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# A Review on Study of Heat Transfer Rate on Multipass Submerged ARC Welding

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*Abstract*—In arc welding the heat flow from the tip of electrode to the base metal. The heat transfer rate is generally based on the work material, weld material, welding process, inert gases etc. The heat transfer rate and rate of cooling in welding can directly controls microstructure and mechanical properties of welded region and base metal. The proposed study going to carry out on multipass submerged arc welding for varying heat input. The one dimensional, two dimensional and three dimensional heat flow equation will be used for the total heat transfer rate in submerged arc welding. The corresponding mechanical properties hardness c-v-n test results tensile strength of welded joint will be studied. This process is use full in joining thick section of components used in various industries. Besides joining SAW can also be used for surface applications. Heat affected zone produced in within the base metal as a result of tremendous heat of arc is of big concern as it affects the performance of welded surfaced structure in service due to metallurgical changes in the affected region. The various changes in the metal can be analyzed by heat transfer rate. The various sub zones in the microstructure were observed in HAZ of SAE weld of partially transformed. The main purpose of proposed work is to investigate and correlate the study of heat transfer rate on multipass submerged arc welding.

***Key words:*** Base Metal, Submerged Arc Welding, Stainless Steel, Heat Transfer Rate, Microstructure of Arc Weld Joint

## I. Introduction

Submerged Arc Welding (SAW) is one of the major metal fabrication techniques in industry due to its reliability and capability of producing good quality weld. The ability to join thick plates (as thick as 1.5 inch) in a single pass, with high metal deposition rate has made this process useful in large structural applications. Indeed various research works have been explored on various aspects of submerged arc welding, yet investigations are still being carried on to study the phenomenon that occurs during the process of submerged arc welding, and many other related matters, so that the process becomes controllable more precisely, and can be monitored well, both manually as well as automatically.

The normal variables of submerged arc welding like required current, voltage, travel speed and bed geometry like height, width, hardness and quality. To understand the quality of specimen and mechanical properties of specimen like strength, toughness, it is important to know the microstructures and micro hardness values of the weld metal and heat-affected zone regions. The essential requirements of weldable steels are enhanced strength, toughness, better microstructure and durability of the welded structures and economy in fabrication. Boiler and pressure vessel plate are the most important structural materials for construction because of their high strength and toughness and relatively low cost. Welding is the most reliable, efficient and practical metal joining process which is widely used in industries such as nuclear, aerospace, automobile, transportation. Submerged arc welding gives the highly strong joints of the plate. Toughness is the ability of a metal to resists fracture while being loaded under the conditions that are unfavourable for energy absorption and plastic deformation, high toughness of weld and heat-affected zone are important characteristics of a weldable steel, high toughness in a certain way ensures good behaviour of the welded structures even in case of severe service conditions. Mild steel exhibits good ductility when an ordinary tensile specimen is tested. When the steel contains sharp notch and temperature is low, however a crack may initiate from the notch, causing brittle fracture of the plate.

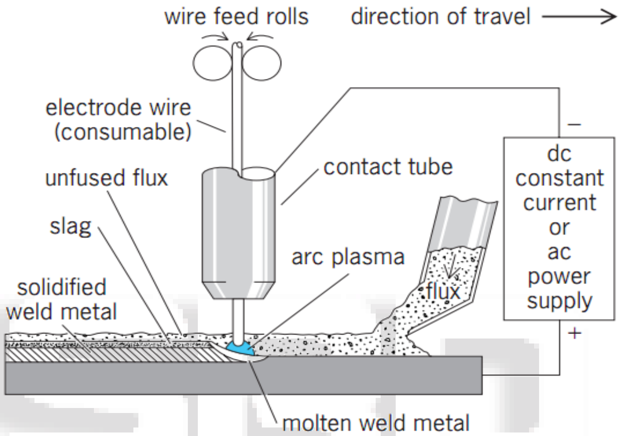



Fig. 1: Submerged Arc Welding process. [Ref.8]

Automated submerged arc welding is a versa-tile process, as it gives best quality, saves time, reduces cost, resurfaces wear surfaces on steel castings, improves repair procedure, process control, increases efficiency and productivity.

In submerged arc welding, various process parameters interact in a complicated ways, and their interactions influence the bead geometry, bead quality also the metallurgical characteristics and mechanical properties of the weldment. Acceptability of the weldment depends on various quality characteristics that confirm functional requirements of the welded joint in the all area of application. In almost cases, quality of the weld is left to depend on the past experience and working skill of operator. But, with the advent of automation, it is now possible to design a machine capable of selecting optimal process parameters to provide desired yield.

## II. Literature Review

The studies of heat input in welding investigated by different researchers are as follows.

In this microstructure, phase analysis; mechanical properties and HAZ width of submerge arc welded specimens for different passes with different heat inputs. They investigated the microstructure of 16mm thick mild steel plate was carried out using metallurgical microscopy with image analysis software. The hardness, impact energy and micro hardness of multipass welded joint were tested by using Rockwell hardness testing machine and charpy V-notch testing machine. The various subzones in the microstructures were observed in the HAZ of SA weld are spheroidized, partially transformed, grain refined and grain coarsened. The proportionate value of micro hardness was observed for low heat input where as for increased heat input variations in hardness value was observed. They concluded welding parameters of SAW used to control the microstructure, phases and mechanical properties of welded joint and help to get the robust welded structure of mild steel [1]. Heat affected zone (HAZ) for bead on joint welding were calculated and analyzed using design of experiment software and fractional factorial technique developed for the multipass SAW of boiler and pressure vessel plates. They have work in to investigate and correlated the relationship between various parameters and micro hardness and micro hardness of single "V" butt joint boiler and pressure vessel plate SA- 516 grade 70 and predicting weld bead qualities before applying to the actual joining of metal by welding process. It is found that the micro hardness of weld metal and heat affected zone decreased when the number of passes increases that is total heat input increased. The results are found that the multipass welding process parameters are directly affecting the number of passes and total heat input. The individual effect of current, voltage, speed on hardness of weld and HAZ is higher. It is observed that the hardness is higher in the HAZ than the weld metal. With increasing cooling rate, hardness increases by 4.29% in the weld metal. When welding current is increased the micro hardness of the plate is reduced. Effect of voltage can be observed that micro hardness decreases linearly with an increase in arc voltage from 30 to 38 volt. When welding speed increased in the heat input per pass as well as total heat input is reduced in multipass welding and average cooling rate is increased and so the hardness is increased. Chemical composition of the boiler and pressure vessel plate are shown below [2].

| Elem-ent | C | Mn | S | P | Si |
|---|---|---|---|---|---|
| % | 0.20 | 0.75 | 0.035 | 0.035 | 0.016 |

Table 1: Chemical composition of the plate. [Ref.2]

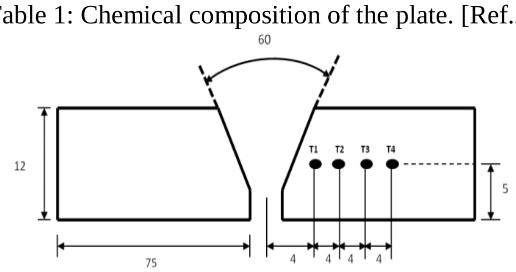



Fig. 2: Plate dimension and thermocouple position.

Optimization of the Parameters for Two-Wire AC-AC Submerged Arc Welding on 64 bead-on-plate welds which is made up of EL12 electrodes and a fused acidic flux are analyzed statistically to determine the effects of various parameters on weld configurations and designed to quantitatively determine the effect of plate thickness and welding current, voltage, travel speed, electrode sickout and electrode angle on such types of weld-zone features as penetration and shape of the bead. The main purposes of 64 experimental runs, was to provide adjusting welding parameters to understand undesirable weld-geometry features, such as excessive reinforcement, undercutting, and inadequate joint penetration and provide information for selecting the parameters that would not able to increase in weld travel speed, thus increasing the throughput at the welding facilities. . It observed that bead depth was greater at high current, high electrode angle, or low travel speed. Bead height was lower at low current, low electrode sickout, low electrode angle, high voltage, or high travel speed. Bead width was greater at high voltage, low travel speed, and in thinner plate. The distance was smaller at low current and high travel speed. The angle between the base metal and weld bead was smaller at low current, short sickout (extension), low electrode angle, high voltage, and high travel speed [3]. Comparison between Friction Stir Weldments and Submerged Arc Weldments in HSLA-65 Steel made on a production-size machine using a W-Re tool exhibited the satisfactory mechanical properties and minimal transverse weld distortion. In a Friction stir welding (FSW) is a welding process the results in less weld distortion than the arc welding. The hardness across the FSW base metal, HAZ, TMAZ, and SZ is generally uniform, with most readings between about 190 and 230 HV, and one reading of 243 HV in the SZ. The SAW base metal and HAZ is also fairly uniform, but the weld metal hardness is 256–282 HV. This is attributed to the strengthening effects of the Mn, Ni, Cr, and Mo in the MIL 100S electrode, which is designed for welding the HY/HSLA-80 and HY/HSLA-100 steels [4]. In this Characterization of Submerged Arc Welds from the World Trade Centre Towers As Deposited Welds and Failures Associated with Impact Damage of the Exterior Columns. Lessons learned from then investigation of building materials, construction, and conditions contributing to the disaster of 9/11 can be used to improve existing and future structures. Integral and aircraft impact damaged welds from the exterior columns of the World Trade Center towers were evaluated. The fillet welds joining the various steel plates composing the built-up box columns were primarily deposited using submerged arc welding. Analysis of integral submerged arc welds from the exterior columns of the WTC towers indicated that appropriate welding procedures and joining materials were used during construction of WTC. The failure mode of the joints as a result of the aircraft impact was expected. Splitting of the exterior columns into the four individual plates occurred by fracture through the HAZ as this region had a lower cross-sectional area than the weld throat. Additionally, the heat of welding likely degraded the mechanical properties (ductility, hardness) of the material in the HAZ resulting in the crack propagating solely within this feature. Based upon the localized ductility of the fracture and the lack of web plate thinning, failure of the welds absorbed that very little of the energy of aircraft impact [5]. Penetration depth monitoring and control in Submerged Arc Welding. In the submerged arc welding process is modeled the partial penetration depth and feedback controlled based on the base metal current. The base metal current that controls weld penetration is directly reduced, and the ability to adjust the base metal current to control weld penetration without reducing deposition rate is introduced into SAW. It was found that the base metal current is the dominant parameter that determines weld penetration with a sufficient accuracy when other major parameters are in their stated ranges [6]. Effect of heat input on dilution and heat affected zone in submerged arc welding process has useful in joining thick section component used in the various industries and SAW can also be used for surfacing applications. Heat affected zone (HAZ) produced within the base metal for a result of extreme heat of arc is of big concern as it affect the performance of welded surface structure in service due to metallurgical changes in the affected region. This work was investigating the effect of polarity and other SAW parameters on HAZ size and dilution to found their correlation [7]. By using Taguchi technique and regression analysis to obtain the optimal process parameters for submerged arc welding (SAW). The experiment were determined by using semiautomatic submerged arc welding machine and the signal to noise ratio are measured to determine the optimum parameters. The results from ANOVA were indicate that welding current and arc voltage are the significant welding process parameters that can be affect the bead width [8]. Theoretical predictions of the effect of current, electrode polarity, electrode diameter and electrode extension on the melting rate, bead height, bead width and weld penetration, in submerged-arc welding. Experiments are conducted using submerged arc welding process parameters which is welding current, voltage and welding speed on mild steel to study the effect of these parameters on penetration depth [9]. In submerged arc welding process, parameters are current, arc voltage, travel speed and nozzle to plate distance. They all affect the microstructure and mechanical property of the welded joints. A Mechanical properties of hardness, tensile strength and toughness in arc welded mild steel plates were found to be higher in the heat affected zone and reduce to the base metal value under all the welding conditions. Impact of initial metal preheat on mechanical properties diminishes with increased temperature in the heat affected zone. Microstructures of preheated specimens differ from the no preheat specimen, showing traces of precipitation of bainite [10]. Development of welding products for surfacing with a Type of 316L low ferrite stainless steel alloy involves investigation of the transformation of delta ferrite to sigma phase in 316L-LF alloys. In the alloys studied At 850° C the transformation of ferrite to sigma phase occurs very rapidly. Taking in account both the slow cooling rates during strip welding and the fact that the ferrite pools have smaller dimensions in a weld metal than in the cast or forged steels, it is probable to advocate the presence of sigma phase in as deposited weld metal[11]. Effect of filler metal composition on the microstructure and mechanical properties of four wire tandem submerged arc welded API 5LX65 steel were studied. Different types of tests were carried out like Micro hardness, Charpy impact, and all weld longitudinal round tensile to evaluate the mechanical properties of the weld metals. The microstructure of the specimens was studied by optical and scanning electron microscopes. The micro structural observations showed that the more acicular ferrite was formed in the microstructure; the mechanical properties were achieved better [12].

## III. Discussion

From the available literature studied by various researchers the following discussion is made.

### A. *Effect of heat input and preheating on microstrucre of material.*

The optical and scanning electron microscopy (SEM) micrographs, as well as the volume fraction of different phases, are taken from the different passes shown in Fig. 3 The schematic view of the welding pass sequence are shows the numbers of passes on outside diameter (OD) and inside diameter (ID) of the API 5LX65 steel plate.

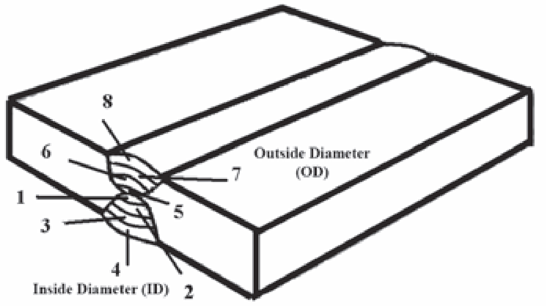
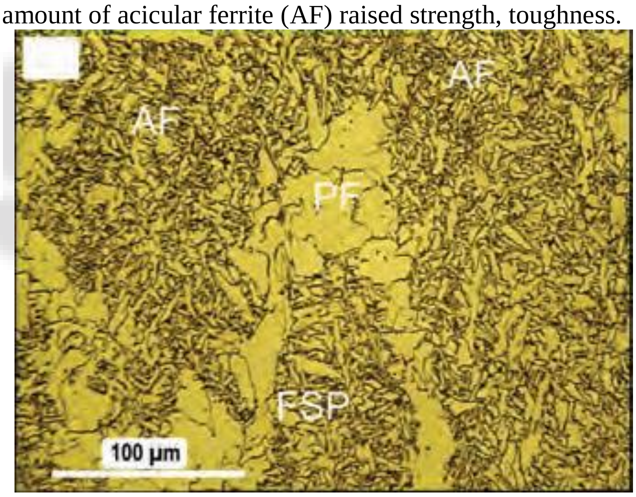
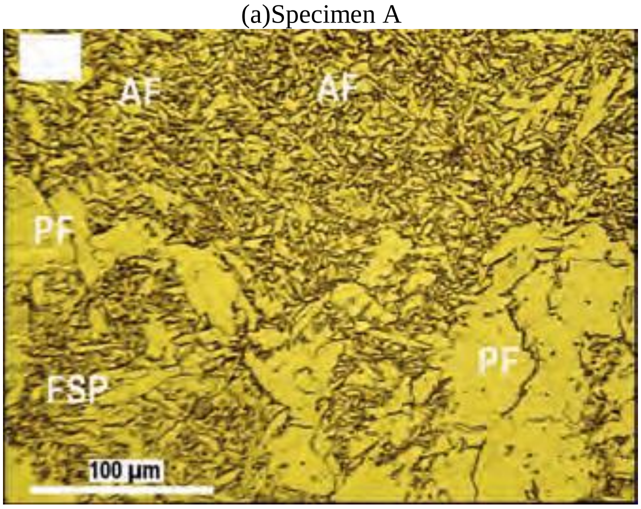



Fig. 3: Schematic view of the welding pass sequence. [Ref.12]

It can be seen from the corresponding micrographs that a mixed microstructure of polygonal ferrite (PF), acicular ferrite (AF), and ferrite with aligned second phase (FSP) was obtained in each specimen shown in fig.4. The effect of filler material on the microstructure of weld metal can be study in the practical TSAW process are increased amount of acicular ferrite (AF) raised strength, toughness.

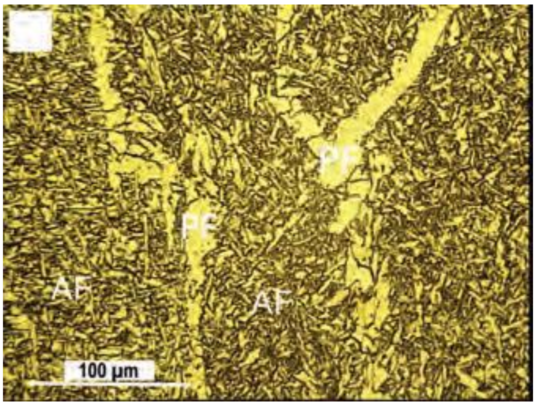



(a)Specimen A

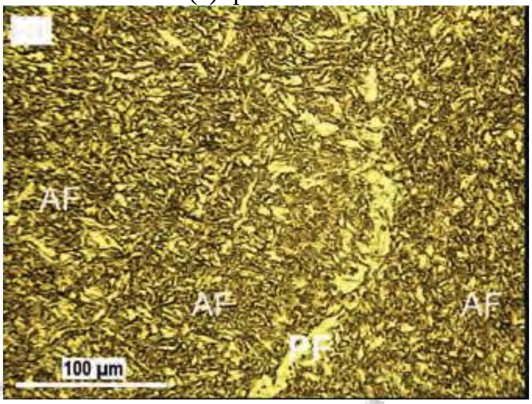



(b)Specimen B




(c)Specimen C




(d)Specimen D

Fig. 4: Optical micrographs of OD region. A — Specimen A; B — specimen B; C — specimen C; D — specimen D. [Ref.12]

According to Figs. 4, it is clear the microstructures were dominated by different morphologies of ferrite. The AF matrix is described by small effective grain size with high angle boundaries, high density of dislocations, and chaotic structure. During the two-pass TSAW process, the HAZ produce by the first SAW pass partly reheated by the second pass. The intercritically reheated coarse-grain HAZ is produce in these joints.

*B. Effect of heat input on metal and Mechanical properties of material.*

When the welder starts the arc, both the base metal and the filler metal are melted to create the weld. Heat input is a relative measure of the energy transferred per unit length of weld. It influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld metal and HAZ.

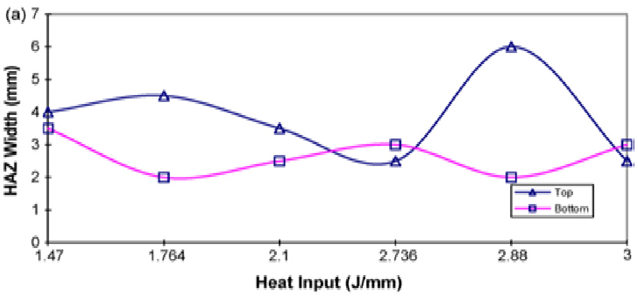



Fig. 5: Influence of heat input on heat-affected zone (HAZ) width. [Ref.1]

Variation of heat affected zone width is a function of heat input as heat input increases gradually increases the HAZ width shown in Fig (5).

*C. Effect of heat input on Current and Welding Speed.*

Fig.6 show the combined effect of welding current and welding speed on microhardness of weld and heat affected zone. Increase in microhardness is higher at the welding speed lower and decreased in microhardness is very low at welding speed higher for the varying current.

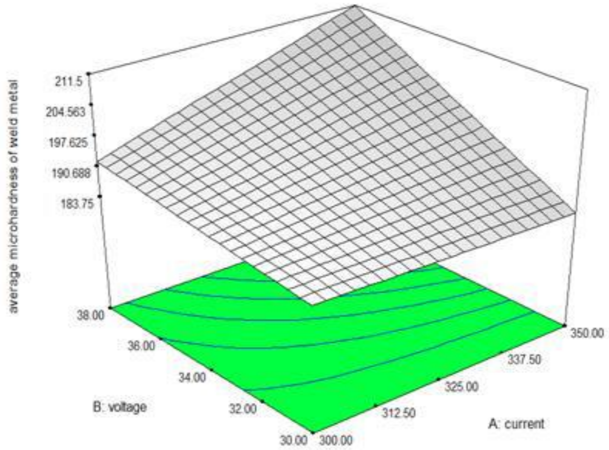



Fig. 6: Effect of Current and Welding Speed [Ref.2]

From available literature it is observed that for estimation of Heat affected zone, micro hardness measurement from weld metal to base metal is necessary, by which HAZ and its sub-zones can be thoroughly studied. In the multipass welding process parameters are directly affect on the number of passes and total heat input. The individual effect of current, voltage, speed on hardness of weld and HAZ is higher. In multipass welding the number of passes deposited in the welded groove are less for high heat input and more number of welding passes at low heat input. The penetration depths in welding square butt joints are determine by the base metal current with an acceptable accuracy.

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