A Modified GMAW System for Distortion Reduction and Travel Speed Increase through Separate Heat Input and Deposition Rate Control

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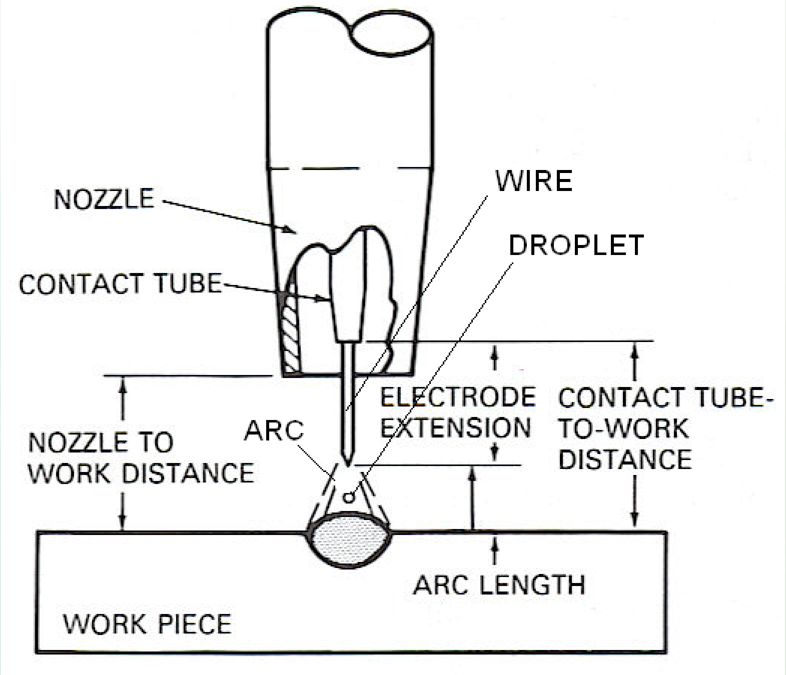
YuMing Zhang* and Lee Kvidahl**
ymzhang@adaptiveintelligentsystems.com

***Adaptive Intelligent Systems, Lexington, Kentucky**
****Northrop Grumman Shipbuilding - Gulf Coast**

Process Fundamentals

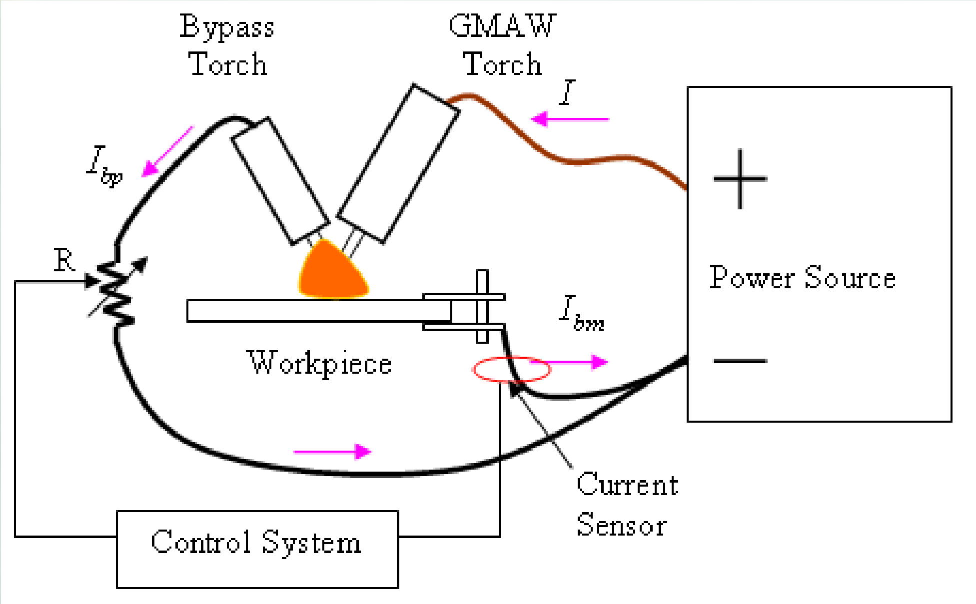
Conventional GMAW

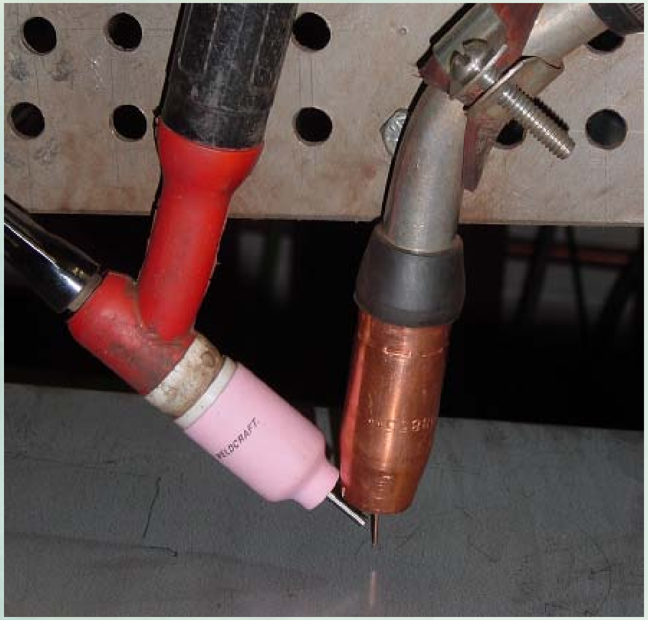
- Melting current = base metal current ➔ high productivity (melting speed) = high base metal heat input & high arc pressure
- Applications with restricted heat input or arc pressure = limited melting/deposition speed or productivity
- Also, higher base metal heat input ➔ typically higher distortion



Process Fundamentals
Double-electrode GMAW

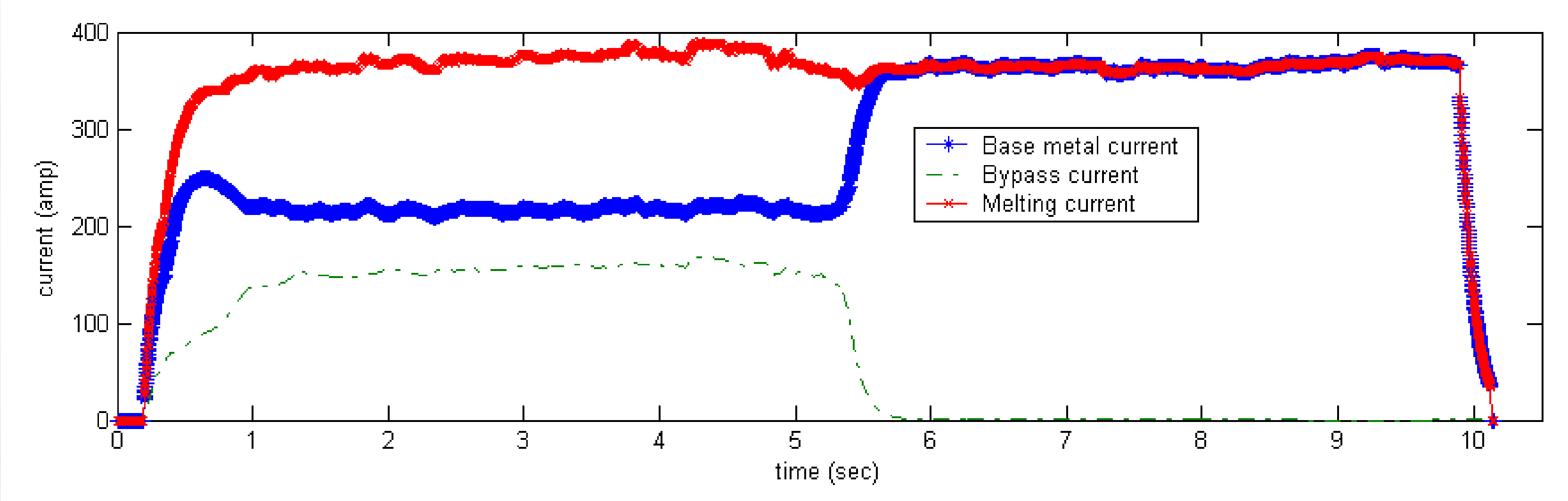
- Melting current = base metal current + bypass current
- Independent control of melting speed and base metal heat input (via independent control of melting and base metal currents)
- Possible: increase melting speed without increasing the base metal heat input and distortion.





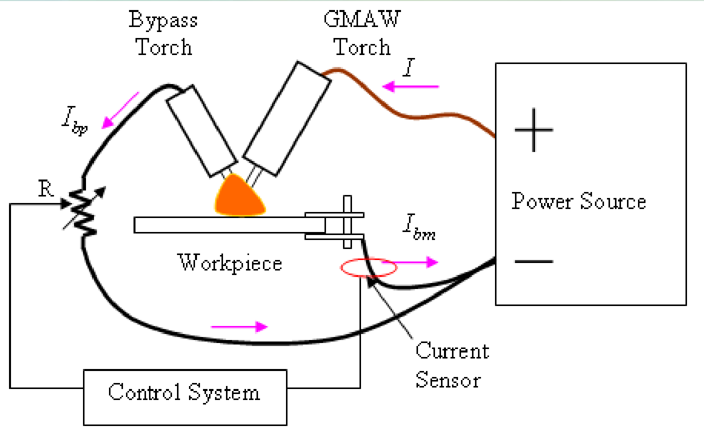
Process Fundamentals

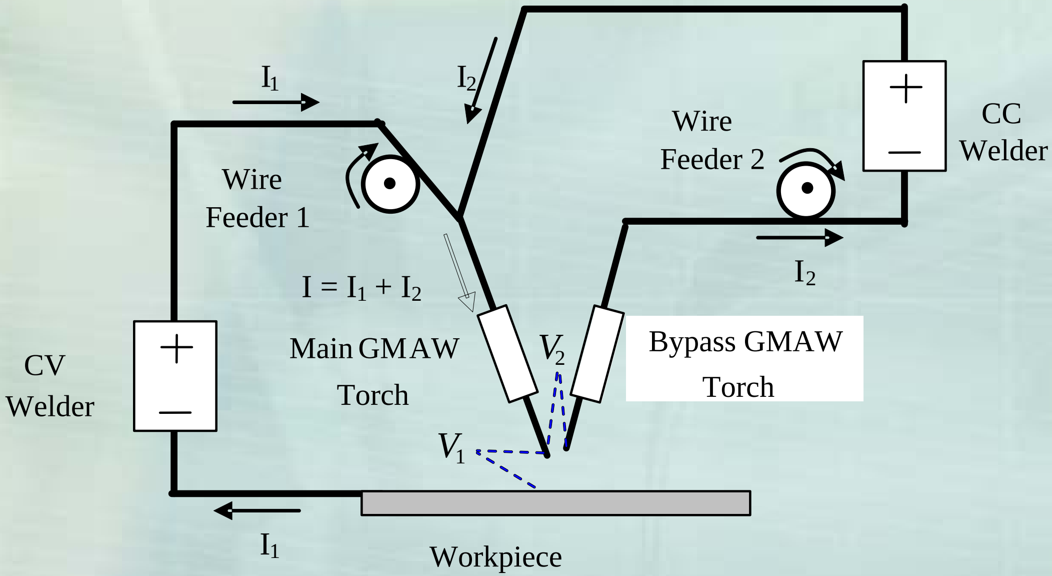
Base Metal Current Control and Its Effectiveness



Process Fundamentals
Consumable DE-GMAW

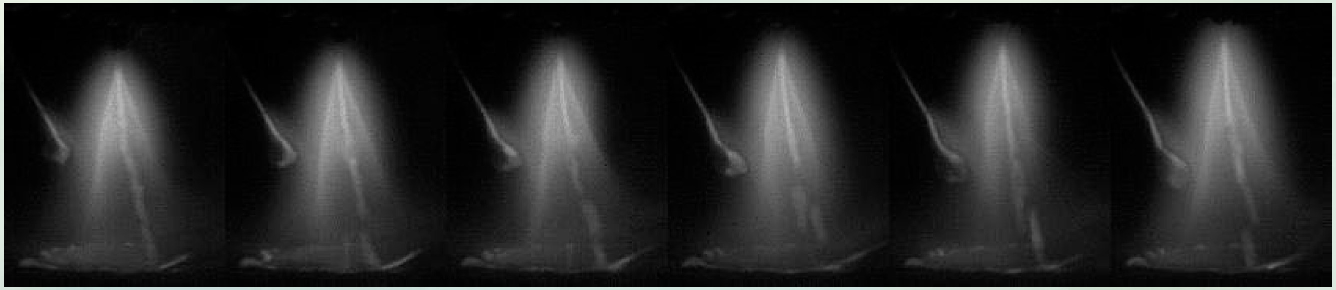
- Bypass current energy is wasted in the non-consumable DE-GMAW.
- Non-consumable tungsten→ **consumable** welding wire.



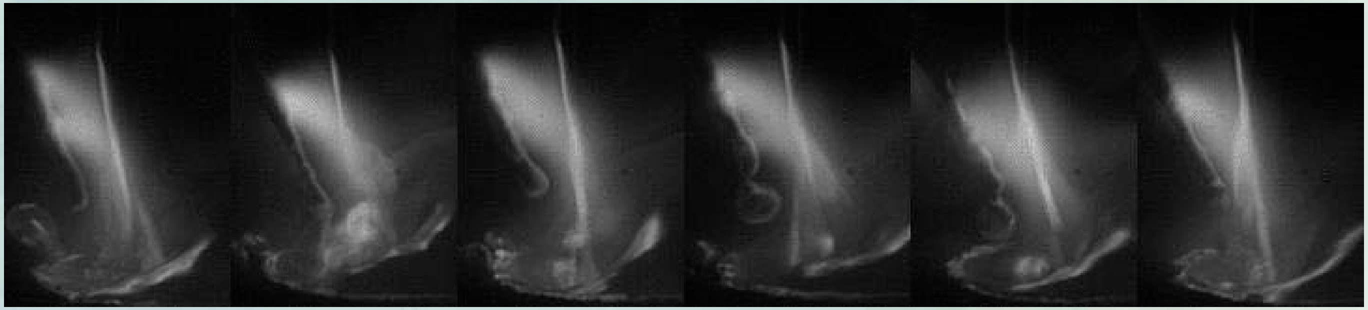


Process Fundamentals

Metal Transfer, No Spatters



I_1 = 230amps and I_2 = 120amps.



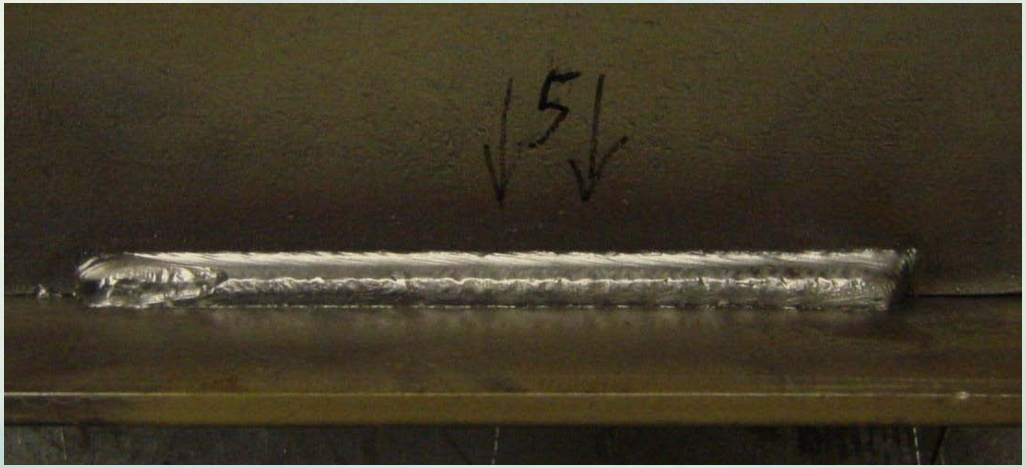
I_1 = 145amps and I_2 = 240amps.

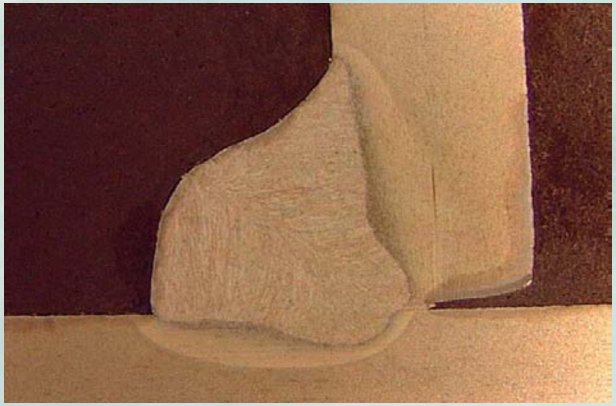
Process Fundamentals

Technology Summary

- Bypass: introduces a method to achieve independent control of melting speed and heat input
- Increase productivity without increasing base metal heat input
- Reduce the heat input, arc pressure, and distortion without reducing the productivity
- Desired high productivity and desired base metal heat input
- Wide ranges for bypass and base metal currents
- Easy spray transfer with low base metal current/arc pressure
- No modification to existing conventional GMAW systems

Phase I Preliminary Result: Fillet Weld One Pass





Setting parameters:

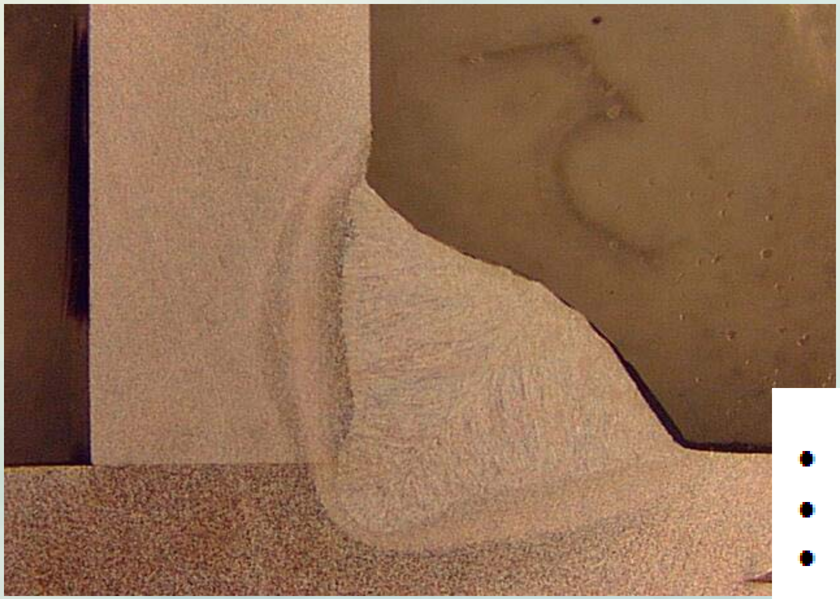
- V_1^* and V_2^*: 38 V and 35 V respectively
- w_1 and wire w_2: 700 imp and 600 ipm respectively
- v: 40 ipm
- Weave: none

Monitored parameters:

- I_1 : 240 A approximately
- I_2: 262 A approximately

Fillet weld: DH-36, 1/4 inch, 90% Ar-10% CO_2

Phase I Preliminary Result: Fillet Weld One Pass



Setting parameters:

- V_1^* and V_2^*: 38 V and 35 V respectively
- w_1 and wire w_2 : 700 imp and 600 ipm respectively
- v: 50 ipm
- Weave: none

Monitored parameters:

- I_1 : 325 A approximately
- I_2: 195 A approximately

Fillet weld: mild steel, 1/4 inch, 90% Ar-10% CO_2

Phase I Preliminary Result: Flat Position One Pass- No Weave

Setting parameters:

- V_1^* and V_2^*: 37 V and 38 V respectively
- w_1 and wire w_2 : 600 imp and 600 ipm respectively
- v: 20 ipm
- Weave: none

Monitored parameters:

- I_1 : 143 A approximately
- I_2: 315 A approximately

V-Groove, 50 degree, DH-36, ½ inch thick, 90% Ar-10% CO2

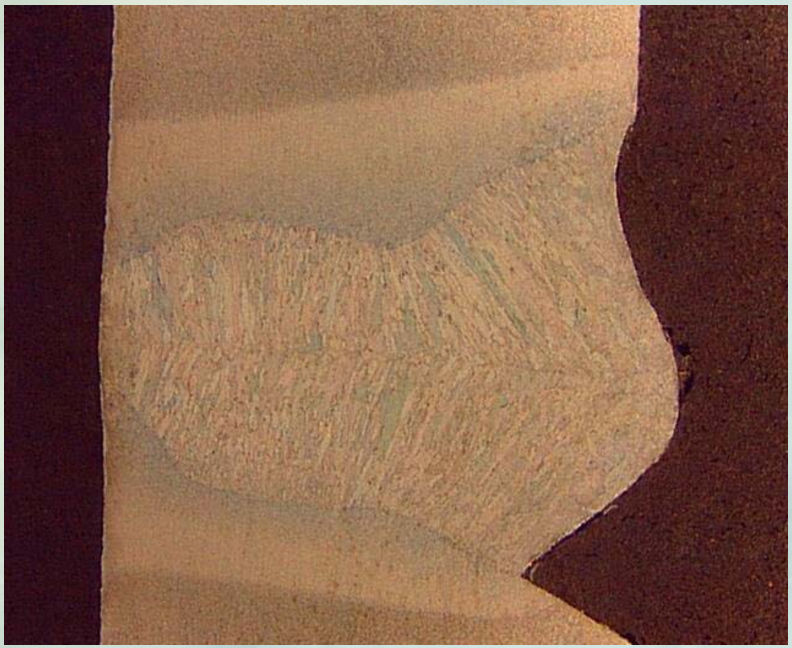
Phase I Preliminary Result: Flat Position One Pass-Weaved

V-Groove, 50 degree, DH-36, ½ inch thick, 90% Ar-10% CO_2-Weaved

Phase I Preliminary Result: Flat Position Two Passes-Weaved

V-Groove, 50 degree, DH-36, ½ inch thick, 90% Ar-10% CO_2-Weaved

Phase I Preliminary Result: Horizental Position
One Pass – No Weave



Setting parameters:

- V_1^* and V_2^*: 36 V and 39 V respectively
- w_1 and wire w_2: 650 imp and 520 ipm respectively
- v: 20 ipm
- Weave: none

Monitored parameters:

- I_1 : 184 A approximately
- I_2: 292 A approximately

V-Groove, 50 degree, DH-36, ½ inch thick, 90% Ar-10% CO2

Heat Input Analysis Fundamentals

- Effective Heat: heat which melts the wire
- Excessive Heat: heat which is directly imposed onto the base metal
- Basic Fact/Assumption: wire is primarily melted by the anode heat in GMAW and its variants, excessive heat is determined by the cathode heat
- Cathode voltage is significantly greater than the anode voltage in GMAW and its variants: approximately 6/4

Heat Input Analysis

GMAW or Its Variants

- Effective Heat: Anode Voltage X Current
- Excessive Heat: Cathode Voltage X Current
- Excessive Heat: proportional to the Effective Heat
- Cathode Voltage > Anode Voltage ➔ Excessive Heat > Effective Heat

Consumable DE-GMAW

- Effective Heat: Anode Voltage X (Base Metal Current + Bypass Current) + Cathode Voltage X Bypass Current
- Excessive Heat: Cathode Voltage X Base Metal Current
- Excessive Heat: controlled at a minimal level needed to assure the fusion

Heat Input Analysis
½ Inch V-Groove-Accumulative

Consumable DE-GMAW

- Excessive Heat/Effective Heat=Base Current*0.6/(Total Current*40%+Bypass Current * 60%)=143*0.6/(445*0.4+315*0.6)=23%
- Total Heat Input: 123% of Effective Heat (needed to melt the wire to fill the groove)

GMAW and Variants

- Excessive Heat/Effective Heat=Cathode Voltage/Anode Voltage=6/4 (fixed)=133% of Effective Heat
- Total Heat Input: 233% of Effective Heat (needed to melt the wire to fill the groove)

- Heat Input Reduction: approximately 50% from the accumulative heat input of GMAW and its variants

Heat Input Analysis
½ Inch V-Groove-Single Pass Comparison

Assumption: 3 passes for submerged

Heat Input in One Pass in Submerged: 233%/3=78% of Totally Needed Effective Heat

Heat Input in DE-GMAW in the Single Pass; 123% of Totally Needed Effective Heat

Heat Input Increase from one GMAW (or its variant) Pass: (123-78)/78=58% (Would this input increase in a single pass adversely affect the materials properties significantly? Testing (in process) will be done to verify. If yes, we can use two passes and still reduce the accumulative heat input, control each pass heat input unchanged, and increase the productivity by reducing from 3 passes to 2 passes.)

Horizontal: even greater productivity improvement because more than 3 passes are needed

Phase II Efforts/Directions

Materials? DH-36 and HSLA? Others?

Positions? Flat, horizontal, fillet? Others

GMAW first? Then Submerged and Flux Cored as option or in Phase III?

Stand-alone system first for Phase II and add-in system second in Phase III?

Which Program to go first? Application example details?

Military Qualification Needed for this process?

Recommendation of manufacturers, marketers and service providers

Materials donation welcome! Participation Welcome!