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*Research Article*

# To Evaluate the Effect of Saw Parameters on Slag Content of Weld Metal

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***Abstract***

*The operating variables used in the SAW process results in varying heat input in the element. The consequence of this is the deterioration of the chemical constituents of the weld bead. Therefore, the properties of the parent metal cannot adequately match those of the element to ensure good performance in service, especially in low temperature services. The objective of the present work is to evaluate the effect of SAW parameters for hardness and slag contents of weld bead. The response function of the trial conditions would match the constituents of transfer elements with the base metal. The experimentation was done on SS 310 plates of dimensions 110mm x 55mm x8mm. The welding current, voltage and welding speed could be regulated, displayed and preset on the panel of the tractor for the convenience of the operator. The polarity is kept positive. The nozzle distance is kept constant i.e 20 cm. The purposed work is to evaluate the effect of SAW parameters for slag contents of weld bead. In this work the experimentation is done to analyze that which factor is most contributing towards the various element transfers in weld bead. Submerged arc welding is done on SS 310 Plates as work material by using three controllable process parameters using Taguchi technique. Real life application of this study is that, the results and conclusion will be beneficial for providing the optimal combination for slag contents to the operator, so that maximum hardness and slag contents will be transferred to the weld bead according to the need of property of weld bead.*

***Keywords:*** *SAW, Weld Metal etc.*

## 1. Introduction

*Submerged Arc Welding*

The SAW process is frequently preferred because it offers high production rate, high melting efficiency, simplicity of automation and low operator skill requirement. It was first used in industries in the mid 1930's as a single-wire welding system. The operating variables used in the SAW process results in varying heat input in the element. The effect of this is the deterioration of the chemical constituents of the weld bead. Therefore, the properties of the parent metal cannot sufficiently match those of the element to make sure good performance in service, especially in low temperature services. An arc is maintained between the end of a bare wire electrode and the work. As the electrode is melted, it is fed into the arc by a set of rolls, driven by a governed motor. Wire feed speed is automatically controlled to equal the rate at which the electrode is melted, thus arc length is constant (similar to mig/mag - constant voltage). The arc operates under a layer of granular flux, hence submerged arc. Some of the flux melts to provide a protective blanket over the weld pool. The rest of the flux is unaffected and can be recovered and re-used, provided it is dry and not contaminated. A semi-automatic version is available in which the operator has control of a welding gun that carries a small quantity of flux in a hopper

## 2. Literature

**1993:** N. Murugan, R.S. Parmar & S.K. Sud concluded that Penetration and width decreases with increase the speed but reinforcement decreases to an optimum value with increase in speed. Nozzle to plate distance has no effect on reinforcement and width but penetration and dilution decreases with increases the nozzle to plate distance.

**1994:** N.D Pandey, A. Bharti & R.S. Gupta have studied the influence of submerged arc welding (SAW) parameters and flux basicity index on the weld chemistry and transfer of elements such as manganese, silicon, carbon and sulphur. It was concluded that for controlling the weld-metal composition, welding voltage was more effective than is welding current. The basicity index value of fluxes had a definite relationship with silicon but the same cannot be correlated with the weld-metal manganese, carbon and sulphur contents.

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**1998:** R. S. Chandel, H. P. Seow, F. L. Cheong through their study on mild steel plates 350x220x25mm as test material, showed that The impact properties of welds made with powder addition are superior. The weld metal is stronger and tougher than the base metal.

**1999:** Gunaraj & Murugan studied the effect of controllable process variables on the heat input and the area of the heat-affected zone (HAZ) for bead-on-plate and bead-on joint welding using mathematical models developed for the submerged arc welding of pipes. A comparative study of the area of the heat-effected zone between bead-on-plate and bead-on-joint welding was then carried out.

**2001:** Vera Lu´ cia Othe´ro de Brito, Herman Jacobus Cornelis Voorwald The aim of their work is to evaluate the effect of a post weld heat treatment (PWHT) on the microstructure and mechanical properties of the base metal, heat-affected zone (HAZ) and weld metal of an submerged arc welded pressure vessel steel. The material used was ASTM A537 C1 steel. From this study they concluded that

1. Reduced tensile properties for the base metal. However both yield strength and tensile strength were slightly above the lower limits established by ASTM.
2. Higher toughness for the weld metal and a reduction of this property for the HAZ and base metal.

**2002:** Y.S. Tarng, S.C. Juang, C.H. Chang have used grey-based Taguchi methods to determine submerged arc welding process parameters in hard facing. For Experimentation they deposited a martensitic stainless steel hard facing layer on 30x80x120mm mild steel plate by SAW process. Using grey relation they have done evaluations on dilution rate, hardness and deposition rate, finally done the analysis of variance. From this study they concluded that the performance characteristics such as harness, dilution and deposition rate are improved together by using grey relation.

**2003:** Ana Ma. Paniagua-Mercado, Paulino Estrada-Diaz, Victor M. Lo´pez-Hirata. A study of chemical and structural characterization of fluxes for submerged-arc welding was conducted. Three flux formulations were prepared using mineral oxides for agglomerating and sintering processes. A commercial agglomerated and sintered flux was used for comparison. The four fluxes were then analyzed chemically by atomic absorption and X-ray diffraction to determinate the quantity and type of oxides formed. Differential thermal analysis was carried out from 1000 to 1350 $^{0}$C in order to determine the temperatures for phase transformations and melting of the different compounds formed in the sintering process.

**2005:** N. Murugan, V. Gunaraj. Through their study on prediction and control of weld bead geometry and shape relationships in submerged arc welding of pipes they concluded that

1. Arc voltage had a less significant negative effect on penetration and reinforcement but had a positive effect on bead width, penetration size factor and reinforcement form factor.
2. Wire feed rate had a significant positive effect but welding speed had an appreciable negative effect on most of the important bead parameters. Penetration increased by about 1.3mm as wire feed rate was increased from −2 to +2 limit whereas penetration decreased by about 1mm as welding speed was increased from −2 to +2 limit.

**2006:** T. Kannan, N. Murugan with the hep of their experimentation they have concluded that Dilution increases with the rise in welding current and welding speed and decreases with the rise in nozzle-to-plate distance and welding torch angle. Weld bead width increases with the rise in welding current. Penetration increases with the rise in welding current and welding speed and decreases with the rise in nozzle-to-plate distance and welding torch angle. Bead width increases with the increase in welding current at all levels of welding speed.

**2007:** Shigeo OYAMA, Tadashi KASUYA & Kouichi Shinda have studied on High-speed One-side Submerged Arc Welding Process. They concluded that the high-speed one side submerged arc welding process (NH-HISAW) that dramatically increases the welding speed in the panel assembly process in shipbuilding–at least twice as fast as the conventional process. The authors are confident that the NHHISAW process will contribute to improved productivity and product quality in the shipbuilding industry.

**2009:** Saurav Datta and Siba Sankar Mahapatra have studied on Multi-Objective Optimization of Submerged Arc Welding Process. They concluded that Weld quality in SAW depends on bead geometry, mechanical-metallurgical characteristics of the weld as well as on weld chemistry. The weld quality development is treated as a multi-factor, multi-objective optimization problem. The practical application of SAW requires efficient optimization methodology because process parameters are expected to interact in a complex manner The developed methodology based on RSM, desirability function and PSO (Particle Swarm Optimization) algorithm can be applied in practice for continuous quality improvement and off-line quality control. RSM has been applied to derive a mathematical model of overall desirability represented as a function of process control parameters. This mathematical model has been optimized within an experimental domain.

**2010:** Krishankant, Sandeep Jindal & Shashi Kant Shekhar have studied on Determination of Flux Consumption in Submerged arc Welding by the Effect of Welding Parameters by Using R.S.M Techniques. They concluded that

1. RSM can be used efficiently in analyzing the cause and the effect of process parameters on response.The RSM is also used to draw contour graphs for various responses to show the interaction effects of different process parameters.

**2011:** Ghosh A, Chattopadhyaya S, Das R K and Sarkar P K addressed the issue associated with the uncertainties involved with the heat affected zone

(HAZ) in and around the weldment produced by SAW process. It was concluded that the grains are predominantly of smaller variety and the counts for larger grain are almost negligible. The absence of larger size grains in the image vouch for the soundness of the weld in comparison to the competing welding methodologies of structural steel plates.

**2012:** A. Bhattacharya, A. Batish, P.Kumar has done experimental investigation for multi response optimization on plain carbon steel 200x75x12mm as test material. The multi response from the observation was converted to grey analysis using MATLAB code. Finally they concluded that Welding current is most significant for maximizing Depth of penetration & Minimizing Bead height and bead width.

**2012c:** Shahnwaz Alam,& Mohd.Ibrahim Khan have studied on Prediction of the Effect of Submerged Arc Welding Process Parameters on Weld Bead Width for MS 1018 Steel. They concluded that the developed model can be effectively used to predict the weld width in the submerged arc welding within the range of parameters used. And Weld width rapidly increases with voltage, slowly increases with current and wire feed rate and decreases with welding speed and nozzle to plate distance.

**2012d:** Hari Om, Sunil Pandey & Dinesh Rathod have studied on mathematical modeling of heat affected zone in SAW process using factorial design technique. They concluded that

1. HAZ width varies more effectively with wire feed rate at all the levels of open circuit voltage under electrode negative condition.
2. Influence of process variables on HAZ area are found similar to that on HAZ Width.
3. Electrode negative polarity produces lesser HAZ under all conditions, in general, Except at higher wire feed rates.

**2012e:** S. Shena, I.N.A. Oguochaa, & S. Yannacopoulosb have studied on Effect of heat input on weld bead geometry of submerged arc welded ASTM A709 Grade 50 steel joints. They concluded that when we increase the heat input the Reinforcement, bead width, penetration, penetration and deposition areas, and HAZ size increased but the bead width-to-depth ratio and percent dilution remained practically unchanged.

**2013a:** Pranesh B. Bamankar & Dr. S.M. Sawant have studied on study of the effect of process parameters on depth of penetration and bead width in SAW process. They concluded that Increase in welding current increases the depth of penetration. It can be reasonably assumed that this extra heat contributes to more melting of the work piece. As current increases the temperature of the droplets and thus the heat content of the droplets increases which results in more heat being transferred to the base plate. Increase in current reduces the size but increases the momentum of the droplets which on striking the weld pool causes a deeper penetration or indentation.

**2013b:** Brijpal Singh, Zahid Akthar Khan and Arshad Noor Siddiquee have studied on Review on effect of flux composition on its behavior and bead geometry in submerged arc welding (SAW). They conclude that flux constituents has a major effect on flux behavior and bead shape geometry. The load carrying capacity of the welded joint does not only depend on microstructure but it is also affected by the physical behavior of the flux, and bead geometry.

**2013c:** Shashank Soni, Ravindra Mohan , Dr. Lokesh Bajpai & Dr. S. K. Katare have studied on Optimization of Submerged Arc Welding Process Using Six Sigma Tools. they concluded that Six Sigma was found to be the greatest motivator behind moving everyone in the organization and bringing radical change.

**2013d:** Pradeep Deshmukh, M. B. Sorte have studied on Optimization of Welding Parameters Using Taguchi Method for Submerged Arc Welding On Spiral Pipes. They concluded that the developed of model is a powerful tool in experimental welding optimization, even when experimenter does not have to model the process. Modular network model predicts accurately and equivalent sensitivity analysis revels that bead width is highly sensitive to welding current, weld reinforcement and bead hardness are sensitive to electrode join out and depth of penetration is sensitive to welding speed.

**2013e:** R.P. Singh, R.C. Gupta and S.C. Sarkar have studied on Prediction of Weld Width of Shielded Metal Arc Weld under Magnetic Field using Artificial Neural Networks. They concluded that-

1. The current is increased, weld width generally increases.
2. The voltage of the arc is increased, weld width generally increases.

**2013f:** Xiaoquan Li, Zonghui Yang, Yajie Chu, & Jialin Cheng have studied on the influence of electrochemical reactions induced by an external circuit on SAW metal. They concluded that the action of external electric field can effectively reduce the size of inclusions in weld metal. The electron beam emission caused by the external circuit improves the conductivity of molten slag and makes the welding arc more stable.

**2013g:** Hari Om and Sunil Pandey have studied on Effect of heat input on dilution and heat affected zone in submerged arc welding process. They concluded that HAZ width/area rises more efficiently with wire feed rate at all the levels of open circuit voltage under electrode negative condition. the reason for wider HAZ is increased heat input concentration as the bead gets narrower and more heat per unit area is transferred into base metal which in turn alters its metallurgy deeper into base metal.

**2014a:** Joshua Emuejevoke Omajene, Jukka Martikainen, & Paul Kah have studied on Effect of welding parameters on weld bead shape for welds done underwater. They concluded that The effect of water depth and the cooling rate of the weld metal from the water temperature influence the effect of welding current, welding speed, and voltage on the weld bead geometry during underwater welding.

**2014b:** Degala Ventaka Kiran and Suck-Joo Na have studied on the Experimental Studies on Submerged Arc Welding Process. They concluded that Increase in welding current enhances the melting rate of the electrode and flux, weld width, penetration and reinforcement height.
**2014c:** Mohit Sharma & Karun have studied on Application of Taguchi Method to Study the Effect of Saw Parameters on Nickel Element Transfer. They concluded that Welding Current is the most major factor for transfer of nickel element to the Weld metal.
**2014e:** Ke Li, Zhi-sheng Wu, Cui-rong Liu and Feng-hua Chen have studied on Arc characteristics of submerged arc welding with stainless steel wire. They concluded that With an increase of welding parameters in SAW the short-circuiting peak in the probability density distribution (PDD) curve of arc voltage decreases gradually until it disappears welding current has only one peak, and the change of the peak is similar to that of the arc voltage peak.

## 3. Experimental Setup

The whole experiment was done on Submerged Arc Welding Machine, Model -Tornado Saw M-800 transformer and FD10-200T welding tractor available at MM University. The electrode is EH14.The experimentation was done on SS 310 plates of dimensions 110mm x 55mm x8mm.

*3.1 Work Material*

The work material selected for experimentation is SS 310.

Length = 110 mm, Breadth = 55 mm, Height = 8 mm
Chemical Composition of Work material

| | | |
|---|---|---|
| **C** | Percentage by weight | 0.18 |
| **Mn** | | 1.29 |
| **Si** | | 0.24 |
| **S** | | 0.018 |
| **P** | | 0.022 |
| **Cr** | | 24.45 |
| **Ni** | | 19.36 |
| **Mo** | | 0.1 |
| **Cu** | | 0.19 |

*3.2 Methodology Used*

The full factorial design is referred as the technique of defining and investigating all possible conditions in an experiment involving multiple factors while the fractional factorial design investigates only a fraction of all the possible combinations. The methodology involves identification of controllable and uncontrollable parameters and the establishment of a series of experiments to find out the optimum combination of the parameters which has the greatest influence on the performance and the least variation from the target of the design.

**Table 3.2** Factors & their levels

| Sr. No. | Factors (Units) | Symbols | levels | | |
|---|---|---|---|---|---|
| 1 | Current (Amp) | I | 300 | 330 | 345 |
| 2 | Voltage (Volt) | V | 24 | 28 | 32 |
| 3 | Welding speed (m/h) | ws | 30 | 32 | 34 |

**4.** Result and Discussion for Slag Contents

**Table 4.1** Taguchi Analysis: Slag versus I( Amp), V(Volt), ws(m/h)

| I( Amp) | V(Volt) | ws(m/h) | SLAG(gm) | SNRA1 | MEAN1 |
|---|---|---|---|---|---|
| 300 | 24 | 30 | 6.69 | 16.5085 | 6.69 |
| 300 | 28 | 32 | 7.17 | 17.1104 | 7.17 |
| 300 | 32 | 34 | 12.37 | 21.8474 | 12.37 |
| 330 | 24 | 32 | 13.36 | 22.5161 | 13.36 |
| 330 | 28 | 34 | 10.55 | 20.465 | 10.55 |
| 330 | 32 | 30 | 17.27 | 24.7458 | 17.27 |
| 345 | 24 | 34 | 8.4 | 18.4856 | 8.4 |
| 395 | 30 | 18 | 13.58 | 22.658 | 13.58 |
| 395 | 33 | 24 | 18.96 | 25.5568 | 18.96 |

Various graphs and tests have been constructed to determine which factors have a statistically significant effect on the hardness. Analysis of variance for S/N ratios and means for slag contents calculated from software.The average slag contents obtained from the slag test conducted on 18 specimens sampled out from the nine samples (welded plates) three specimen from each sample using L9 orthogonal array.

*Linear Model Analysis: SN ratios versus I( Amp), V(Volt), ws(m/h)*

**Table 4.2** Response table for SN ratio

| Level | I(Amp) | V(Volt) | ws(m/h) |
|---|---|---|---|
| 1 | 18.49 | 19.17 | 21.30 |
| 2 | 22.58 | 20.08 | 21.73 |
| 3 | 22.23 | 24.05 | 20.27 |
| Delta | 4.09 | 4.88 | 1.46 |
| Rank | 2 | 1 | 3 |

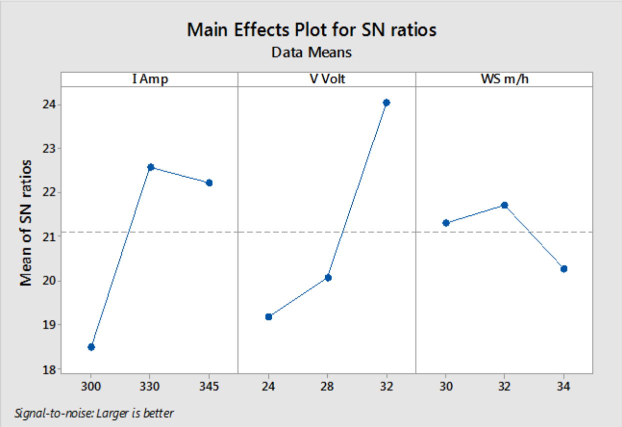


**Figure 4.1** Main effects plot for SN ratios

The slag contents increases as the current is increased from 300A to 330A but after that slag contents decreases when current increases from 330A to 345A. Main effects plot for S/N ratios between welding voltage and slag contents show that the slag contents value increases linearly when voltage increases from 24V to 28V but after that slag contents increases very fast when voltage increases from 28V to 32V.

**Table 4.3** Analysis of variance for SN ratio

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| I( Amp) | 2 | 30.843 | 30.843 | 15.421 | 3.99 | 0.2 |
| V(Volt) | 2 | 40.416 | 40.416 | 20.208 | 5.23 | 0.16 |
| ws(m/h) | 2 | 3.394 | 3.394 | 1.697 | 0.44 | 0.7 |
| Residual Error | 2 | 7.731 | 7.731 | 3.865 | | |
| Total | 8 | 82.383 | | | | |

S = 1.966 R-Sq = 90.6% R-Sq(adj) = 62.5%

From ANOVA table it is found that all the three factors I(Amp), V(Volt) & ws(m/h) have same contribution for slag contents element. This means all the above factors are significant for production of slag contents during the welding.

*Linear Model Analysis: Means versus I( Amp), V(Volt), ws(m/h)*

**Table 4.4** Response table for Means

| Level | I(Amp) | V(Volt) | ws(m/h) |
|---|---|---|---|
| 1 | 8.743 | 9.483 | 12.513 |
| 2 | 13.727 | 10.433 | 13.163 |
| 3 | 13.647 | 16.200 | 10.440 |
| Delta | 4.983 | 6.717 | 2.723 |
| Rank | 2 | 1 | 3 |

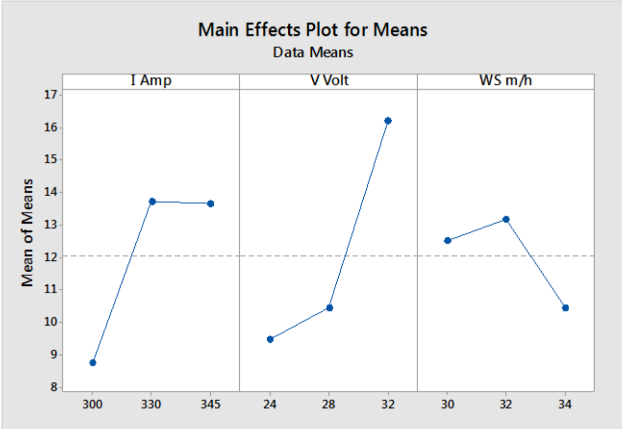


**Figure 4.2** Main effects plot for Means

The slag contents increases as the current is increased from 300A to 330A but after that slag contents decreases when current increases from 330A to 345A. Main effects plot for Means between welding voltage and slag contents show that the slag contents value increases linearly when voltage increases from 24V to 28V but after that slag contents increases very fast when voltage increases from 28V to 32V. Main effects plot for Means between welding speed and slag contents show that the slag contents value increases linearly when welding speed increases from 30m/h to 32m/h. but after that slag contents decreases when welding speed increases from 32m/h to 34m/h. From this we can easily conclude that the welding voltage has the most significant effect on the slag content

**Table 4.5** Analysis of variance for Means

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| I( Amp) | 2 | 48.883 | 48.883 | 24.441 | 7.00 | 0.125 |
| V(Volt) | 2 | 79.271 | 79.271 | 39.635 | 11.36 | 0.081 |
| ws(m/h) | 2 | 12.138 | 12.138 | 6.069 | 1.74 | 0.365 |
| Residual Error | 2 | 6.980 | 6.980 | 3.490 | | |
| Total | 8 | 147.271 | | | | |

S =1.868 R-Sq = 95.3% R-Sq(adj) = 81.0%

From ANOVA table it is found that all the three factors I(Amp), V(Volt) & ws(m/h) have same contribution for slag contents element. This means all the above factors are significant for production of slag contents during the welding.

## Conclusion

It is concluded that for Slag contents be maximum factor I(Amp) has to be at high level 2, V(Volt) has to be at high level 3 & Ws(m/h) has to be at high level 2. As shown in table below.

**Table** Optimal combination for Slag contents

| Physical | Optimal Combination | | |
|---|---|---|---|
| Requirements | I(Amp) | V(Volt) | ws(m/h) |
| Maximum Slag content | 330 | 32 | 32 |
| | Level-2 | Level-3 | Level-2 |

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