RE-PAIR

Large scale remanufacturing and reuse of cast & forged components enabled by new AM-repair technology

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RE-PAIR

- Scope
  - Use SAAM (Submerged Arc Additive Manufacturing) to repair and manufacture large parts for the energy sector.
    - Achieve sufficient material properties in two demonstrators.
  - Develop a business model for re-use of parts.
  - Start Re-usage centers at ESAB, SAAM AB and University West.
- Partners
- Financing

VINNOVA Sveriges innovationsmyndighet Ökad resurseffektivitet, industrins bidrag till en cirkulär ekonomi

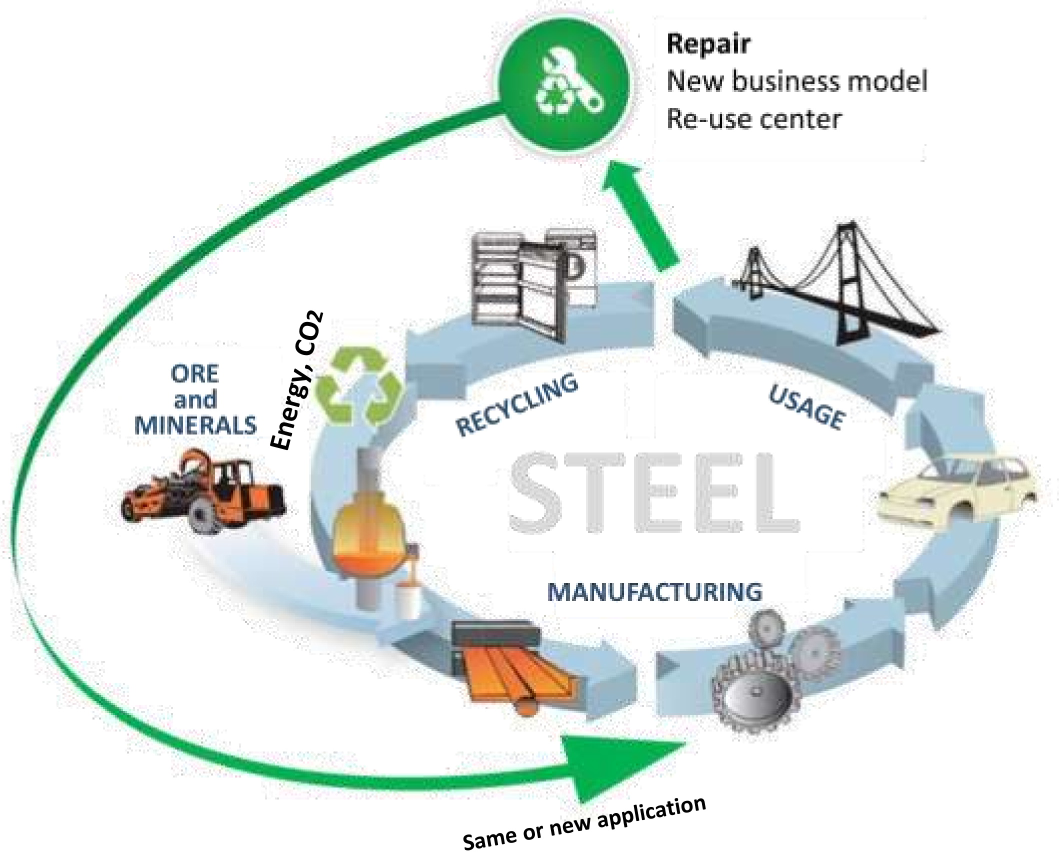
- Project duration

2023 October – 2026 October

SWERIM · UNIVERSITY WEST · VOITH Engineered Reliability · Subseatec A part of Scana · ESAB · SAAM

New business model

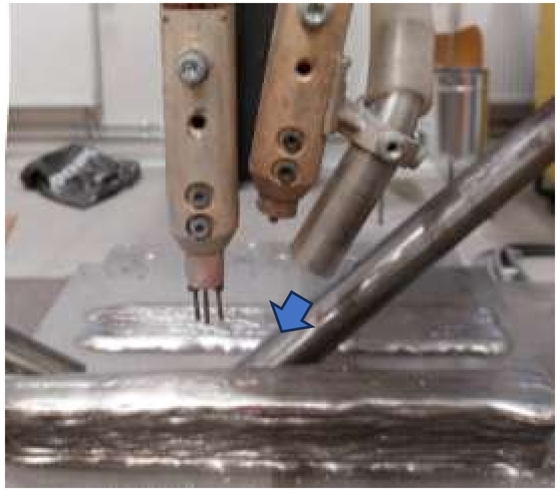
- Resilient Value chain
- Re-use centre
    - Available technology

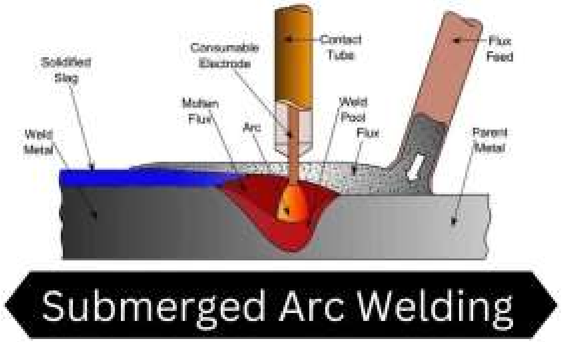


The process SAAM

STRIP. Submerged arc (SAW) / Electroslag (ESW)

WIRES. Submerged Arc Welding- SAW





Techniques For Submerged Arc Welding at Matthew Mendelsohn blog

Up to 100kg/h

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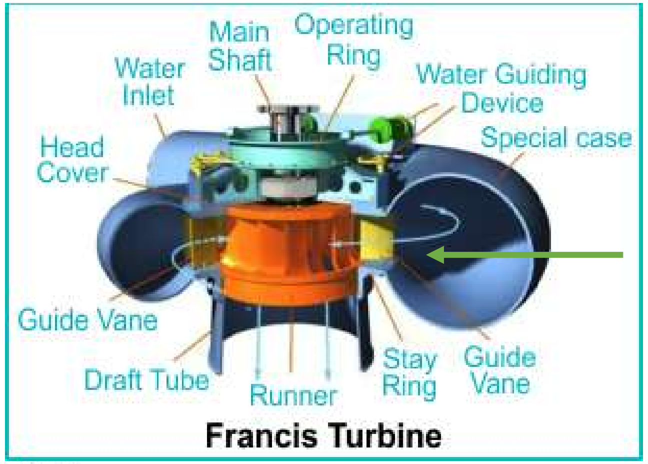
Demonstrators

Picture of completed demonstrator

Stress joints – re-use/build up




Guide Vane - re-pair



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Stress Joint

A prototype was build by SAAM and Subseatec and SAAM process was optimized in iterations.

Demand of properties based on subsea standards (ASME IIIV, 500bar pressure):

- Ultrasonic testing – defects
- COD – crack opening displacement testing. Fracture toughness.
- Charpy-V testing. Toughness.

- Then the demonstrator was built, see image.
  - Post heat treatment was done of the full component.

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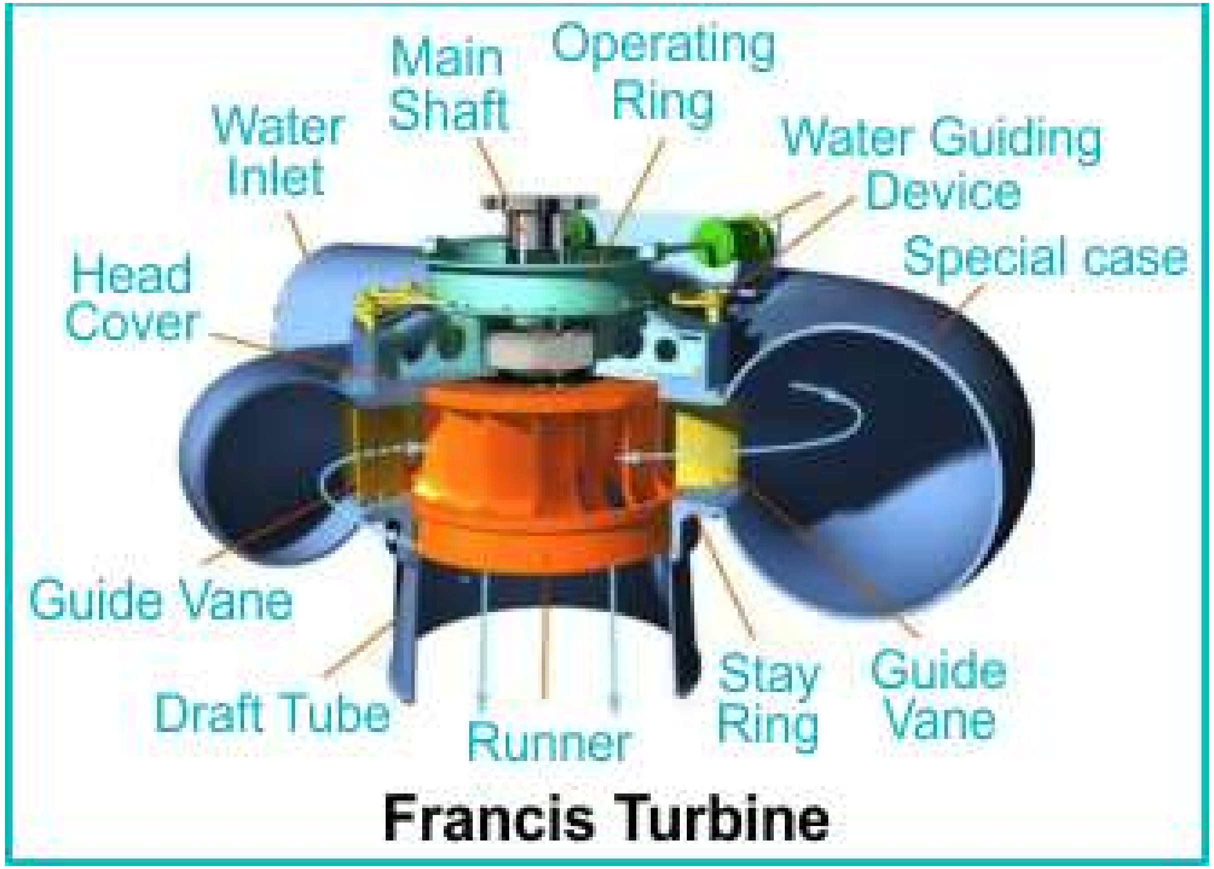
Guide Vane

Parallell paths

- SAW (wire**s**)
- SAW/ESW (strip)



Guide Vane (SAW-wire)
Process parameters´ development – test plan

Using these identified parameters, 4 experiments were conducted using 316L and 309L wires, and cross sections investigated

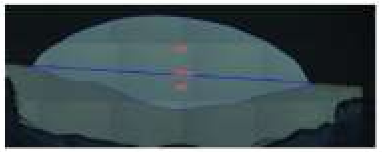
Designation	Type	1st layer	2nd layer	Polarity
SB1	Single bead	316L	-	DC-
MB1-L1	1 layer 5-beads	316L	-	DC-
SB4	Single bead	316L	-	AC
MB4-L1	1 layer 5-beads	316L	-	AC
SB2	Single bead	309L	-	AC
MB2-L1	1 layer 5-beads	309L	-	AC
MB2-L2	2 layer 5-beads	309L	316L	AC
SB3	Single bead	309L	-	DC-
MB3-L1	1 layer 5-beads	309L	-	DC-
MB3-L2	2 layer 5-beads	309L	316L	DC-

Experiments 1 and 4:
Fixed 316L alloy and change polarity

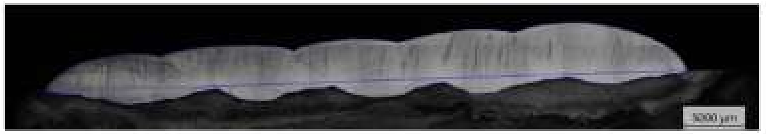
Experiments 2 and 3:
Fixed 309L as buffer layer and change polarity

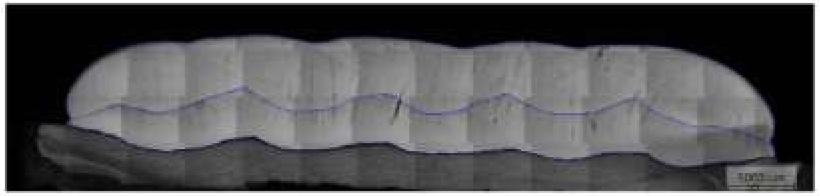
3. CHARACTERIZATION – DILUTION, 309L+316L

Ref.	Pol.	DIL.
SB2	AC	31.6%
MB2-L1	AC	29.3%
MB2-L2	AC	23.2%



Ref.	Pol.	DIL.
SB3	DC-	23.5%
MB3-L1	DC-	19.5%
MB3-L2	DC-	24.4%





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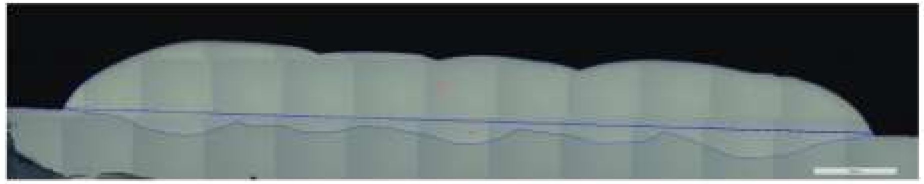
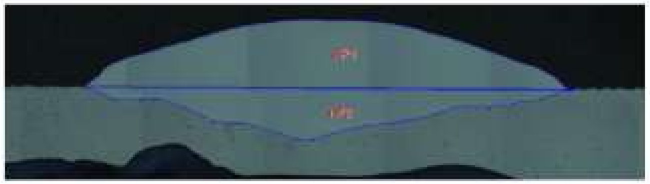
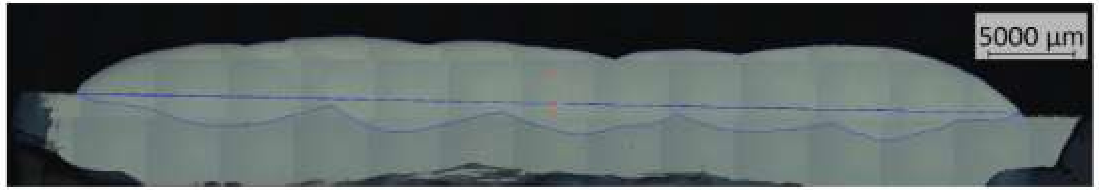
3. CHARACTERIZATION – DILUTION, 316L

Ref.	Pol.	DIL.
SB1	DC-	29.4%
MB1-L1	DC-	19.4%



Ref.	Pol.	DIL.
SB4	AC	35.4%
MB4-L1	AC	26.9%



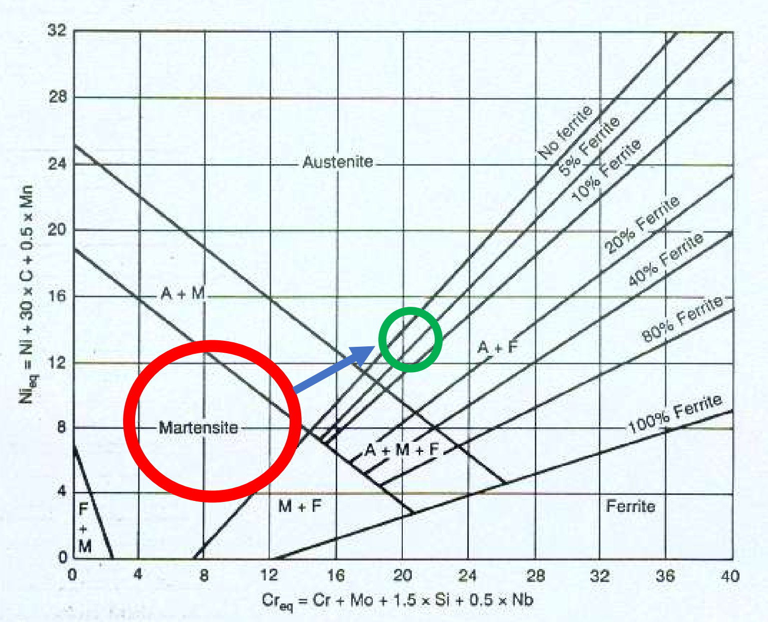


PRELIMINARY CONCLUSIONS

- Both DC- and AC process parameters ensured enough penetration, and lack of fusion was not observed.
- DC - parameters resulted in lower dilution than AC parameters
- Using 316L in the first layer resulted in martensite formation, the more dilution, the more martensite.
- Using 309L in the first layer resulted in mostly fully austenitic microstructure due to large dilution values.
- Martensite was always found in the fusion boundary with the substrate
- In 309L multibead, fully austenitic microstructure + associated restraints caused by multi-bead resulted in solidification cracks.
- CPT test showed low corrosion resistance. (Critical pitting temperature)

Guide Vane (SAW)- second iteration

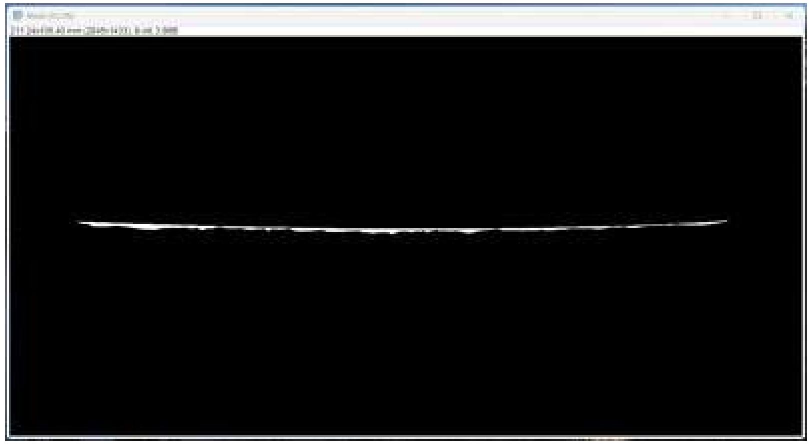
- The SAW ICE process has 3 wires that can be controlled individually – this enable precise mixing of the wires and possibility to alloy development in the melt bath.
- With a mixing of 19-35% of base material, the approach to lower the martensite formation is to increase the alloying element in the Ni-eq and Cr-eq. On-going.



1 Schaeffler constitution diagram for stainless steel weld metal

Guide Vane (ESW/SAW-strip)

- Degree of dilution. Initial trials on steel sheet substrate



Guide Vane (ESW/SAW-strip)

Omgång 2:

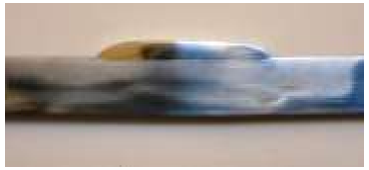
ESW 309L	Area
Area cladding inside plate [mm^2]:	49
Area cladding outside plate[mm^2]:	346
Total cladding [mm^2]	395
Degree of dilution [%]:	12,31%

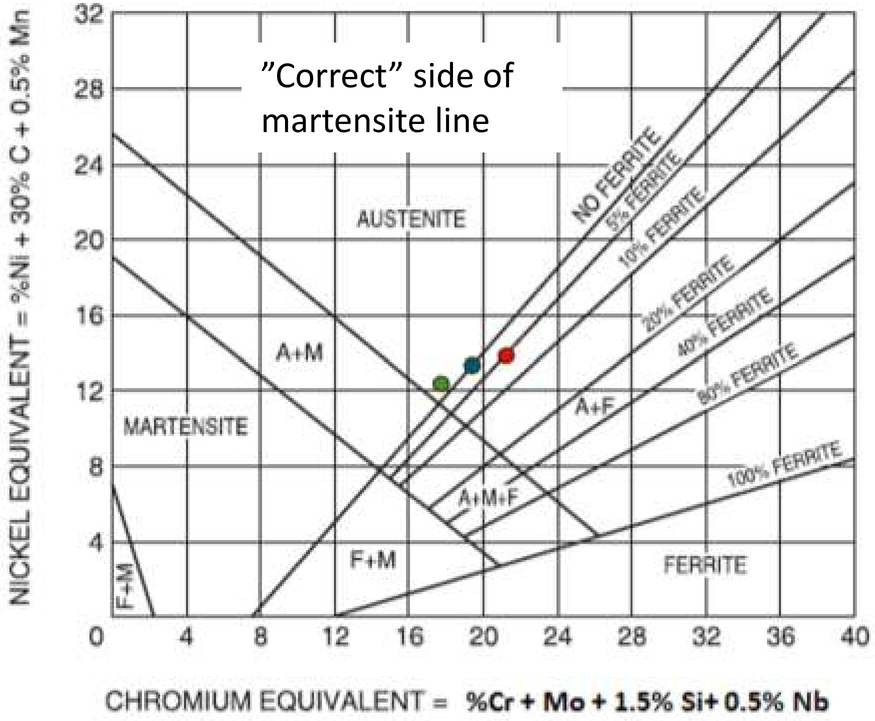
SAW 309L	Area
Area cladding inside plate [mm^2]:	52
Area cladding outside plate[mm^2]:	197
Total cladding [mm^2]	249
Degree of dilution [%]:	20,88%

SAW 316L	Area
Area cladding inside plate [mm^2]:	32
Area cladding outside plate[mm^2]:	180
Total cladding [mm^2]	212
Degree of dilution [%]:	15,09%

SAW 316L Double	Area
Area cladding inside plate [mm^2]:	80
Area cladding outside plate[mm^2]:	405
Total cladding [mm^2]	485
Degree of dilution [%]:	16,51%

SAW 309L Double	Area
Area cladding inside plate [mm^2]:	81
Area cladding outside plate[mm^2]:	445
Total cladding [mm^2]	526
Degree of dilution [%]:	15,40%





Electroslag 309L Dilution 12.3% (Cr-eqv 21.5 and Ni-eqv 13.9)

SAW 309L Dilution 20.9% (Cr-eqv 19.5 and Ni-eqv 13.3)

SAW 316L Dilution 15.1% (Cr-eqv 17.8 and Ni-eqv 12.5)

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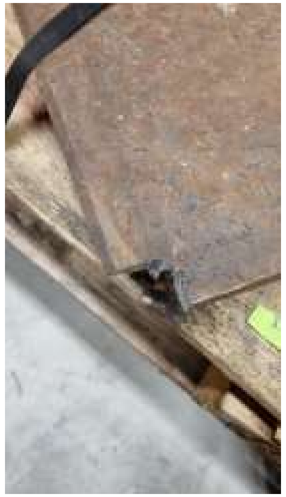
Guide Vane (ESW/SAW-strip)

- Trials on demonstrator. GDOES (Glow Discharge Optical Emission Spectroscopy)

CEV (IIW)
0,47

Element	Halt (viktsprocent)
Al	0.03%
As	0.01%
B	0.00%
C	0.36%
Ca	0.00%
Cd	0.00%
Co	0.01%
Cr	0.00%
Cu	0.02%
Fe	97.90%
Mg	0.00%
Mn	0.66%
Mo	0.00%
N	0.55%
Nb	0.00%
Nd	0.00%
Ni	0.00%
P	0.01%
Pb	0.00%
S	0.02%
Sb	0.01%
Si	0.39%
Sn	0.01%



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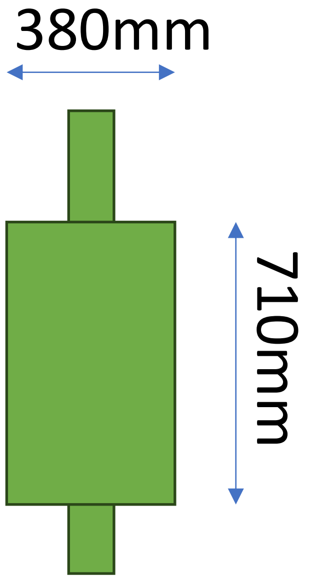
Guide Vane (ESW/SAW-strip)

Calculations:

C-content is too high for good predictability acc. to EN1011-2 but it indicates:

- Method A = no preheating
- Method B = 130-170°C preheating, avoid cold cracking
- T8/5 = 58 seconds, i.e. substantial grain size in HAZ
- No risk for reheat cracking ΔG_I
- But Mn/S ratio is too low, only 33 when it should be 80 or more (so, we have some risk for liquation cracking, which appear as 1-2mm long surface cracks along weld fusion line)



- Electroslag 309L Dilution 12.3% (Cr-eqv 21.5 and Ni-eqv 13.9)
- SAW 309L Dilution 20.9% (Cr-eqv 19.5 and Ni-eqv 13.3)
- SAW 316L Dilution 15.1% (Cr-eqv 17.8 and Ni-eqv 12.5)

															cm/min			uppmätt	
	name	base plate	filler	batch	thickness	width (mm)	wire feed rat	stick out (mm) FROI	flux	pre-heat conditions (t,T)	batch	feeding rate	heat input (k	dep rate(kg/l	travel speed	interpass ten	current (A	voltage(V)	power source
first bead	1 bead	355	309		0.5	60	155	25, triangular edge	10.05 men	new bag=no heating		N/A	14	22	16	-	1250	24	2ST ESAB LAF 1601

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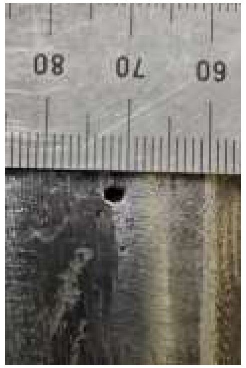
Guide Vane (ESW-strip)

- first side blasted
- second side blasted + grinded with angle grinder.



Guide Vane (ESW)

- Pre-heating/interpass temperature: 170 °C

- Next step
  - cross sections for defects/dilution, and corrosion properties.

Ongoing activities

- Publication in Welding in the World and presentation at IIW Annual assembly 2026, Salzburg
- Further verification of material properties
- LCA – Life cycle analysis
  - Compare energy and CO_2 - New manufacturing vs re-pair
- Scalable business model
- *Seminar in standardisation of SAAM (13th of May)*