Effects of Cold-Wire Gas Metal Arc Welding (CW-GMAW) Process Variables on Energy Input and Deposition Rate during Repair of S275JR Structural Steel.

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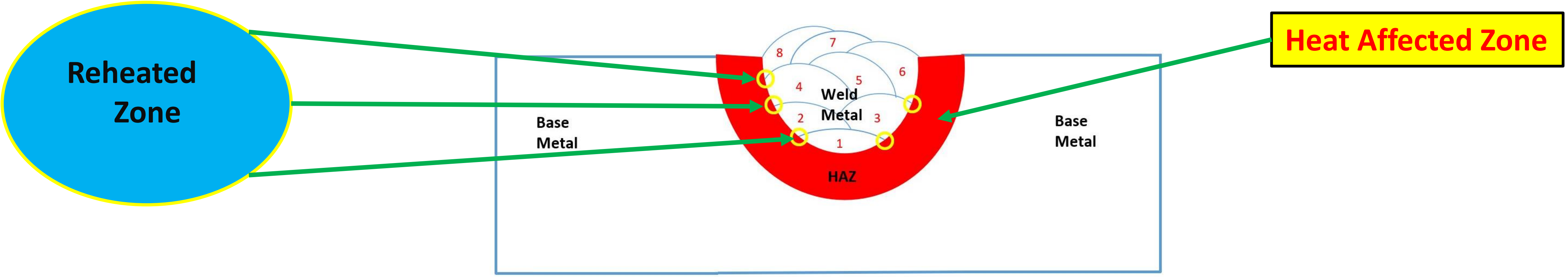
Introduction

Background of the Study

- Structural steels (HSLA, S355, S275JR) – used to improve transport efficiency of hydrocarbons in the oil and gas industries, and as reinforcements in the construction industries.

Statement of Research Problem

- Failure of these components is associated with heavy economic and environmental losses.
  - Repair through welding is easy and reliable.
  - Studies have shown repeated thermal cycles have an adverse effect on the material.



Schematic showing a partially repaired plate

Aim and Objectives of the Study

The aim of this research is to investigate the effects of varying cold wire gas metal arc welding (CW-GMAW) parameters to improve repair productivity and quality.

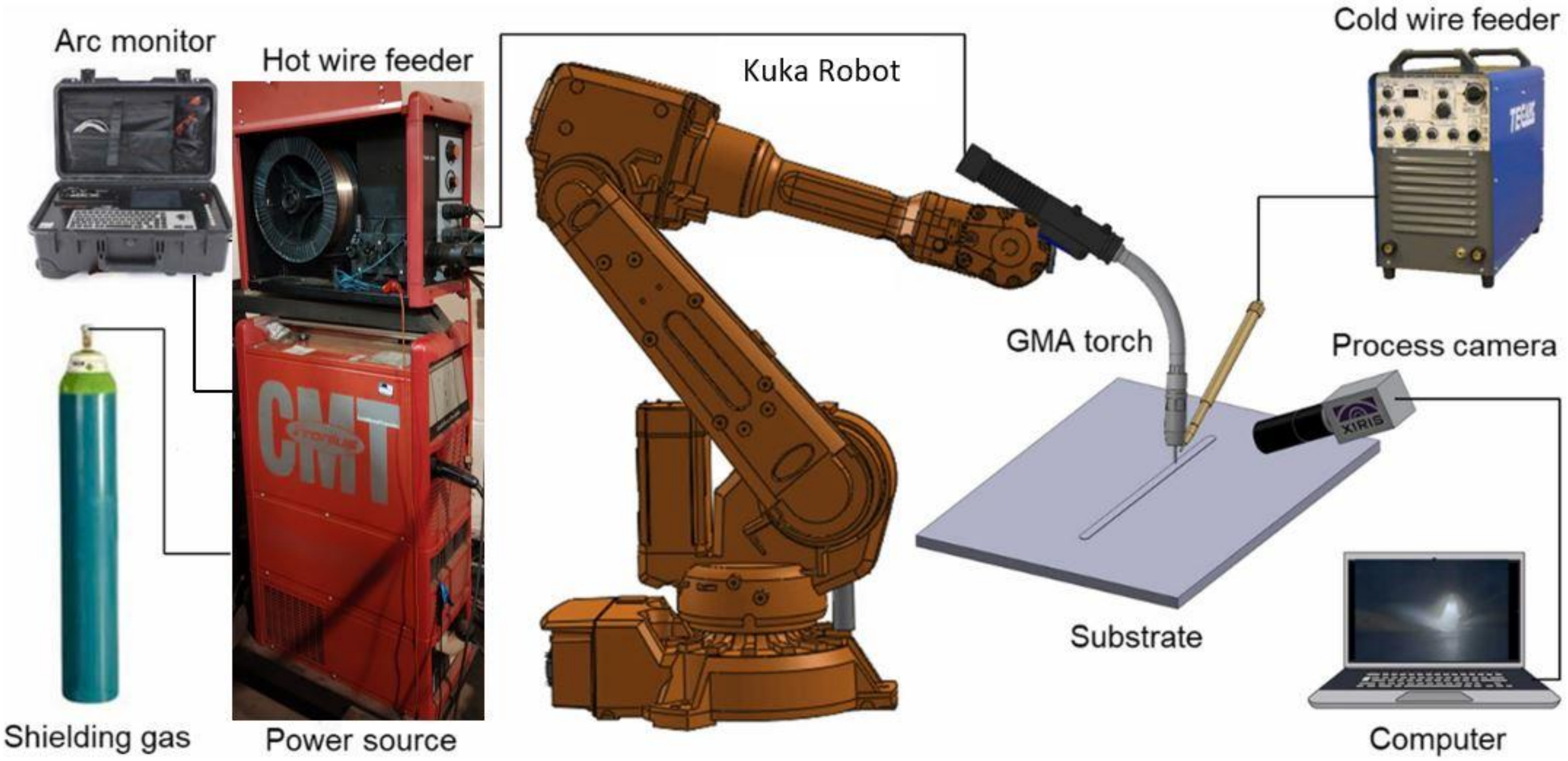
The specific objectives to be addressed are as follows:

1. Determine the energy consumption of different shielding gases used for gas metal arc welding

2. Systematic analysis of these key welding parameters:
    - Welding current
    - Voltage
    - Weld travel speed
    - Cold wire feed speed

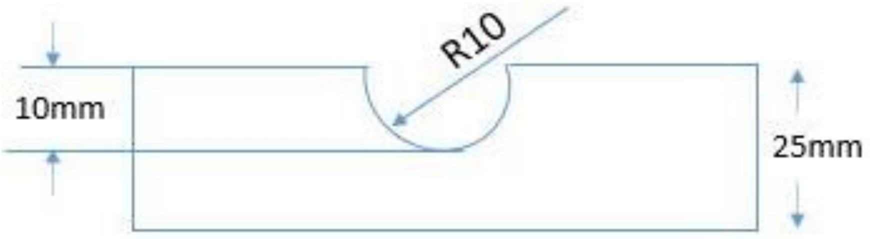
3. Determining which of these parameters has the most significant effect on the heat input

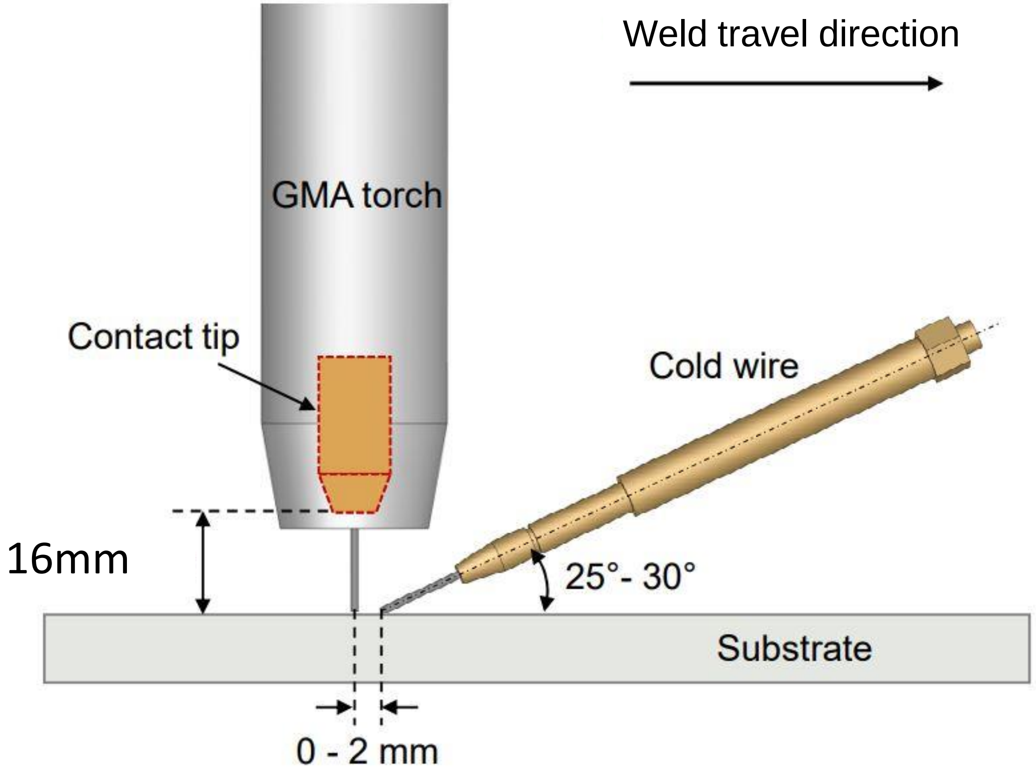
Experimental Setup - Equipment

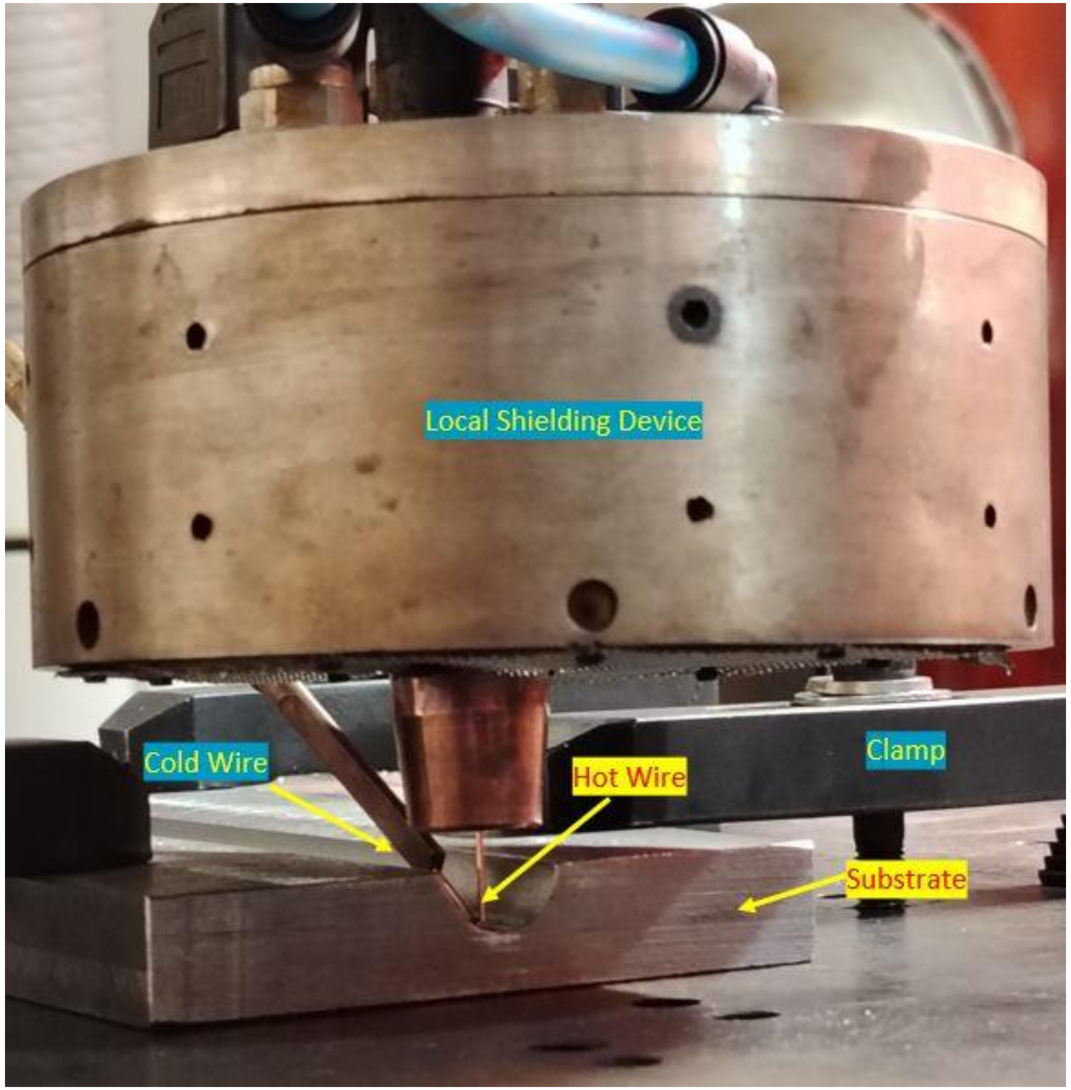


- Shielding Gas: 2.5% CO_2 and 97.5% Argon at 18 l/min
- Hot and Cold Wire: ER70S-6, 1.2 mm

Experimental Setup – Configuration of CW-GMAW Process







Methodology

- The energy input (EI) in kJ/mm, was calculated using Equation [1] according to ISO/TR 17671-1:2002(E).

$$EI = \frac{\eta_a V\, I}{\upsilon_t} \qquad [1]$$

where V, I, and υ_t are voltage, current and welding travel speed, respectively. η_a is the arc efficiency, which depends on the welding process. An arc efficiency of 0.8 was used for GMAW.

- The deposition rate (DR) in kg/hr, was calculated using Equation [2]

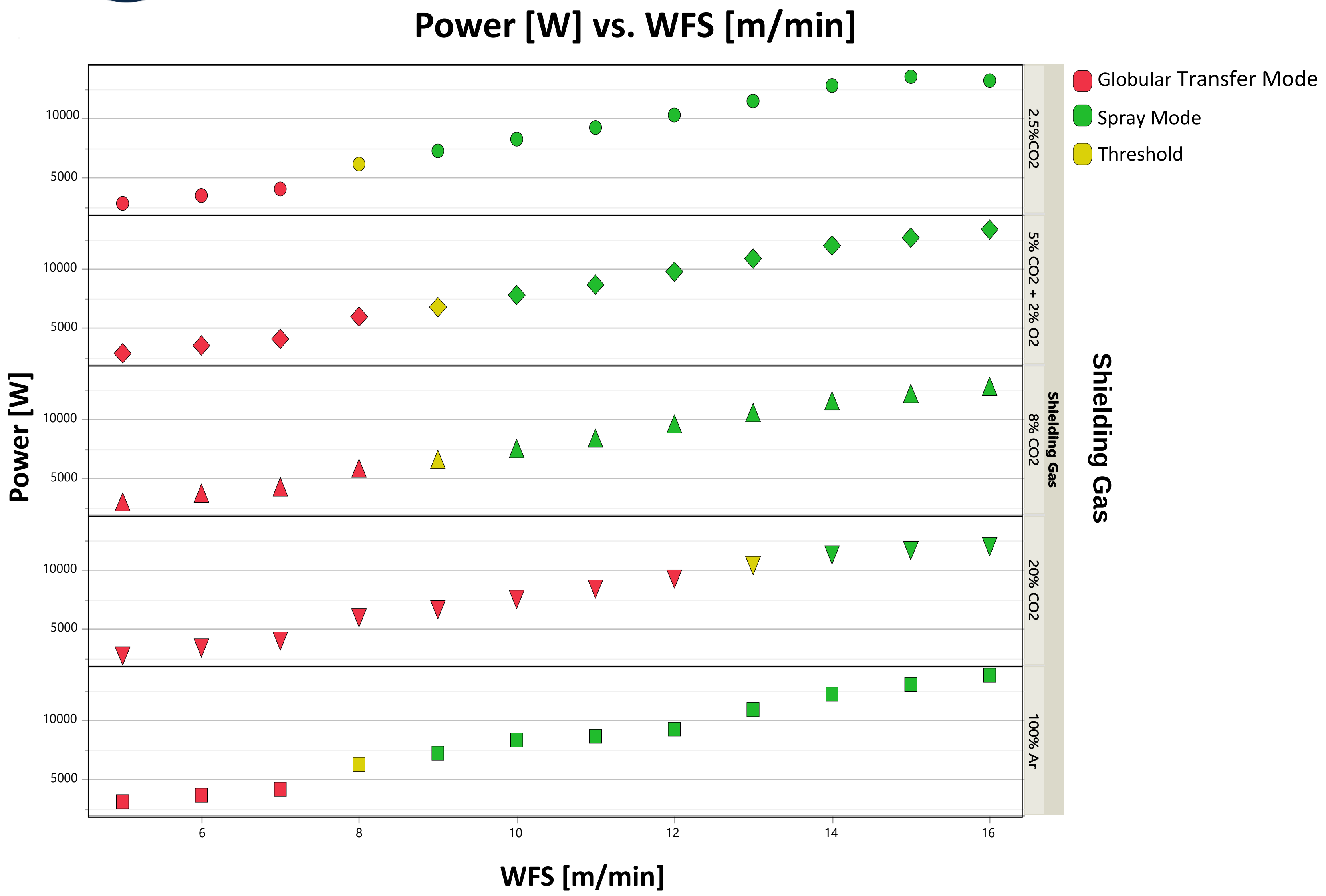
$$DR = \rho\, \pi \frac{d^2}{4}\, (\upsilon_h + \upsilon_c) \qquad [2]$$

Where ρ is the density of the welding electrode, which for the ER70S-6 wire is 7833.4 kg/m^3 ; d is the diameter of the wire (1.2mm for both hot and cold wires), υ_h and υ_c are the wire feed speed (WFS) of the hot and cold wires respectively.

- The material feed rate (MFR) was calculated using Equation [3],

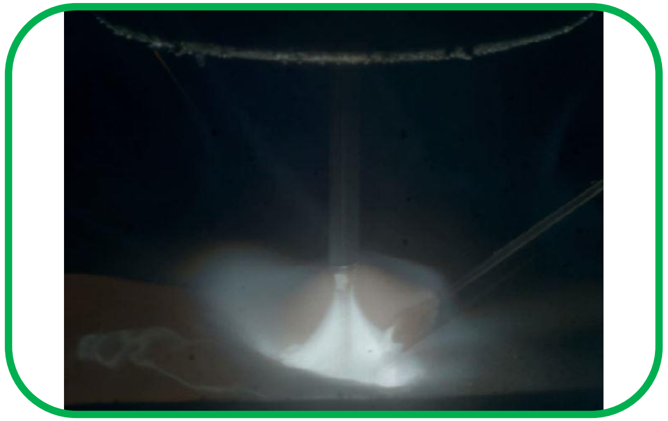
$$MFR = \frac{\upsilon_h + \upsilon_c}{\upsilon_t} \qquad [3]$$

Energy Consumption for Different Shielding Gases

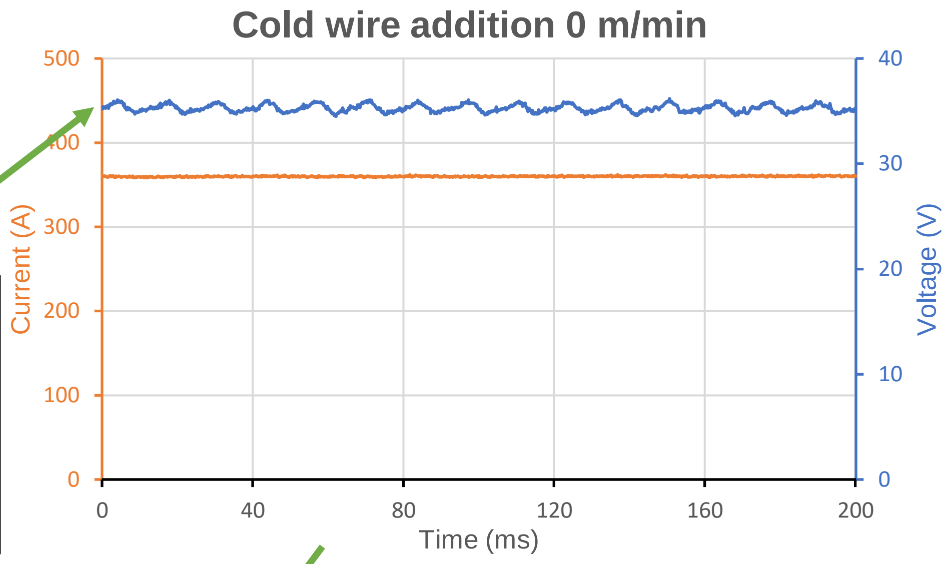


Global transfer mode

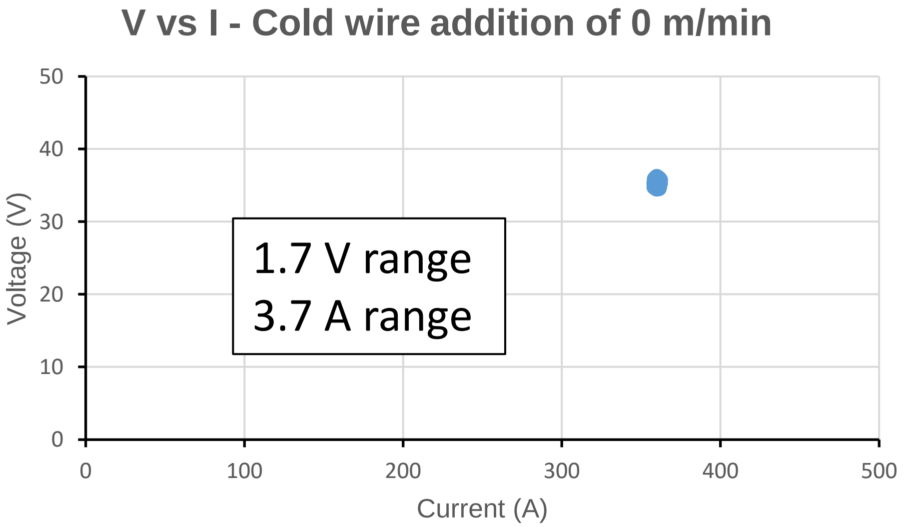
Spray transfer mode



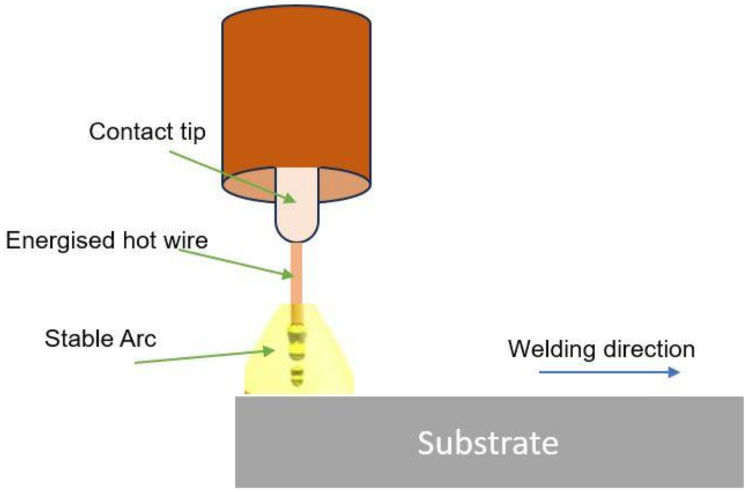
Waveform Characteristics of the Position of the Cold Wire in Relation to the Hot Wire

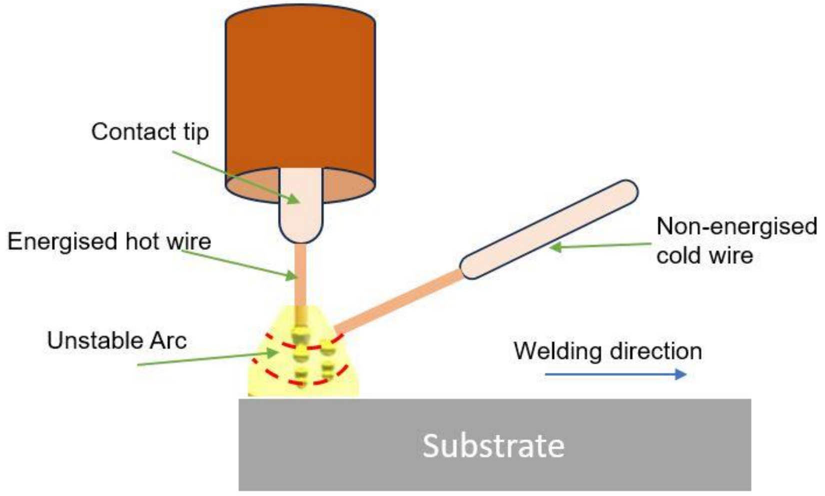


Arc stability without cold wire addition

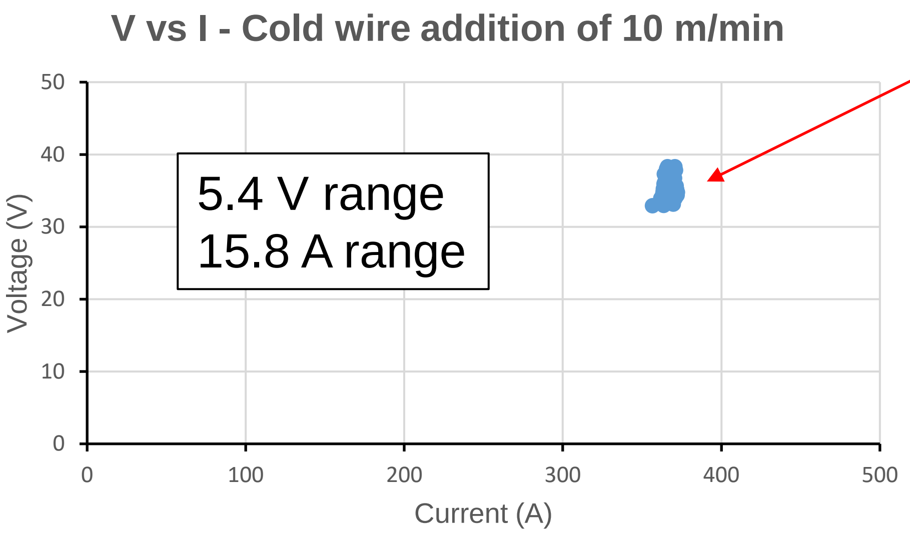


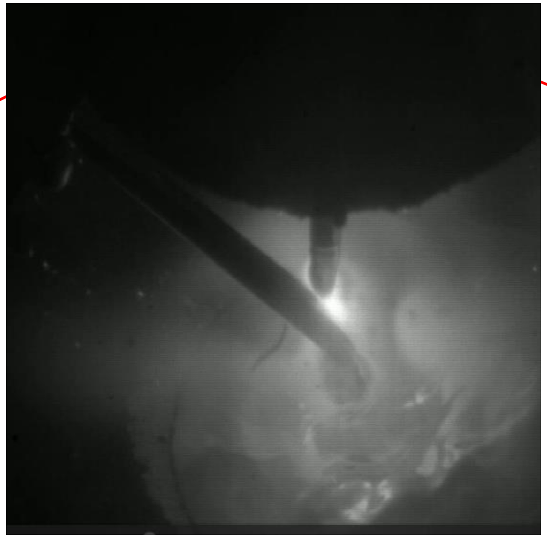
1.7 V range
3.7 A range

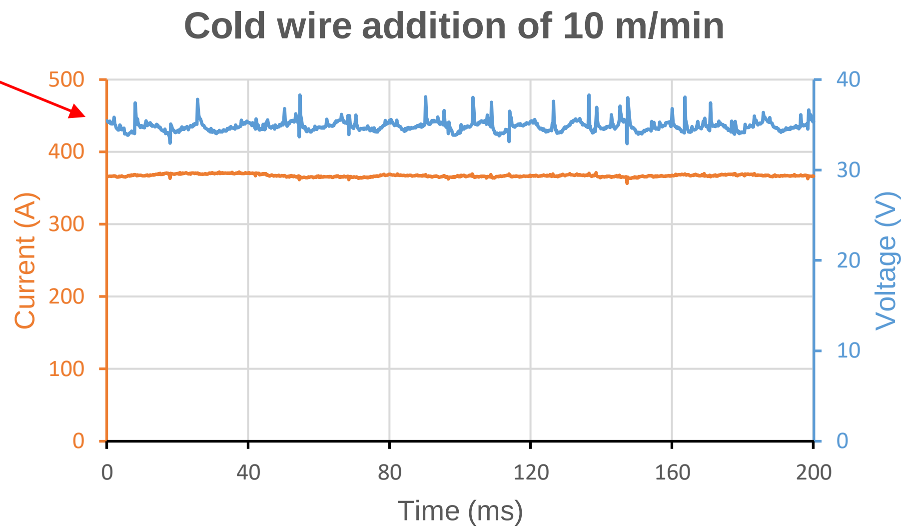


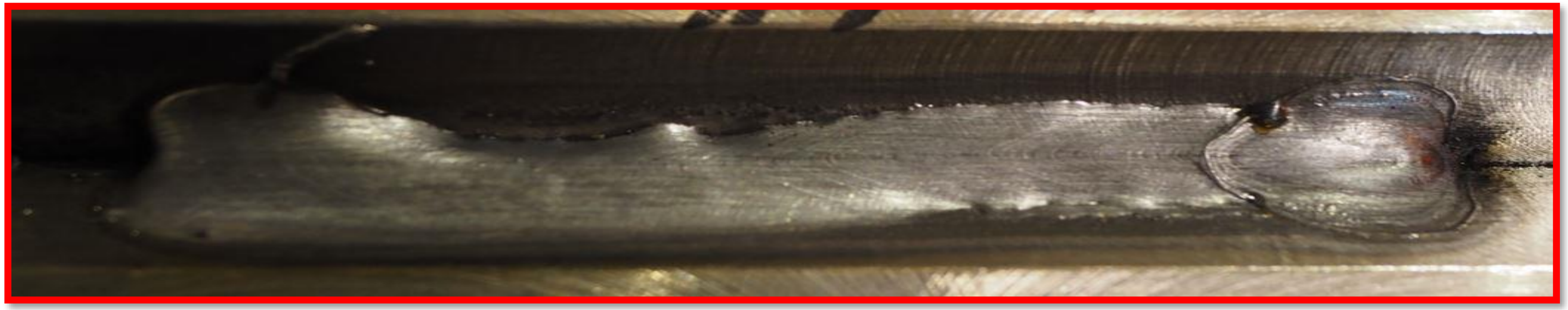


Arc Instability Due to Improper Position of the Cold Wire



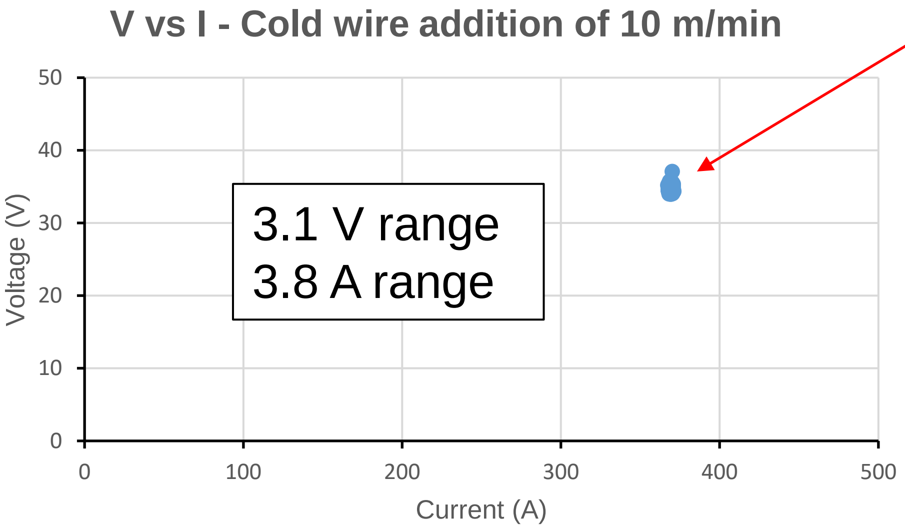


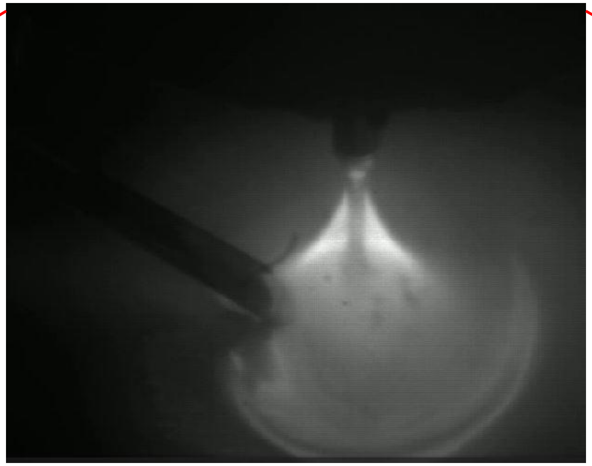


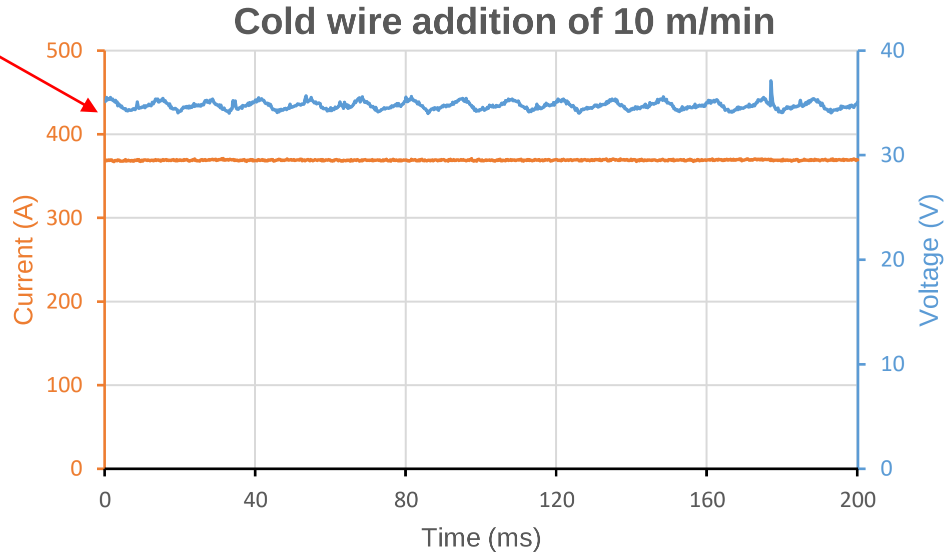


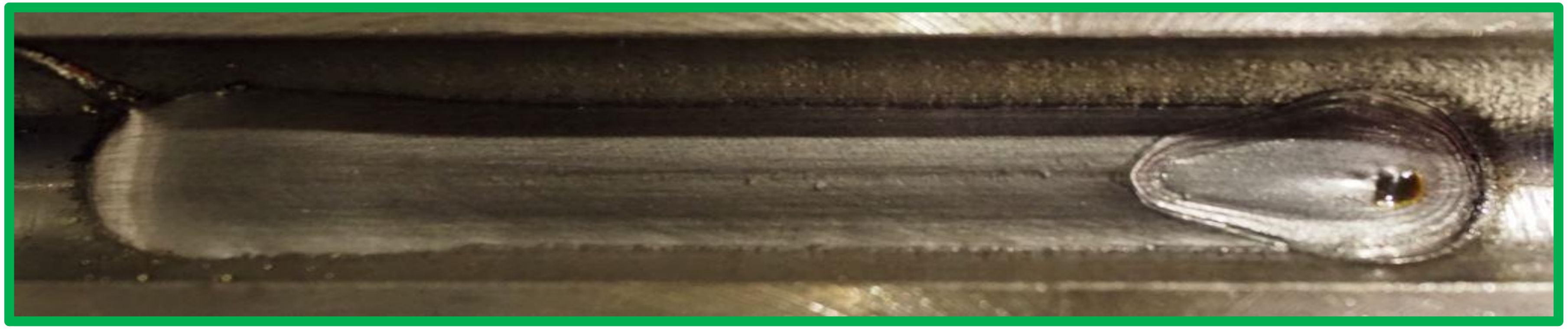
Unacceptable bead

Arc Stability Increased with Position Control of the Cold Wire







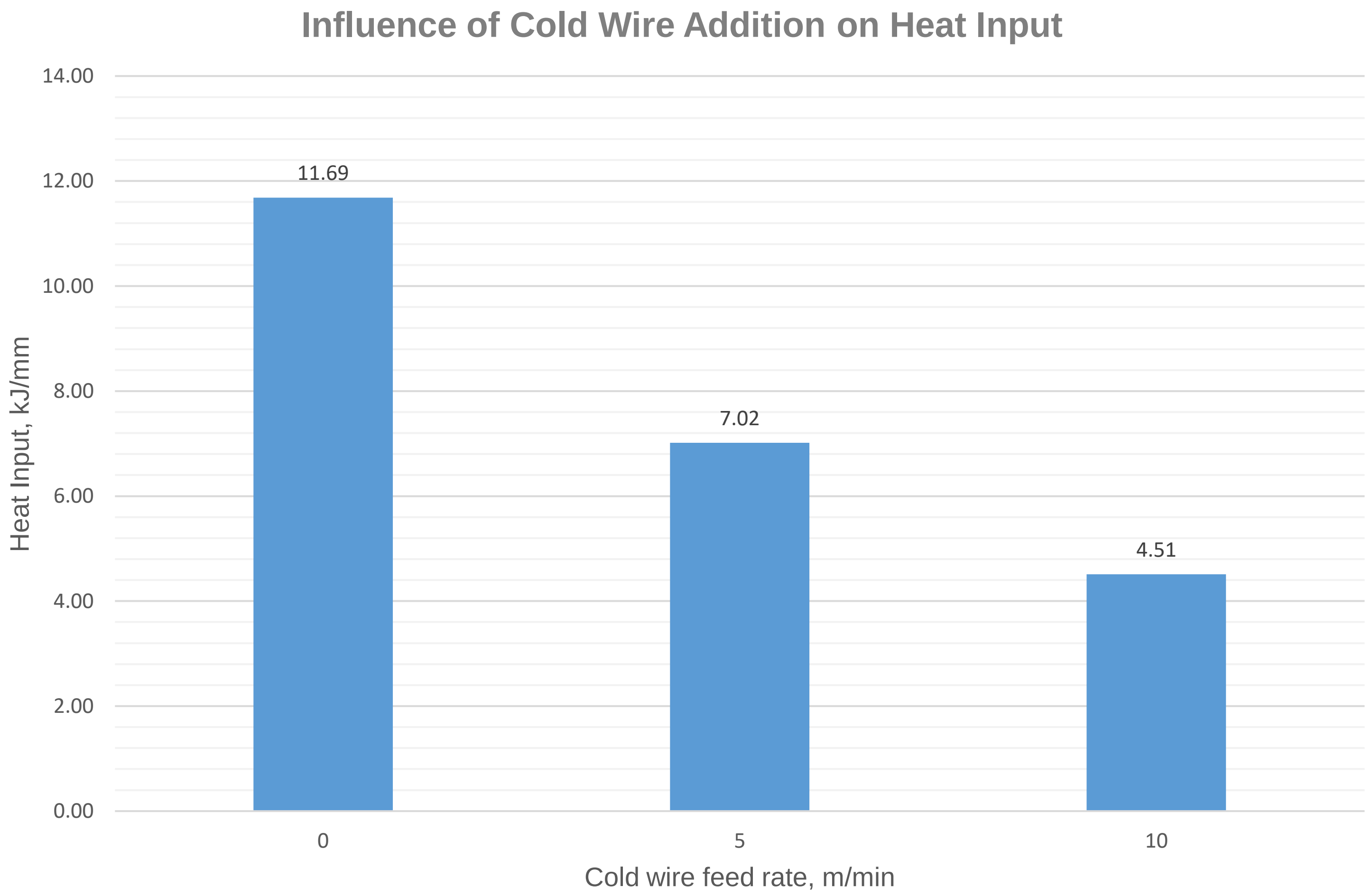


Acceptable bead

Effect of Cold Wire Addition on Heat Input

Constant Hot Wire Feed Speed = 11m/min

Constant Travel Speed to Total Wire Feed Speed Ratio = 0.04



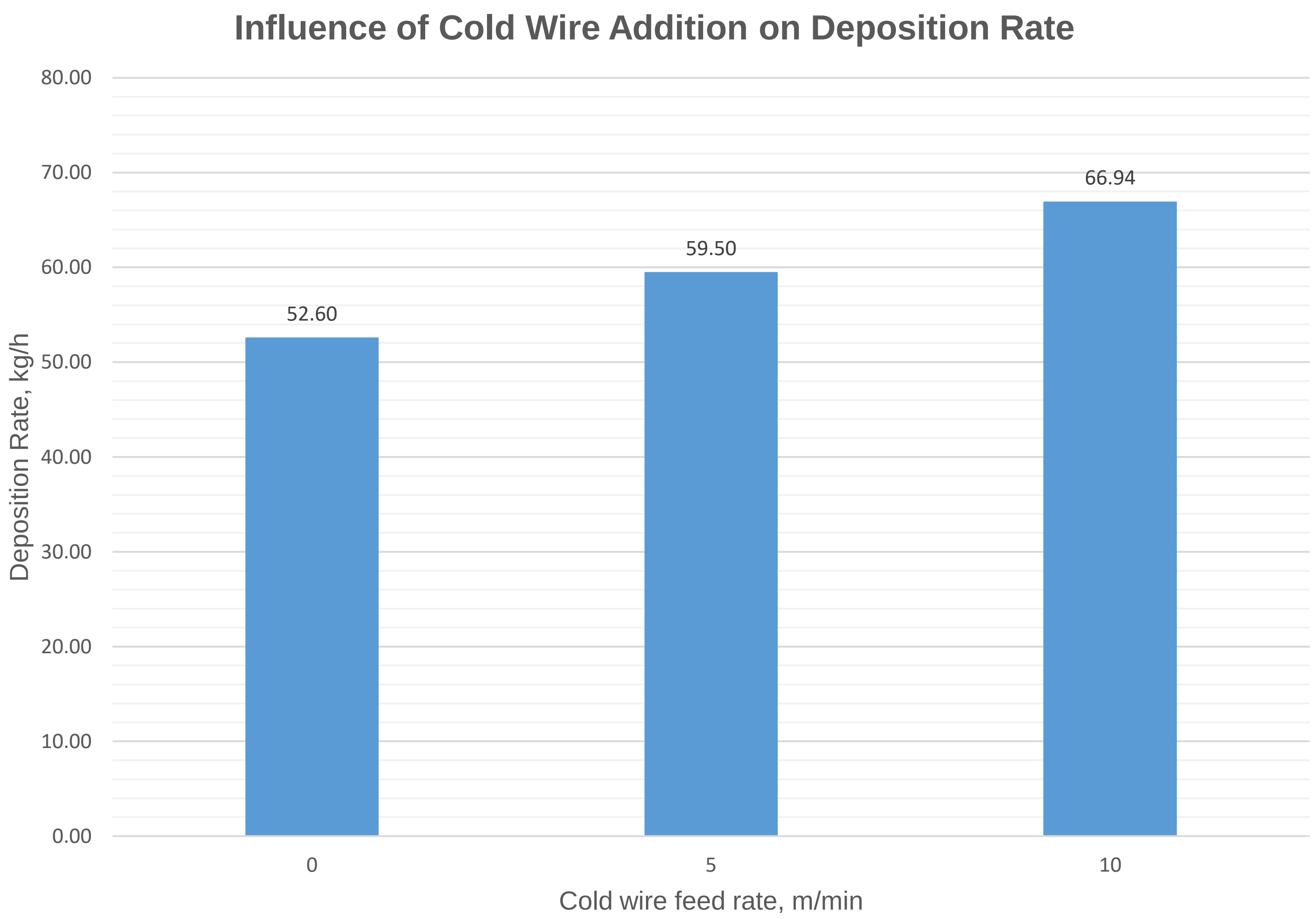
Travel Speed was simultaneously increased with addition of cold wire

- Cold wire, 0 m/min – Travel speed, 0.47 m/min
- Cold wire, 5 m/min – Travel speed, 0.65 m/min
- Cold wire, 10 m/min – Travel speed, 0.82 m/min

Effect of Cold Wire Addition on Deposition Rate

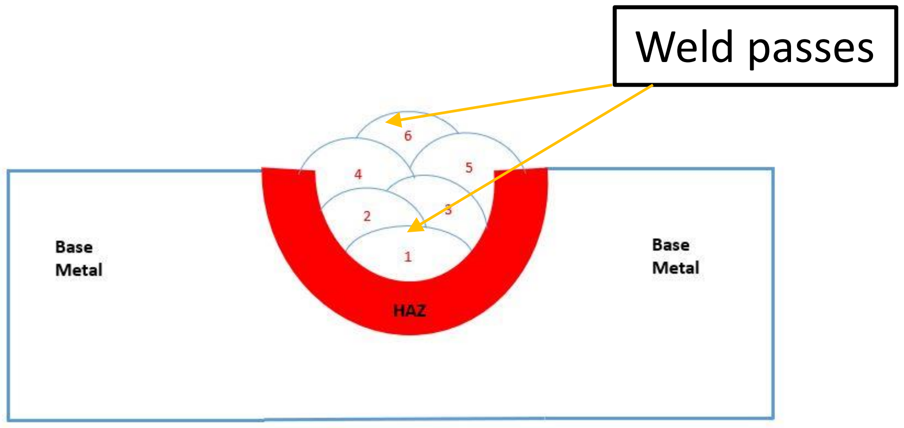
Constant Hot Wire Feed Speed = 11m/min

Constant Travel Speed to Total Wire Feed Speed Ratio = 0.04



Number of Passes to fill the groove with cold wire addition of;

- 0 m/min – 9 passes
- 5 m/min – 7 passes
- 10 m/min – 6 passes



Reduction in Number of Weld Passes to Fill the Groove with Addition of Cold Wire

Number of Passes	Total Heat Input (kJ/mm)	Total Deposition Rate (kg/h)
9	11.69	52.60

Number of Passes	Total Heat Input (kJ/mm)	Total Deposition Rate (kg/h)
6	4.51	66.94

Conclusions and Future Work

- The heat input was significantly reduced by 61.42% i.e. from 11.69 kJ/mm with no cold wire addition (0 m/min) to 4.51 kJ/mm at cold wire feed rate of 10 m/min. Therefore, a reduced risk of thermal damage was achieved.

- The deposition rate was increased by 21.42% i.e. from 52.60 kg/hr with no cold wire addition (0 m/min) to 66.94 kg/hr at cold wire feed rate of 10 m/min

- The CW-GMAW offers a faster and more efficient repair process with potential cost savings in large – scale welding operations.

Future work

Investigate microstructural effects, mechanical properties (hardness, tensile, and impact tests) and fatigue failure analysis of the CW-GMAW weld joints.

Acknowledgments

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Technical Team

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Thank You For Listening.

Any Questions?