Submerged Arc Welding of Stainless Steel in India

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I. Introduction

Leading Indian fabricators are using submerged-arc welding process extensively for carbon and low alloy steels. Mostly, they depend upon imported wire and flux for welding of pressure vessels and boilers. However, they are hesitant to extend this process for austenitic steels also.

Due to increase in labour cost and other relevant factors, submerged-arc welding of austenitic steels should normally gain importance. It is comparatively economical and the deposition rates of manual metallic arc welding, MIG welding and submerged-arc welding process are shown in Table 1.

There are many factors which inhibit use of this process :

(1) Poor operational and running characteristics of welding consumables.

(2) Difficulty in forecast of the chemistry of the weld metal deposit.

(3) No single source of wire and flux which, together, guarantees the desired chemistry in the weld metal.

Starting with submerged-arc welding of ferritic steels as a base point, tests were conducted with welding of Chromium-Nickel austenitic steels, using imported and indigenous materials. It was observed that by use of slightly over-alloyed wires with either basic or neutral flux, it was possible to obtain the required composition of the weld metal. By proper choice of Chromium to Nickel ratio, one can arrive at the required level of ferrite also. The desired chemistry can be obtained either through wire or through the flux. However, for stainless steel submerged-arc welding, the tendency is to eliminate the alloy bearing fluxes, thereby ensuring consistently reproducible results on production basis. However, for hard facing applications, where Ferritic-Martensitic structures are involved, use of alloy flux is predominant.

II. Welding Consumables

There are two principal constituents in submerged-arc welding, namely wires and fluxes. Apart from the chemistry of the wire, flux plays a very significant role in balancing the loss or gain of different elements. Depending upon the type of fluxes which have been employed, pick up behaviour as well as burn out of elements can be reliably forecast. American literature indicates a loss of Chromium as high as 30% in certain type of fluxes (1). But addition of Al_2O_3 and CaF_2 in the flux lowers the loss of oxidation considerably. Alternatively, Ferro Chromium can be added to the flux. Of the various parameters used in welding, voltage has the greatest single influence in burn out and, pick up behaviour where currents upto 600 amps and speeds upto 20″ per minute have no significant influence. The transfer of alloy elements is a function of SiO_2 CaO and CaF_2. The loss of Chromium generally gives rise to increase in Silicon and pronounced oxidation of Manganese. These two elements, namely Manganese and Silicon have no direct influence on the corrosion property but have a significant effect on the ferrite

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content of the weld deposit. In certain fluxes, Silicon pick up and Manganese burn out cause sigma phase embrittlement due to increased ferrite content. However, it has been observed by many continental authorities that the chances of sigma phase formation are less in two pass sq. butt welding due to lower heat input. (2). In multi-pass submerged-arc welding, slow cooling rates can cause more ferrite to be found than what can be predicted from the metallurgical consideration. The present day tendency is to opt for neutral fluxes from Chromium and Niobium burn out points of view. The usage pattern of different fluxes since 1960's is shown in Figure 1. It indicates that the Chromium percentage in the wire has been considerably reduced as the fluxes do not give rise to heavy oxidation of Chromium.

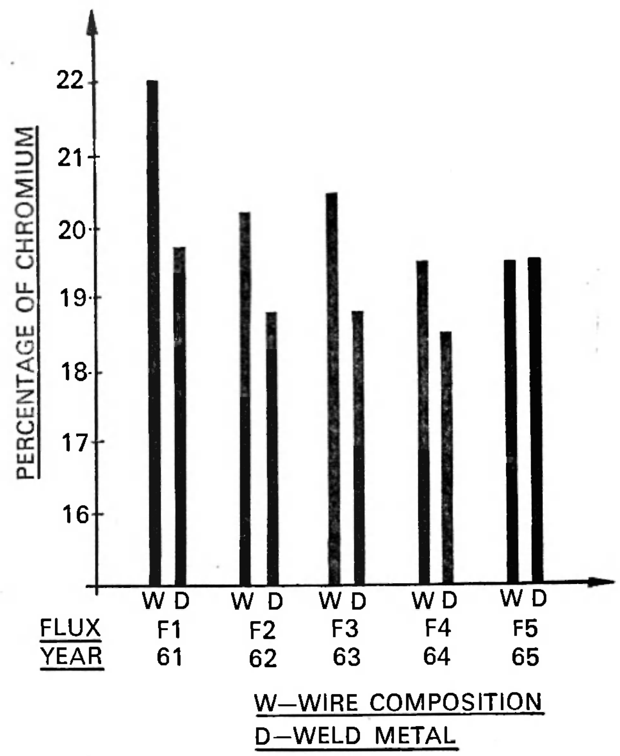

Fig. 1. Influence of fluxes on the burn off of chromium in submerged Arc Welding.

At Powai General Workshop of Larsen & Toubro, we have investigated the operating characteristics of imported agglomerated and fused fluxes. Simultaneously, we have started development work of indigenous agglomerated fluxes in co-operation with a leading electrode manufacturer. The result with imported agglomerated fluxes was satisfactory whereas with fused flux, we experienced difficulties in deslagging. Our first object was to introduce this process for stainless steels 304 L and 316 L which we handle extensively. Using corresponding ELC wires, we were able to obtain the desired chemistry in the weld metal deposit as well as 5 to 8% ferrite. In this connection, it may also be mentioned that work carried out by Swedish engineers indicate that the ferrite content should not generally exceed 10% especially in multi-pass welding.

It is well known that full austenitic steels are prone to hot cracking and hence about 5 to 8% ferrite is generally welcome. On the other hand, ferrite exerts a noticeable influence on the workability of the material. While aiming at 5 to 8% ferrite, sigma phase embrittlement should not be overlooked. The high heat input to submerged-arc welding process is conducive to sigma phase formation in the weld metal deposit. Hence, in multipass submerged-arc welding, inter-layer cooling is to be strictly observed and interpass temperature should be held at 175°C. Cooling rates can be increased by air blast or by water depending the configuration of the joints.

III. Case Studies :

Our extensive development work gave us enough confidence to introduce this process for three jobs to start with (Fig. 2 & 3).

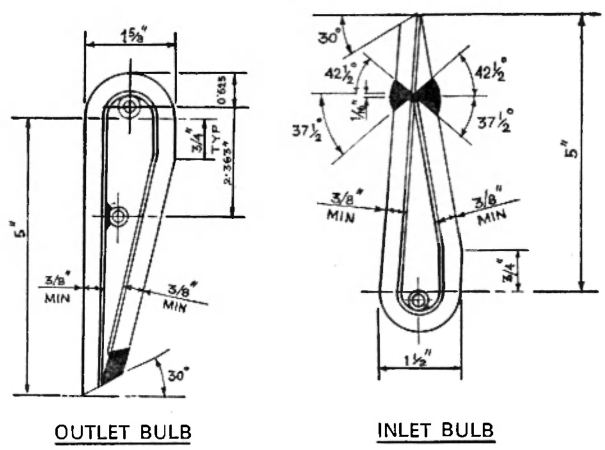

Fig. 2.

1. Welding of 25 mm thick bulbs of Calandria meant for Kalapakam Power House, Madras. Material 304 L—Inspection by Power Projects Engineering Division of Department of Atomic Energy.

2. Welding of Polymerisers—Material 316L—16 mm thick, L & T Inspection.

3. Welding of Autoclaves—Material 316L, 35 mm thick, Inspection by Lloyds.

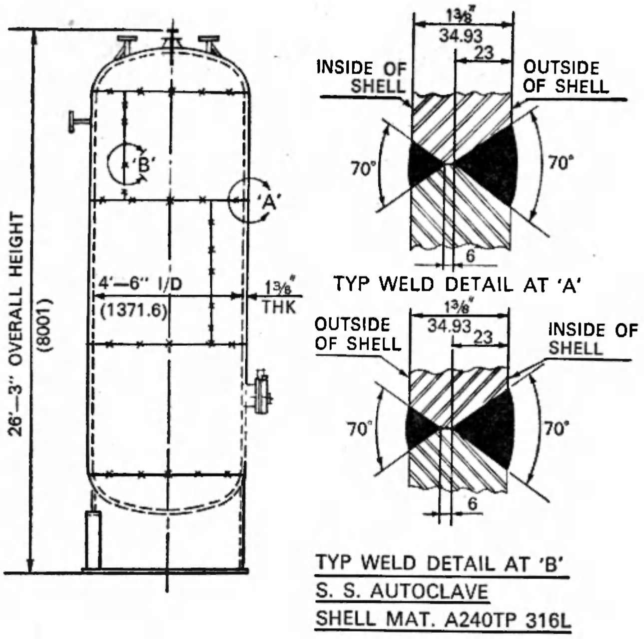

Fig. 3.

As these three jobs came under the purview of different Inspection Authorities, detailed procedural and performance tests were conducted. In particular, measurement of the extra low carbon in the weld metal was carefully checked and confirmed by Bhabha Atomic Research Centre laboratory also. We used extra low carbon wires throughout and as a double check, bits of wires from each spool were cut out and sent to Sweden for checking the carbon.

While applying theoretical principles to actual weld joints, consideration must be given to the subject of inter-mixture of weld metal deposit with parent material. The size of wire varied from 3.15 to 5 mm and currents upto 500 amps were used. The speed of welding ranged from 14″ to 22″ per minute. In the capping runs, welding parameters have to be carefully adjusted to have minimum reinforcement.

IV. Conclusion :

Strip cladding has been practised for atleast two decades in Europe whereas conventional stainless steel submerged-arc welding itself has not made adequate progress in India. Only one other Indian fabricator has started stainless steel submerged-arc welding. Extension of this process to stabilised stainless steels like 321 and 347 has certain inherent problems. Normally, Titanium bearing 321 and Columbium bearing 347 are welded with 347 electrodes only. Special care has to be taken to arrive at the Niobium content in the weld metal deposit which is about 8 times the carbon level. About 20 to 30% Niobium is lost in the arc itself and hence the Niobium content in the wire should be about 15-20 times carbon in the wire. For depositing 347 materials, one school of opinion feels that it is more economical to add Ferro Columbium in the flux and use 308 ELC as electrodes. It may also be mentioned that Swedish opinion on this subject indicates that high heat input process like submerged-arc welding should be limited either to ELC or stabilised types only.

We have so far welded more than 1200 metres with very good X-ray results. Thicker joints are also planned to be submerged arc welded during the coming months. Extension of this process depends upon the availability of filler materials, economical length of joints etc. It will not be out of place to mention that Russians have successfully submerged-arc welded stainless steel of 80 mm thickness(4).

As mentioned earlier, we have started extensive development work with indigenous fused and agglomerated fluxes. Results are encouraging, but slag detachability and silicon pick up in multipass welding still pose problems. Finally, the welding flux should not contain any MnO if the slag detachability is to be satisfactory(5). We hope to extend this process to high proof stainless steels also. In this case, the heat input has to be high, as this will slow down the cooling rate thereby favouring high ferrite forming tendency. This will balance the effect of Nitrogen. In a similar fashion, we intend extending the application for welding low ferrite stainless steels also.

TABLE 1
Deposition Rates

Procedure	*Wire dia in mm*	*Deposition rate Kg/Hr*
Coated Electrodes	2.0	0.75
	4.0	1.50
	6.0	2.50
MIG	0.8	2.80
	1.6	4.50
	2.4	5.50
Submerged Arc Welding	2.4	2.90
	4.0	5.40
	5.0	7.80

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