Metrode Products Limited

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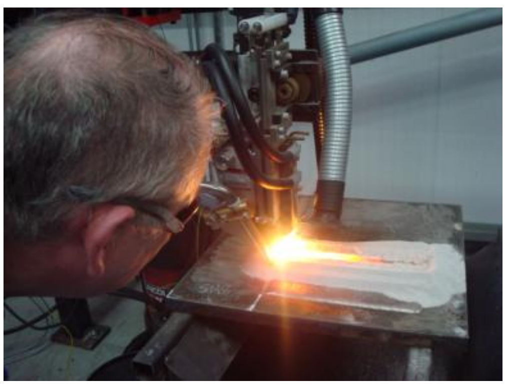
Strip Cladding Profile



Rev 02 – May 2011

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Introduction

Cladding is a fundamental process to the fabrication industry and is applied across the whole spectrum of applications; from Nuclear, Petrochemical and Oil and Gas. The ability to fabricate in C/Mn, Low alloy steels for the main structure , utilising the strength and other physical properties, then applying a corrosion resistant layer in the area where this is needed, provides unique flexibility and cost savings.

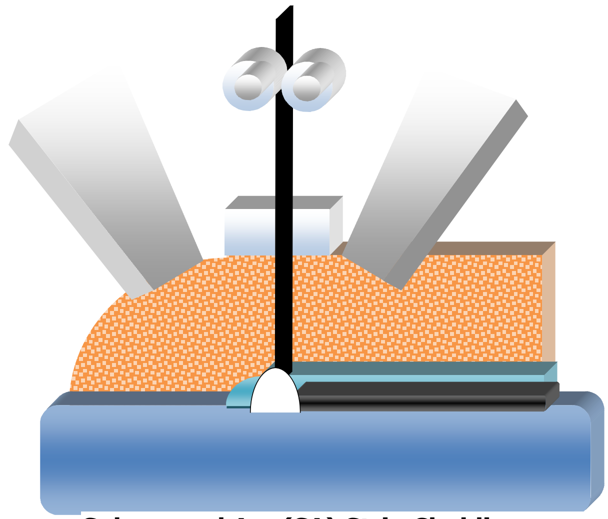
There are many ways to apply this corrosion resistant layer from Roll Cladding at the steel rolling stage and Explosive Cladding of existing plate, however the most flexible is Weld Cladding. All the welding processes can be utilised however due to constraints in the physical requirements, some are better suited than others.

Cladding Processes

In the main GTAW with cold or hot wire feed is used for smaller areas and in restricted access situations i.e. internal bore cladding. This can be automated, resulting in a reproduceable deposit. For larger, thicker sections, the GTAW process lacks the deposition rate and therefore Strip Cladding processes are better suited.

Strip Cladding Process

There are two strip processes .**Submerged Arc Strip Cladding** utilises an arc that runs back and forth at high speed along the strip, depositing weld metal onto the base material. Because this is an arc process there will be penetration into the base material resulting in dilution levels of ~ 20%. Deposition rates are in the region of 10/12kg/hr for 60mm strip and are restricted by how much current can be applied. Care must also be applied to the overlap area as any residual slag will not be re-melted and result in lack of fusion. For a similar reason it is not recommended for lane closures of roll clad plate in the area where the roll cladding meets the base material.



Submerged Arc (SA) Strip Cladding

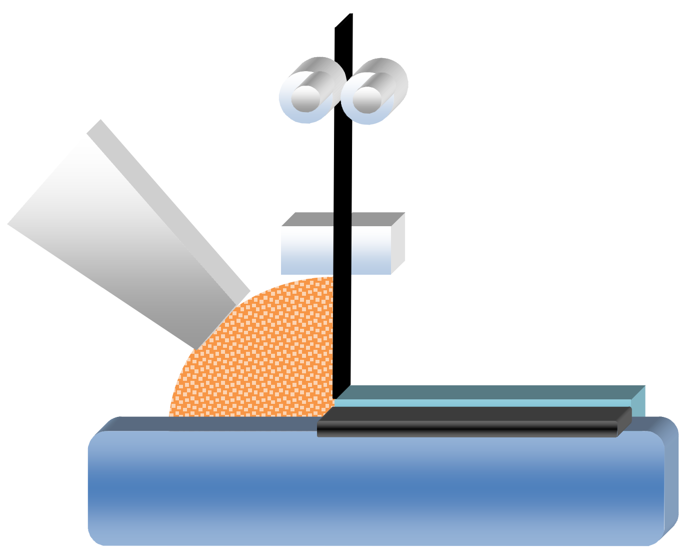
Electro Slag Strip Cladding (ESW) utilises a conductive flux and the resulting Joule heating effect to melt the strip into the liquid slag; which is transferred into molten metal deposited onto the base material. The ESW process has significant advantages over its SAW counterpart:

1. As there is no arc present, there is limited dilution into the base material, typically 10% (compared with 20% SAW for 60x0.5mm strip). This can be further enhanced by tailoring flux type and deposition technique .Leading to the ability to deposit single layer full chemistry with over alloyed strip.

2. Electroslag refining occurs when the molten metal passes through the slag bath, resulting in cleaner weld metal with lower O_2 levels.

3. Higher current levels can be used giving deposition rates of 22-25kg/hr for 60mm strip.(SAW 10/12kg/hr)

4. Utilising high speed fluxes, dilution levels can be reduced and the area coverage (M^2/hr) can be increased



Electroslag Strip Cladding (ESW)

Material Availability

Metrode manufacture a range of Fluxes and Strips for both cladding processes

- **ES200 Flux** is a highly basic Electroslag Flux for use with Stainless Steel and Nickel based strips. It is also designed to enable high speed cladding. The flux has neutral characteristics with respect to the strip. It has good slag detachability and produces smooth bead profile with side aspects to produce flat deposits.

- **ES400 Flux** is a highly basic Electroslag Flux for use with Stainless Steel and Nickel based strips. The flux has neutral characteristics with respect to the strip. It has good slag detachability and produces smooth bead profile with side aspects to produce flat deposits.

Typical strip/weld deposit analysis, wt%

Strip/Flux Layer	C	Mn	Si	Cr	Ni	Mo	Nb	N	Cu	Fe	FN/Other
EQ316L OA Strip	0.014	1.66	0.18	20.56	13.31	2.85	0.005	0.036	0.12	-	
EQ316LOA/ES200One	0.020	1.49	0.30	19.40	12.85	2.72	0.01	0.04	0.01	-	8
EQ347 OA Strip	0.011	2.00	0.29	21.39	11.30	0.13	0.63	0.034	0.31	-	
EQ347 OA/ES200 One	0.028	1.52	0.43	19.54	10.40	0.12	0.46	0.04	0.27	-	7
EQ308L Strip	0.015	1.76	0.32	20.10	10.35	0.07	0.05	0.03	0.05	-	
EQ308L/ES200 Two	0.016	1.47	0.47	19.32	9.95	0.07	<0.001	0.03	0.05	-	8
EQ347 Strip	0.023	1.85	0.20	20.01	10.81	0.05	0.53	0.02	0.05	-	
EQ347/ES200 Two	0.021	1.51	0.38	19.38	10.47	0.05	0.42	0.02	0.04	-	7
EQ309L Strip	0.015	1.48	0.38	23.66	13.27	0.08	0.013	0.05	0.04		
EQ347 Strip	0.023	1.85	0.20	20.01	10.81	0.05	0.53	0.02	0.05	-	
EQ309L/EQ347/ES200 One	0.027	1.29	0.53	21.08	12.06	0.08	0.009	0.03	0.04	-	7
EQ309L/EQ347/ES200 Two	0.018	1.45	0.42	19.90	10.78	0.05	0.36	0.03	0.04	-	7
EQ62.50 Strip	0.006	0.042	0.045	21.80	bal	8.89	3.26	-	0.09	0.48	-
EQ62.50/ES200 Two	0.006	0.06	0.35	21.10	bal	8.78	3.08	-	0.09	2.07	
EQ347 Strip	0.023	1.85	0.20	20.01	10.81	0.05	0.53	0.02	0.05	-	
EQ347/ES400 Three	0.017	1.43	0.32	19.75	10.57	0.05	0.41	0.03	0.06	-	8
EQ308L Strip	0.015	1.76	0.32	20.10	10.35	0.07	0.05	0.03	0.05	-	
EQ308L/ES400 Three	0.015	1.44	0.45	19.58	10.32	0.07	0.09	0.03	0.09		8
EQ62.50 Strip	0.006	0.042	0.045	21.80	bal	8.89	3.26	-	0.09	0.48	-
Strip/Flux Layer	**C**	**Mn**	**Si**	**Cr**	**Ni**	**Mo**	**Nb**	**N**	**Cu**	**Fe**	**FN/Other**

EQ62.50/ES400 Three	0.006	0.07	0.29	21.15	bal	8.83	3.21	-	0.08	1.22	-
EQ82.50 Type	0.007	0.76	0.34	22.37	39.01	3.00	-		1.72	31.30	-
EQ82.50 (type)/ES200 Three	0.012	0.65	0.77	22.45	39.05	2.64	-	-	1.68	32.15	
EQ82.50 Type	0.007	0.76	0.34	22.37	39.01	3.00	-		1.72	31.30	-
EQ82.50 (type)/ES400 Three	0.010	0.97	0.74	22.44	39.12	2.64	-	-	1.69	32.27	-

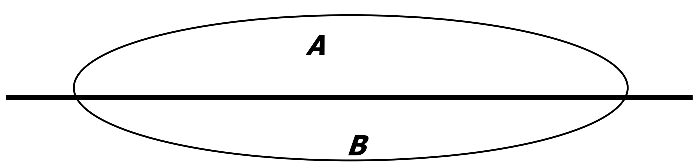
Base material: Pressure vessel quality C/Mn plate. Welding conditions: 1150-1250Amps, 24-26V, 180mm/min

Dilution

The level of dilution is dependent on the amount of penetration into the base material and is process related. Typical levels are as follows:

SMAW: 25-30%
SAW Wire: 25-35%
SAW Strip: 18-25%
ESW Strip: 8-12%

Overlapping with the adjacent bead will reduce the apparent dilution and steady state conditions are achieved after the third run.



$$\text{Dilution} = \frac{A}{A+B}$$

Where A= the area above the plate and B= the area penetrated in the plate thickness

Individual element can be calculated as follows knowing the dilution level (or estimation of)

Ec = (Bc x D%)+[(Sc + Av)x(1-D%)]

Ec Element Concentration
Bc Base Concentration
D% Dilution %
Sc Strip Concentration
Av Alloying Vector

The alloying vector is dependent on the flux strip combination and typical values for the main elements are as follows:

Alloying Vectors for ESW Fluxes.

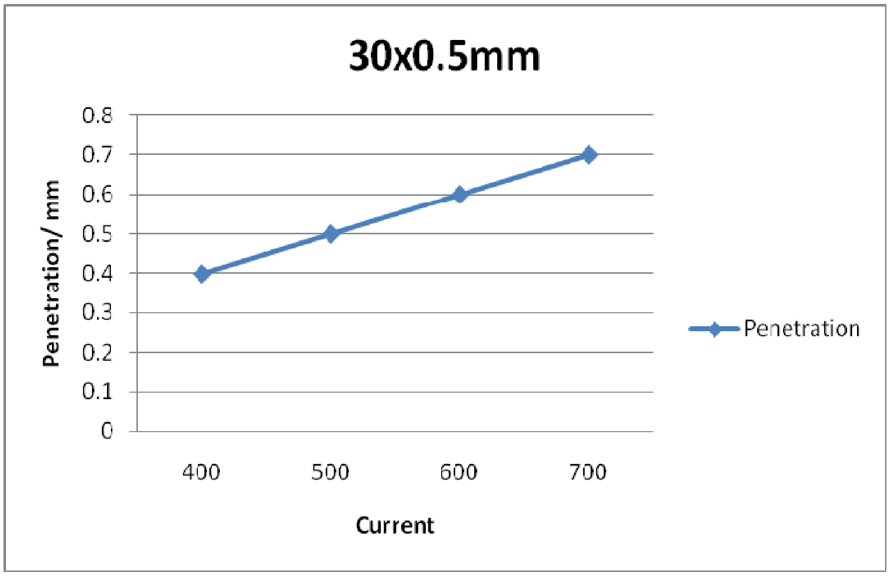
Flux/Strip	C	Mn	Si	Cr	Ni	Mo	Nb
ES200/EQ308L	0	-0.34	+0.14	-0.48	0	0	-
ES200/EQ347	0	-0.38	+0.19	-0.34	0	0	-0.1
ES400/EQ308L	0	-0.32	+0.13	-0.52	0	0	-
ES400/EQ347	0	-0.42	+0.12	-0.26	0	0	-0.1
ES200/EQ62.50	0	0	+0.23	-0.69	0	0	-0.2
ES400/EQ62.50	0	0	+0.25	-0.65	0	0	0

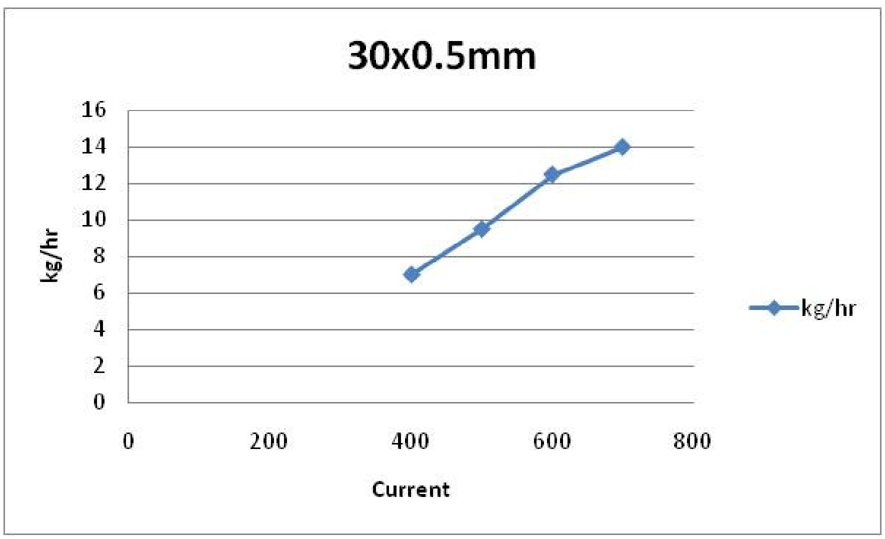
The alloy vector (Av) can
Further useful calculation information can be obtained by downloading "CALCULAT" from our website using the following link. www.metrode.com

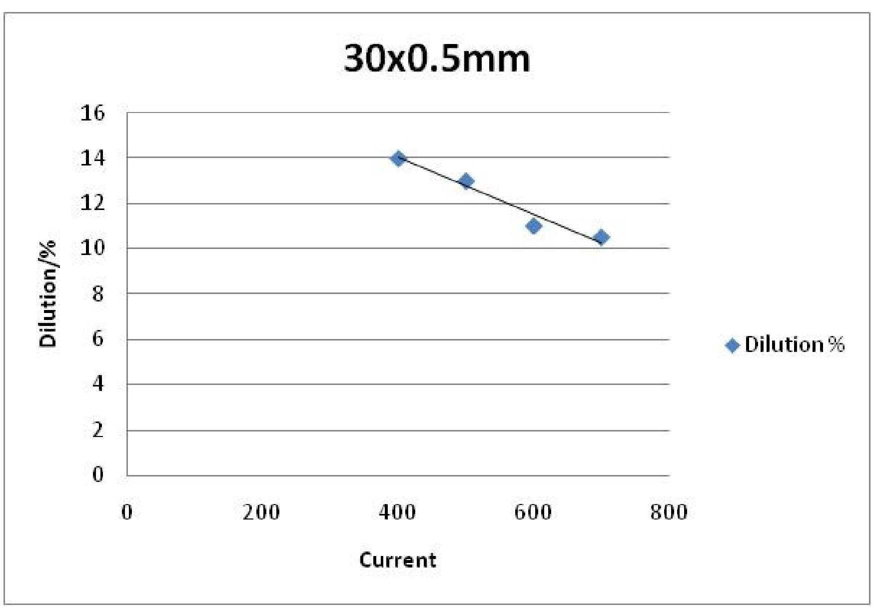
Parameter Effects

All the following data refers in the main, to 30x0.5mm strip. It is generated using the ES400 type flux.

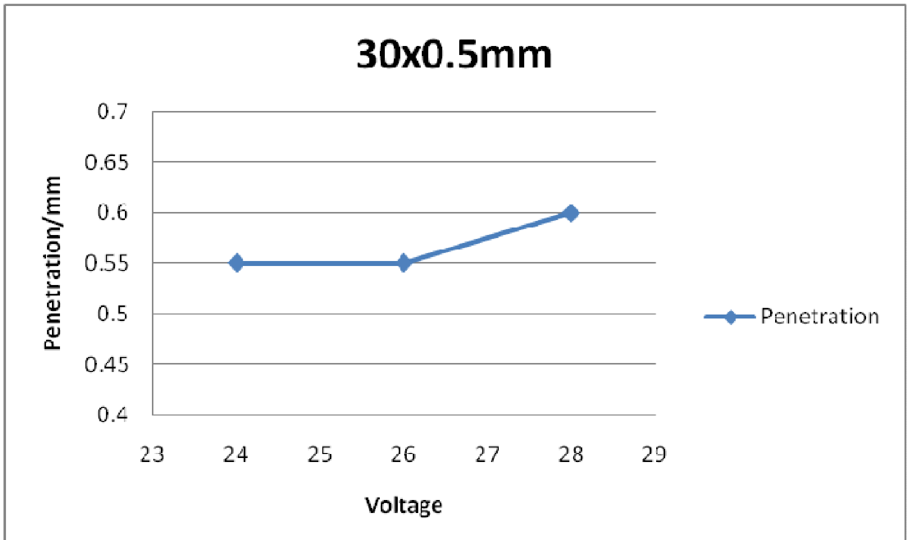
Current

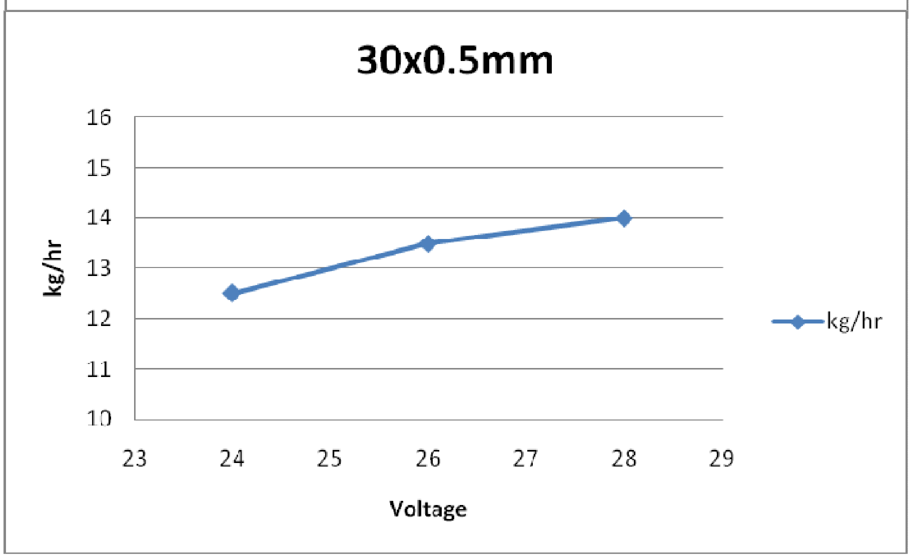


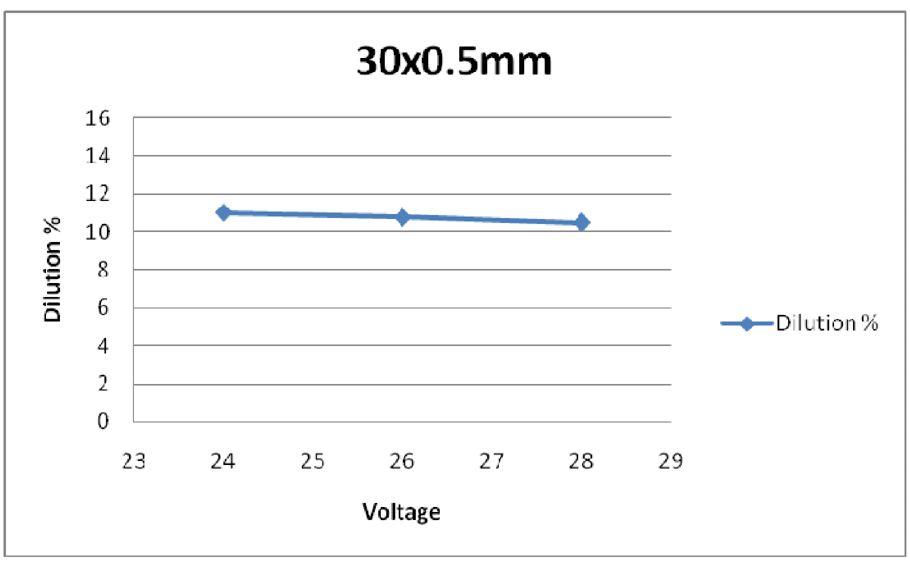




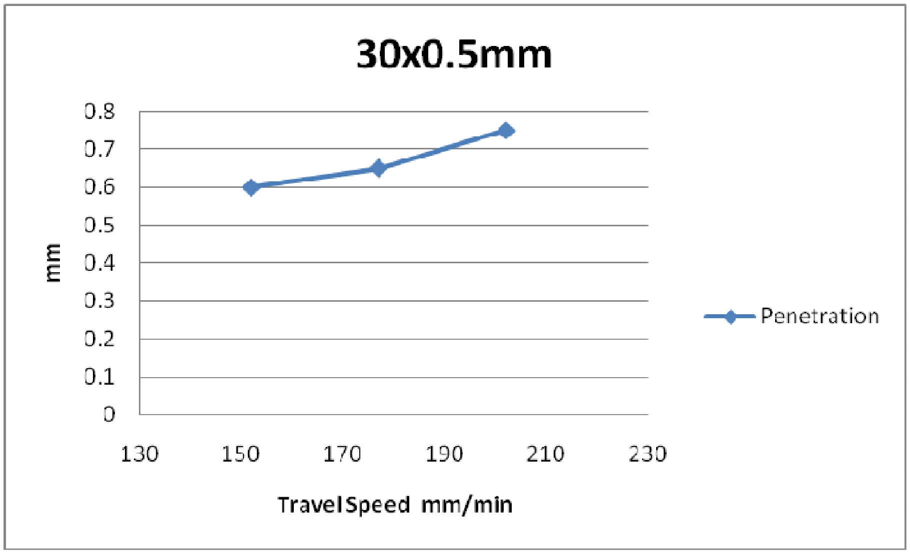
Voltage

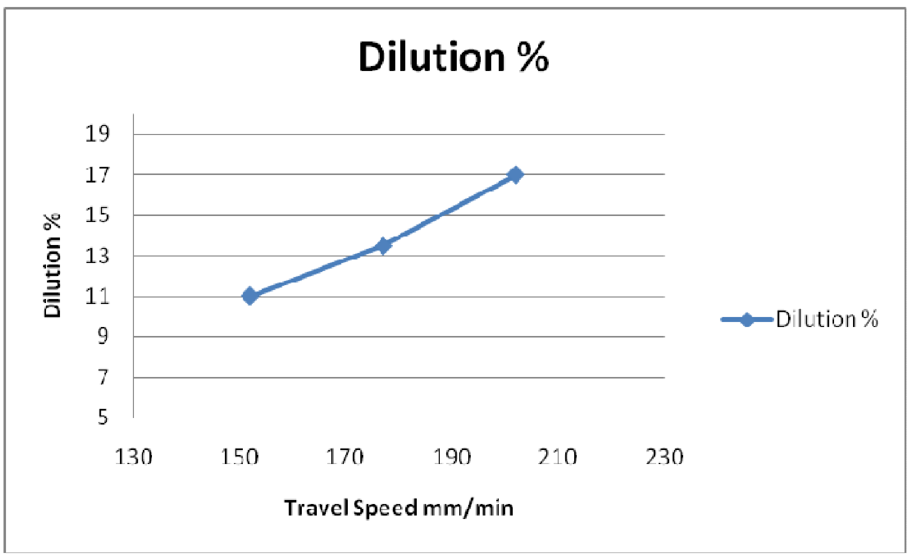

30x0.5mm
Penetration/mm
0.7
0.65
0.6
0.55
0.5
0.45
0.4
23 24 25 26 27 28 29
Voltage
Penetration


30x0.5mm
kg/hr
16
15
14
13
12
11
10
23 24 25 26 27 28 29
Voltage
kg/hr

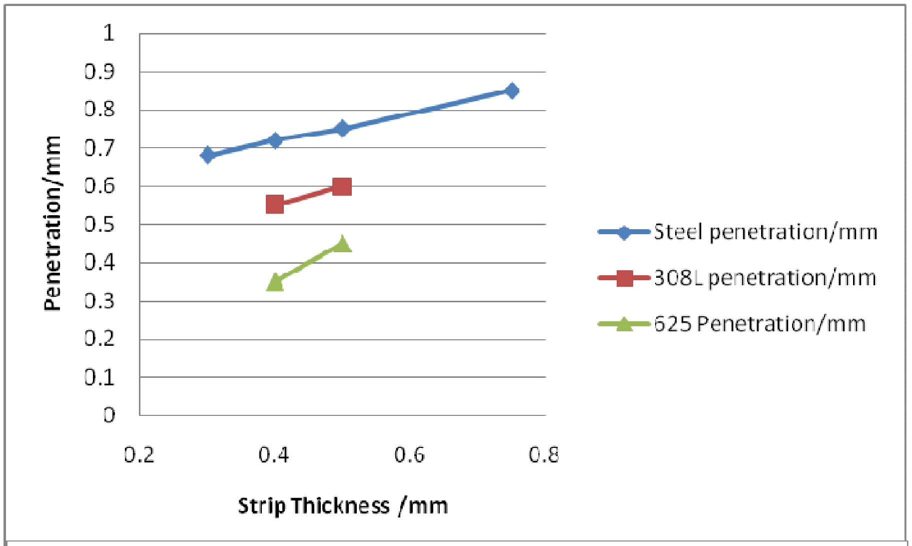

30x0.5mm
Dilution %
16
14
12
10
8
6
4
2
0
23 24 25 26 27 28 29
Voltage
Dilution %

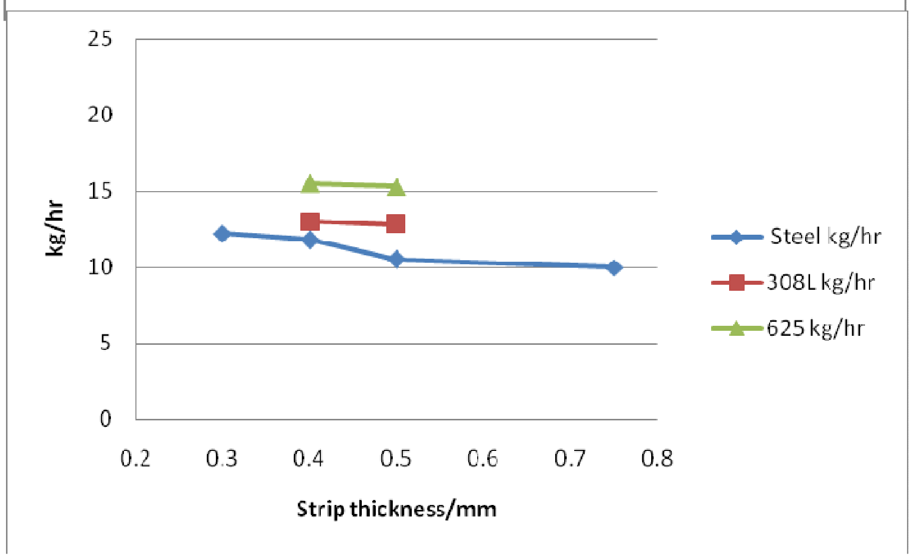
Travel Speed

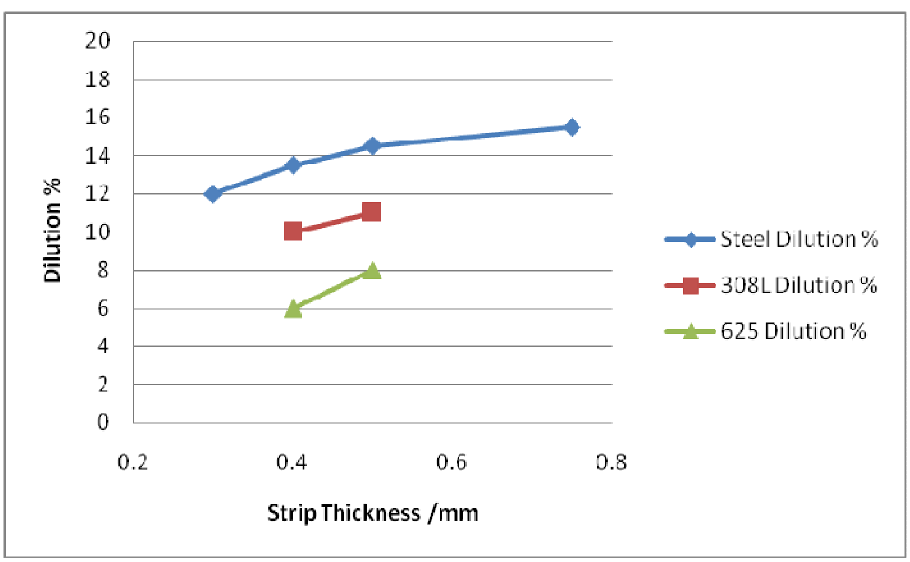




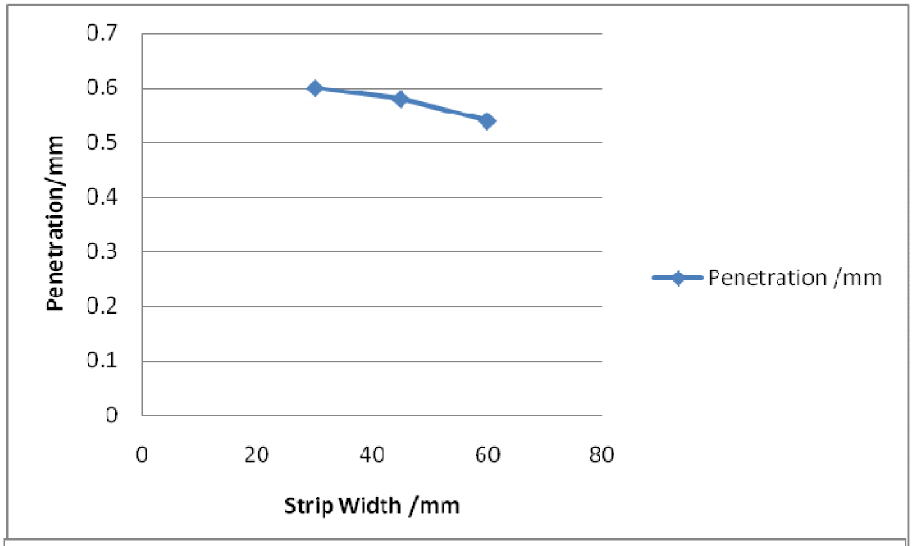
Strip Thickness (Constant heat input)

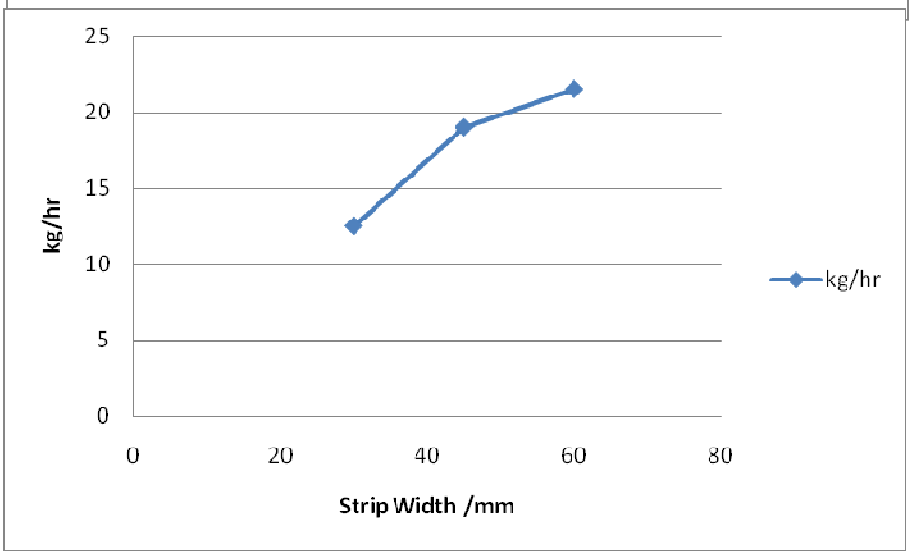


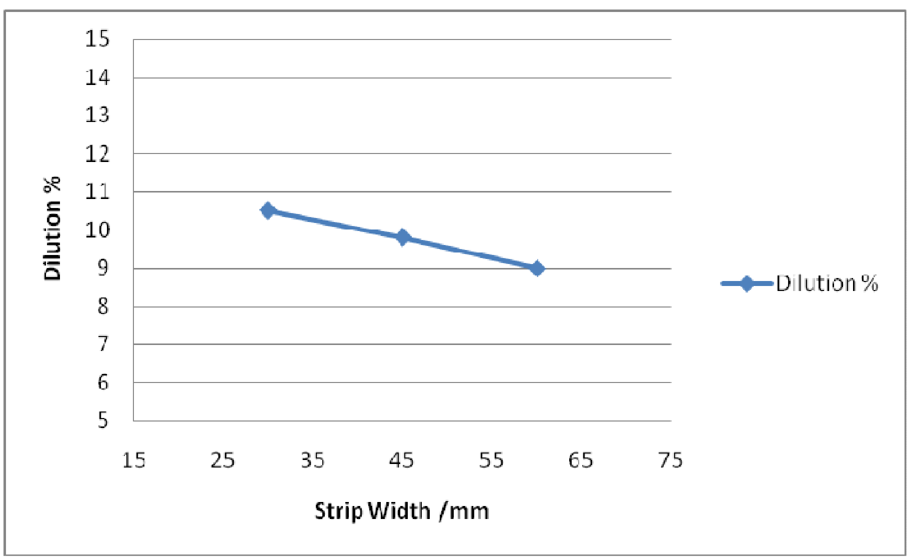




Strip Width (308L, Constant Current Density)







Heat Input

The classic heat input equation is given below:

$$\text{Heat Input/ kJ/mm} = \frac{A \times V \times 60}{S \times 1000}$$

Where
A= Amps
V= Volts
S=Speed mm/min

This gives the "point" heat input and when it is used for strip cladding, the values are considerably higher than comparative wire processes. In strip processes the heat is delivered over the width of the strip and consequently bead width influences the heat input. A point calculation is therefore, misleading and a term for the bead width needs to be introduced. The equation now becomes:-

$$\text{Heat Input kJ/mm}^2 = \frac{A \times V \times 60}{S \times 1000 \times W}$$

W= Bead width/mm

Examples and comparisons between the processes are given below:

Process	Ø-Strip Width/Bead Width mm	A	V	Speed/mm min $^{-1}$	kJ/mm	kJ/mm^2
SAW Wire	4.0/20	550	32	457	2.3	0.12
SAW Strip	60x0.5/65	750	26	140	8.35	0.13
ESW Strip	60x0.5/70	1250	25	180	10.41	0.15

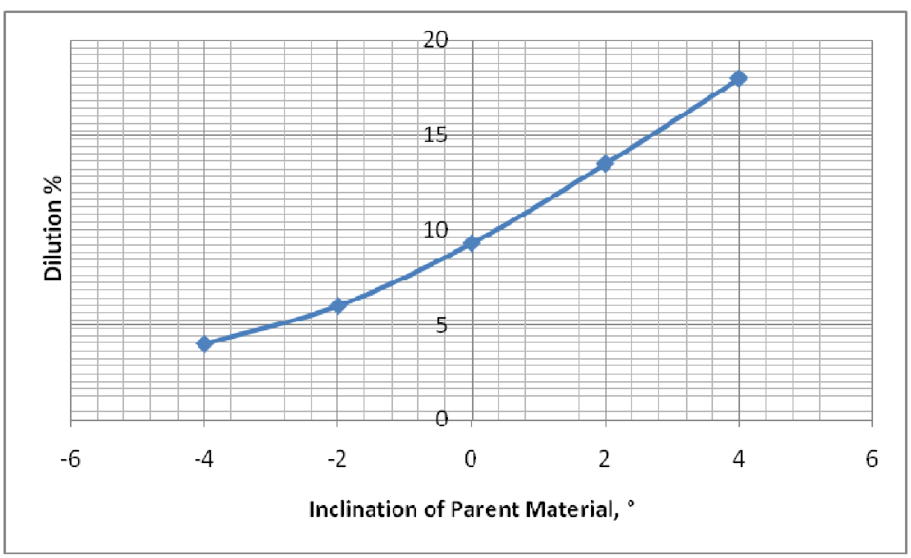
Strip

Strip in dimensions of 30, 60, 90, 120mm widths x 0.5mm thick (The Japanese tend to use 50,100,150mm x 0.4mm thick). The choice of strip width is dependent on the base material thickness, vessel diameter and the amount of welding current that is available.

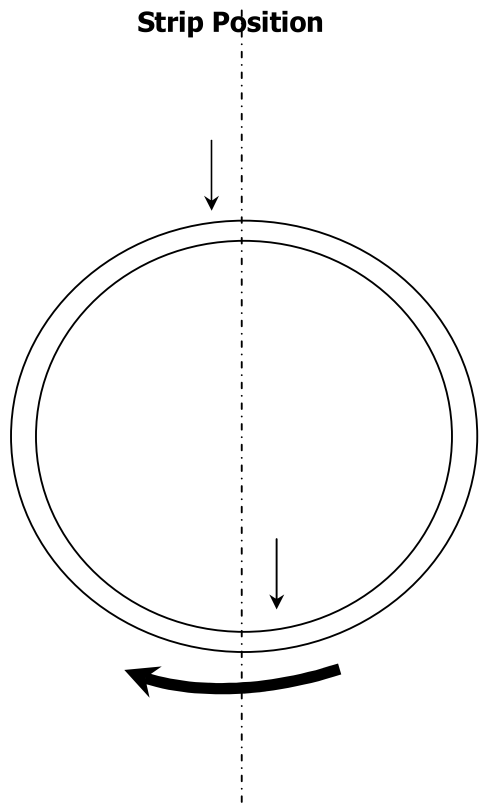
Strip Width/mm	Minimum Thickness/mm	ID Minimum/mm		OD Minimum/mm	
		Longitudinal	Circumferential	Longitudinal	Circumferential
30	30	200	300	400	250
60	45	460	700	500	500
90	75	660	1070	1000	1300
120	100	960	1940	1500	2400

Strip Positioning (Circumferential Cladding)

When cladding a vessel it is essential to position the strip so that the weld pool is solidifying in the bottom dead center (inside) or Zenith (outside position). This then has an effect on the dilution level. Incorrect positioning can be seen to give substantialy higher levels in dilution than would be expected. In addition with fully Austenitic materials there is a danger of solidification cracking if the inclanation is too posittive!



1250A,26V,140mm/min



Residual Stresses

As with all welding processes, cladding produces residual stresses. In overlay cladding they peak 2-3mm below the clad surface in the base material. For a full discourse on the magnitude, measurement and effects please use the following link:
www.stralsakerhetsmyndigheten.se/Global/.../SKI%202006-23%20Web.pdf

In essence the main points are as follows:

Residual stresses peak value will be related to the yield strength of the cladding material.

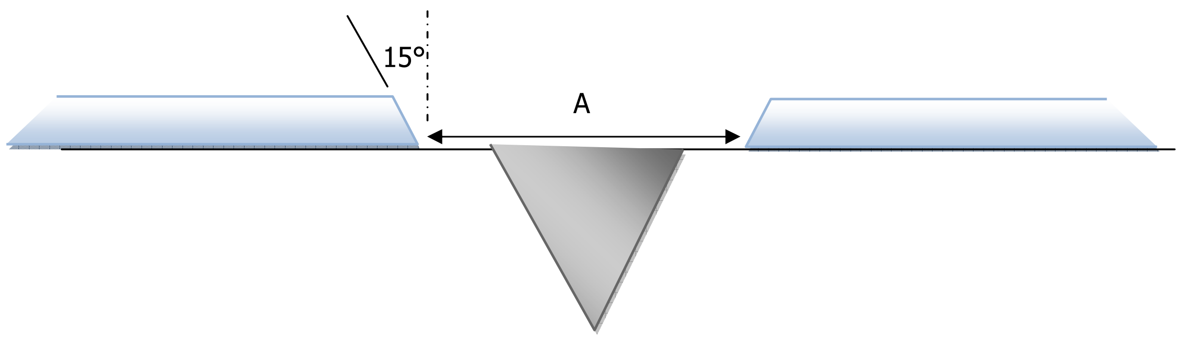
Dependent on the base material thickness, distortion can occur . For example cladding a 1.2M diameter 30mm thick C/Mn vessel with 62.50 strip 60x0.5mm, at 1150A,25V 180mm/min, reduced the circumference by 25mm.

This reduction acts only on the part that has been clad and some fabricators use 30x0.5mm strip to clad the beginning and end of the rolled section to avoid problems with fit up with the next rolled section to form a column. The middle sections use 60x0.5mm strip.

The residual stresses reduce with operating temperature.

Lane Closure

When Roll Clad material is used to fabricate a vessel, replacement corrosion resistant material has to be deposited over the area where the cladding has been cut back to allow the C/Mn base material to be welded. ESW strip cladding offers a “one hit” process to maximise production rates for both longitudinal and circumferential seams. A typical cladding preparation is shown below:



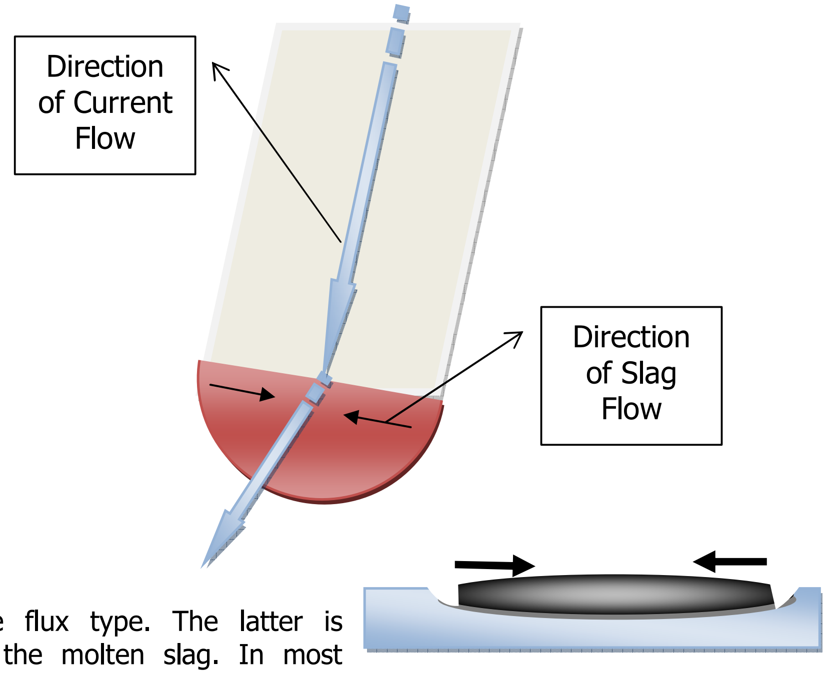
The cut back dimension, A, is dependent on the thickness of the base material.

SAW strip cladding is not suitable for this application as residual slag is trapped at the toes where the roll clad material meets the base material.

Magnetic Steering.

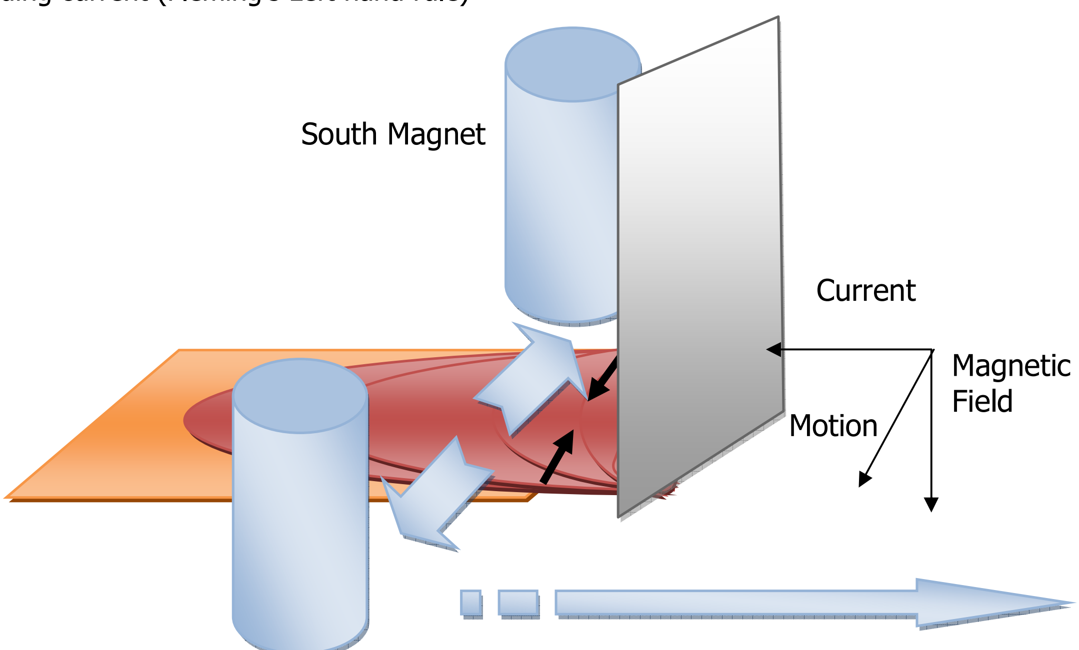
- In the ESW process electric current runs in parallel from the strip to the back of the molten pool.

- This produces a fluid force that has a squeezing effect on the molten slag, metal pool and results in shortage of metal at the edges. This results in undercut.



- The point that this phenomena occurs depends on the current level and consequently the strip width together with the flux type. The latter is dependent on the fluidity of the molten slag. In most instances 30mm wide strip width does not suffer from this effect.

- To counter this fluid force an external magnetic field is applied and acts on the magnetic fluid slag bath. Lorentz force is generated when the external magnetic field interacts with the welding current (Fleming's Left hand rule)



Increased Stick-Out Effects

The standard stick-out length for both SAW and ESW strip cladding is 30mm. If this is increased, then there will be an increased pre-heating, I^2R , effect on the strip. Stick-out lengths of 60 to a 100mm can be used instead of the standard 30mm. The effect of heating the strip results in increased deposition rate and reduced dilution. By pre-heating the strip electrically, the amount of energy used to melt the strip in the slag pool or across the arc, is reduced with beneficial consequences.

It should be noted that a cladding head that crimps the strip before entering the slag pool (ESW) or across the arc (SAW) is required. The crimping increases the columnar strength of the strip and makes it easier to start the process.