Application of laser and arc based hybrid process in pipeline welding

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Why laser and arc Hybrid?

Complementary ... th...

The mutual complementarities make laser arc hybrid a very attractive for pipeline welding

However, optimisation of parameters and compatible weld set up is essential to realise the benefits

...ges
- ...ase in filler addition
- More tolerant to fit-up

Limitations
- High heat input
- Less productive as compared to high power density processes

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Outline

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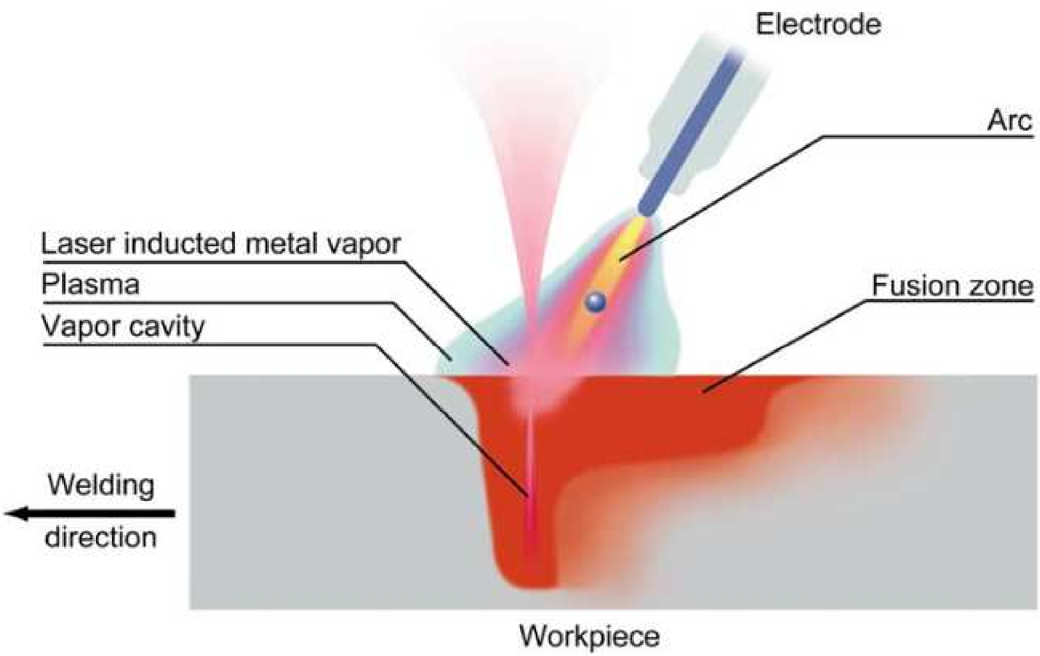
- Basics – Configuration - arc or laser leading, laser power, wire feed speed
- Application examples;
  - Full welding of 11.5 mm thick pipe
  - Root pass welding of 25 mm thick X65 grade
- Effect of bevel design and laser-arc configuration on weld metal mixing
- Other application possibilities
  - Tack welding
  - Hyperbaric welding

Laser Hybrid Welding



Video Courtesy of TWI

Link Hybrid welding

Configuration – leading trailing heat sources

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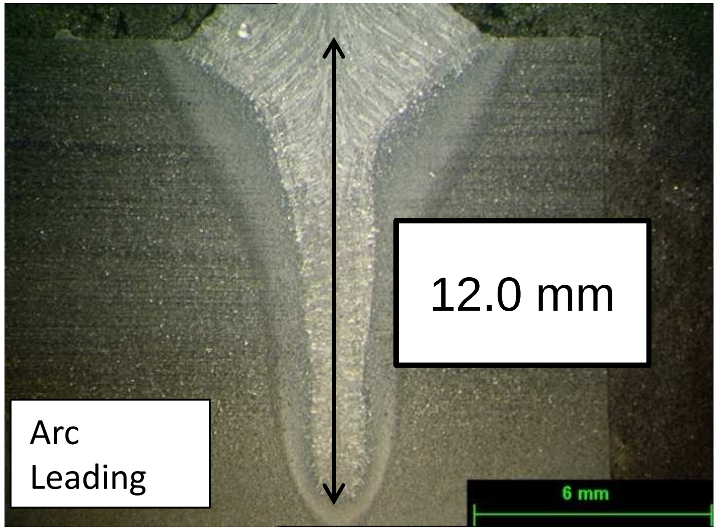
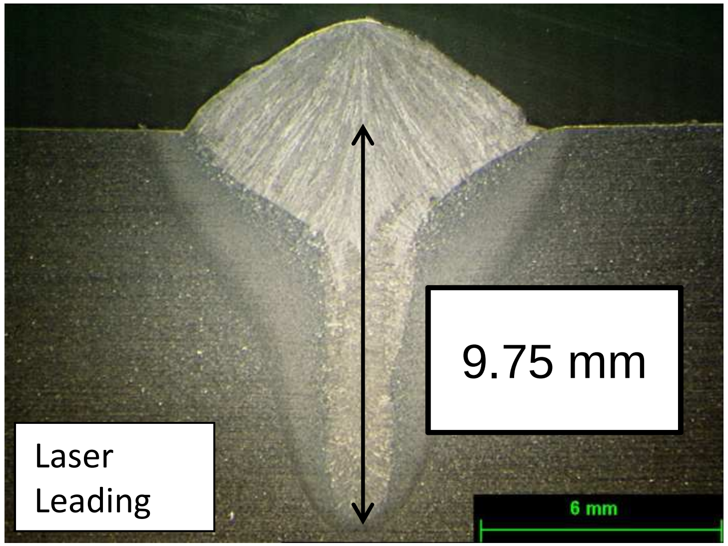
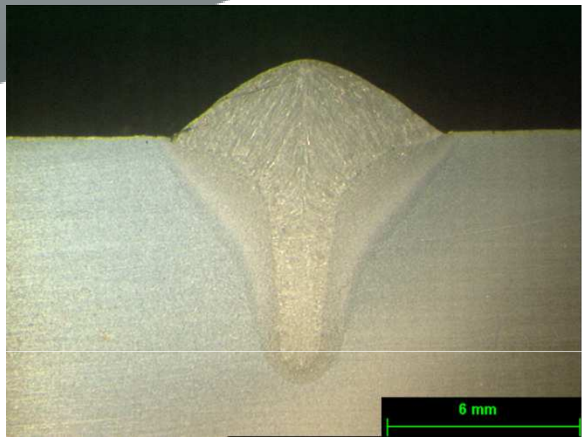


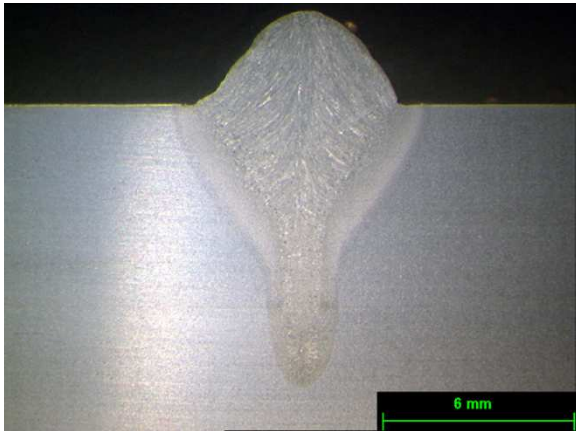


Configuration – leading trailing heat sources

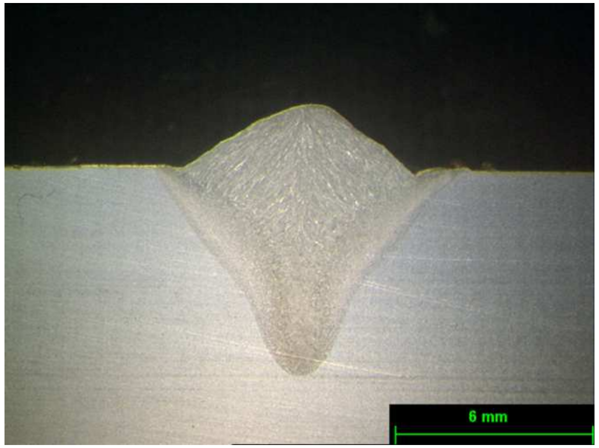
P=6 kW, TS=1.5 m/min, SS=0.6 mm



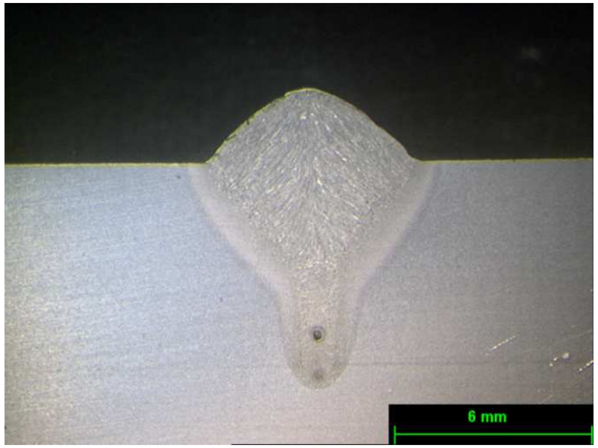
Laser leading; WFS=20 m/min



Arc leading; WFS=20 m/min



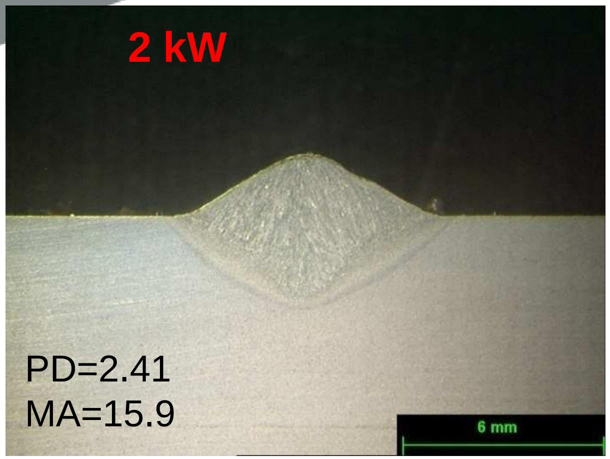
Laser leading; WFS=15 m/min

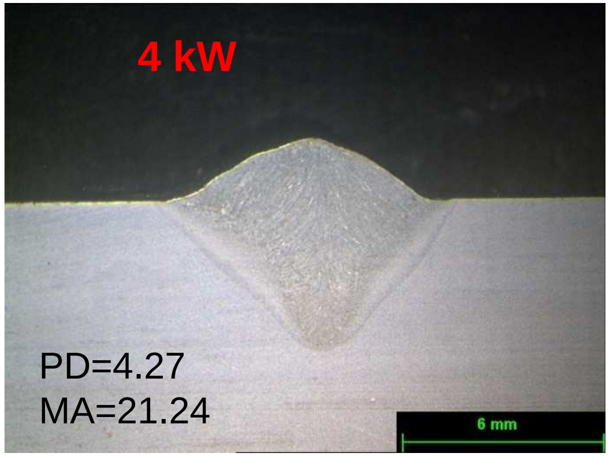


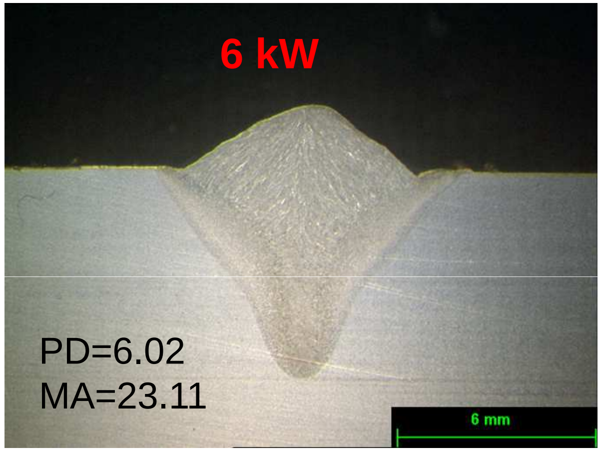
Arc leading; WFS=15 m/min

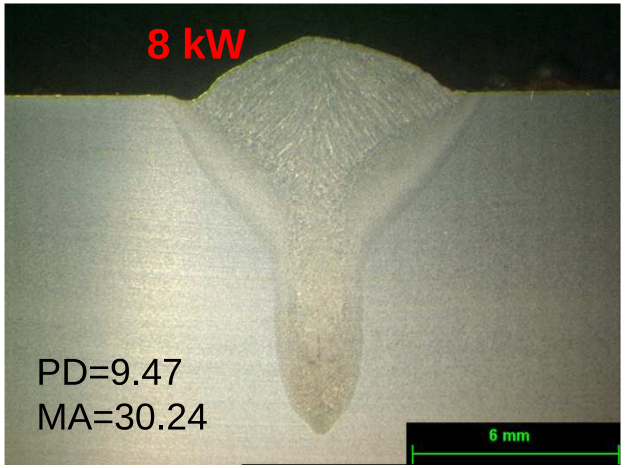
WFS – wire feed speed [m/min];
SS – spot size [mm];
TS – travel speed [m/min];
P – laser power [kW]

Increasing laser power controls penetration depth









Other parameters:
WFS = 15 m/min,
TS = 1.5 m/min,
Spot Size = 0.6 mm
PD = penetration depth
MA = melting area

Wire feeding rate – determines fit-up tolerance

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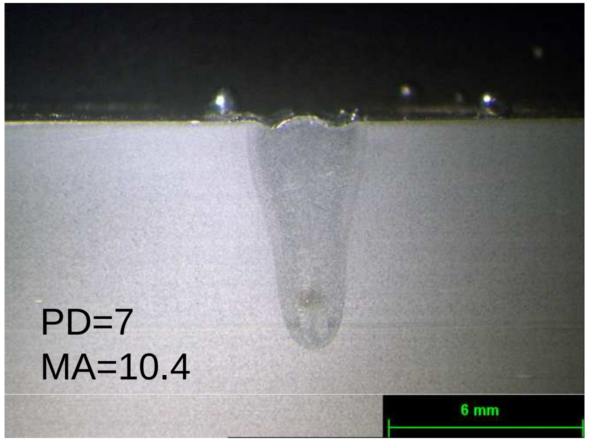
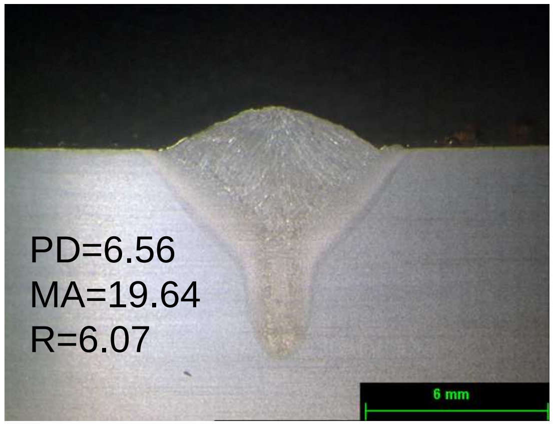
WFS – wire feed speed [m/min];
DB – beam diameter [mm];
TS – travel speed [m/min];
P – laser power [kW]
PD – penetration depth [mm]
MA – melting area [mm^2]
R - reinforecement

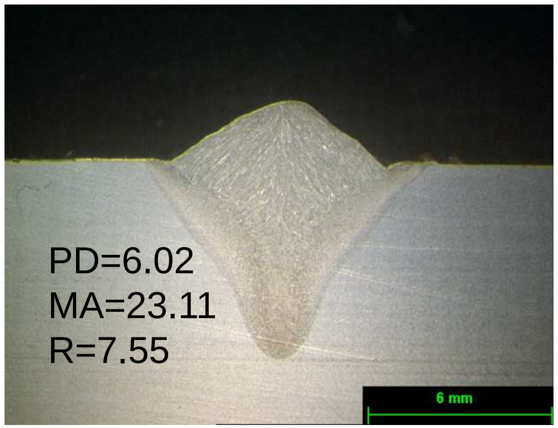
P=6 kW, TS=1.5 m/min, DB=0.6 mm

Laser only

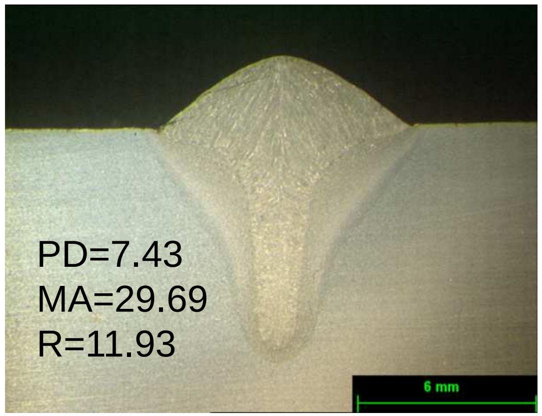




WFS=10 m/min

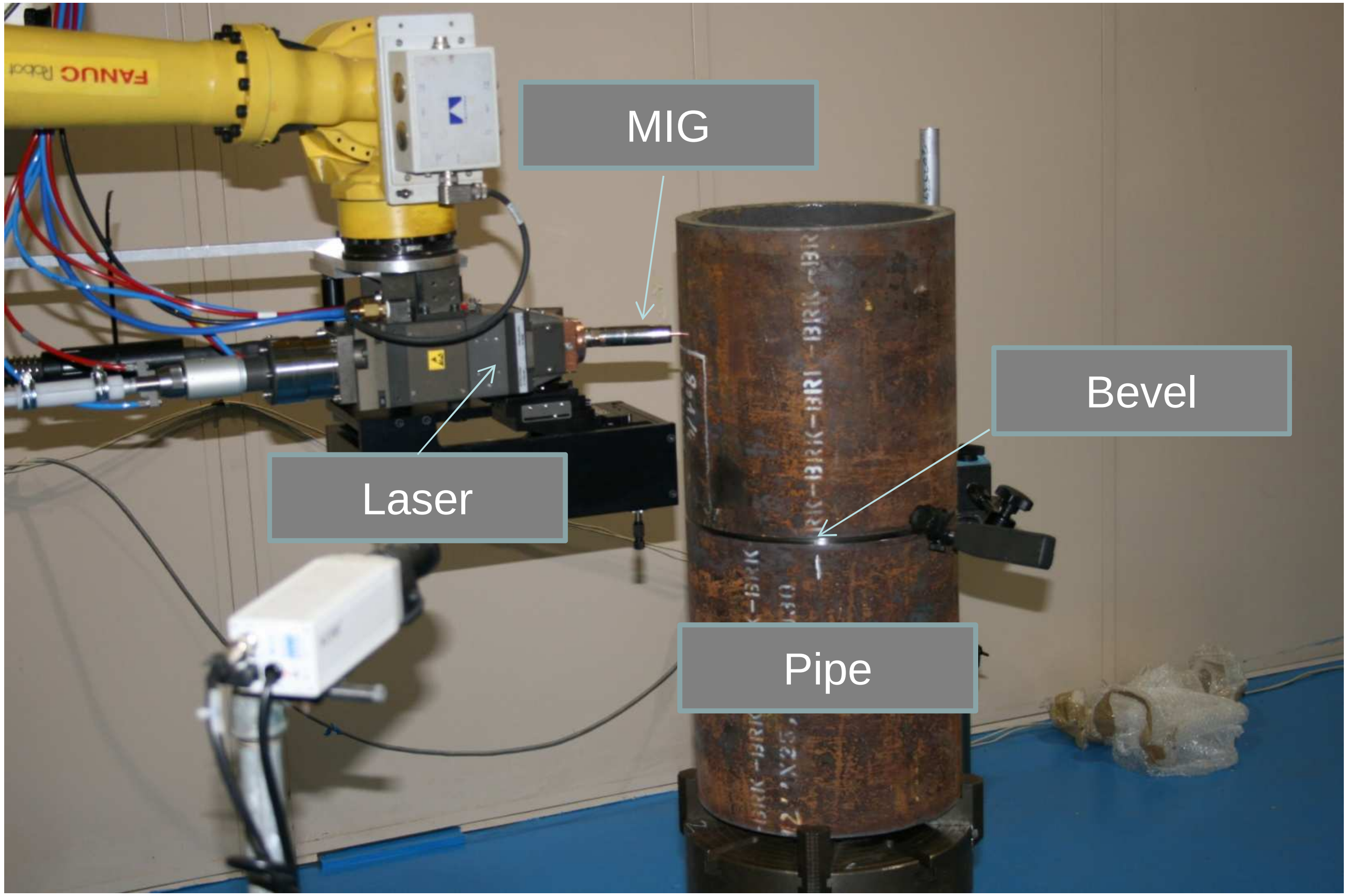


WFS=15 m/min

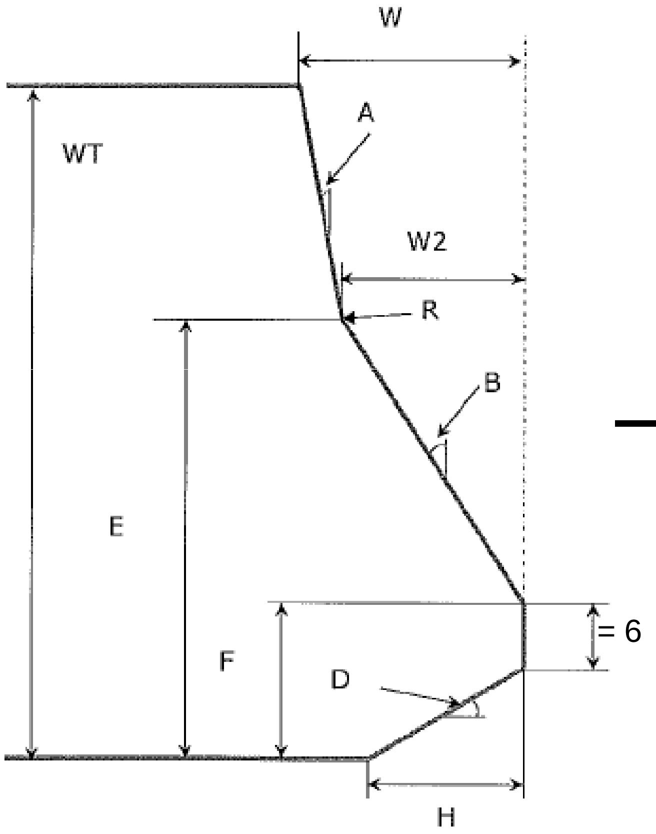


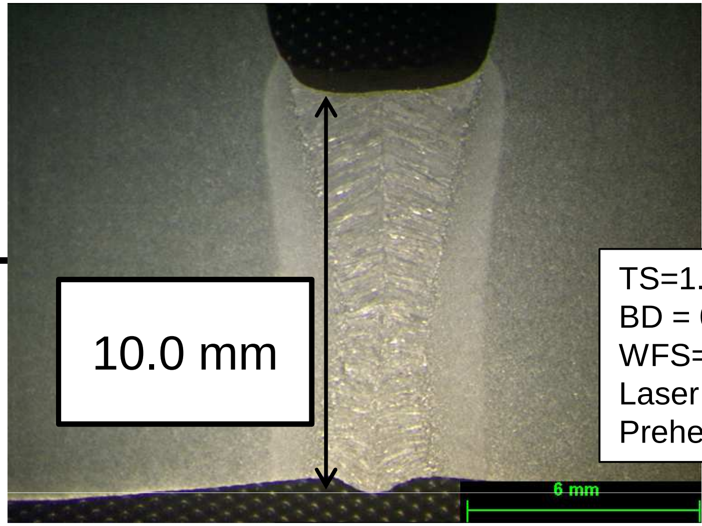
WFS=20 m/min

Root pass welding of a 25 mm thick X70 grade pipe– 2G configuration

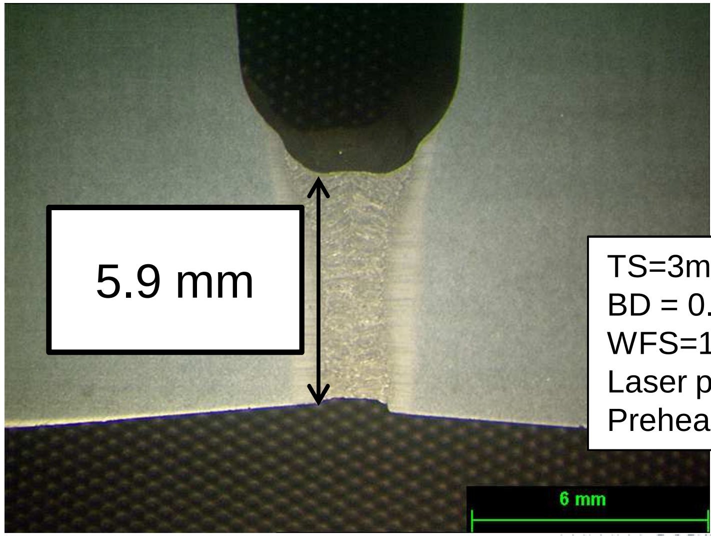


Effect of heat input



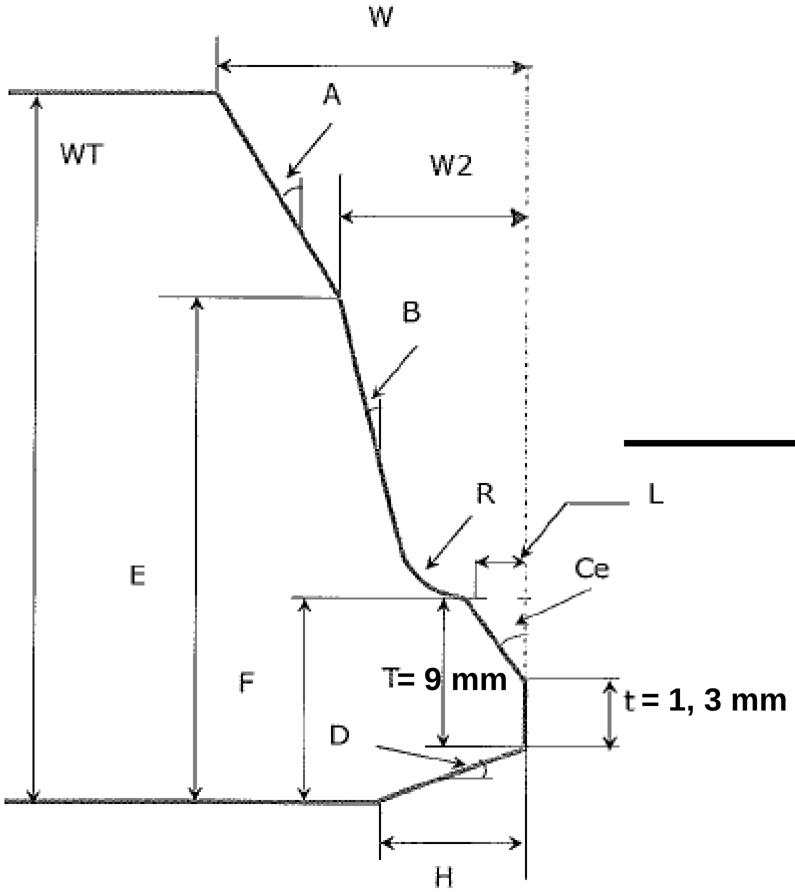


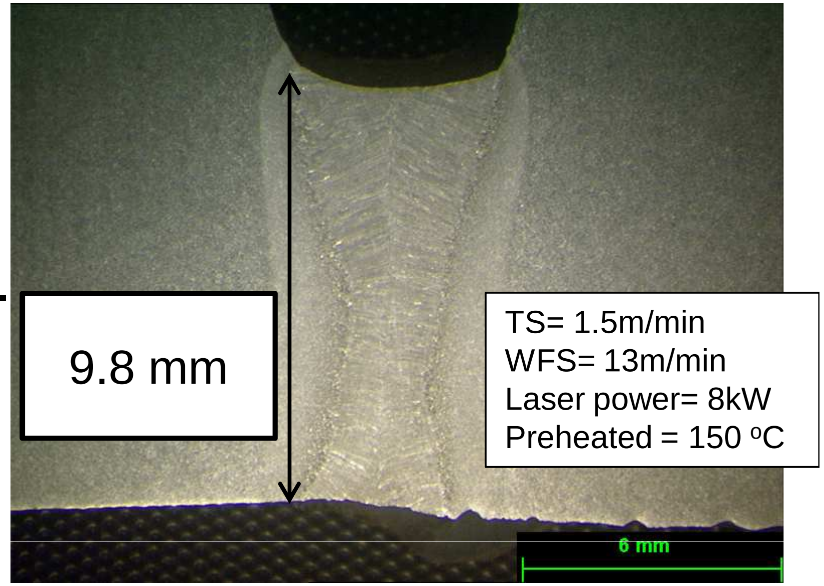
TS=1.5 m/min
BD = 0.63 mm
WFS=13 m/min
Laser power=8 kW
Preheat = 150 ℃

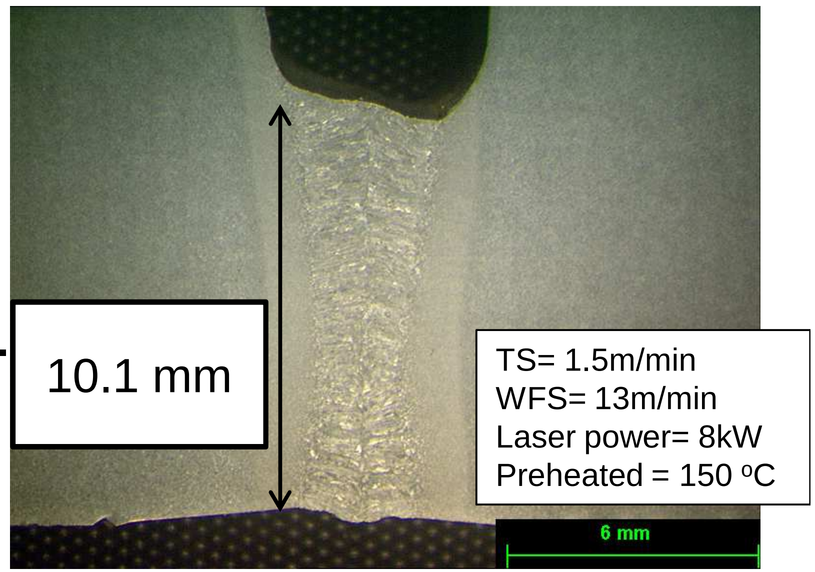


TS=3m/min
BD = 0.63 mm
WFS=13m/min
Laser power= 8kW
Preheat = 100 ℃

Effect of bevel design







Summary

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The laser arc hybrid process is capable of welding root pass which would enable improved productivity in laying of pipelines. By use of the hybrid process welding of root and hot pass no longer remains the critical process determining the rate of laying of pipeline.

A full procedure qualification of the complete pipe, using GMAW alone as fill passes, showed conformance to the required standard.

A feasibility study on laser-arc girth welding of 11.5 mm thick pipeline

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Chemical Compositions and Carbon Equivalent

Grade	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	C.E
K-55	0.39	0.26	1.44	0.013	0.005	0.07	0.02	0.01	0.02	0.63
L-80	0.26	0.33	1.20	0.010	0.003	0.03	0.03	0.05	0.03	0.46
Supra MIG	0.07	1.00	1.61	0.011	0.014	0.02	0.01	0.02	<0.01	0.34
LNM Ni1	0.07	0.70	1.11	0.007	0.011	0.05	0.86	0.07	0.01	0.32

Bevel Designs

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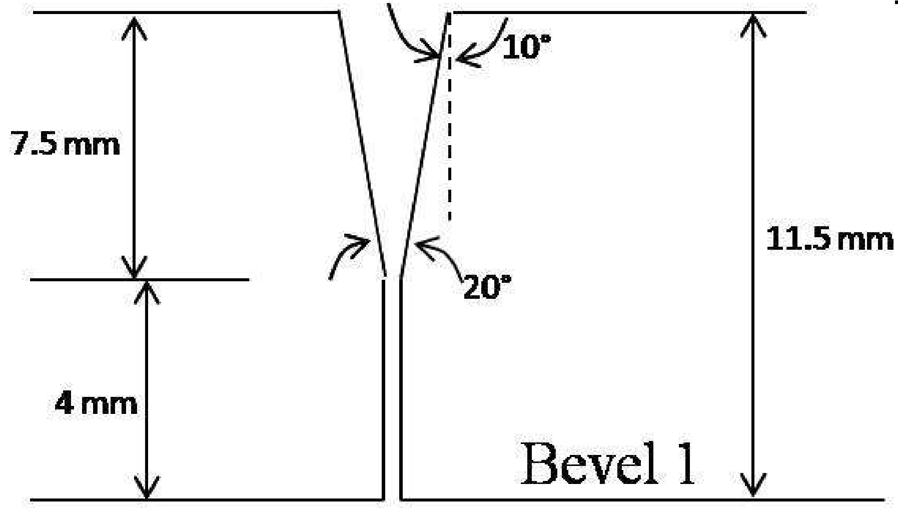
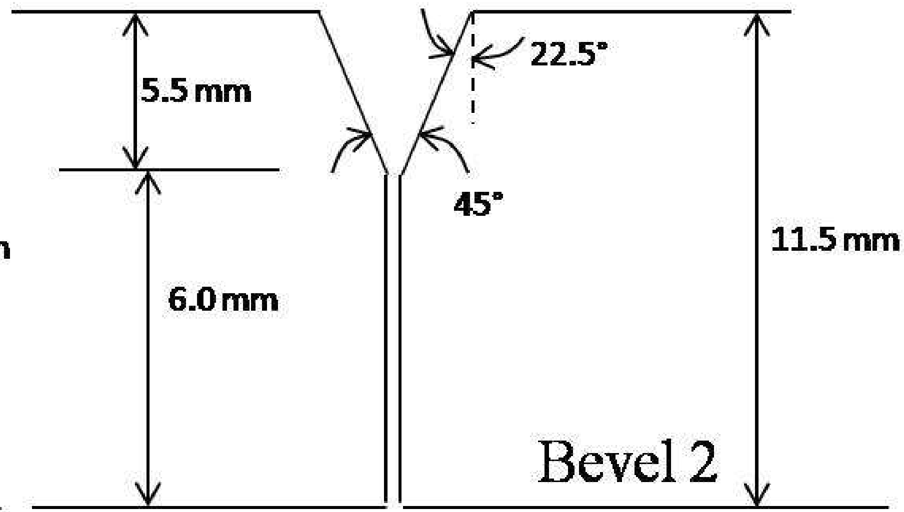
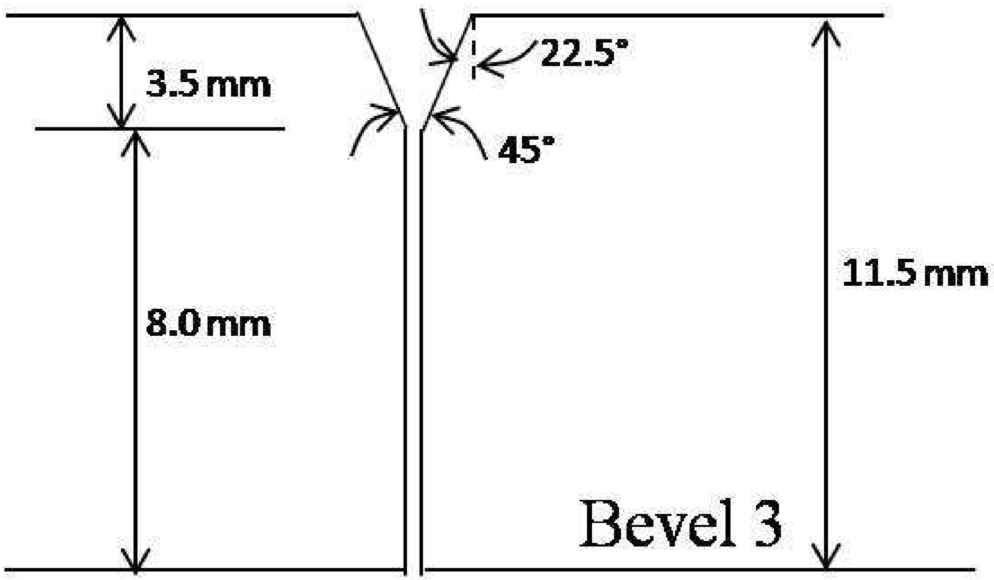


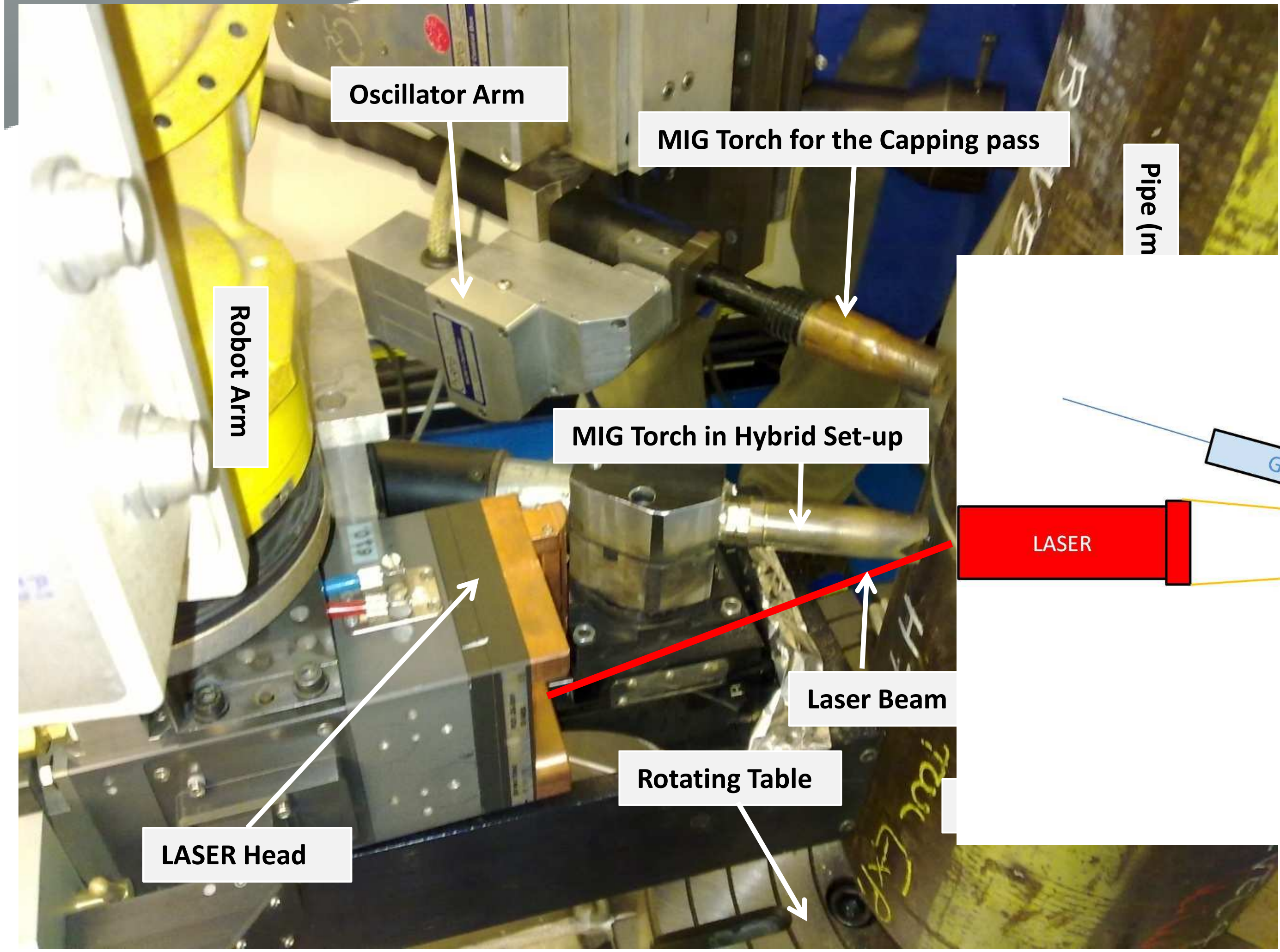


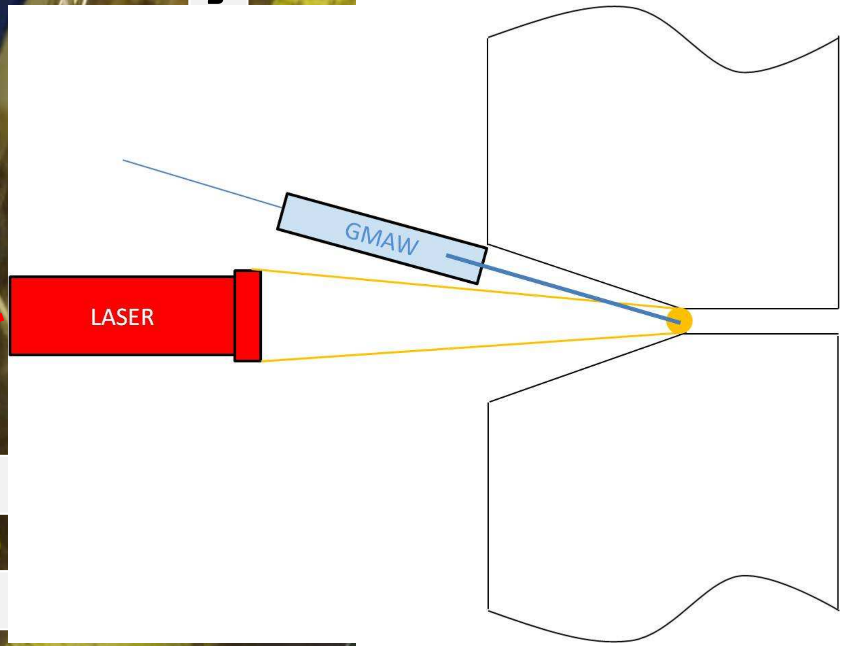


The bevel designs are based on:

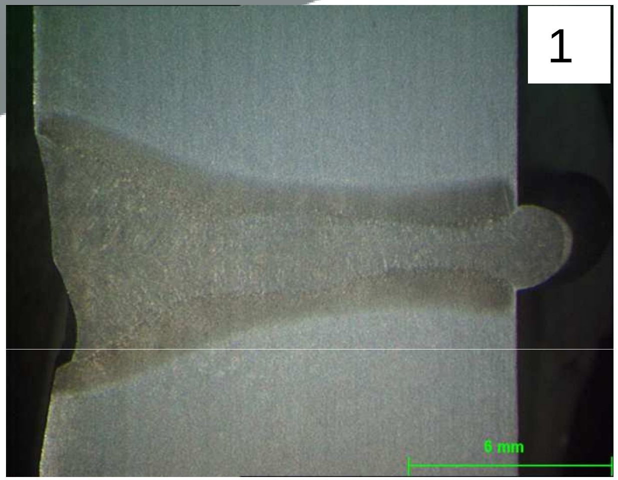
- Different root faces and
- included angle

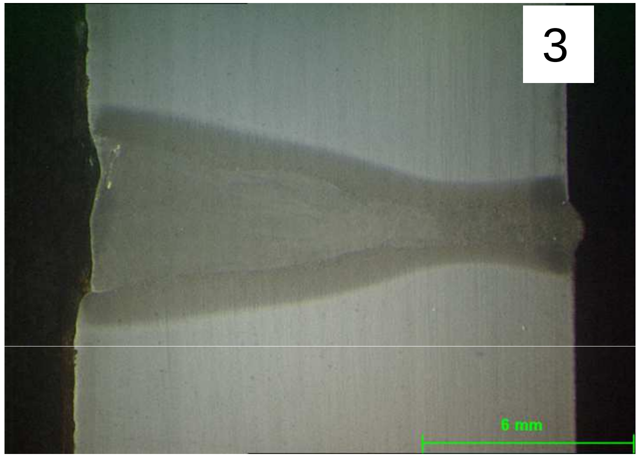
The experimental Set-up

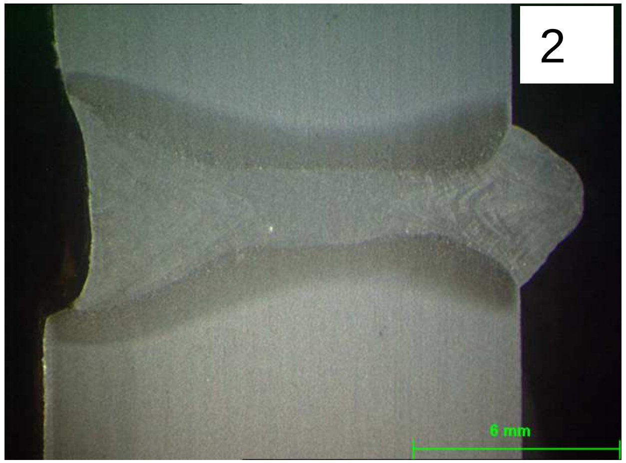


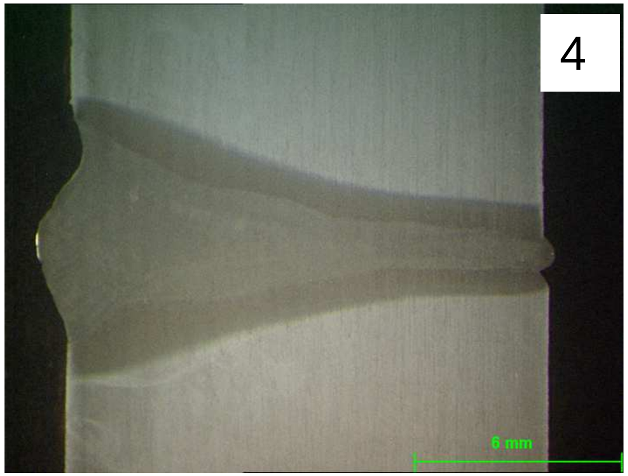


Macrographs of single pass hybrid welds









Other parameters:

Macrograph 1, 2 = bevel 2

Macrograph 3,4 = bevel 3

Laser = 6-7.5kW

TS=1.5 m.min^{-1}

SS=0.6 mm

GMAW source

WFS – 20 m.min^{-1}

Current ~ 300 A

Voltage ~ 27 V

Macrographs of welds with a capping pass

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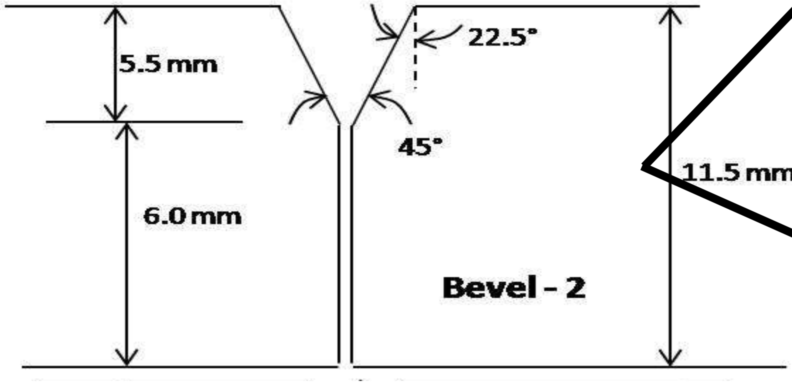

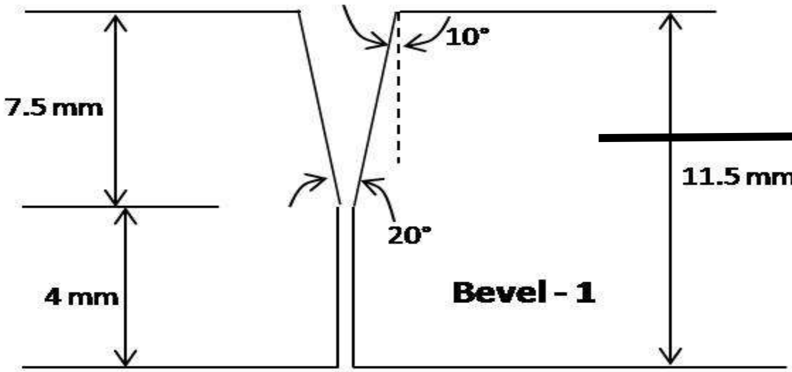

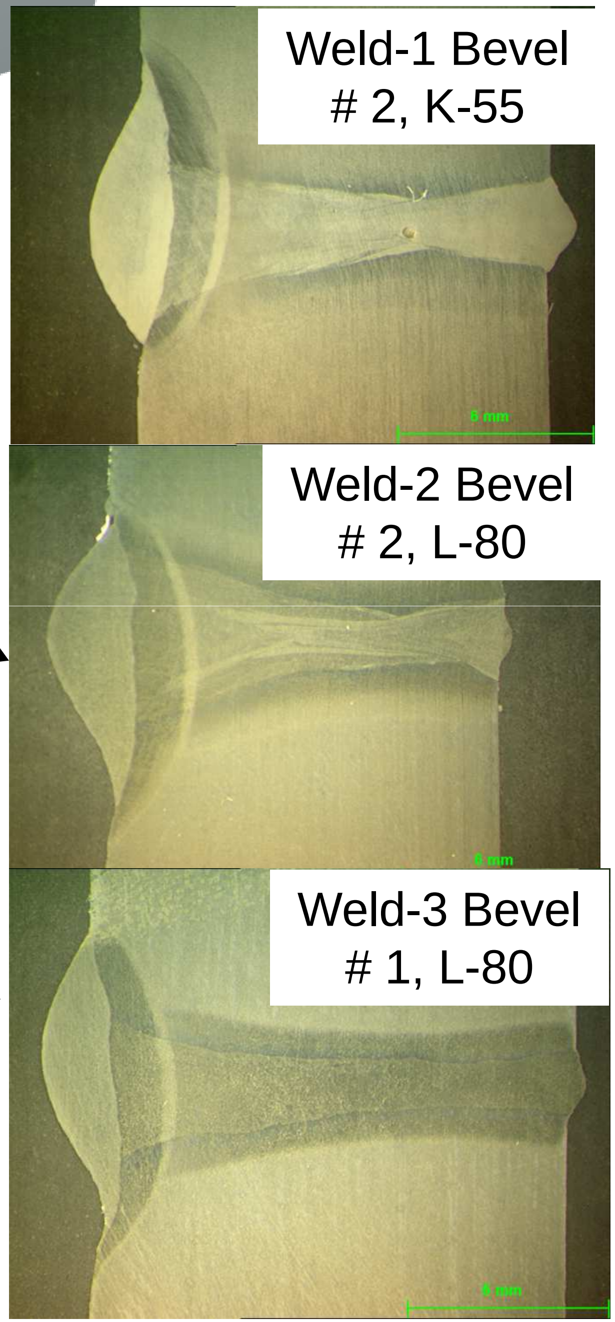

Parameters:
Hybrid 1st pass
Laser = 7 kW
TS=1.5 m.min^{-1}
SS=0.6 mm
GMAW source
WFS – 20 m.min^{-1}
Current ~ 300 A
Voltage ~ 27 V

Capping pass
TS – 0.5 m.min^{-1}
WFS – 3 m.min^{-1}
Oscillation
Width – 4mm
Hertz – 9.166 s^{-1}

Through thickness hardness profiles of the K55 weld

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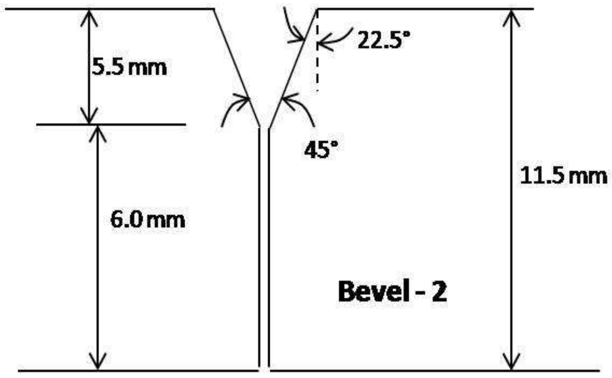
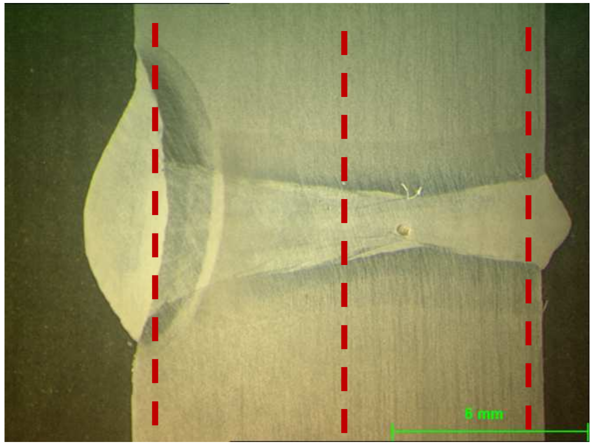
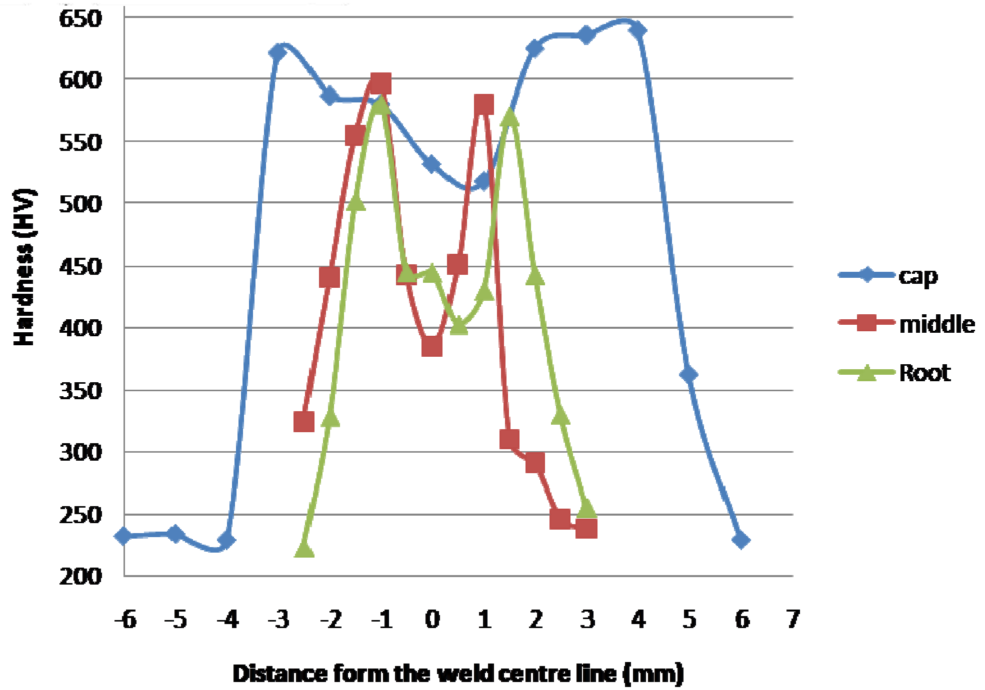
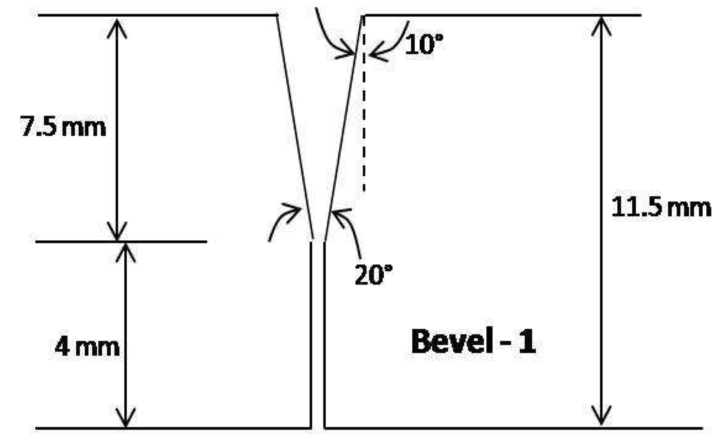
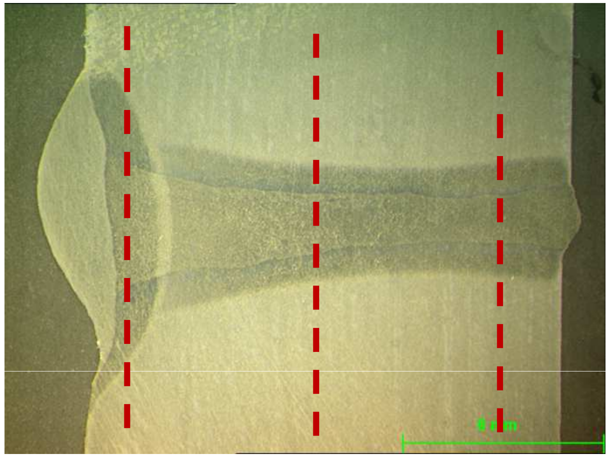


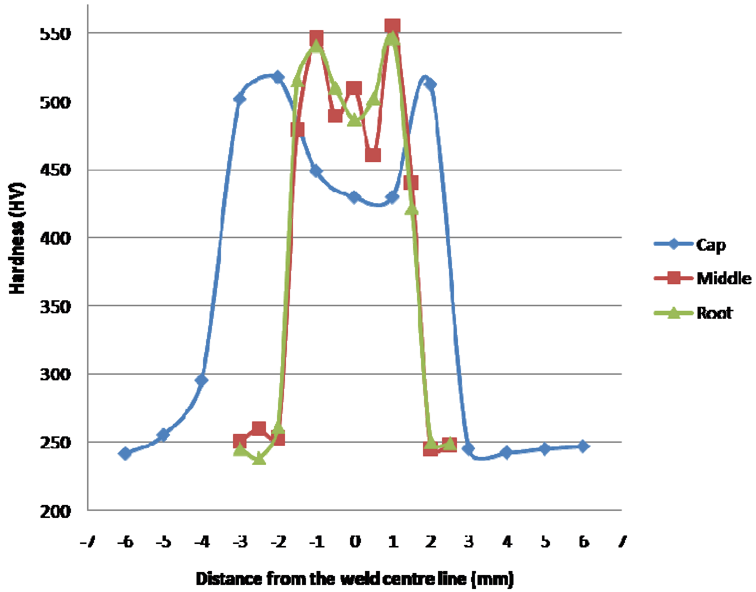




Through thickness hardness profiles of the L80 weld

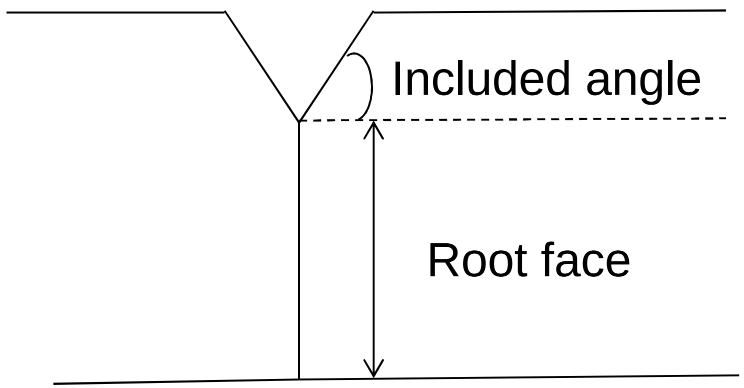






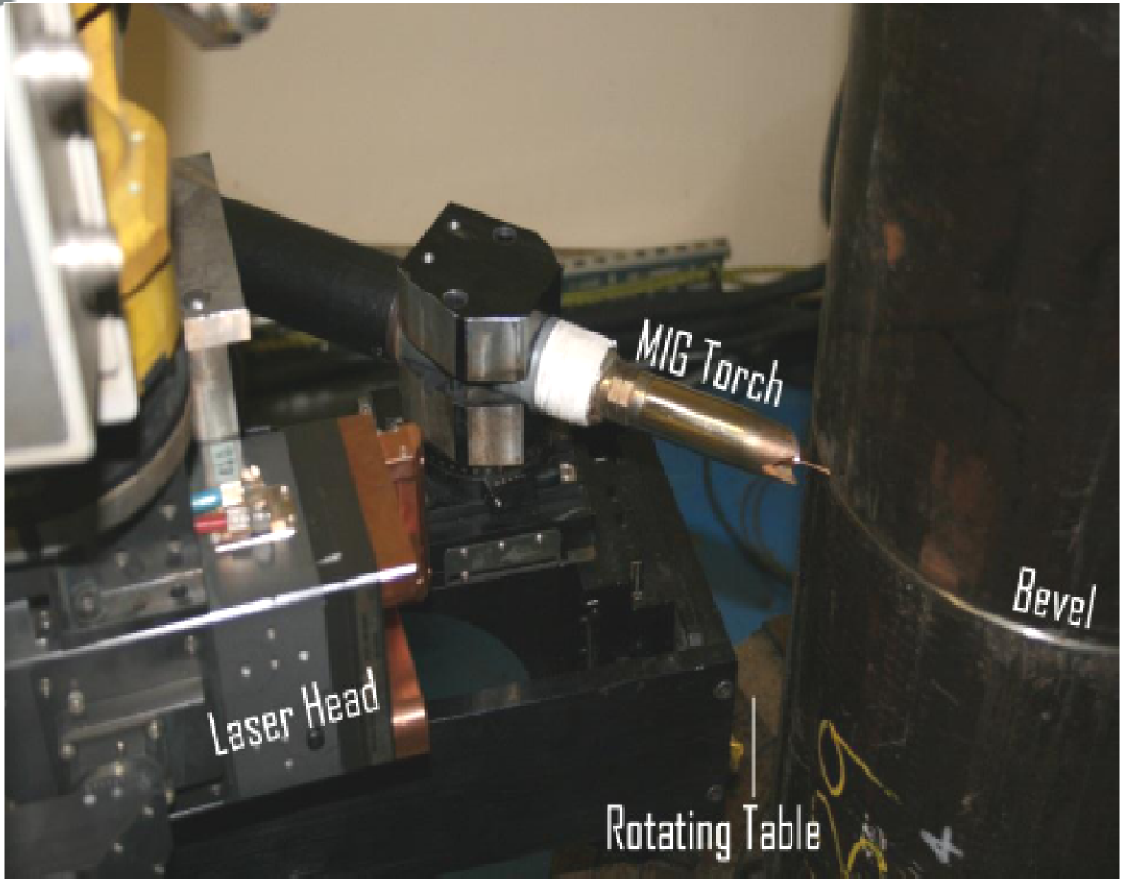
Laser Hybrid Welding – Mixing?

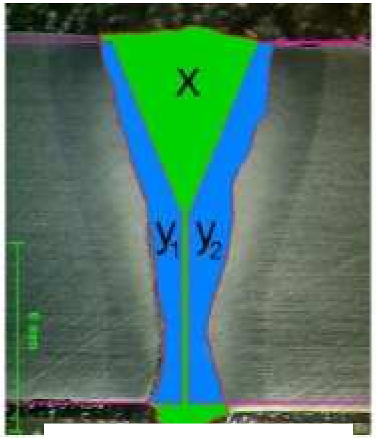
From the previous study it is clear that bevel design has an important influence on the filler addition and therefore on the homogeneity of the weld metal. In the following work an evaluation has been made as to the effect of bevel design and included angle on the through thickness homogeneity

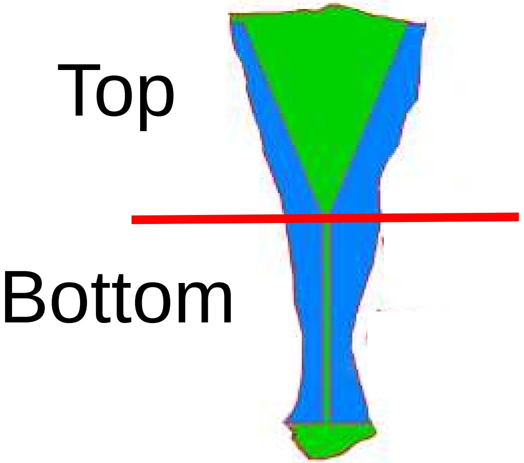


What is the effect of the root face and included angle

Experimental set-up for mixing study







High Cr filler wire (2.5%) was used to map its distribution by EDS

Effect of included angle – 4 mm root face

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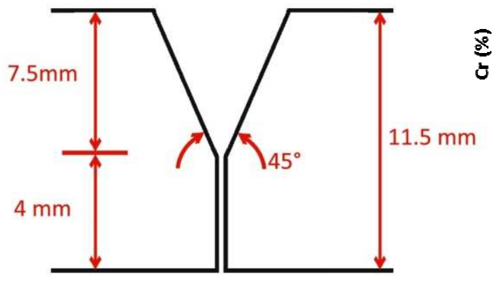
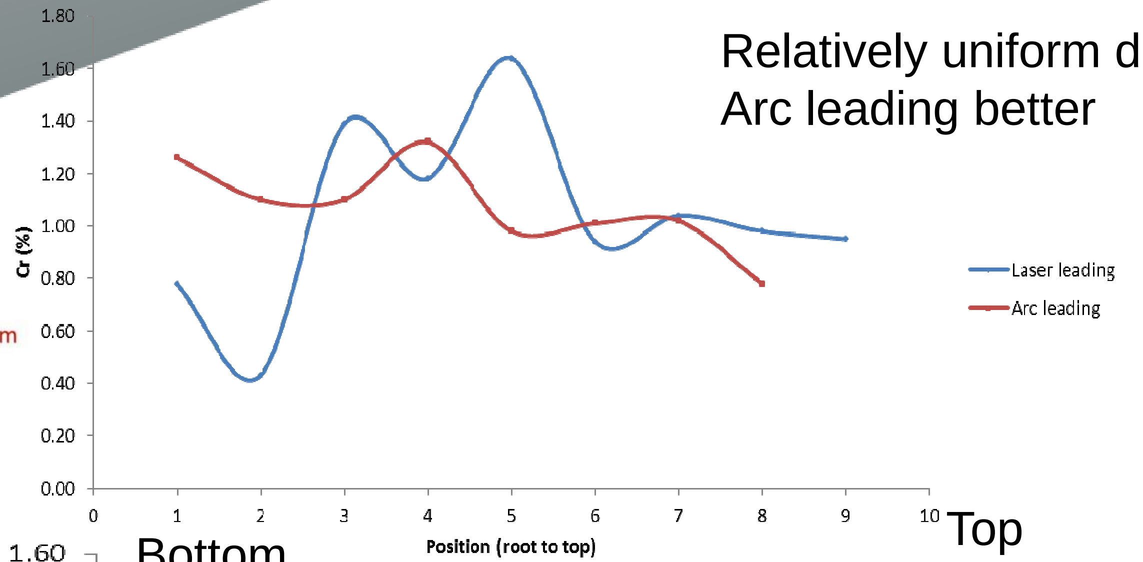


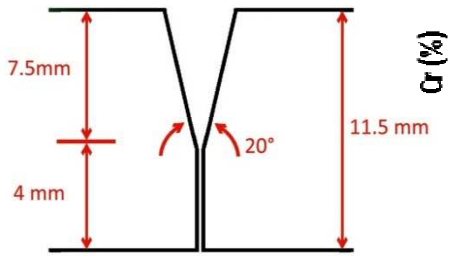
45°



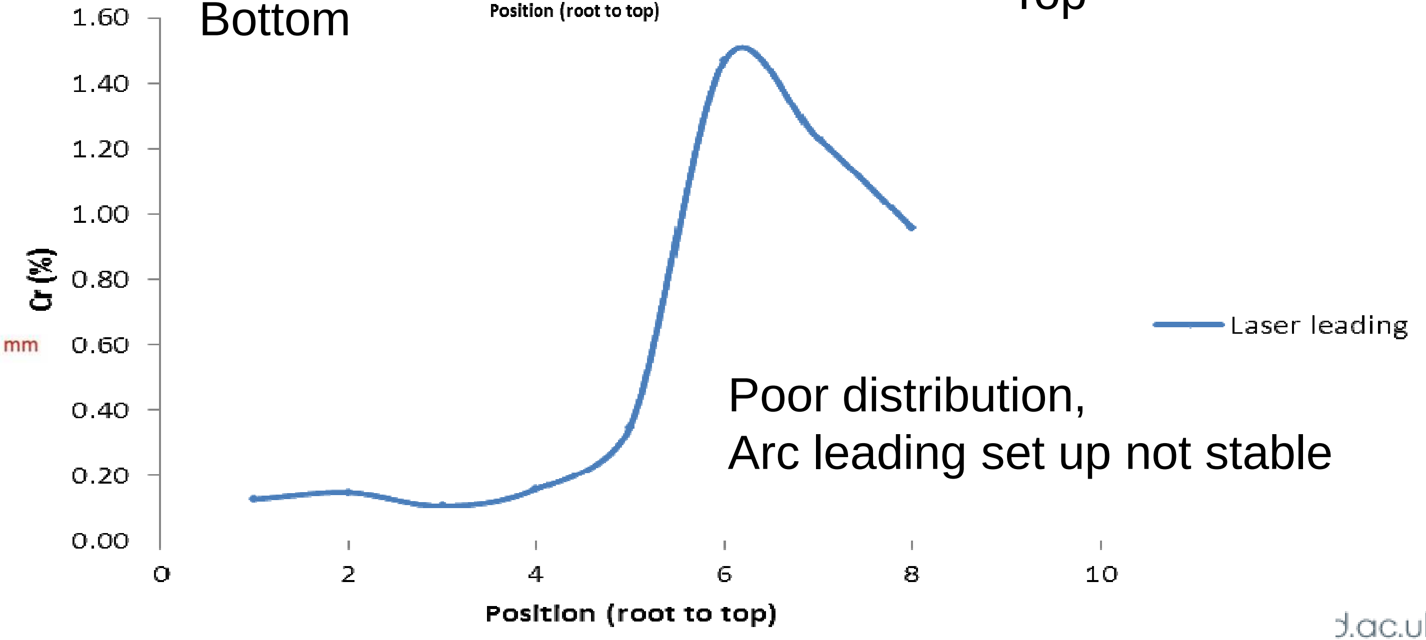
Relatively uniform distribution,
Arc leading better

Bottom

Top

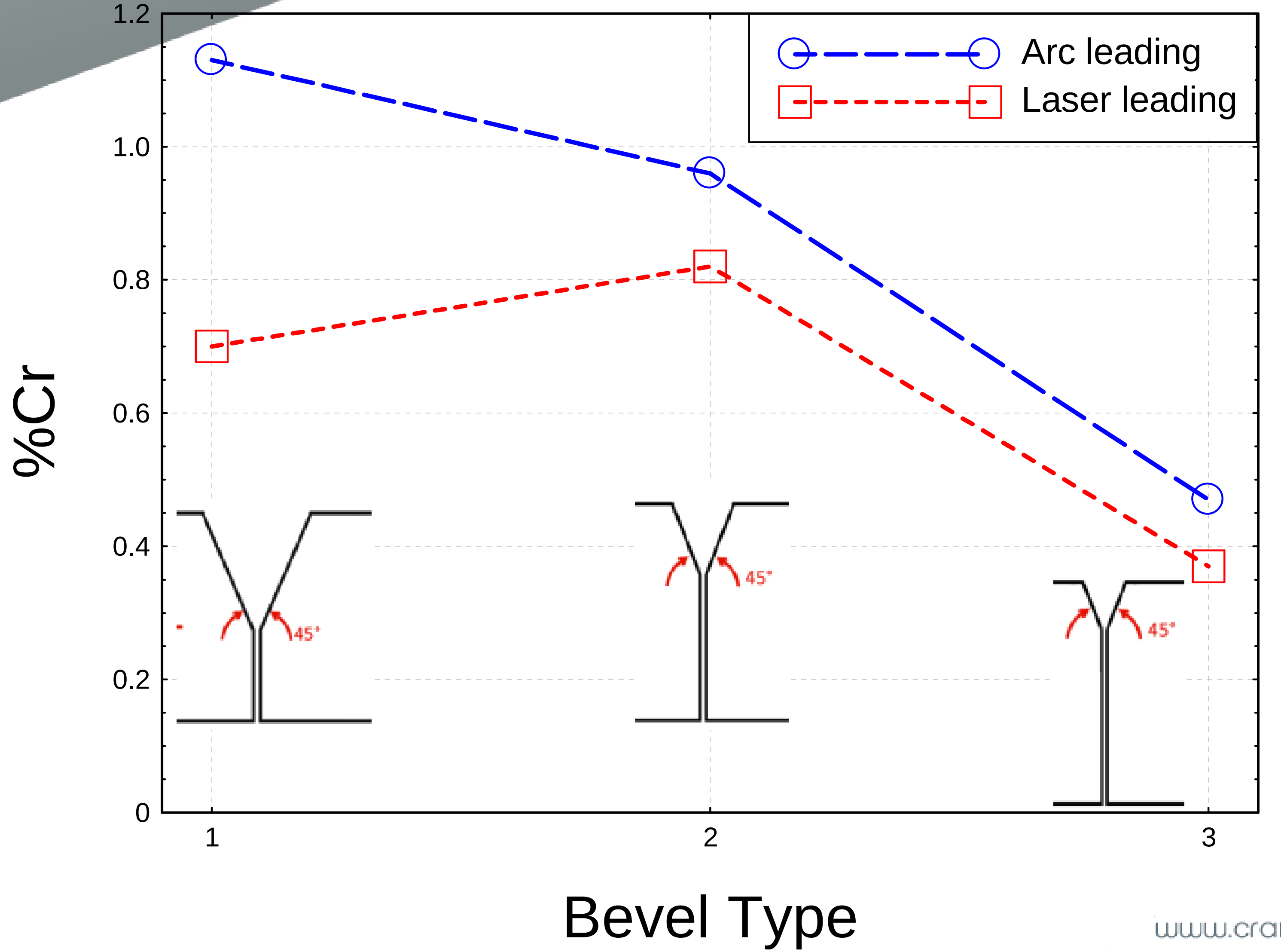


20°



Poor distribution,
Arc leading set up not stable

Effect of root face on Cr% at the Bottom



Summary

The high power density of laser beam enables deep penetration welding in a single pass.

However, as addition of filler wire is important from the point of weld metal strength and mechanical characteristics, there remains a trade off between the productivity and quality.

Some other applications – Tack welding

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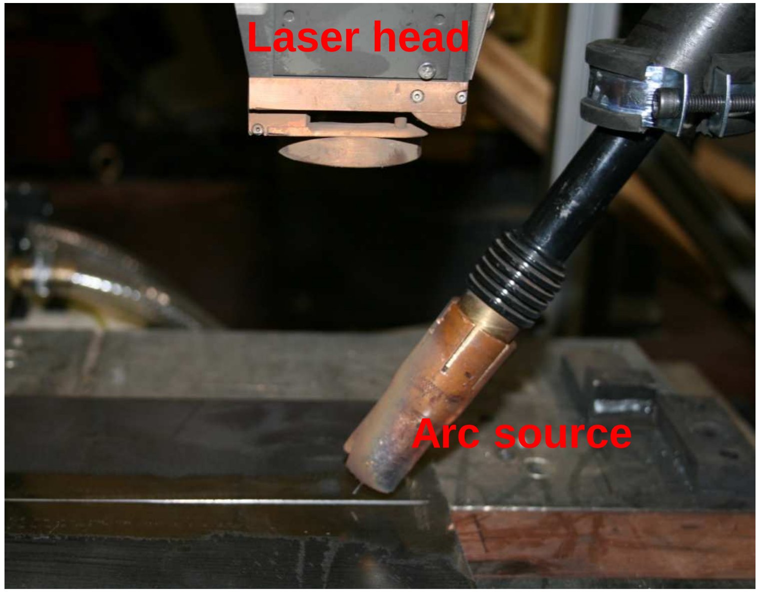
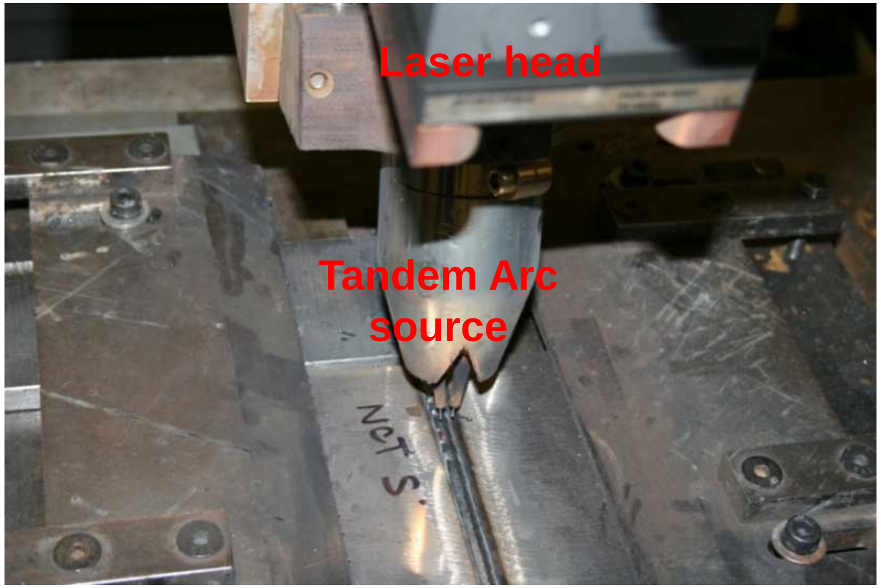
Experimental set-up



Single arc – laser hybrid set-up



Tandem arc – laser hybrid set-up

Laser-arc hybrid trials – Increasing wire feed in tandem set-up

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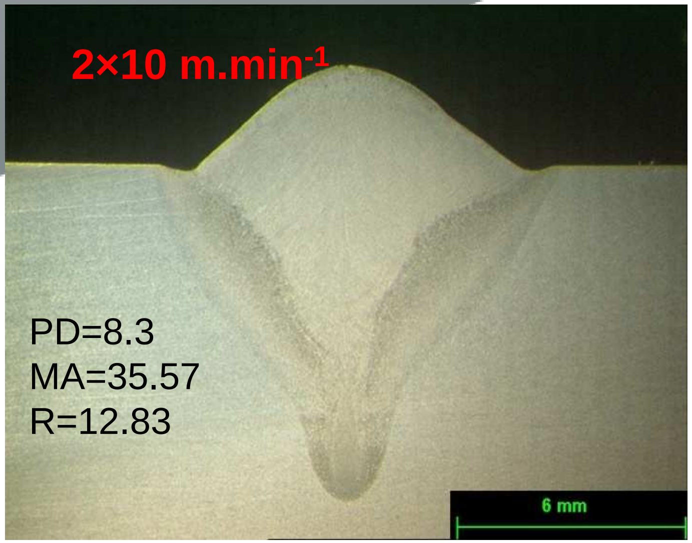
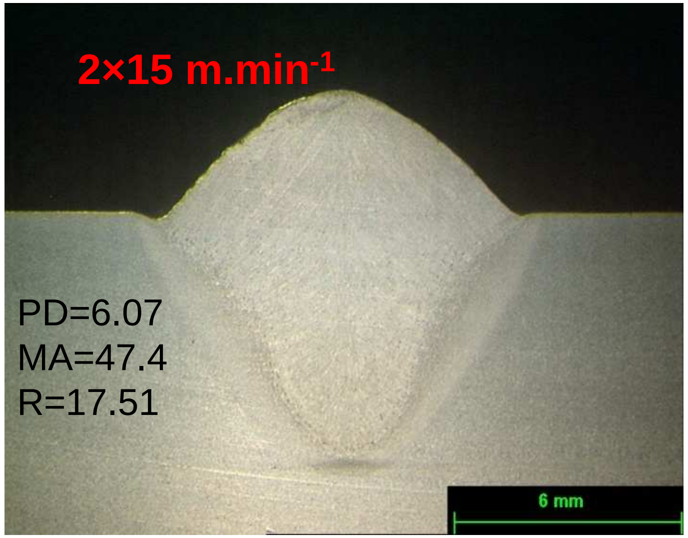
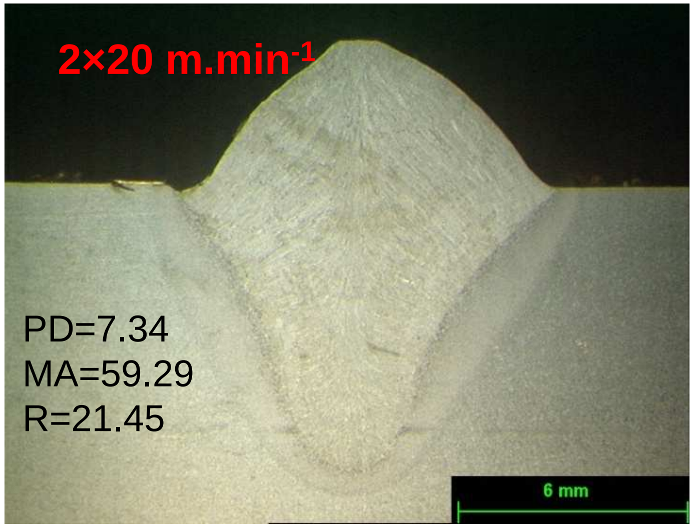
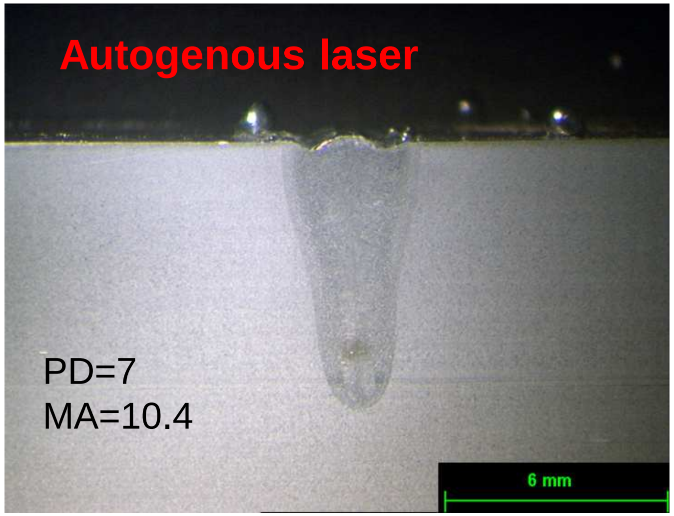


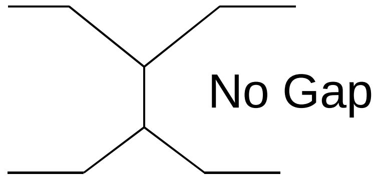


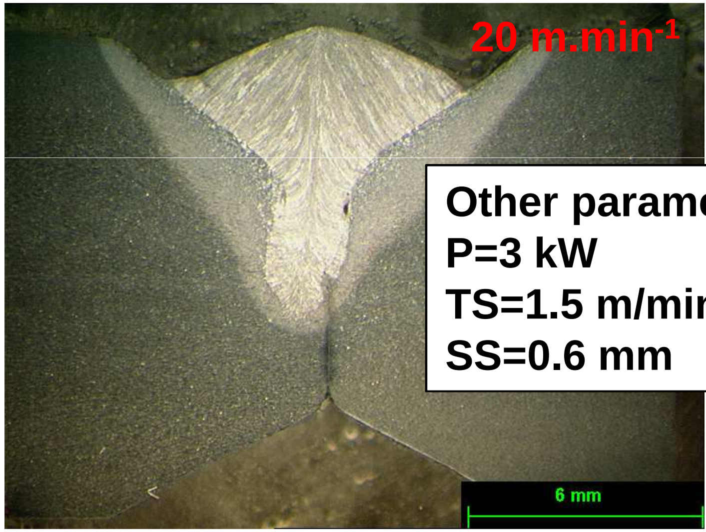




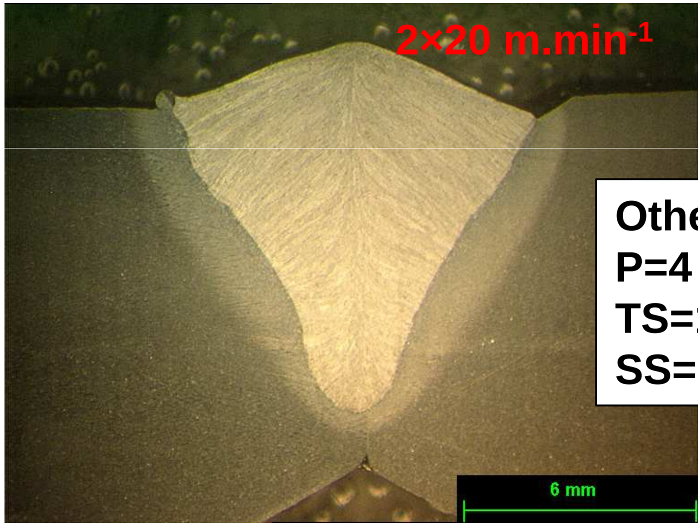
Other parameters:
P=6 kW
TS=1.5 m/min
Spot size = 0.6 mm

Laser-arc hybrid trials
- Tandem vs. Standard



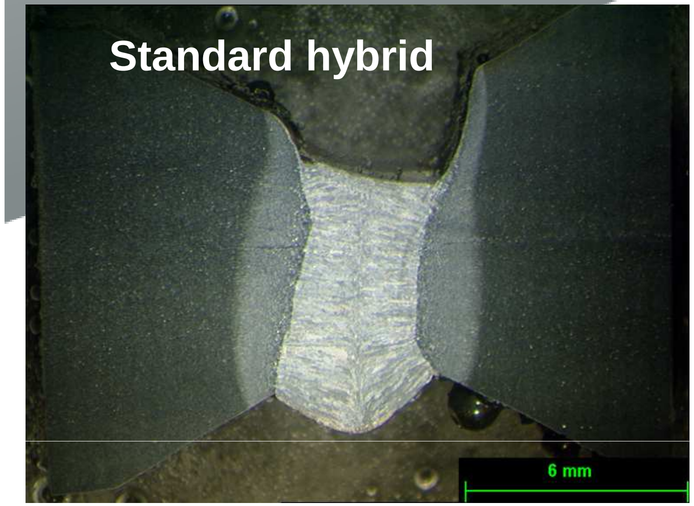


Other parameters:
P=3 kW
TS=1.5 m/min
SS=0.6 mm

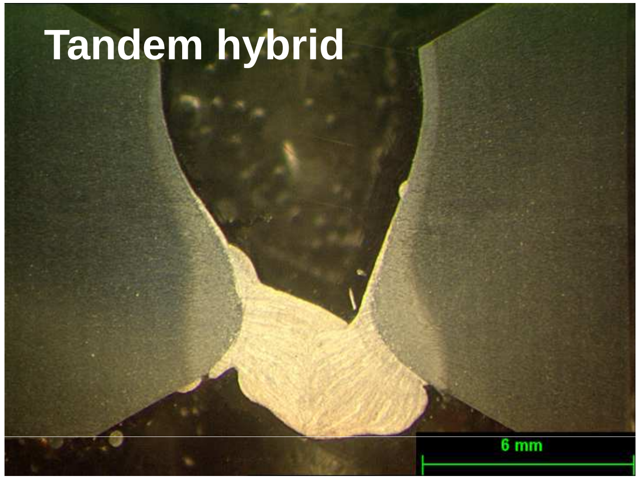


Other parameters:
P=4 kW
TS=1.5 m/min
SS=0.6 mm

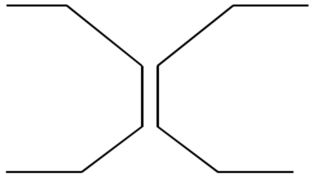
Laser hybrid welding - fit up tolerance study



P=5 kW; TS=1.5 m/min;
WFS=20 m/min; **DB=1.8 mm**

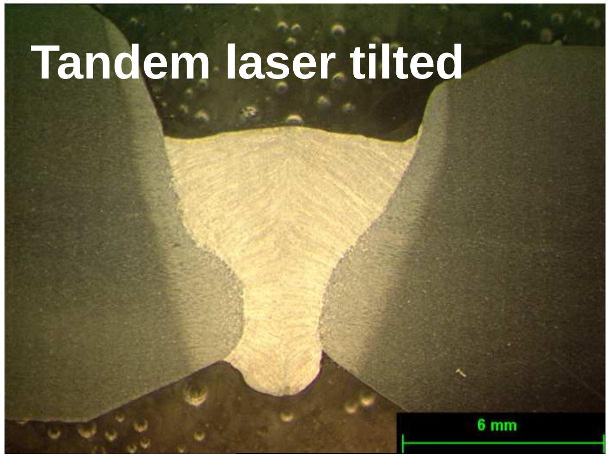


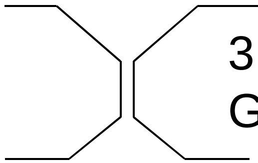
P=5 kW; TS=1.5 m/min;
WFS=2x20 m/min; DB=0.6 mm



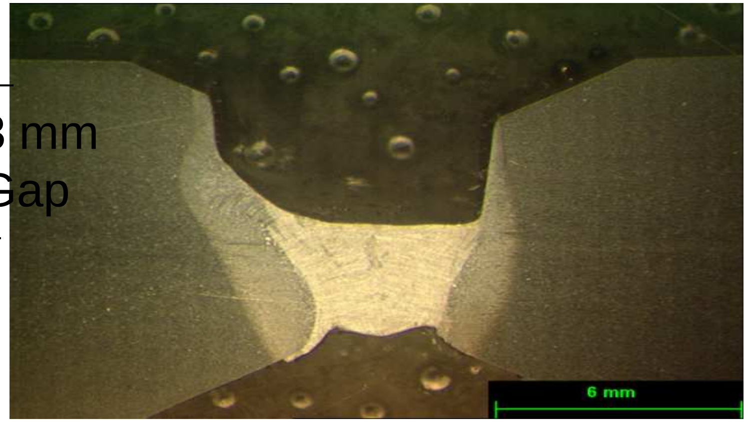
2 mm Gap

WFS – wire feed speed [m/min];
DB – beam diameter [mm];
TS – travel speed [m/min];
P – laser power [kW]





3 mm
Gap



P=5 kW; TS=1.5 m/min; DB=1.2 mm;
WFS=2x15 m/min; laser tilted

Some other applications – laser assisted hyperbaric welding

Context:

Deep sea dry hyperbaric welding is characterised by the tendency of forming hydrogen cracking due to faster cooling rate at a higher ambient pressure. Also the traditional GMAW process generates spatter which may cause problem during welding at depth where human intervention is not possible.

Laser assisted welding would enable high heat input irrespective of the GMAW process to slower down the cooling rate. Also low heat input novel processes e.g. Cold metal transfer could be used to reduce the spatter.

laser assisted hyperbaric welding – initial trial at one atmosphere

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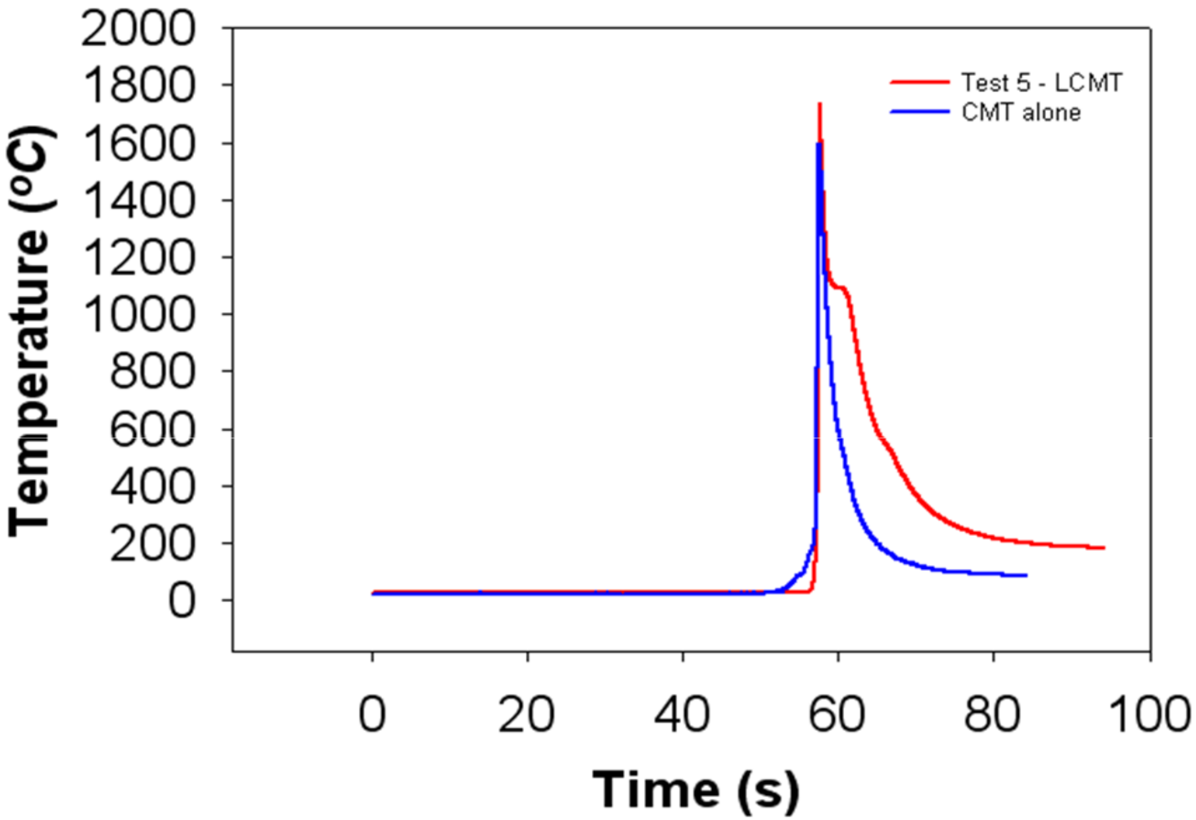

Comparison of the weld metal cooling rate obtained by CMT alone and laser assisted CMT processes.

A 30% reduction in cooling rate has been observed. This however, depends on the laser intensity and interaction time and the distance between the two heat sources

Laser assisted hyperbaric welding – Effect of process distance on thermal power

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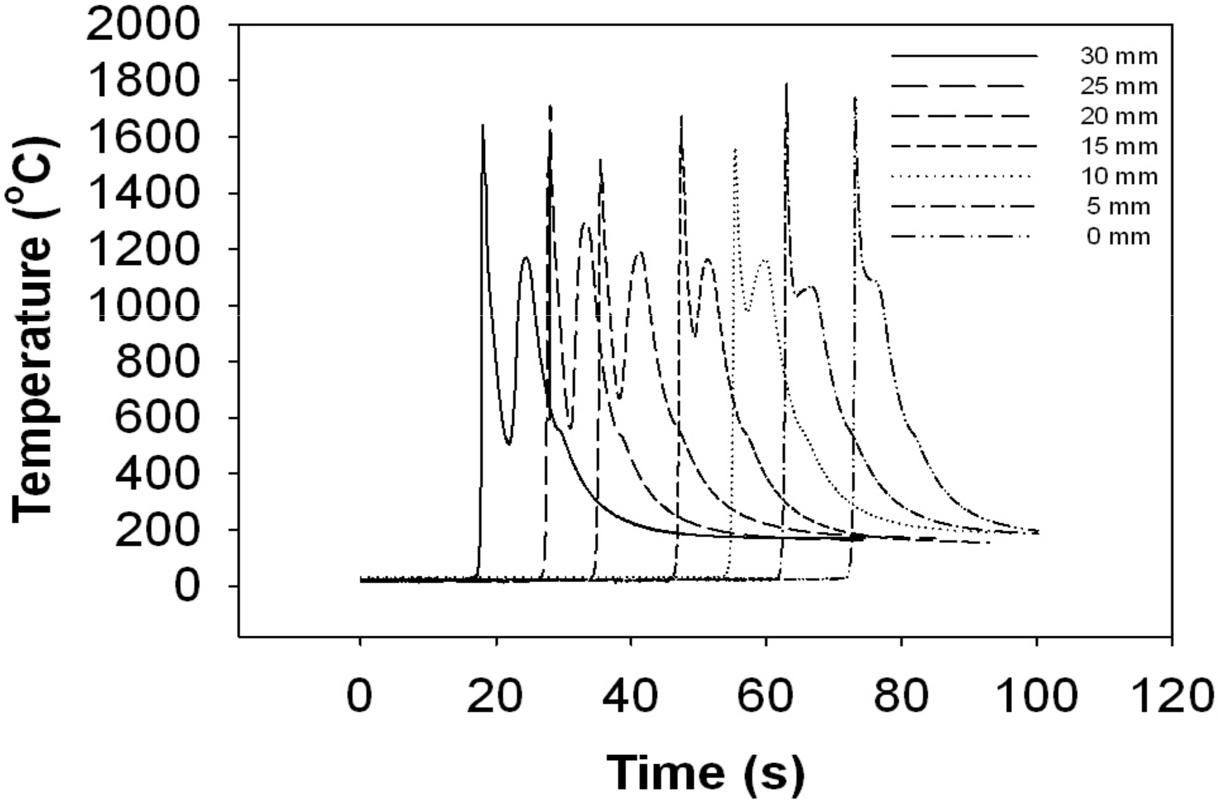

Maintaining weld metal temperature high enough for sufficient time would enable H diffusion and reduce the susceptibility of the weld metal to HAC.

laser assisted hyperbaric welding – future plan

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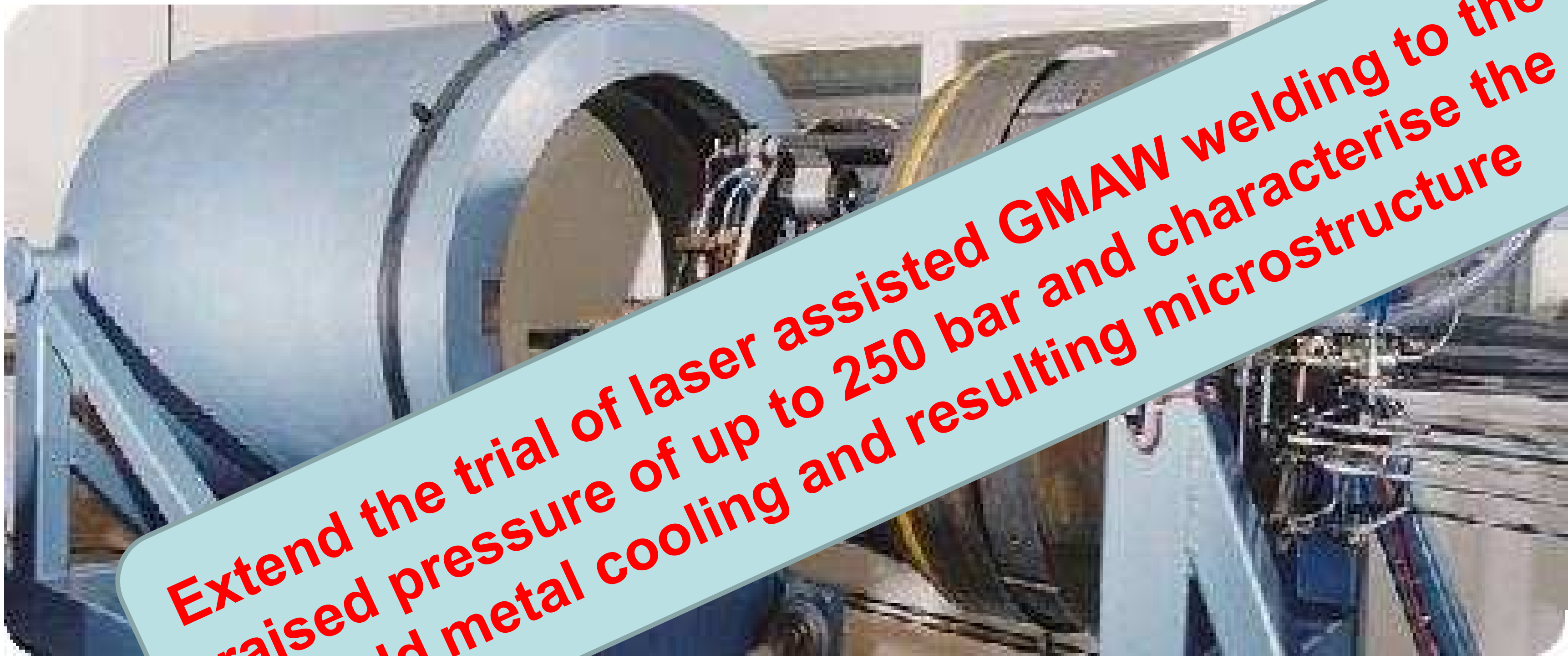

Extend the trial of laser assisted GMAW welding to the raised pressure of up to 250 bar and characterise the weld metal cooling and resulting microstructure

Presentation summary

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- It has been demonstrated that the laser arc hybrid welding process could be applied in a variety of applications in the area of welding of pipeline.
- Other structural applications in aerospace and automotive sector are also possible with different arc processes and laser modes.

Acknowledgement

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Thanks for listening