A REVIEW ON EXPERIMENTAL EVALUATION AND FINITE ELEMENT ANALYSIS OF ACTIVATED TIG WELDING PROCESS FOR DISSIMILAR MATERIAL LIKE STRUCTURAL STEEL AND STAINLESS STEEL

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Abstract : TIG welding is widely used in industries such as oil refineries, power stations, etc. TIG welding is a stronger and high accuracy process. But drawback of TIG welding is less penetration. Due to less penetration, more weld bead pass is required in welding of thicker material. To achieve high penetration with less weld bead pass in thicker material, A-TIG welding process is introduced. In this dissertation, Experimental evaluation will be conducted to weld dissimilar material like stainless steel and structural steel by A-TIG welding process. Also testing mechanical properties and Finite Element analysis of A-TIG welding will performed to establish the temperature distribution during process in base metal.

***IndexTerms* – A-TIG, Activated TIG Welding, Tungsten Inert Gas welding, dissimilar material weld**

I. INTRODUCTION

The introduction about TIG (Tungsten inert Gas) welding, which is generated by electric arc struck between non-consumable tungsten and work pieces to fuse metal in joint area and produce a molten weld pool. In TIG welding shielding gas protect weld pool & non-consumable electrode. TIG welding is most frequently used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. TIG welding is a stronger and high accuracy process. But drawback of TIG welding less penetration & multipassing process required in high thickness plate or pipe and high amount of heat dissipation. This welding process slow so decrease the productivity

Due to that's reason TIG welding process used with activated flux. In this process a thin layer of flux is deposited on surface that to be weld after the mixing with suitable solvent like acetone or ethanol.This mixture used with help of brush or spraying.

A-TIG welding process involves application of thin coating (10-15 μm thick) of activated flux on the joint area prior to welding and the process is found to produce affected increase in penetration of 300% in single pass welding.

1.1 WORKING PRINCIPLE OF A-TIG WELDING PROCESS

First,a low voltage high current supply supplied by the power source to the welding electrode or tungsten electrode. the electrode is connected to the negative terminal of power source and work piece to positive terminal. This current supplied form a spark between tungsten electrode and work piece. Tungsten is a non –consumable electrode, which give a highly intense arc. This arc produced heat which melts the base metals to form welding joint. The shielded gases like argon, helium is supplied through pressure valve and regulating valve to the welding torch. These gases form a shield which does not allow any oxygen and other reactive gases into the weld zone.

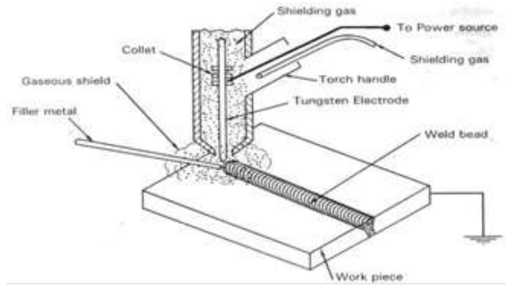

Fig. 1.1 A-TIG Welding process[16]

1.2 PROCESS PARAMETERS OF WELDING

Welding current

For welding process, the amount of heat developed is the main factor affecting the welding. Heat developed during welding is directly related to the welding current and heat flux density. Heat flux is directly proportional to the close circuit current [3].

Welding speed

Welding speed is the average linear travel speed of the welding torch over the base plate/pipe to be welded during welding. Welding speed influence the total heat input per unit length of the weld and hence has an effective impact on weld fusion zone geometry. Welding speed affects weld bead geometry by affecting the heat input rate, peak temperature, Marangoni forces and the electro-magnetic forces in the weld pool. Narrow and shallow weld bead formation takes place at high welding speed, while deep and wide weld bead appear with low welding speed[3].

Arc length

Arc length is the distance between the workpiece and the tip of the tungsten electrode. Arc length in the TIG welding process affects the amount of heat generated and supplied to the work piece for fusion. An arc in A-TIG welding is created between the electrode and workpiece by the ionization of the gases present [3].

Shielding gas

Shielding gases are necessary in A-TIG welding to protect the weld area from atmosphere gases such a nitrogen and oxygen from oxidization. Commonly argon and helium used as shielding gas. It depend upon which material use for weld[4].

Preparation of Flux

The activating fluxes of micro size are mixed with either acetone or ethanol to form a paste, which is applied on the surface of the material to be welded. The paste can be applied with a brush or spray. Types of flux is used in A-TIG welding process : SiO_2, TiO_2, MnO_2, ZnO, Al_2O_3, MoS, MoO_3, NiO, CrO_3, $CaCo_3$, CaF, NaF, KBr[4]

1.3 Advantages of A-TIG Welding

- Use of small layer of flux coating on surface increase penetration.
- Reduce number of passes required.
- This process can weld in all positions smooth welds with fewer spatters.
- Enhanced productivity and reduced consumption of filler wire.
- Residual stresses are reduced expressively in A-TIG weld joints. compare to conventional TIG weld joints and the weld joints are distortion free.
- Significant reduction in the cost of fabrication.
- Improvement in creep-rupture life.

II. Literature Review

The literature survey for this study has been carried out through national/international journals, periodicals, conference proceedings, books, codes of practice and recent sources from internet. Performance based seismic design engineering is still an evolving methodology and a lot of research work is still going on in this area. The literature presented in this section focuses mainly on understanding the effect of TIG/A-TIG welding process.

B. Arivazhagan, M. Vasudevan (**2014**)[1] on studies on A-TIG welding of 2.25Cr-1Mo (P22) steel. In this paper, the double side square butt joint welding process on 12 mm 2.25cr-1Mo plate. In this welding process parameters are current 250A, voltage 14.3V, speed 70 mm/min. check effect on microstructure & mechanical properties. The method using for optical emission spectroscopy (OES) and optical and scanning electrode microscope (SEM) for chemical analysis & microstructural examination. Chemical composition observed little variation alloying element. The weld is a free from crack and observed that weld joint exhibited high hardness and good impact toughness values.

Surinder Tathgir, Anirban Bhattacharya (2015)[2] on activated-TIG welding of different steels: influence of various flux and shielding gas. In this paper discussed about using different flux on different material and without flux TIG welding process with different process parameters current 100 A/125A, H_2 & He adding shielding gases and identify increase the penetration used SiO_2, MoO_2, MoS_2,CrO_2 flux.

R.S.Vidyarthy, D.K. Dwivedi, (2015)[3] on activating flux tungsten inert gas welding for enhanced weld penetration. effect of marangoni convection effect on surface tension variation with temperature. The effect of marangoni of TIG welding negative surface tension temp. co- efficient and A-TIG welding positive surface tension temp. co- efficient.

Her-Yueh Huang (2008)[4] on effects of shielding gas composition and activating flux on GTAW weldments. In this paper, A-TIG welding process with nitrogen content adding in argon based shielding gas (2.5 to 10 vol%) and effect on mechanical properties, delta-ferrite content, angular destruction, penetration for austenitic S.S steel. Increase penetration, decrease angular destruction, reduce the delta ferrite content for A-TIG welding experiment results compare the TIG welding.

Akhilesh Kumar Singh, et.al (2017)[5] on a study to enhance the depth of penetration in grade p91 steel plate using alumina as flux in FBTIG welding. In this paper, weld penetration of bead on plate TIG welding was compared with flux-bounded TIG (FBTIG) welding which was carried out on 6-mm-thick P91 plates. Sodium silicate was used instead of acetone in the experiments to bind the flux on to the plates. In similar heat inputs, the penetration in FBTIG has been found to be greater than penetration in TIG welds. The average grain size of TIG welds was smaller than the average grain size of FBTIG welds. The hardness at the weld zone and heat-affected zone of the TIG-welded samples was found to be more compared to the hardness found in similar areas in FBTIG welds.

Shigetaka, Okano, Masahito, Mochizuki (2016)[6] on transient distortion behavior during TIG welding of thin steel plate. In this paper The distortion, temp. profiles large deformation thermal elastic plastic analysis and thermomechanical behavior during thin plate TIG welding process .The distortion increase with welding heat input profile and transient distortion effect calculated analysis method in good agreement. Plastic strain developed by not only temperature also Plastic strain developed by transient distortion during weld. Both longitudinal bending and angular distortions monotonically increased with welding heat input when buckling transpired. Excessive longitudinal bending distortion and the secondary generation of angular distortion involved with buckling were experimentally observed during the cooling process.

R.S. Vidyarthy, et,al (2017)[7] on study of microstructure and mechanical property relationships of A-TIG welded P91-316L dissimilar steel joint. In this paper, the effect of activating flux tungsten inert gas (A-TIG) welding on the microstructural, mechanical and corrosion behaviour of the 316L stainless steel and P91 steel weldment. Both materials frequently used in high performance power plants. A-TIG welding process possesses a different kind of challenges due to the difference in material properties such as chemical composition, thermal and electrical conductivity, and coefficient of thermal expansion.
316L-P91 steel has been successfully welded using single pass A-TIG welding. The weld joint was free from any kind of welding defect such as porosity, crack, undercut, and lack of penetration. Tensile test specimens were failed from the 316L side weld fusion boundary. The UTS of the weldment was lower than that of the parent metals. 316L side weld interface was found to be maximum corrosion resistance, while minimum corrosion resistance was shown by P91 side weld interface.

P. Vasantharaja, M. Vasudevan, (2011)[8] on studies on A-TIG welding of Low Activation Ferritic/Martensitic (LAFM) steel. In this paper, Determine microstructure, tensile and impact of toughness. Resulting of A-TIG welding compare to TIG weld grain size was coarser due to high per temperature. Observing tensile & toughness test. Find out, weld joint stronger than base metal properties after A-TIG welding process.

Josiane Dantas Costa, et.al (2016)[9] on obtaining and characterization of Ni-Ti/Ti-Mo joints welded by TIG process. In this paper, TIG welding process in on Ni-Ti/Ni-Mo dissimilar material & effect of time and temp. on weld quality chemical composition. Resulting of compotation the change of percentage element in melting zone. The corrosion results specify the influence of the parameters of heat treatment (time and temperature). It was observed that the tests carried out at lower temperature with shorter time resulted greater resistance to corrosion, which is supposed to be due to the formation of the precipitate Ni4Ti3. The increase of temperature and heat treatment time reduced the formation of precipitates, and hence a decrease was observed in the corrosion resistance of the samples.

Hsuan-Liang Lin, Tong-Min Wu, (2016)[10] on effects of activating flux on weld bead geometry of inconel 718 alloy TIG welds. In this paper, The experimental procedure of A-TIG welding with the same welding conditions and flux produced full penetration of weld bead on a 6.35mm thickness of Inconel 718 alloy plate with single pass weld.

K. Nanda Naik et.al (2014)[11] on Finite element simulation of A-TIG welding of duplex stainless steel 2205 using SYSWELD. In this paper, Determine temperature distribution, bead geometry and thermal history using finite element analysis is carried on SYSWELD software. The process parameters are current 100A, voltage 14.5V, speed 90mm/min and arc gap 3 mm. Outcome to the percentage of error for depth penetration and bead width of FE simulation profile and Experiment profile is 2.91% and 0.52%. Increase width of bead to current & Temperature increase.

K. Devendranath Ramkumar, et.al (2016)[12] on studies on the weldability, microstructure and mechanical properties of activated flux TIG weldments of Inconel 718. In this paper, The average fusion zone hardness was slightly greater for both the weldments compared to the base metal. The moderate cooling and low heat input due to high energy density of the A-TIG welding resulted in better hardness values SiO2 and TiO2 flux assisted weldments showcased better tensile properties.

M.J. Attarha, I. Sattari-Far, (2011)[13] on study on welding temperature distribution in thin welded plates through experimental measurements and finite element simulation. In this paper, Comparison between the finite element and experimental results revealed that the developed model had good capability for predicting the temperature cycles throughout welding. Comparing the peak temperatures in the dissimilar joint of St37 carbon steel and 304 stainless steel, it is revealed that the S304 peak temperature near the weld melt line is higher than st37.

Kamal H. Dhandh, Vishves J. Badheka, (2015)[14] on effect of activating fluxes on weld bead morphology of P91 steel bead-on-plate welds by flux assisted tungsten inert gas welding process**.** In this paper, bead on plate trials, Fe_2O_3,TiO_2,CaO, ZnO, MnO_2 and CrO_3 out of six activated fluxes, four of them Fe_2O_3, ZnO, MnO_2 and CrO_3 are suitable to weld P91 steel plates of 6 mm thickness in single pass under 100% argon shielding .

Xinxin Wang, et.al (2016)[15] on investigation of heat transfer and fluid flow in activating TIG welding by numerical modeling. In this paper, The heat transfer and fluid flow in TIG and A-TIG welding of stainless steel SUS304 are investigated based on a 3D unified model. Results shallow and wide weld pool shape in TIG welding and deep weld pool shape in A-TIG welding.

Siddharaj Prajapati, Prof. Ketan Shah, (2016)[16] on experimental study on activated tungsten inert gas welding. In this paper, A-TIG welding process on 304L stainless steel with using different flux. Used A-TIG welding with mixture of Sio_2 and Tio_2 flux to achieved to Increase the weld depth and Decrease angular distortion.

Varma Prasad V.M. et.al (2015)[17] on 3D simulation of residual stress developed during TIG welding of stainless steel pipes. In this paper, Due to non- Uniform distribute thermal & strain around weld pool, large amount of residual stresses and deformation are effect on welding parameter and FEM analysis in ANSYS. Process Parameters using Welding speed 80 mm/min, welding Current 140-160 A, 304L S.S steel material. Residual stress changes from compressive to tensile from outer surface to inner surface after welding. Large range of residual stress distribution with Increase current of welding.

Table 2.1 Summary of Literature Review

Sr.No	Title	Process parameter	Outcomes
1	Studies on A-TIG welding of 2.25Cr-1Mo (P22) steel.	Current 250A, voltage 14.3V, Welding Speed 70mm/min, Arc length 3mm Shielding gas: Argon, Material: P22 (2.25Cr-1Mo)	• Chemical composition observed little variation alloying element. • The weld is a free from crack and observed that weld joint exhibited high hardness and good impact toughness values.
2	Activated-TIG Welding of Different Steels: Influence of Various Flux and Shielding Gas.	Current 50/100/250A, voltage 14.3V, Welding Speed 75mm/min, Arc length 3mm, Shielding gas: Argon, Material: 304L,316L, Duplex 2205,ASIS4340	• Identify increase the penetration used SiO_2, MoO_2, MoS_2, CrO_2 flux.
3	Activating flux tungsten inert gas welding for enhanced weld penetration.	Current 160A, voltage 14.3V, Welding Speed 0.75 mm/s, Arc length 1 mm Shielding gas: Argon	• The effect of marangoni of TIG welding negative surface tension temp. co- efficient and A-TIG welding positive surface tension temp. co-efficient.

4	Effects of shielding gas composition and activating flux on GTAW weldments.	Current 125A, voltage 14.3V, Welding Speed 75mm/min, Arc length 3mm Shielding gas: nitrogen contain add Argon in with 2.5 to 10 vol%, Material: 304L, flux 80% MnO_2 + 20% Zno	• Increase penetration, decrease angular destruction, reduces the delta ferrite content for A-TIG welding experiment results compare the TIG welding.
5	A Study to Enhance the Depth of Penetration in Grade P91 Steel Plate Using Alumina as Flux in FBTIG Welding	Current 150/250A, voltage 26.67/14.49V, Welding Speed 25/15cm/min, Arc length 2.5mm Shielding gas: Argon, Material: P91(9Cr–1Mo–V), Binder: Sodium silicate	• In similar heat inputs, the penetration in FBTIG has been found to be greater than penetration in TIG welds. • The average grain size of TIG welds was smaller than the average grain size of FBTIG welds.
6	Transient distortion behavior during TIG welding of thin steel plate.	Current 50/100/150A, voltage 14.3V, Welding Speed 75 mm/min, Arc length 3mm Shielding gas: Argon, Material: 304L	• The distortion increase with welding heat input profile and transient distortion effect calculated analysis method in good agreement. • Plastic strain developed by not only temperature. Also Plastic strain developed by transient distortion during weld.
7	Study of microstructure and mechanical property relationships of A-TIG welded P91-316L dissimilar steel joint	Current 250A, voltage 14.3V, Welding Speed 75 mm/min, Arc length 3mm Shielding gas: Argon, Material: P91-316L	• The weld joint was free from any kind of welding defect such as porosity, crack, undercut, and lack of penetration • Tensile test specimens were failed from the 316L side weld fusion boundary
8	Studies on A-TIG welding of Low Activation Ferritic/Martensitic (LAFM) steel.	Current 225A, voltage 14.7V,Welding Speed 100mm/min, Arc length 1mm Shielding gas: Argon, Material: LAFM steel.	• Weld grain size was coarser due to high per temperature. • Observing tensile & toughness test. Find out, weld joint stronger than base metal properties after A-TIG welding process.
9	Obtaining and characterization of Ni-Ti/Ti-Mo joints welded by TIG process.	Arc length 3 mm Shielding gas: Argon, Material: Ni-Ti/Ti-Mo	• Resulting of compotation the change of percentage element in melting zone.
10	Effects of Activating Flux on Weld Bead Geometry of Inconel 718 Alloy TIG Welds.	Current 170/180/190A, voltage 14.3V, Welding Speed 150mm/min, Arc length 2mm Shielding gas: Argon, Material: Inconel 718 alloy	• The experimental procedure of A-TIG welding with the same welding conditions and flux produced full penetration of weld bead on a 6.35mm thickness of Inconel 718 alloy plate with single pass weld.
11	Finite element simulation of A-TIG welding of duplex stainless steel 2205 using SYSWELD.	Current 100A, voltage 14.5V, Welding Speed 90mm/min, Arc length 3mm Shielding gas: Argon, Material: duplex 2205 steel	• Outcome to the percentage of error for depth penetration and bead width of FE simulation profile and Experiment profile is 2.91% and 0.52%. • Increase width of bead to current & Temperature increase.
12	Studies on the weldability, microstructure and mechanical properties of activated flux TIG weldments of Inconel 718	Current 120/140/160/180A, voltage 14.3V, Welding Speed 110mm/min, Arc length 3mm Shielding gas: Argon, Material: Inconel 718 alloy Flux SiO_2 & TiO_2	• The moderate cooling and low heat input due to high energy density of the A-TIG welding resulted in better hardness values. SiO_2 and TiO_2 flux assisted weldments showcased better tensile properties.
13	Study on welding temperature	Current 101/100/100A, voltage	• Comparing the peak temperatures in the

	distribution in thin welded plates through experimental measurements and finite element simulation	14.6/17.8/15.5V, Welding Speed 1.8/3.125/2.3 mm/s, Shielding gas: Argon, Material: 304L, ST37 carbon	dissimilar joint, the S304 peak temperature near the weld melt line is higher than ST37.
14	Effect of activating fluxes on weld bead morphology of P91 steel bead-on-plate welds by flux assisted tungsten inert gas welding process.	Current 250A, voltage 14.3V, Welding Speed 70mm/min, Arc length 3mm Shielding gas: Argon, Material: P91	• Fe_2O_3,TiO_2,CaO,ZnO, MnO_2 and CrO_3 out of six activated fluxes, four of them Fe_2O_3, ZnO, MnO_2 and CrO_3 are suitable to weld P91 steel plates of 6 mm thickness in single pass under 100% argon shielding
15	Investigation of heat transfer and fluid flow in activating TIG welding by numerical modeling.	Current 200A, voltage 14.3V, Welding Speed 100mm/min, Arc length 3mm Shielding gas: Argon, Material: steel	• Results shallow and wide weld pool shape in TIG welding and deep weld pool shape in A-TIG welding.
16	Experimental Study on Activated Tungsten Inert Gas Welding.	Current 140A, voltage 14.3V, Welding Speed 100mm/min, Arc length 2mm Shielding gas: Argon, Material: 304L	• Used A-TIG welding with mixture of Sio2 and Tio2 flux achieving Increase the weld depth and Decrease angular distortion.
17	3D simulation of residual stress developed during TIG welding of stainless steel pipes.	Current 100/160/220A, voltage 9.5V, Welding Speed 80mm/min, Arc length 3mm Shielding gas: Argon, Material: 304L	• Residual stress changes from compressive to tensile from outer surface to inner surface after welding. Large range of residual stress distribution with Increase current of welding.

III. Findings from Literature Review

According the literature review, Using TIG welding process with activated flux.

- TIG welding required multipassing process of weld and higher Thermal distribution.
- Identify required process parameter used for dissimilar material.
- Penetration is most important factor in the welding for more then 3 mm thickness.
- Identify preferable flux to set of penetration depth and width to welding process.

IV. Identify problem

From the literature review, it is found that lack research or performance done on the dissimilar material like 304L/P22, P91/304L, Inconel 718 alloy-Duplex steel 2205/carbon steel in and finite element analysis of that welding. So it decided to work on that 304L and P91 material for application of A-TIG welding process. Obtain experimental & FEA result.

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