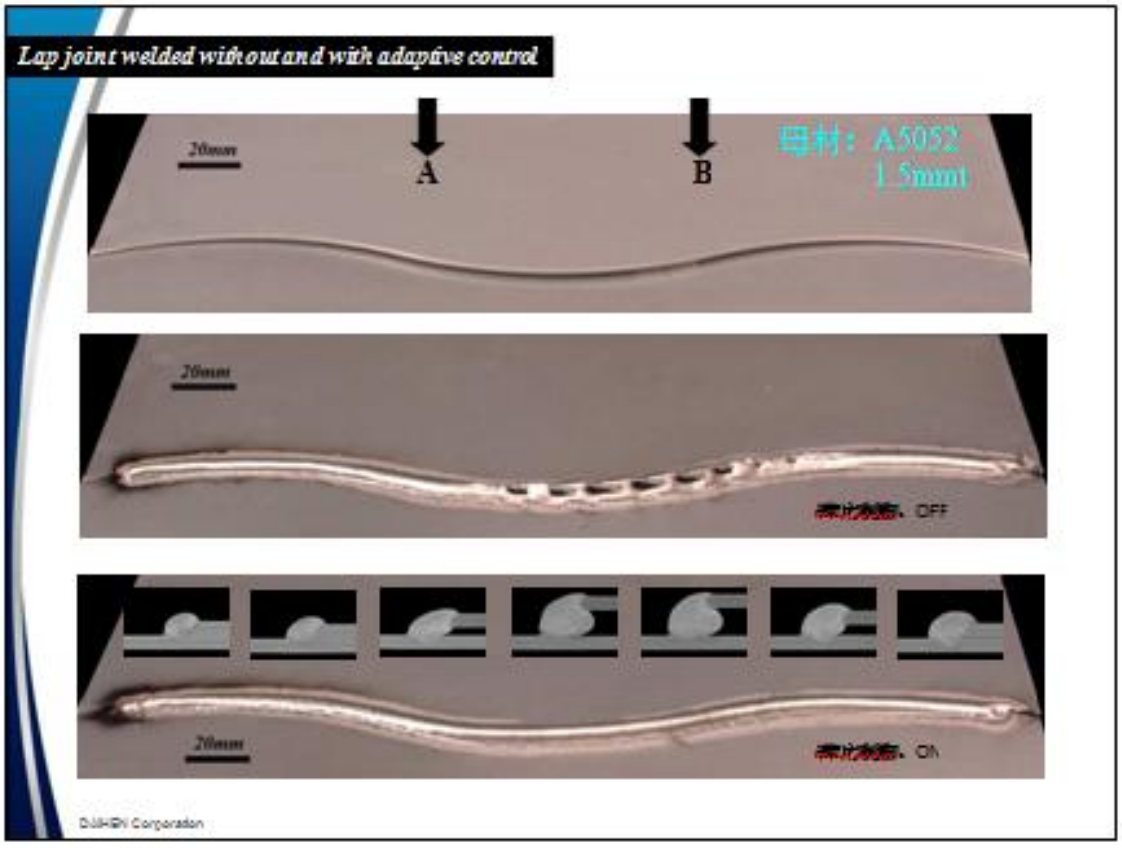

Suspension member welding application


Adaptively controlled arc welding robotsystem
3D Laser sensor
Torch position and its contro
Seam Tracking
Root gap detecting
Welding speed setting
EN ratio setting
Adaptive contro
Robot controller
AC pulsed GMAW power source


Lap joint welded without and with adaptive control
20mm
A
B
母材：A5052
1.5mmt
20mm
OFF
20mm
ON
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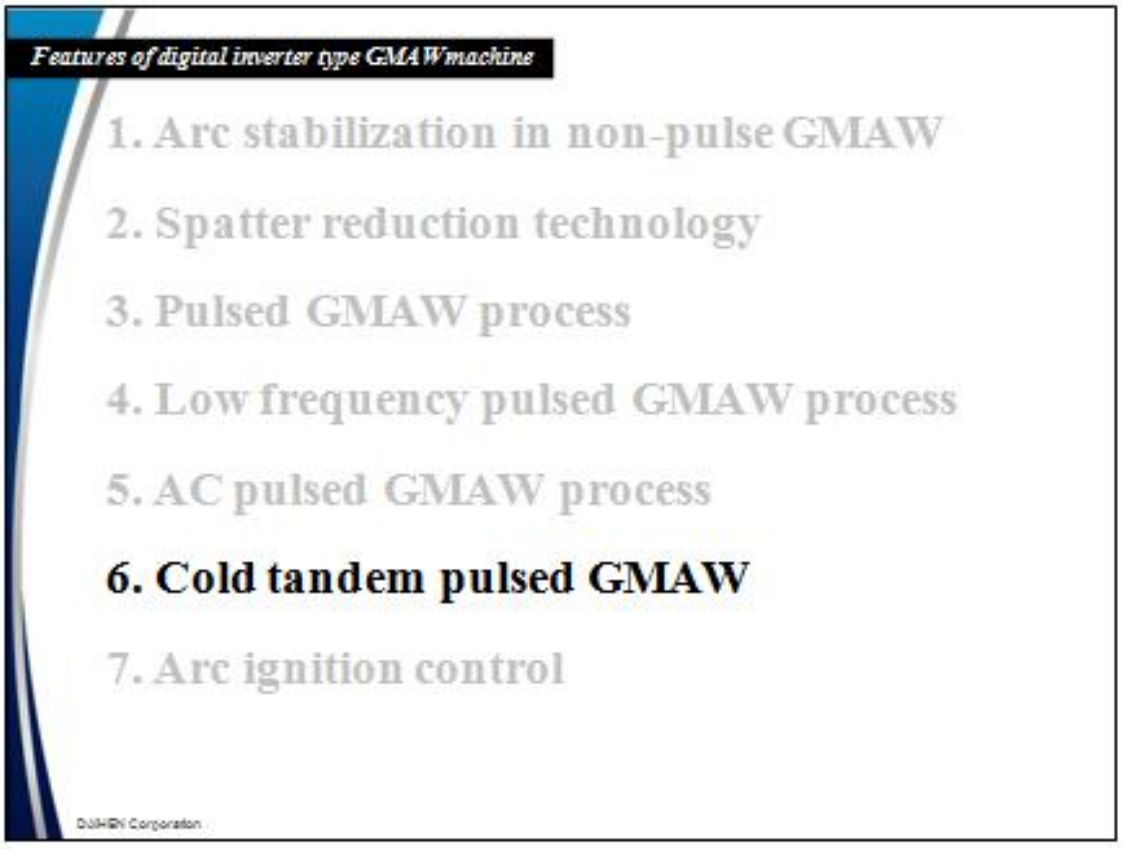
Features of digital inverter type GMAW machine
1. Arc stabilization in non-pulse GMAW
2. Spatter reduction technology
3. Pulsed GMAW process
4. Low frequency pulsed GMAW process
5. AC pulsed GMAW process
6. Cold tandem pulsed GMAW
7. Arc ignition control
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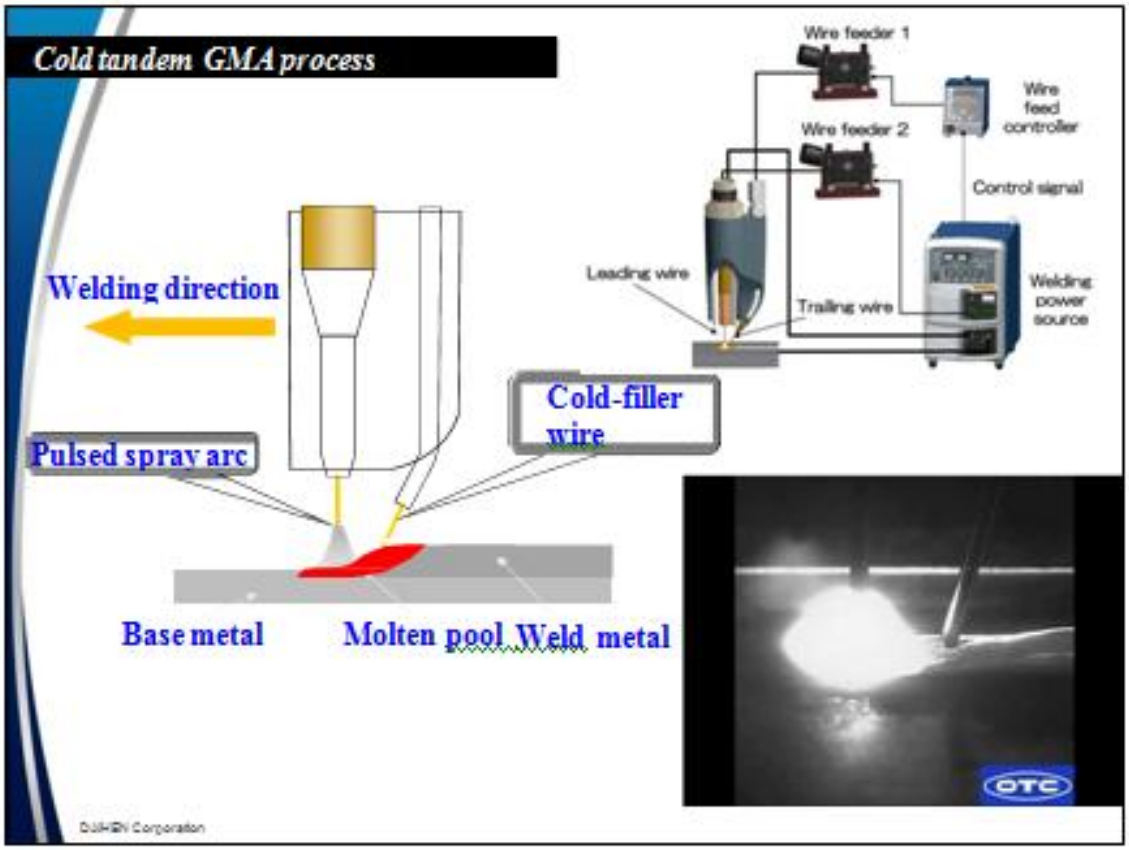
Cold tandem GMA process
Wire feeder 1
Wire feeder 2
Wire feed controller
Control signal
Welding power source
Leading wire
Trailing wire
Welding direction
Cold-filler wire
Pulsed spray arc
Base metal
Molten pool
Weld metal
OTC
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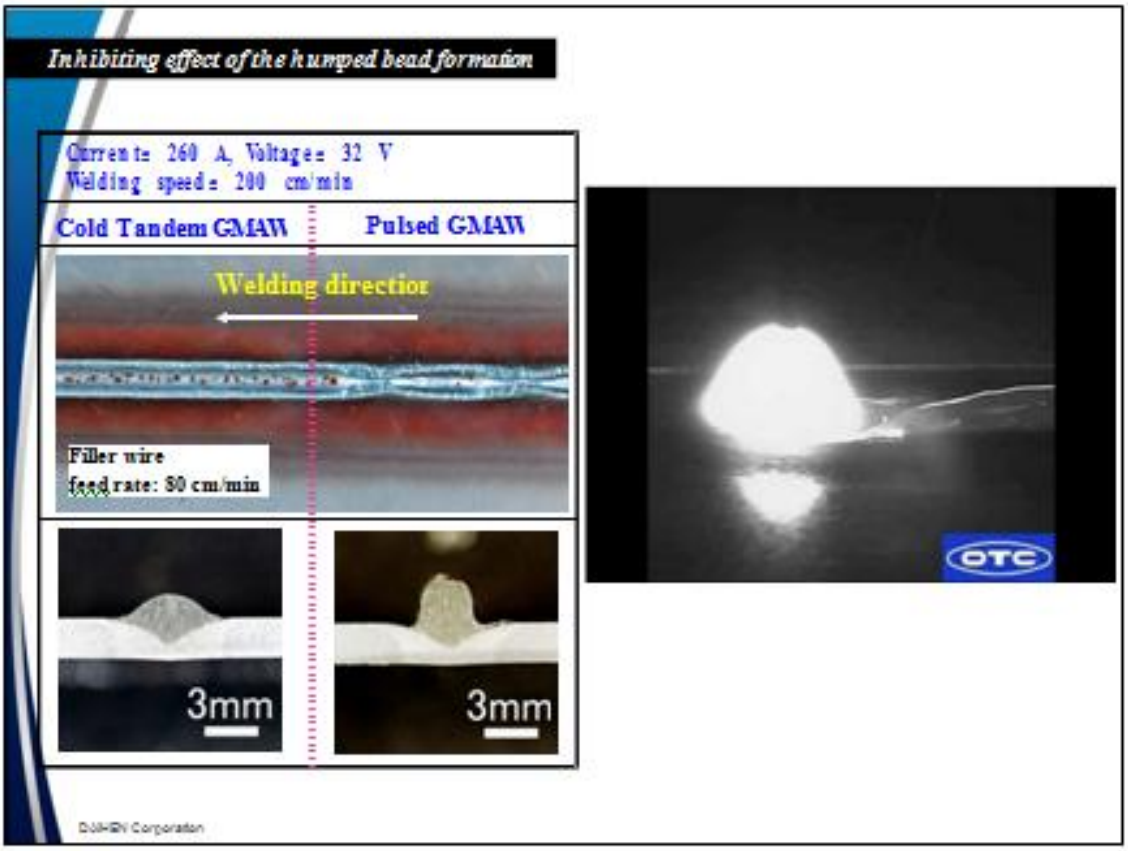
Inhibiting effect of the humped bead formation
Current: 260 A, Voltage: 32 V
Welding speed: 200 cm/min
Cold Tandem GMAW
Pulsed GMAW
Welding direction
Filler wire
feed rate: 80 cm/min
3mm
3mm
OTC
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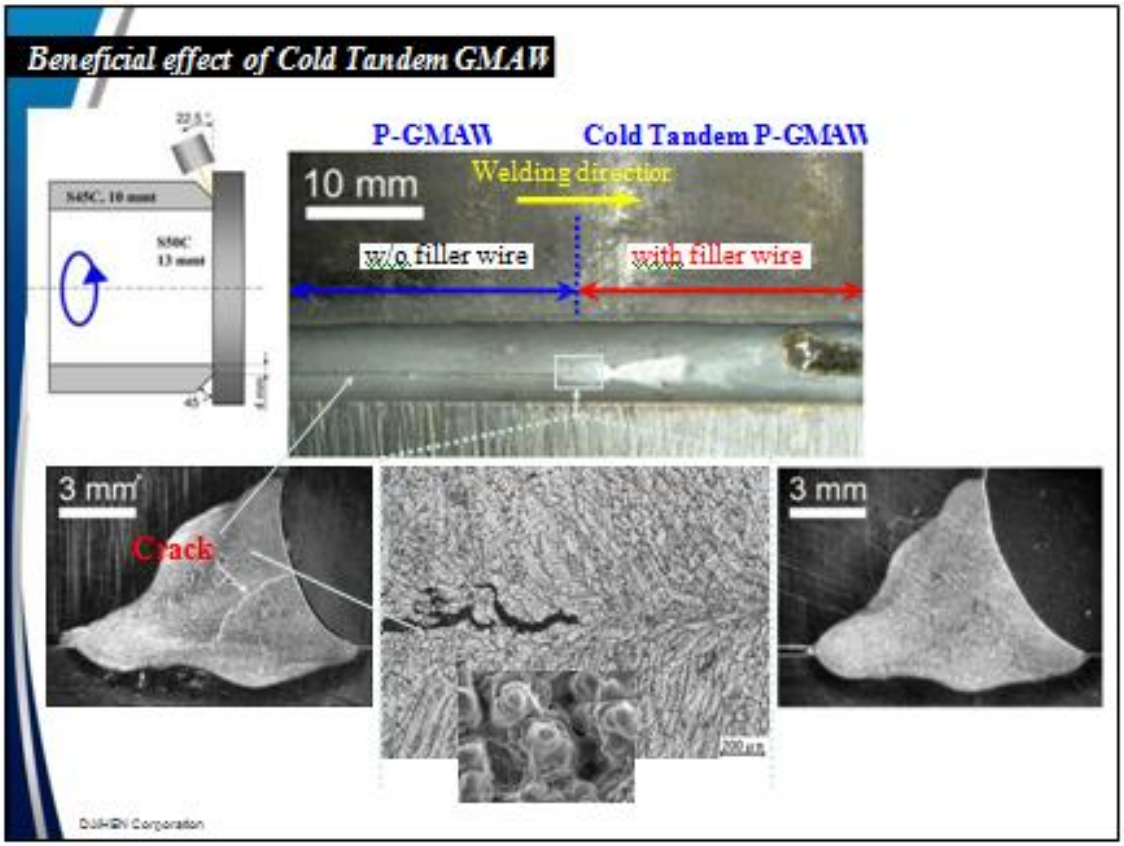
Beneficial effect of Cold Tandem GMAW
P-GMAW
Cold Tandem P-GMAW
10 mm
Welding direction
w/o filler wire
with filler wire
3 mm
Crack
3 mm
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Tire wheel welding application –Result-
Bead appearance
18 mm
Cross-section
Welding condition
Welding current= 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
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Truck frame application

thickness: 4.5~

Setting

Bead appearance

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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%CO_2, 25L/min

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6. Cold tandem pulsed GMAW
7. **Arc ignition control**

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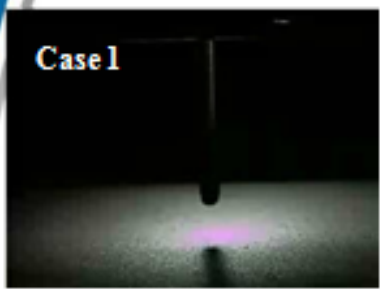
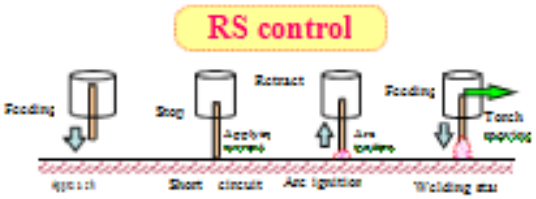
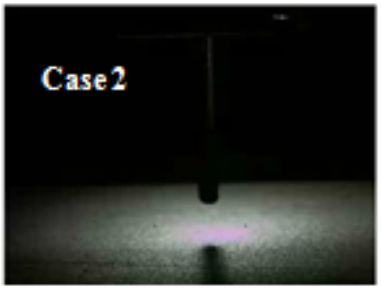
Arc ignition control







Conventional arc ignition

RS control

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Hvala Lepa
ご清聴有難うございました
Thank you for kind attention
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