Bernd Rutzinger

Influence of the welding process to the dilution rate of weld overlays on unalloyed steel using the weld consumable ERNiCrMo-3 (Alloy 625)

Abstract: Nickel based alloys are used in different applications of the industries like power generation or the petro chemical industry. Out of the variety of these protection methodologies, weld overlay with ERNiCrMo-3 (Alloy 625) has proven to be the most widely accepted. This paper describes weld overlays of ERNiCrMo-3 (Alloy 625) with the welding methods GMAW Pulse, CMT, Tandem, CMT Twin, TIG cold wire, TIG hot wire and Laser Hybrid. The investigation of these probes includes the Fe dilution of the base material, the distribution of the Fe concentration through the weld overlay, and further on the welding speed and weld deposition rate.

Keywords: ERNiCrMo-3, Alloy 625, nickel alloys, welding methods

Introduction

Weld overlay cladding utilizes the welding consumable to apply an adherent layer onto the surface of a component. This process is mainly used for hard facing, corrosion protection, intermediate layers (buffering) and for repairing worn surfaces. The component body serves as the substrate, with sufficient elastic and static properties [1]. The weld cladding acts as a functional surface that protects the component from stresses such as corrosion, wear and extreme temperature. A critical factor influencing the quality of an overlay weld is the dilution of the base metal. This dilution must be kept as low as possible, yet while ensuring sufficient bonding to the base metal. This paper investigates the behavior of the welding consumable ERNiCrMo-3 (Alloy 625) with the welding processes CMT, CMT Twin, GMAW Pulse, Tandem, TIG Cold wire, TIG Hotwire and Laser Cladding in relation to deposition rate, dilution and welding speed.

B. Rutzinger Fronius International GmbH

Compared welding processes

GMAW Pulse

GMAW Pulse welding is a proven welding process for weld overlay applications for many years. It is characterized by arc stability and a low spatter ejection. Due to the high current peak (see figure 1) which is needed for a continuous and even droplet detachment, the energy input into the weld is increased. This tends to result in a higher dilution rate with the base material.

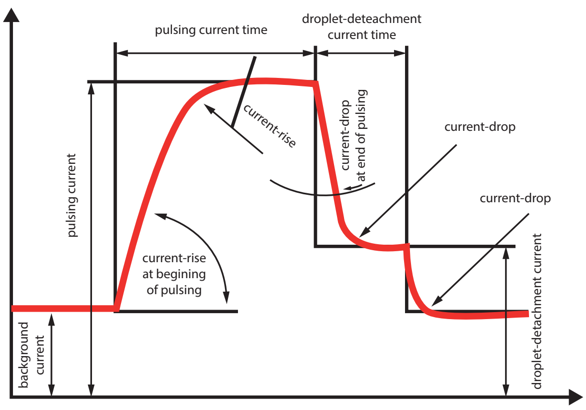

Fig. 1. Overview pulse parameter

CMT

CMT (Cold Metal Transfer) was originally developed as a thin sheet metal joining process for the car industry. Now this welding process is giving advantages in weld clad overlays. CMT enables a low heat input due to the fact that the wire is withdrawn from the molten weld pool with a low welding current [2]. (see figure 2)

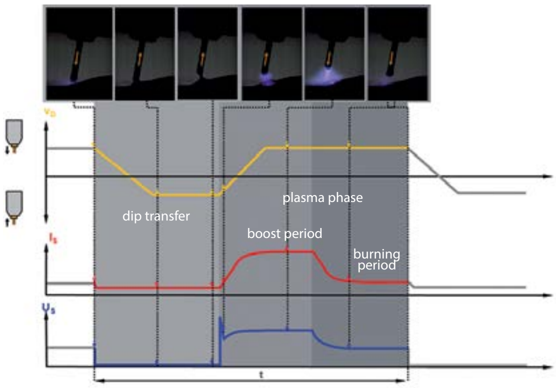

Fig. 2. CMT arc sequence

Tandem GMAW (Time Twin)

Tandem welding (Time Twin) is using two from each other isolated welding electrodes which are molten in a common weld pool (see figure 3). Due to the separation of the electrical potentials different arc combinations can be realized. This enables the process to regulate welding speed and deposition rate.

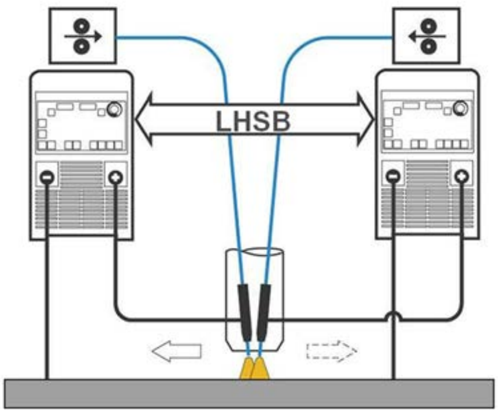

Fig. 3. Tandem process principle

CMT Twin

CMT Twin is an upgrade of the Tandem process. Similar to the Tandem process, CMT Twin operates with two digital controlled power sources which are completely independent from each other. The system offers a large variation of the wire feed speeds and allows the use of two CMT arcs or a mix of different arc combinations. The advantage of CMT Twin is the arc stability and the reduced heat input.

Fig. 4. Configuration CMT Twin

Gas Tungsten Arc Welding Cold wire (GTAW CW)

GTAW (Gas Tungsten Arc Welding) is a universally accepted welding process which distinguishes itself through high quality welds. This advantage proves also for GTAW Cold Wire. The filler wire is mechanically fed, although the arc and welding wire are decoupled from each other and can be regulated separately. This enables clean and precise weld overlays on complex component geometries

Gas Tungsten Arc Welding Hotwire (GTAW HW)

The GTAW Hotwire process differs in electrical preheating of the welding consumable to the GTAW Cold wire process (see figure 5). Due to this additional energy input, higher welding speeds, depositions rates and lower dilution rates can be achieved.

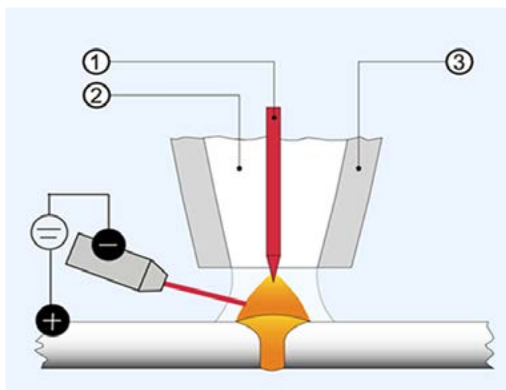

Fig. 5. Principle of GTAW Hotwire.
1: Tungsten, 2: shielding gas, 3: gas nozzle

Laser Cladding

Similar to the GTAW Hotwire process, the Laser Cladding process can control laser power and mechanical feeding of the welding wire separate from each other. The welding consumable is electrically preheated .The laser beam is melting the base material and the filler metal (see figure 6).

Welding results

The different welding processes were compared on the bases of two parameters. On one hand the dilution of the iron content of the base material in the weld overlay and its distribution through the layer (see table 2 and figure 9) and on the other hand the deposition rate of particular process (see table 1)

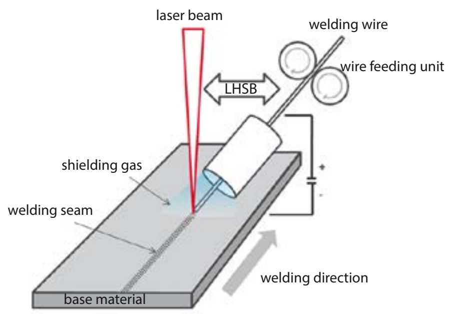

Fig. 6. Principle Laser Cladding

Fig. 7. Weld setup CMT Welding

Fig. 8. CMT welded samples

Weld Setup

To achieve comparable welding results, a standardized welding setup was chosen. The tests were welded with a robot in PA position on an unalloyed steel plates (S 235) with the dimension 500×250×50 mm (see figure 7). Weld overlay segments size 200×200 mm with 30% overlap were applied, it was carried out with one and two layers (see figure 8).

The layer thickness was 2 mm ERNiCrMo-3 (Alloy 625) with a diameter of 1.2 mm was used as a welding electrode. The welding electrodes were from the same production batch. For the GMAW processes a four component gas called Ni10 (30% Helium, 2% H_2, 550 ppm CO_2 /rest argon) was used. Pure argon was the shielding gas for the GTAW processes and laser cladding.

Figure 9 shows the distribution of the iron content through the thickness of the weld overlay. The measurements were taken with EDX line scans. Energy-dispersive X-ray spectroscopy (EDS, EDX, or XEDS), sometimes called energy dispersive X-ray analysis (EDXA) or energy dispersive X-ray microanalysis (EDXMA), is an analytical technique used for element analysis or characterization of a sample. It relies on an interaction of some source of X-ray excitation and a sample [3]. The iron content was measured in steps of 0.5 mm starting from the surface of the weld overlay to the base material. As a reference value for the dilution of the base metal, the Fe–content was used. Welding processes with high energy density or ones with low welding speed (Gas Tungsten Arc Welding

Table 1. Welding data

Welding process	v. [m/min]	Is [A]	I Hd [A]	Us [V]	Vs. [cm/min]	D [kg/h]
GMAW Pulse Ni 10	5,5	153		26,5	60	3,1713
CMT Ni 10	8	201		17,7	60	4,6128
Time Twin Ni 10	9,3/9,3	203/196		24,3/27,7	60	10,72476
CMT Twin Ni 10	6,5/6,5	155/167		15,7/18,8	48	7,4958
GTAW Coldwire	1,3	220		12,3	12	0,74958
GTAW Hotwire	2,8	225	50	13,5	22	1,61448
Laser Cladding	9		190	8	210	5,1894

Table 2. Fe content in the layers 1 and 2

Welding process	Fe% 1. Layer	Fe% 2. Layer
GMAW Pulse Ni 10	18,48	3,4
CMT Ni 10	2,38	0,37
Time Twin Ni 10	15,69	3,6
CMT Twin Ni 10	2,78	0,31
GTAW Coldwire	12,74	2,26
GTAW Hotwire	7,37	1,34
Laser Cladding	16,37	3,96

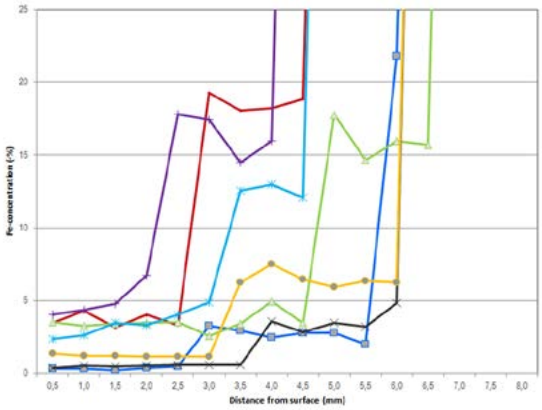

Fig. 9. Graphical display of the Fe profiles

Cold wire and Laser Cladding) exceed the dilution rate of 5% iron content. Welding processes with lower heat input maintain a Fe content below the 5% limit. All samples have in common a steep raise of the iron content reaching the base material.

Conclusions

The main focus of this survey was to compare the different welding process in terms of dilution and deposition rate. GMAW processes tend to result in higher deposition rates than GTAW processes. Especially the Cold Metal Transfer, arc reaches low dilution rate with high arc stability. This paper did not take application specific conditions like torch geometrics lifetime of torch wear parts in account, which have an enormous impact on practical use of the welding process. Laser cladding could be an interesting future option for weld overlays. Some efforts have to be taken to design and develop process components which meet in terms of size and wear properties of the needs of the industry. An optimal universal weld overlay process is not available for the time being. It is left to the user which welding process fulfils the required demands.

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