Direct energy deposition with wires – status and perspectives of a maturing technology field

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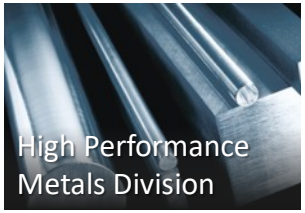
m2i – Dec 2022

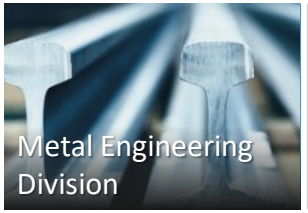
Agenda

- Intro - Vision
- Difference to welding
- A look into the past
- Status standardization
- Where are we now?

WE ARE PART OF VOESTALPINE AG

Tool steel & leading position for high-speed steel & special forged parts

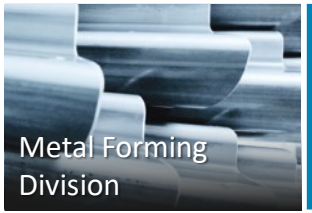




Turnouts, rails, processed wire, seamless tubes & welding consumables

Welding:
608 Mio EUR | 2,300 Employees

Premium steel strip, electrical steel strip, heavy plate, cast products

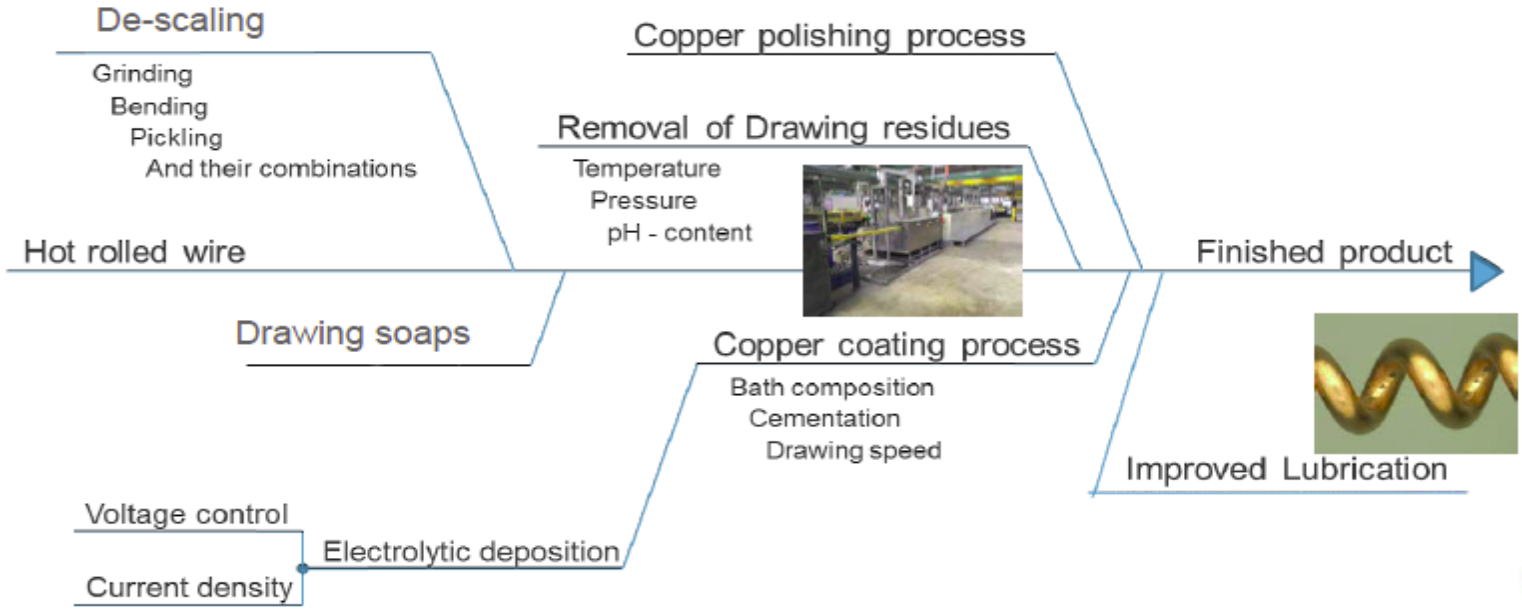


High-quality metal processing solutions, precision steel strip & special components

voestalpine
ONE STEP AHEAD.

Best products for demanding industries

What is different to welding?
Heat accumulation



Metallurgy of Hot Rolled Wire & Wire Drawing Process drive the final properties of WAAM consumables and enable the fabrication of parts with unique or tailormade properties

Our Vision
Manufacturing of tailor made melts

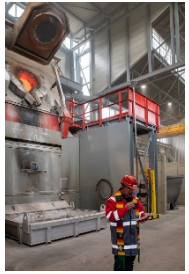
Vacuum-Induction-Furnace
45 kg

Induction-Furnace
3-5t

Vacuum-Degassing

Vertical Continous Casting

Rolling Mill (Wire Rod)

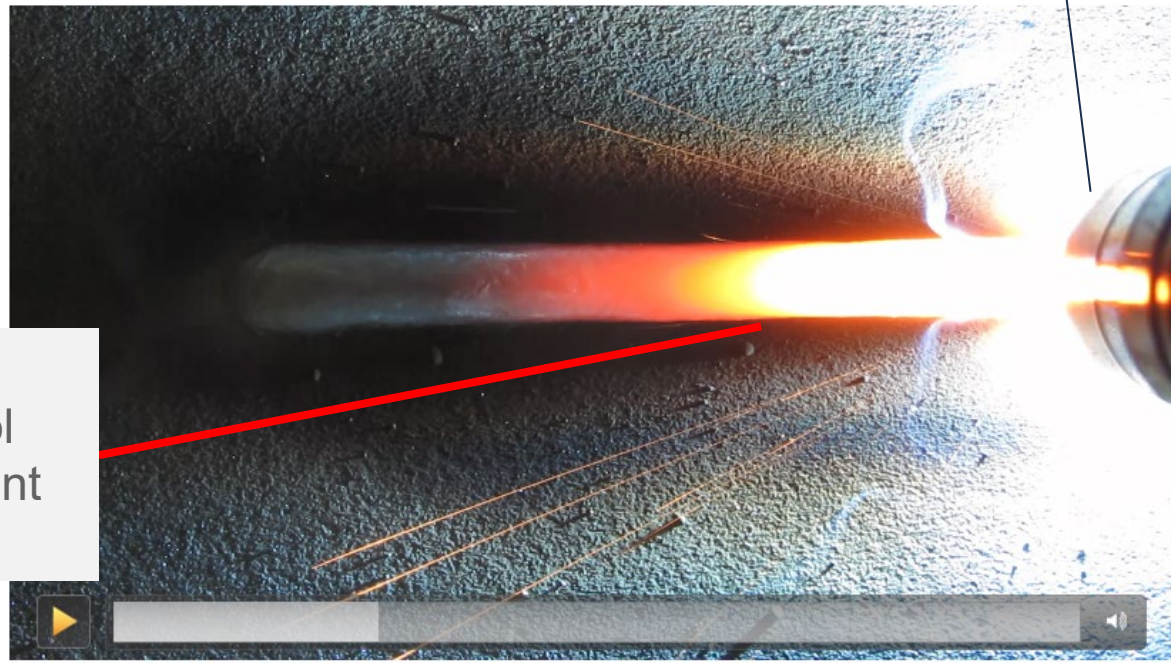


What is different to welding?

What is different to welding?
Heat accumulation

top view during printing

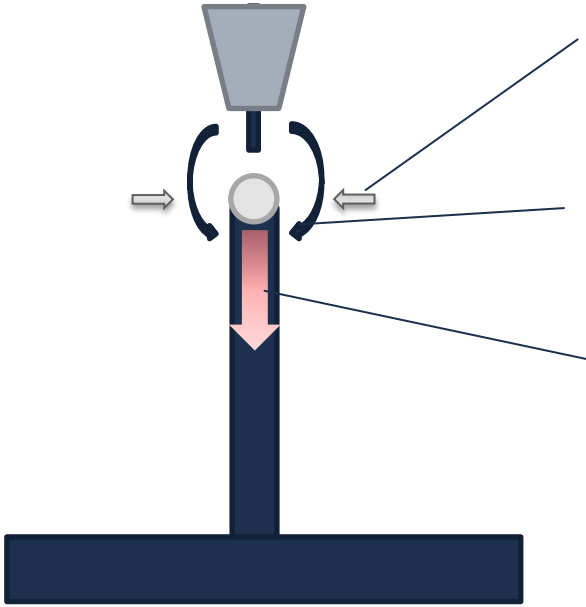
edge of GMAW burner nozzle



printing direction

long heat track, longer melt pool compared to joint welding

What is different to welding?
Heat accumulation



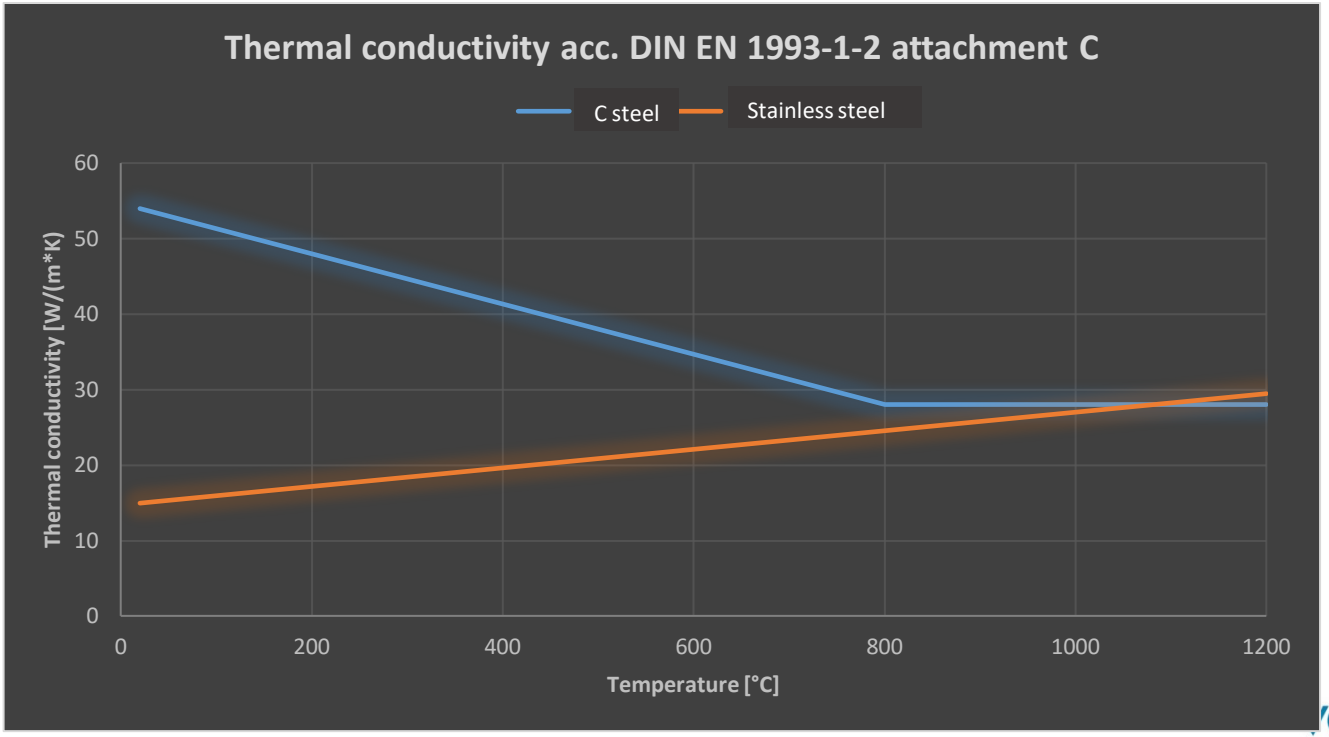
Adjust welding parameters and surface tension and viscosity to keep melt pool in position

Control gas flow and shielding conditions (different from joint welding)

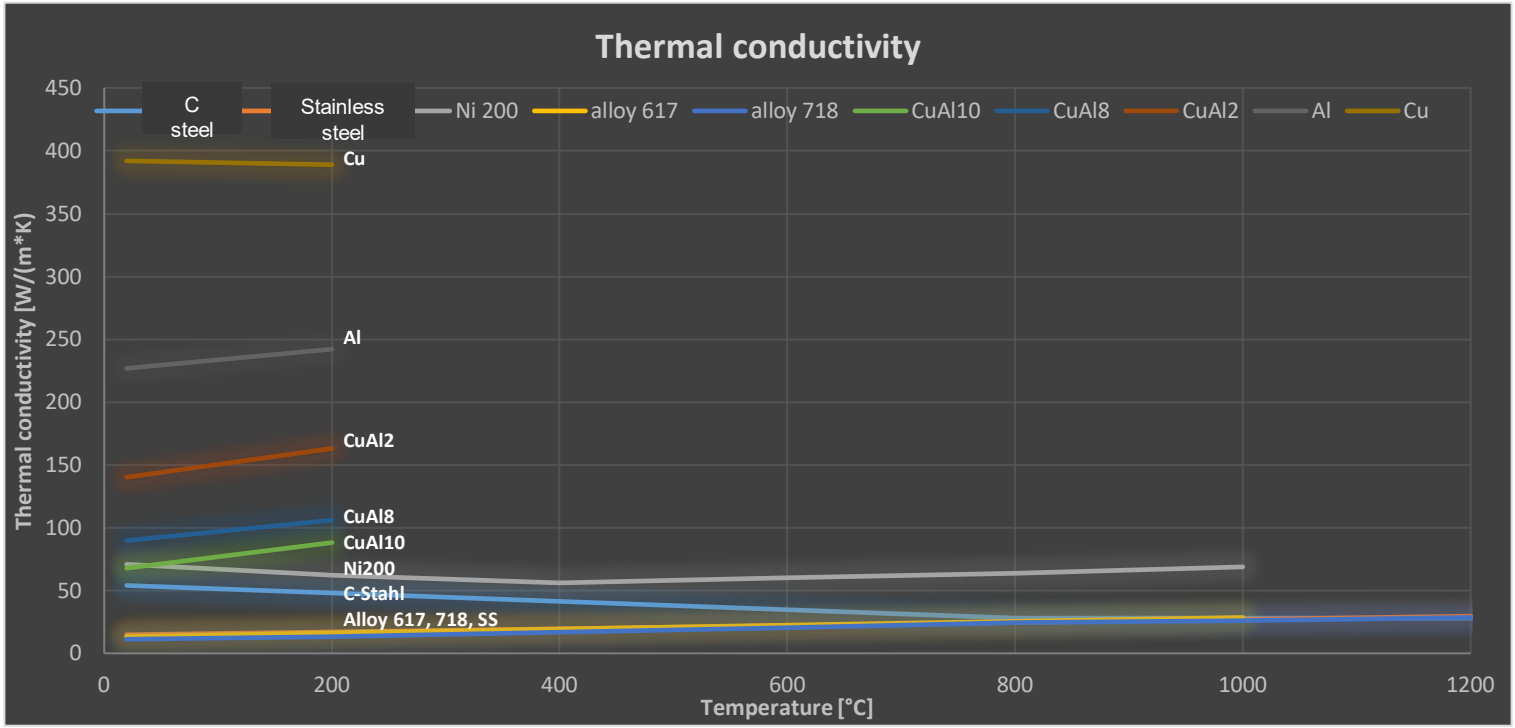
(pores, more silicates)

One dimensional conductive heat flow

What is different to welding?
Heat accumulation – thermal conductivity



What is different to welding?
Heat accumulation - thermal conductivity



What is different to welding?
Heat accumulation - thermal conductivity

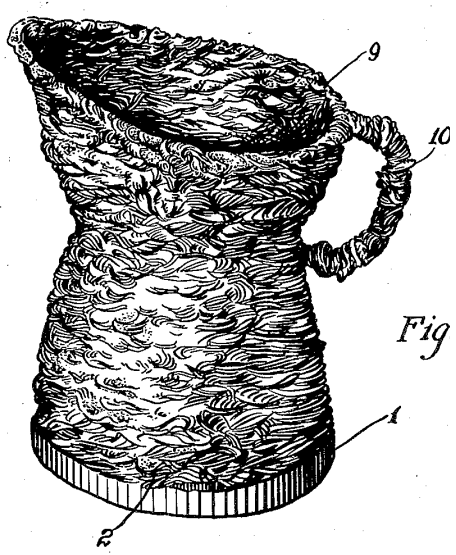
Less sensitive:
CuNi-alloys, unalloyed steels (C-steel)

No or minor heat accumulation expected:
Cu, Al and alloys

A look into the past!

A look into the past
Early documented AM

Ralph Baker – Patent US1533300A (1925) “Method of making decorative articles”



Fig

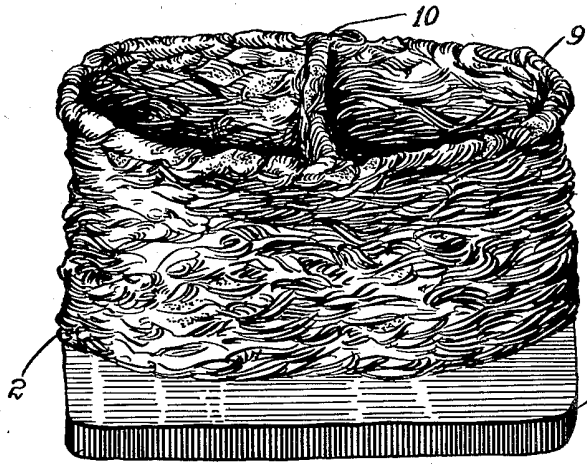
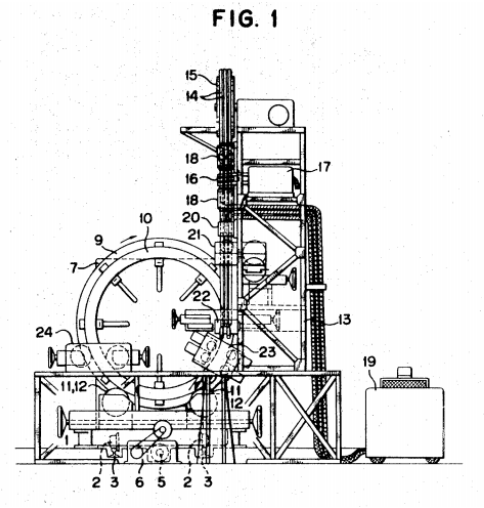
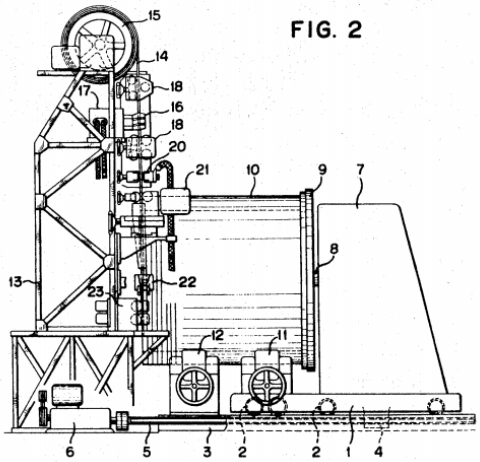


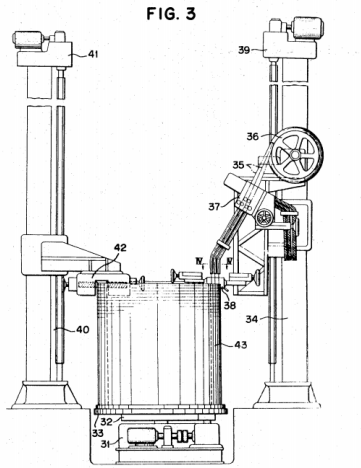
Fig. 2.

A look into the past
Industrial applications

Akira Ujiie – Patent US3558846A (1971) “Method of and apparatus for constructing substantially circular cross section vessel by welding”

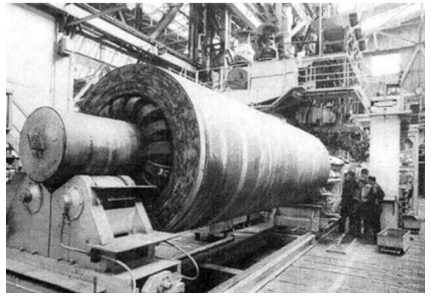


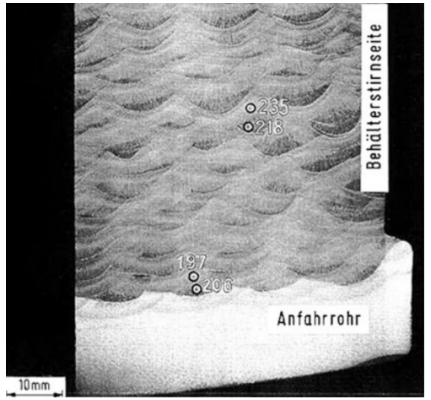


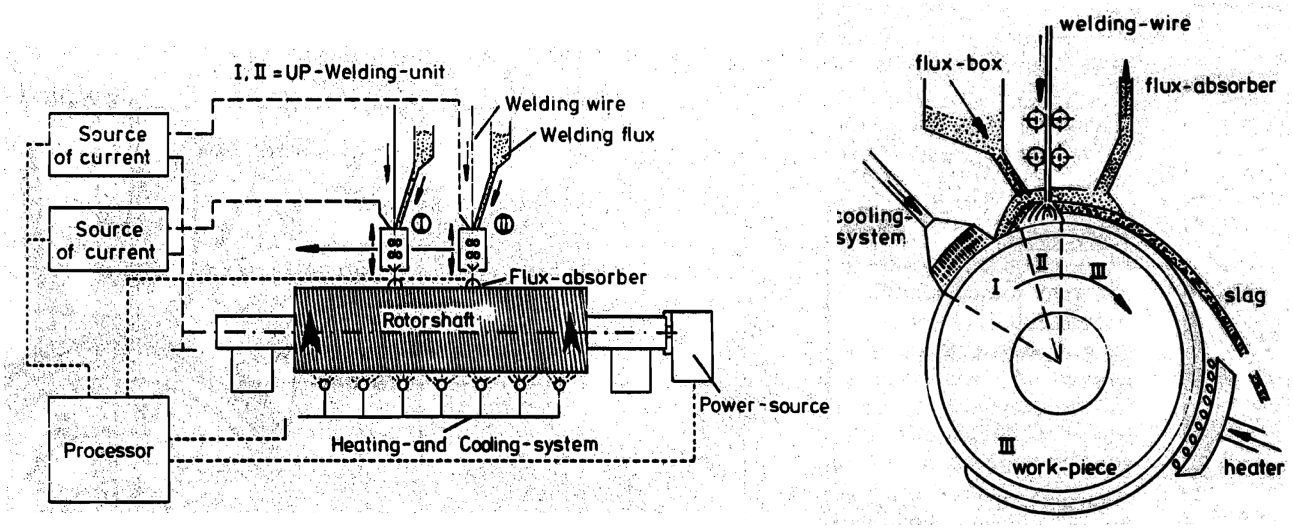


A look into the past
Industrial applications

1983: generative welding of a 72 t pressure vessel section made of a modified reactor vessel steel 20MnMoNi5 5



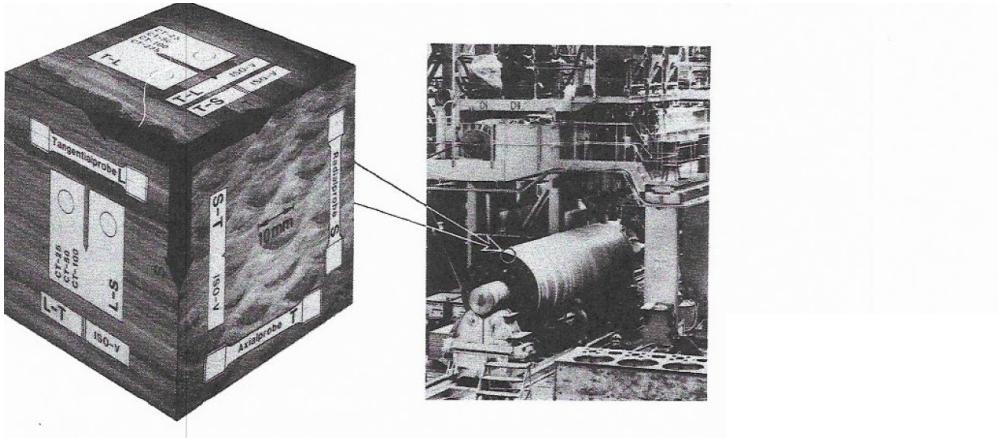




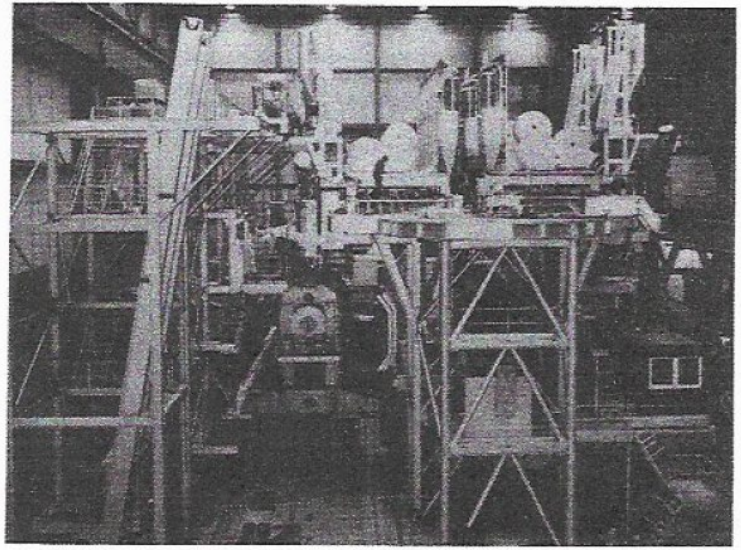
source: Kussmaul et al, Welding Journal, Sep. 1983, S. 19

A look into the past
Industrial applications

Generative welding – mold melting, on highest technical level



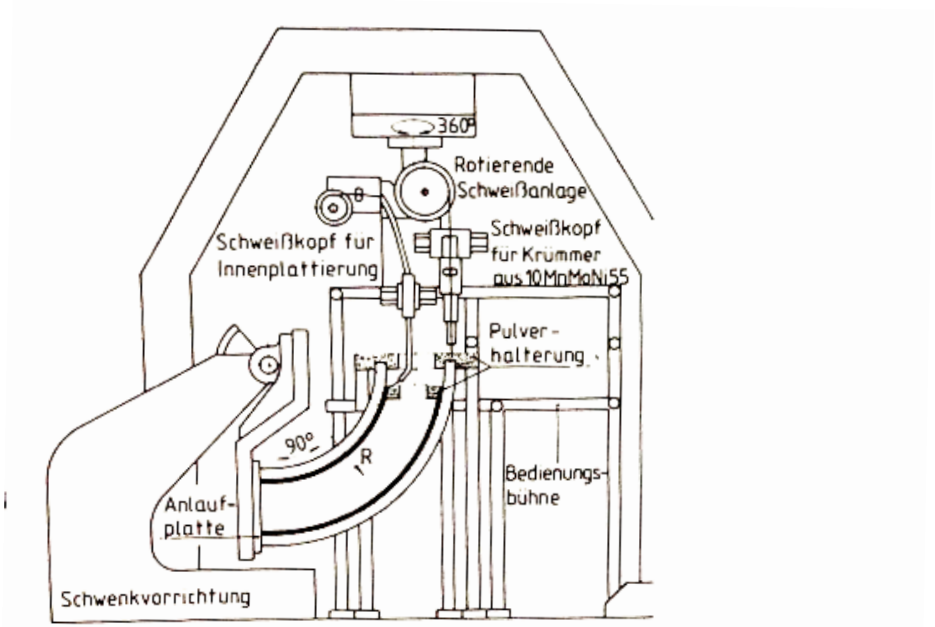
100 t mold melting pilot plant with 72 t vessel section



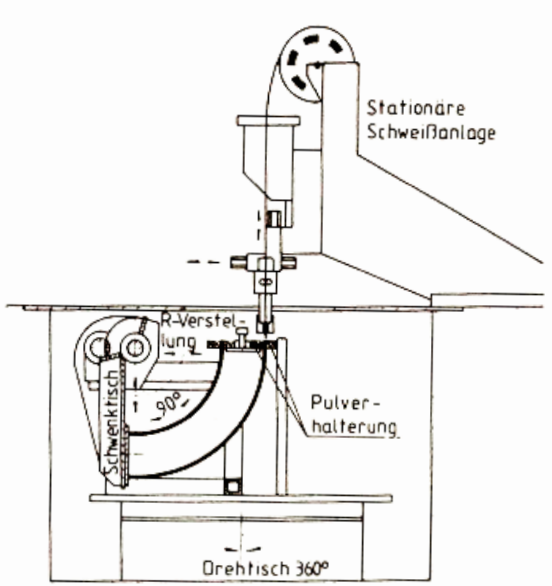
mold melting plant with 16 welding heads for construction parts up to 500 t.
Max. dimensions: 5,8 m diameter, 11 m length, max. deposition rate: 320 kg/h.

source: F.-W. Schoch, K. H. DVS 93, „Schweißen im Anlagen- und Behälterbau“ 1985-02-13/15

A look into the past
Industrial applications



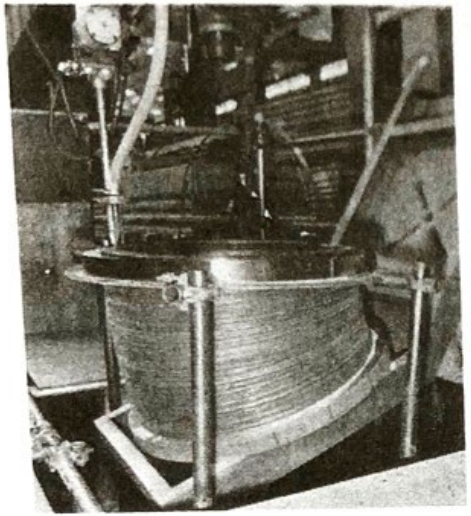
machine for form welding of internally cladded elbows of large dimensions



machine concept for manufacturing of smaller elbow dimensions with stationary welding machine

source: R. Becker, H. Clausmeyer, R. Datta, H. Hantsch, K. Million, H. Zimmermann. DVS 93, „Schweißen im Anlagen- und Behälterbau“ 1985-02-13/15

A look into the past
Industrial applications



Side view of a partially welded internally cladded elbow

Inside view of elbow with two layer internal cladding

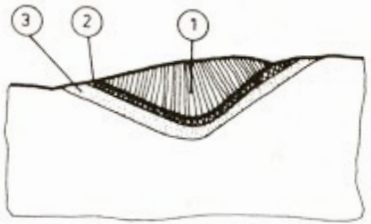
source: R. Becker, H. Clausmeyer, R. Datta, H. Hantsch, K. Million, H. Zimmermann. DVS 93, „Schweißen im Anlagen- und Behälterbau“ 1985-02-13/15

A look into the past
Industrial applications

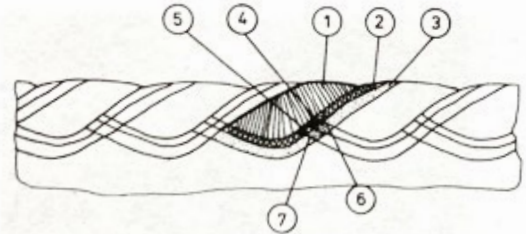
internally cladded elbow for main coolant line of nuclear power plants

source: R. Becker, H. Clausmeyer, R. Datta, H. Hantsch, K. Million, H. Zimmermann. DVS 93, „Schweißen im Anlagen- und Behälterbau“ 1985-02-13/15

A look into the past
Industrial applications

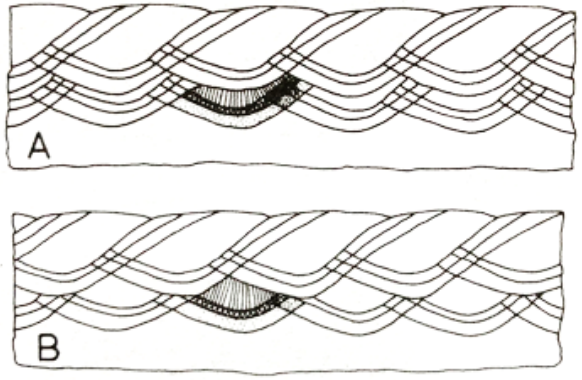


schematic sketch of the macrostructure of a single bead: 1: non-repeated weld metal; 2: well above A_{c3} heated (overheated) weld metal; normalized weld metal



schematic sketch of the macrostructure of a top layer: 1, 2 and 3 – see above sketch

4: twice overheated weld metal
5: twice converted weld metal, normalized and overheated
6: twice converted weld metal, overheated and normalized
7: twice normalized weld metal



schematic sketch of the form weld metal of type
A - bead on bead
B - beads offset by half the bead width

source: R. Becker, H. Clausmeyer, R. Datta, H. Hantsch, K. Million, H. Zimmermann. DVS 93, „Schweißen im Anlagen- und Behälterbau“ 1985-02-13/15

A look into the past
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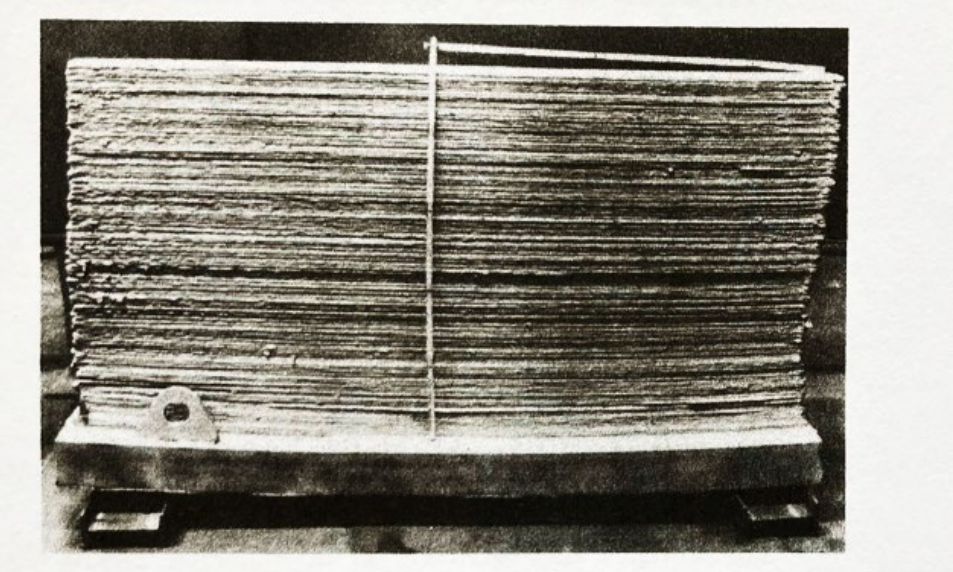
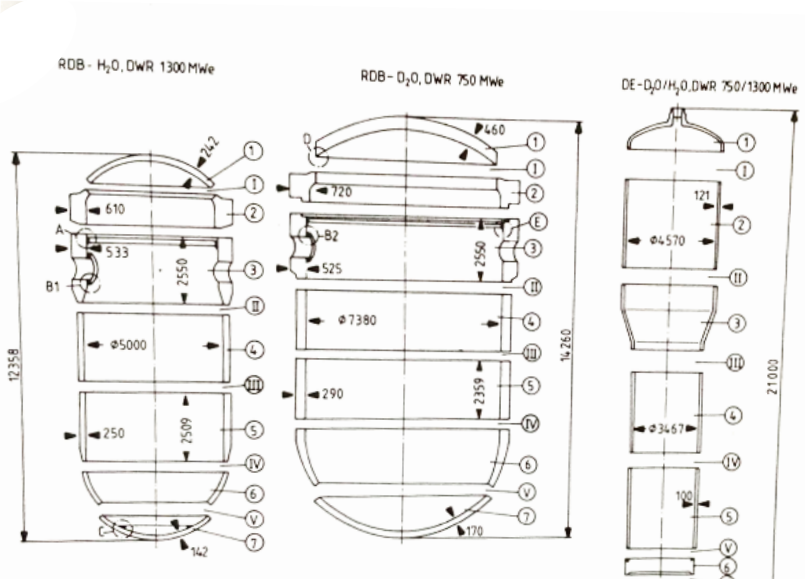


Example of vertical wall, build by submerged arc welding
(2000 x 1000 x 170 mm)

source: K. Million, H. Zimmermann, DVS 106, „Schweißen in der Kerntechnik“ 1986-11-26/28

A look into the past
Industrial applications

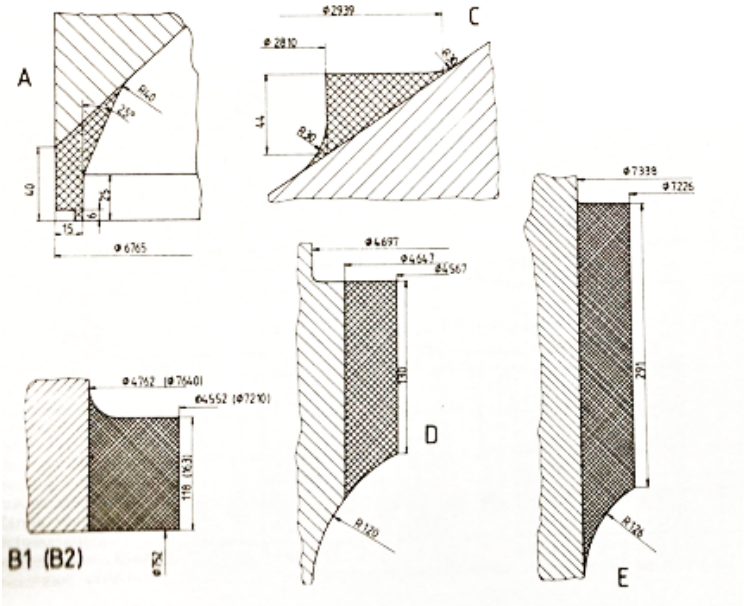


	RDB-H_2O	RDB-D_2O	DE	
Schmiedeteile, Anzahl	7	7	8	Pos. 1 – 8
Rundnähte, Anzahl	5	5	7	Pos. I – VII
Gesamtnahtlänge, m	~ 70	~ 110	~ 80	

Actual status (1986) of the forging part concept for nuclear reactor pressure vessels and steam generators

source: K. Million, H. Zimmermann, DVS 106, „Schweißen in der Kerntechnik“ 1986-11-26/28

A look into the past
Industrial applications



Example of form welded areas in nuclear reactor pressure vessel forged parts

source: K. Million, H. Zimmermann, DVS 106, „Schweißen in der Kerntechnik“ 1986-11-26/28

A look into the past
Industrial applications

What do we learn from the journey into the past? - conclusions

1) Submerged arc welding is a serious alternative especially for huge rotationally symmetrical parts

2) Steel composition has to be metallurgically adapted to work properly in WAAM

3) WAAM manufactured parts have been in service in critical components

4) Do not fiddle around with methods for creating extensive data graves by logging all process data from the GMAW process – it is not necessary

5) No fear for mechanical behaviour in all spatial directions – the most importand one is still the welding direction

6) Prevent worst case scenarios in application of WAAM parts

Status standardization

Status standardization
pressure vessel code – initiative from DE

DIN/TS 17026
„Unfired pressure vessels –
Additional Requirements for pressure equipment and pressure components fabricated with additive manufacturing methods “

Not a standard - „Technical Specification“

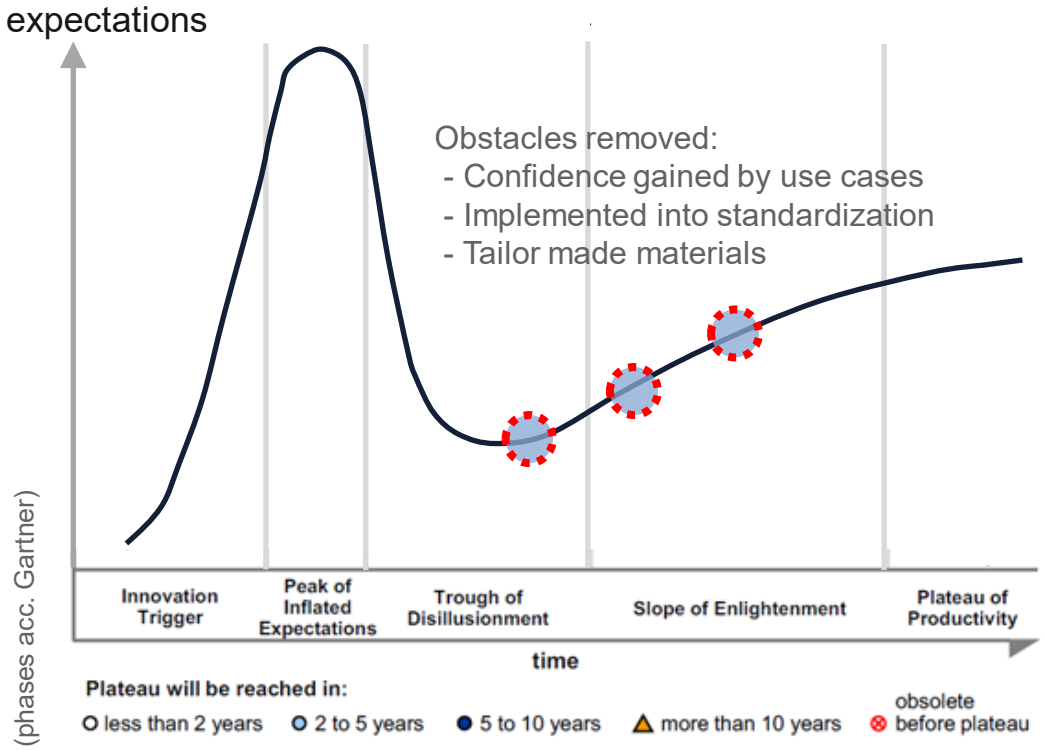
DIN/TS 17026 is discussed in polls in CEN/TC 54 as part of EN 13445 (-14 - Additional requirements for pressure equipment and pressure components fabricated with additive manufacturing method).

Status standardization
Conclusion

- Standardization is in progress.
- Use cases are missing or only rarely available.
- Multi material parts fabricated by WAAM are missing in all Additive Standards up to now.
- How to handle additional cooling?

Where are we now?

Where are we today?
Innovation curve



Thank You!

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