# EFFECT OF WELDING PARAMETERS ON THE WELDABILITY OF ASTM 517 GR.F STEELS

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**ABSTRACT**

Weldability of 30mm thick ASTM 517 Gr.F steel is studied and welding parameters with submerged arc welding process are established. It is seen that heat input for welding such joints is very critical and should be controlled in close tolerances. Maintaining high interpass temperature is also detrimental. It causes to form a brittle heat affected zone.

## INTRODUCTION

ASTM 517 Gr.F steels are categorized as low alloy quenched & tempered steels. Since the steel is already in a heat-treated state, any heating beyond certain temperature will destroy the characteristic properties of these steels. Generally for thicker sections, the assemblies must be preheated prior to welding to prevent cracking but the temperature & time should be meticulously controlled. However, the heat affected zone (HAZ) will be heated far beyond the preheat/ interpass temperatures. Cooling rate in these zones should be fast enough to prevent any undesired precipitation, which otherwise may render the structure very brittle [1,2]. Optimum heat input along with judicious preheat & interpass temperature is the key for successful welding of such grades of steels.

The present work is related to the fabrication work for laying of 820 meter long, 820 meter diameter, 2.4 mm thick ASTM 517 Gr.F steels penstock pipe line for carrying water to the turbines of a Hydro-electric Project. A schematic sketch of the pipeline is shown in Fig.l .

Weld assemblies were prepared at varying welding parameters and heat inputs. The heat input was controlled between 0.8 to 2.1 kJ/mm; varying current, voltage and weld travel speed. Selections of preheat & interpass temperatures were based on the carbon equivalent of the plate [3]. Two ranges were selected, 140±10°C and 220±10°C. The weld joints were subjected to face bend & side bend tests - the selection of bend tests were done to evaluate the ductility of the all-weld metal as well as of the HAZ. The low heat input joint suffered from improper fusion along the interface. High heat input & high interpass temperature during welding was also found detrimental. The weld joints failed along the centreline of the weld and HAZ respectively during the bend test.

In the present study, efforts have been made to study the effects of varying welding parameters to establish a successful welding procedure of ASTM 5l7 Gr.F steels.

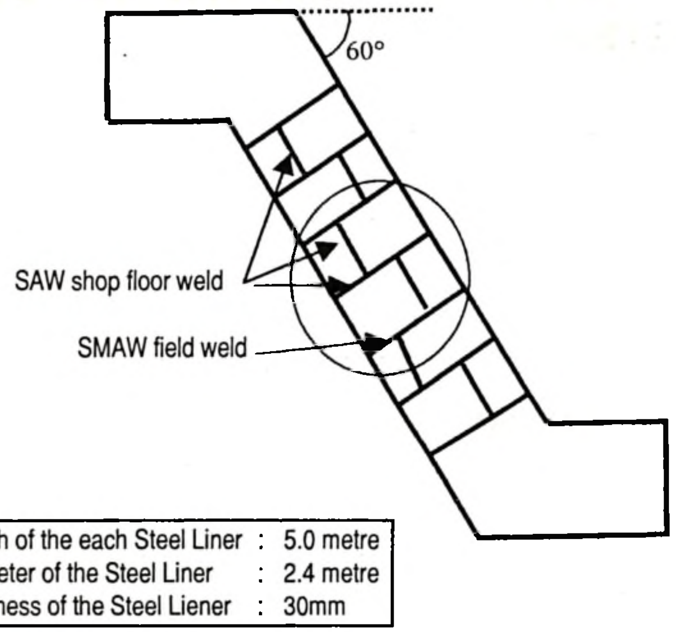



**Fig 1 :** A schematic sketch of the penstock pipelines

## EXPERIMENTAL PROCEDURE

### The Plate

The chemical composition of the plate material was analysed by Spectrometric method and the results are shown in Table-I. The dimensions of each plate were, length-150mm, breadth-100mm and thickness-30mm. The IIW carbon equivalent of this steel was calculated as 0.613.

### Joint design

All welding was conducted in the joint design: 60 angle double V groove with 3.0 – 4.0mm root gap and 2.0 – 2.5mm root face (a schematic sketch is shown in Fig.2a).

**Table 1 :** The specified & obtained chemical composition of the 517 Gr.F plate

| Plate | %C | %Mn | %Si | %Cr | %Ni | %Mo | %Cu | %V | %S | %P |
|---|---|---|---|---|---|---|---|---|---|---|
| **Specified** | 0.1–0.2 | 0.6 – 1.0 | 0.15 – 0.35 | 0.4 – 0.65 | 0.7 – 1.0 | 0.4 – 0.6 | 0.15 – 0.5 | 0.03 – 0.08 | 0.035 max | 0.035 max |
| **Obtained** | 0.18 | 0.90 | 0.291 | 0.502 | 0.751 | 0.51 | 0.26 | 0.066 | 0.012 | 0.022 |

**Table 2 :** Welding parameters ofthe test joints

| | Joint 1 | Joint 2 | Joint 3 | Joint 4 | Joint 5 | Joint 6 |
|---|---|---|---|---|---|---|
| Current, A | 350 | 500 | 450 | 375 | 375 | 400 |
| Voltage. V | 28 | 28 | 32 | 28 | 2R | 28 |
| Travel speed. mm/min. | 750 | 750 | 400 | 400 | 400 | 400 |
| Prehcat temperature. °C | 150 | 150 | 200 | 150 | 225 | 150 |
| Interpass temperature. °C | 140 ± 10 | 140 ± 10 | 140 ± 10 | 140 ± 10 | 220 ± 10 | 140 ± 10 |
| Hcat input kJ/mm | 0.78 | 1.12 | 2.16 | 1.575 | 1.575 | 1.68 |

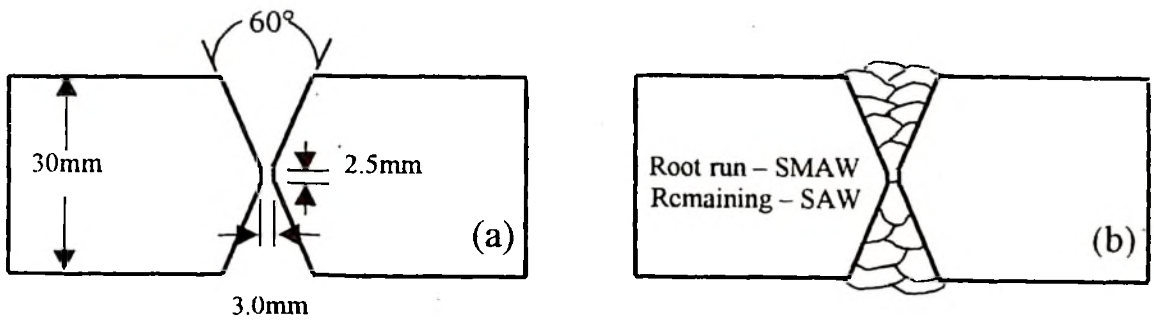



**Fig 2** : Schematic sketch showing the joint configuration
(a) The joint design (b) After weld bead deposition

**Table 3** : Chemical composition of the SAW weld metal

| Elements | %C | %Mn | %Si | %Cr | %Ni | %Mo | %Cu | %V | %S | %P |
|---|---|---|---|---|---|---|---|---|---|---|
| **Specified** | 0.036 | 0.84 | 0.067 | 0.60 | 2.073 | 0.50 | 0.09 | 0.014 | 0.012 | 0.020 |

**Welding procedure**

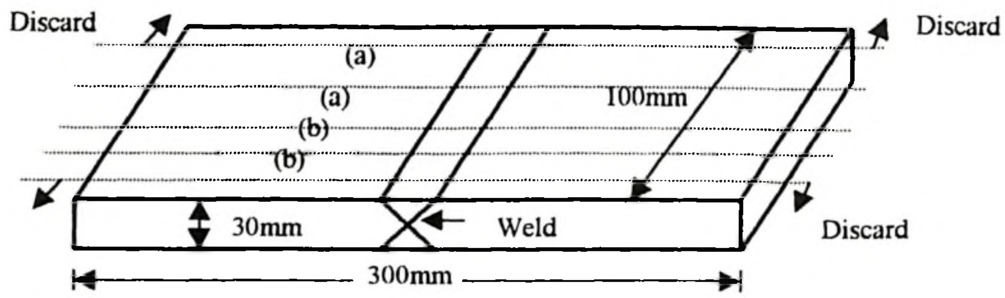
The root run of the joint was completed with 4.0 mm diameter AWS SFA 5.5 class E 11018M type electrode (Advani Oerlikon make Tenacito-80 HH Special) and the capping & filling run by Submerged arc welding (SAW) process, schematically shown in Fig.2b. The weld-assembly was preheated prior to welding in an oven at the desired temperature. The submerged arc welding was conducted with 4.0 mm diameter Fluxocord- 42 (Special) wire with OP 41 TT flux - the weld metal classified according to F11 A8-EC-F5 of AWS SFA A5.23.

For root run, the welding parameters & procedure were same for all the joints. The parameters were, 170 amp, 26 V and 150mm/min travel speed. The welding parameters employed for SAW welding are shown in Table-2. The calculation of heat input was based on the formula, (E * I *60) / S where, E is the voltage, I represents welding current in amp and S is weld travel speed in mm/ minute.

**Tests of the weld assembly**

The reinforcement of the weld joint was machined that and tested for radiography as per 2-2T level of inspection of ASTM E-142, Standard Method for Controlling Quality of Radiographic Testing. Radiographs were free from blowholes, porosity, slag inclusion and lack of fusion.

The ductility of the weld joints was evaluated by conducting face and side bend tests. A schematic sketch for location of extraction of these samples from the weld assembly is shown in Fig.3. For side bend tests, the specimen thickness was 7.5mm and for face bend it was the actual thickness of the assembly i.e., 30mm. The side bend tests were carried out with 30mm & 75mm diameter mandrel and the face bend tests were done with 210mm diameter mandrel. The selection of such odd bending parameters was basically to match with the requirements of actual fabrication where the 30.0mm thick plate has to roller-bend to 2.4metre diameter.




(a) Face bend specimens and (b) Side bend specification
**Fig 3 :** Sample locations in the weld assembly

**RESULTS & DISCUSSIONS**

The undiluted SAW weld metal chemical composition from Fluxocord-42 Special wire & OP 41TT flux is tabulated below (Table-3).

Six joints were made with different welding parameters with varying heat inputs and preheat & interpass temperatures. Among these six joints, the first and the second joint failed along the weld-parent junction. The location of failure is shown in Fig.4. The deposited weld metal didn't properly fuse with the parent plate and was debonded during face bend test along the fusion line. The heat input for these two joints were 0.78 and 1.12 kJ/mm respectively.

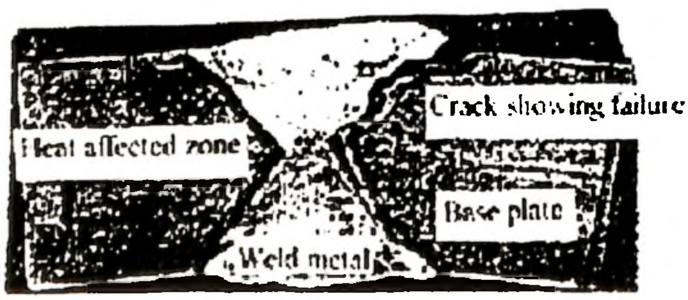



**Fig 4 :** Photograph of a failed joint after bend test - showing the location of fracture along the periphery of the joint geometry

For joint 3, the heat input was increased to 2.16 kJ/mm by reducing the travel speed and increasing the voltage and also the interpass temperature was maintained at 200°C. However, the joint failed along the centerline of the weld during bend test (Fig. 5a). The slow cooling promoted grain coarsening and segregation, which provided an easy path for the crack to propagate & grow.

Joint 4 didn't reveal any crack either in weld or in HAZ during side and face bend tests. The heat input for this joint was 1.575kJ/mm and preheat & interpass temperature were maintained ~150°C.

However, when the interpass temperature was increased to 225°C the joint failed again during the bend test (Joint 5). But the location of failure was along the heat affected zones. The location of failure is shown in Fig.5b.

The welding parameters of joint 4 were repeated and the performance was tested as joint 6. The joint didn't show any crack after bend tests.

**CONCLUSIONS**

The following findings were recorded from the weldability study of 30mm thick ASTM 517 Gr.F steel.

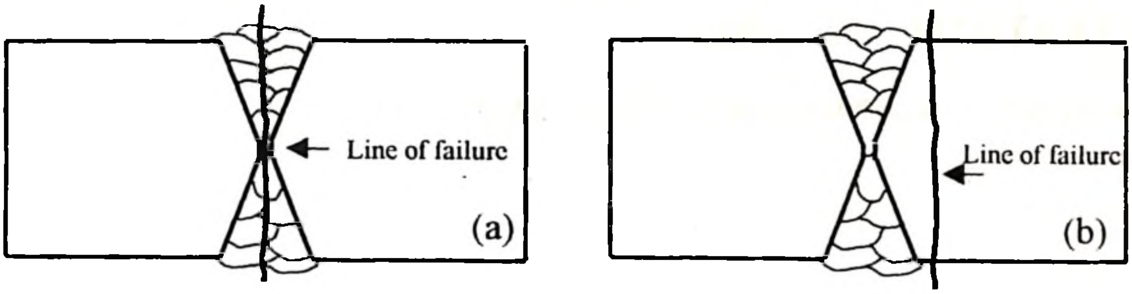



**Fig 5 :** Schematic location of the failure during the bend test
(a) along the weldmetal – Joint 3 and (b) along the HAZ – Joint 5

1. Too low a heat input (~1.0 kJ/mm) results in improper bonding along the fusion line (as seen from the results of Joint 1 & 2).
2. Very high heat input (>2.0 kJ/mm) is also detrimental (Joint 3) as it promotes a brittle HAZ.
3. Even a higher interpass temperature is also undesirable during welding of quenched & tempered steels. Slow cooling from elevated temperature results in coarsening of the grains and formation of brittle HAZ (Failure of Joint 5).
4. Preheat & interpass temperature along with welding heat inputs (~1.60 kJ/mm) must be properly controlled to obtain the best weldability from these steels (Joint 4 & 6).
5. The optimum welding parameters for joining of ASTM 517 Gr.F steel using 4.0 mm ∅ tested wire-flux combinations without fissuring and cracking were found as

   Current : 350 to 400 amp
   Voltage : 28 to 30 V
   Travel speed : 400 mm/min
   Preheat : 140 ± 10°C
   Interpass temp: 140 ± 10°C
   Heat input : 1.5 to 1.7 kJ/mm

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