International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Activated flux tungsten inert gas welding process to improve penetration in copper material

GulamhushenA Sipai[*]Dr. Komal G Dave[**]
[*]PG Student, Department of Mechanical engineering, L D College of Engineering Ahmedabad
[**]Associate Professor, Department of Mechanical engineering, L D College of Engineering Ahmedabad.

Abstract- TIG welding using activated flux or A-TIG welding developed at paton welding institute in 1960. This process can give us higher penetration than conventional process in single pass. High penetration capability of this process attracts the researchers to work on this phenomenon. Recently In my present work, attempts have been made to investigate and review the literature paper published with respect to (1) Mechanisms which explain the reasons for high penetration achieved using A-TIG, (2) effect of process parameters on welding response for A-TIG, (3) effect of various alloying elements in ferrous and non-ferrous metals on penetration achieved by A-TIG, (4) feasibility investigative studies of A-TIG onnon-ferrous metals. In consideration of the above, this research will help in (a) presenting the opportunity of research in A-TIG for copper material to aggrandize its industrial application and (b) to generate stepwise understanding of various factors describing the capability of this process.
Index Terms- Activated flux, A-TIG, Ferrous, Non-ferrous, penetration improvement

I. Introduction

Tungsten inert gas (TIG) welding process is one of the popular fabrication processes occupied for welding of various range of material like stainless steels, titanium alloys, aluminum alloys and other non-ferrous metals because of its better quality welds and low cost equipment. This process is prominent for welding thin section and can be used for numerous welding position like horizontal, vertical and overhead. Using this process we can get neat and smooth weld. In spite of the process attributes several drawbacks, low weld penetration makes it less appropriate for industrial use. To swamp the limitation of low penetration by single pass, design of groove and Multi pass is required to weld thick sections which decrease process productivity. Extra costs are subsumed on edge preparation and fillers required to fill the groove joints.

Various trials have been made to increase the productivity of GTA welding process. Activated flux with GTA welding has been successfully used to improve productivity of the process. The process is also known as flux assisted gas tungsten arc welding (F-GTAW) and A-TIG welding process. In this process a thin flux layer is deposited on the surface that is to be welded, followed by the conventional TIG welding process. Fluxes are generally oxides, chlorides and fluorides. Fluxes are mixed with suitable solvent like acetone or ethanol with proper proportion deposited on the surface with the help of a brush or by spraying. Different materials have different chemical, mechanical, and thermal behavior so that flux composition has to be changed accordingly.

TIG welding using activated flux awfully increase the weld penetration compare to the conventional TIG welding process with same input parameters. The reason behind the increased penetration is narrow the arc, reduce the surface tension of molten metal and concentrate the energy at center. Here the reduction in surface tension of molten metal is known as marangoni effect. According to the literatures the main mechanisms behind the A-TIG are Arc constriction and Marangoni effect.

0) Abstract
1) Introduction
2) Logic behind penetration enhancement in A-TIG
3) Flux deposition techniques
4) Factors which affect the A-TIG responses
5) Experimental Setup
6) Experimentation
7) Results and Discussion
8) Conclusions

II. LOGIC BEHIND PENETRATION ENHANCEMENT IN A-TIG

TIG welding with activated flux has resulted in awfully enhancement in the depth of penetration as compared to the conventional TIG process with the same input criterion. Various forces in arc zone like marangoni force due to surface tension, gravity force due to density difference, drag force due to arc, electro-magnetic force due to current flow, etc. [3, 4] affect the weld penetration for same process parameters in both the cases. The mechanism of increased penetration depth with flux in the weld pool is confer in the subsequent section:

Marangoni Effect

Heiple,C.R.,andJ.R.Roper experimentally investigate that Small additions of selenium to a stainless steel dramatically increase the D/W ratio of GTA welds as shown in figure 2.1 [1] and Heiple,C.R.,andP.Burgardtalso investigate that small additions of SO2 in argon shielding gas improves joint penetration in 21-6-9 and 304 stainless steels[2]. Many more researchers work on the concept of marangoni effect in their research [4,8,11,12,13,15,16,18, 20, and 21].

Marangoni convection can have a dramatic effect on the penetration depth of the weld and also known as surface-tension driven convection or thermo capillary convection. The effect of the marangoni convection depend on the marangoni number which also gives the detail about strength of the thermo capillary flow. Marangoni number is non dimensional and express by

$$Ma = \frac{d\gamma}{dT}\frac{dT}{dx}\frac{L^2}{\eta a}$$

Where dT/dx is the temperature gradient, η is the viscosity, a is the thermal diffusivity and L is the characteristics length. According to this theory, the direction of fluid flow depends on the surface tension gradient in the fluid. Fluids flow from low surface tension region towards the high surface tension region. The marangoni convection was proposed to understand the problem encountered in the case of "cast to cast" variation or variable weld penetration. The presence of surface active elements causes the changes in surface tension (γ) in the weld pool. The surface active elements revers the surface tension gradient ($\frac{d\gamma}{dT}$) from reducing to increasing which makes higher $\frac{d\gamma}{dT}$ at center and gradually decrease to periphery.

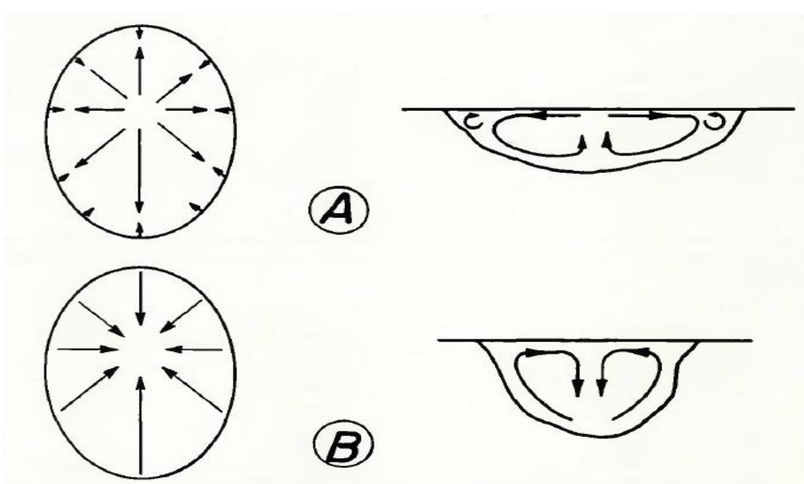

Figure 2.1 *fluid flow on and below the weld pool surface: A—negative surface tension temperature coefficient: B—positive surface tension temperature coefficient (Heiple, C. R., and J. R. Roper-1981)*

Now we understand the marangoni flow in which the concentration of surface active element play a major role for the low level of surface active elements the surface tension gradient is negative which gives outward flow(Figure2.2(a)) same way for the high level of surface active elements the surface tension gradient is positive which gives inward flow(Figure2.2(b) and we know that in actual as the critical temperature approached $\gamma \rightarrow 0$ so positive $\frac{d\gamma}{dT}$ must go through the maximum and and at this point reversal of thermo capillary flow occur(Figure2.2(c)) [3].

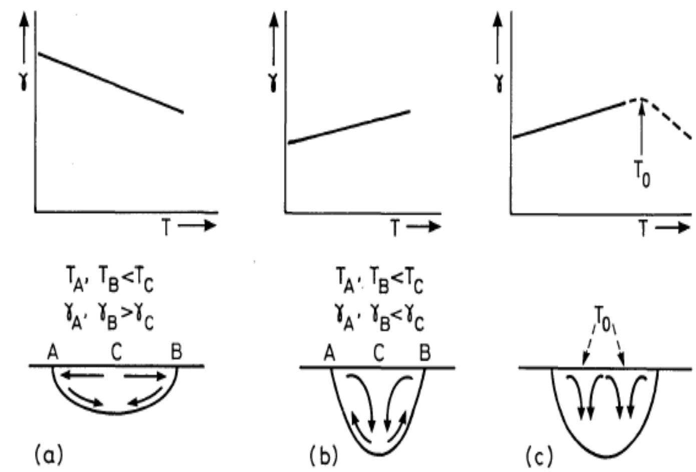

Figure2.2 Fluid flow in weld pool resulting from Marangoni convection (Heiple-Roper theory) (Mills KC, Keene BJ-1990)

Arc Constriction

During GTA welding when the torch moved toward the flux coated surface from bare surface the diameter of the plasma arc column get constrict. This phenomenon was described as an arc constriction in A-TIG welding process [7, 12, 14, 16, 18, and 23]. Tanaka M et al. provide the information of the effect of the heat transfer from the arc to base metal in the TIG welding process. They calculate the current density and heat intensity and found that both are reduced from center to periphery [5]. A reduced arc increase the current density in center and hence heat density increase which produce the narrower and deeper weld penetration than conventional TIG welding. Tanaka M et al. in their research want to clarify a mechanism for the effect of flux on GTA welding process and using spectroscopy found that arc constriction is greatly due to metal vapor [7]. LowkeJJ et al. examine the possible mechanism which increase the depth of penetration in GTAW using flux in which flux vapor attract the electron [12]. HuangH-Yalso observed small anode spot [14]. Sambherao PAB also work on arc constriction to investigate the effect of various oxide fluxes on the weld appearance, weld morphology, retained delta-ferrite content of 6-mm thick SS316 steel welded using the TIG process [16]. HowseDS,LucasW. Investigate an arc constriction by activating fluxes and said that the dominant mechanism for increasing penetration is arc constriction rather than marangonieffect [18]. HuangHY. Takes a photograph of TIG arc and found that the arc constrict using flux[23]

The mechanism behind the arc constriction is based on the vapor which contains oxygen and fluorine from flux. Such gases are known to attract electrons. Electron attachment at the periphery of the argon arc will form negative ions of oxygen and fluorine, which have a low mobility compared with electrons.

Electron attachment at the outer region of the arc to create negative ions could cause arc constriction and an increase in current density at the anode center, thus leading to an increased weld depth, as shown in figure2.3. Figure describe that the results of the effect of electron attachment to oxygen form negative ions.When electron attachment is included there is a marked reduction in the electron density at radii beyond 2.2 cm, with the production of negative ions as shown in figure2.4. Same way to understand the arc constriction as we know that the surface is covered with metal oxides as a flux. This layer will act as an insulating barrier to the arc current. Temperature at the center is sufficient to melt the flux so that electric current can penetrate the flux. Figure 2.5 shows the calculated temperature contour where we can see that the radius of current region is only 2mm which allow the current into the weld pool by evaporate flux.

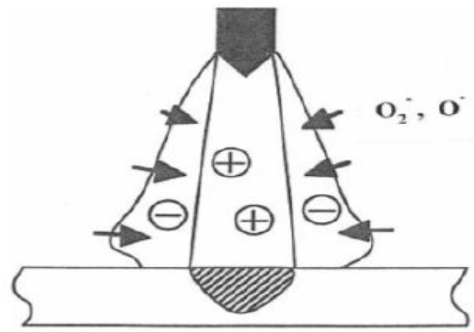

Figure2.3 Negative ion formation at the edge of the arc could increase current density at the Center of the anode and thus increase weld depth. (J JLowke et al.-2005)

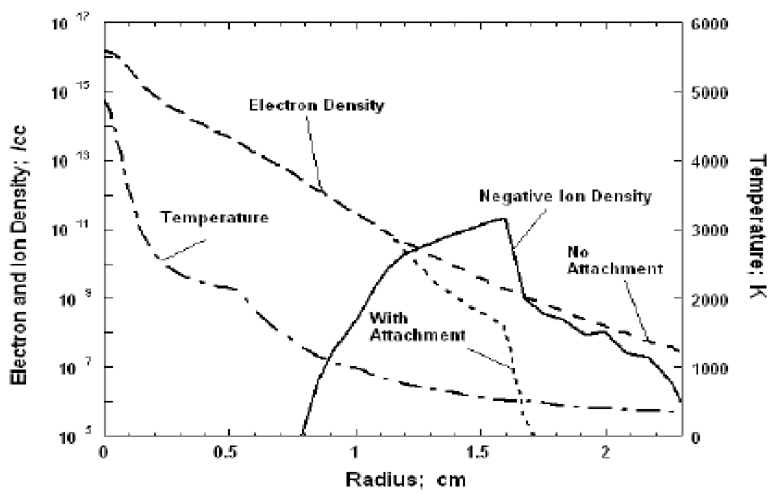

Figure2.4 Calculated particle densities at a very short distance from the weld pool surface (J JLowke et al.-2005)

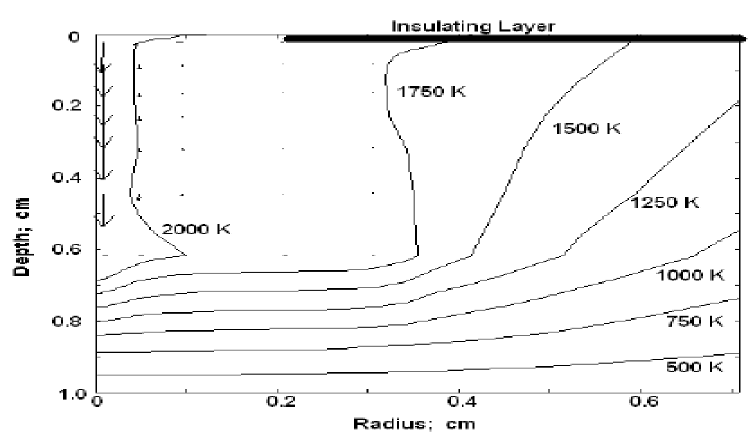

Figure2.5 Calculations of temperature contours in the weld pool where the effect of a flux is simulated by an insulating layer on the outer surface of the weld pool (J JLowke et al.-2005

III. FLUX DEPOSITION TECHNIQUES

The activated fluxes are mixed with either acetone or ethanol to form paint like paste, which is applied on the surface of the work piece to be welded. The paste can be applied with a brush or spray. The layer should be sufficiently thick to prevent the visual observation of the base metal beneath. The width of the layer is generally kept in the range of 10-15 mm.

Luciano de Azevedo AGet al. uses the directed constriction technique on SS316 specimen using TiO2, Fe2O3 and Al2O3 and their mixture as a flux with two different welding speeds i.e. 2.7 mm/s and 3.5 mm/s and three different welding currents i.e. 100 A, 150 A , 180 A. In directed constriction technique (DCT) Rather than a layer that covers the entire joint, two thin bands of flux were deposited, separated by a pre-determined distance. Using this method, the flux layer electrically isolated certain regions of the surface of the piece, thereby concentrating the incidence of the arc towards the center of the joint [13]. Huang H-Y study the effect of activating flux on the weld morphology, arc profile, and angular distortion and microstructure of TIG and plasma arc welding on SS304 and apply the flux directly on the joint using brush as shown in figure 3.1[14].Ames N, Frye C in their research use two methods first flux applied to both tube at same time (S-XXXX) and in second method flux applied to each individually then mated (A-XXXX) for four types of techniques like wide strip, wide pin strip, narrow strip, narrow pin stripe as shown in Figure 3.2.Results of the application techniques of flux shows that narrow strip and narrow pin stripe gives aesthetically better weld [11].

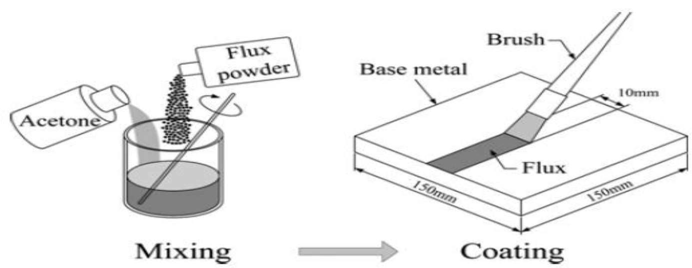

Figure3.1 Schematic diagram showing the specimen preparation for activating flux welding.(Huang H-Y-2010)

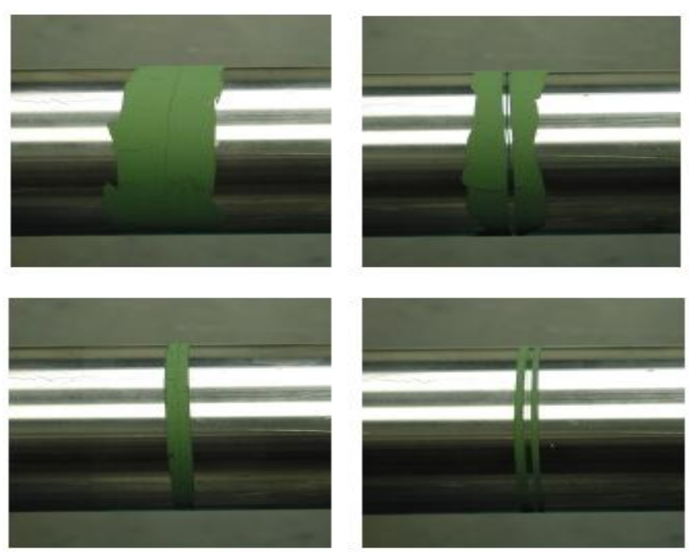

Fig. 3.2. Examples of Flux Application Techniques; A) S-WB, B) SWBP,C) S-NB, and D) S-NBP [Ames N, Frye C- 2005]

Now knowing the techniques for the flux deposition and mechanism behind the A-TIG there are also other factors which affect the performance of the A-TIG welding. These factors are like

1. Forces acting in A-TIG

2. Welding related process parameters like welding current, welding speed, Arc length, electrode geometry, flux composition, shielding gas composition. Which we can understand in our next chapter.

IV. FACTORS WHICH AFFECT THE A-TIG RESPONSES

Forces acting in A-TIG Welding

There are four types of forces reported which affect the penetration during welding. (a) thermo capillary (Marangoni) forces M(+) or M(-) resulting from change in surface tension temperature gradient (b) electromagnetic (Lorentz) forces E resulting from interaction of current (c) buoyancy forces resulting from density differences caused by temperature gradients (d) aerodynamic drag forcescaused by passage of plasma over surface. . Various forces acting on the weld pool are shown in figure 4.1 [3]

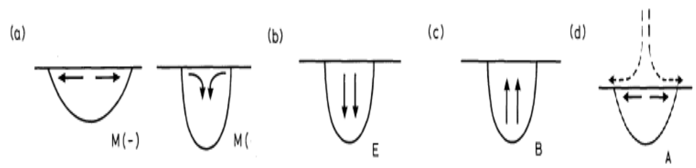

Figure 4.1 (a) thermo capillary (Marangoni) forces M(+) or M(-); (b) electromagnetic (Lorentz) forces E (c) buoyancy forces (d) aerodynamic drag forces (Mills KC, Keene BJ-1990)

Welding Process parameters

Welding current:welding current affect the thermocapilary, electromagnetic and aerodynamic drag forces. Welding current increase heat input which increase the thermocapilary convection and produce better penetration. However situation is more complex because large current increase the electromagnetic force which increase the penetration and also increase the aerodynamic force which produce outward flow and widening the weld pool.[3]

Arc length: More arc length increase the aerodynamic force which widen the weld pool and also reduce the arc efficiency for run carried out at constant current [3].

Weld speed: Increasing speed reduce the heat input which reduce the volume of the weld pool.

Electrode geometry: It can change the arc root area and arc pressure. Arc pressure is maximum at $\Theta=45^{\circ}$ which means current density is maximum for this design. Sometimes frustum wedge electrode also used which can be produce by filing away the conical tip. Increasing diameter of flat surface reduce the maximum arc pressure which reduce the penetration [3].

Flux types: According to the material property and chemical composition various oxides and halides fluxes selected. Some fluxes work as an active fluxes, some as reactive fluxes and some remain neutral.Modenesi PJ et al. use single component fluxes as an activated flux and found that experimental results does not support the marangoni effect or arc constriction [6] while other researcher use oxides, chlorides, fluorides and various composition of them to get their required responses [7-18].

Shielding gas composition: Lu S et al. said that the surface active elements can be added using active gaseous addition to the argon shielding gas [19]. Various active gases compositions with argon shielding gas improve the depth to width ration up to the oxygen solubility limit in the weld after that heavy oxide layer found on the weld pool which restrict the arc to reach at the weld pool and reduce the penetration.[19-23]

Thickness of plate: Thickness of the plates to be welded also affect the depth and width of the weld.TamásSándor, JánosDobránszky compare the various penetration profiles of different TIG process variations on SS304 [31]. Both found that using He with Ar shielding gas increase the penetration for small thickness but as the thickness increase no difference found in penetration so we cannot suggest to use He with Ar to increase the penetration in high thickness plate. While using A-TIG process for higher thickness we get the penetration at lower limit of current.Same way regarding the weld width the variation for conventional TIG, using He and A-TIG are more with smaller thickness are variations are less for higher thickness. These variations regarding penetration and weld width somehow depend on the flux composition and brushing techniques [31].

Composition of metal and their property: Materials can be broadly classified into two categories (a) ferrous and (b) non-ferrous. Literature review reveals that The A-TIG process is well proven technology for ferrous material like stainless steel [1,2,6,7,8,12,14,16,17,18,19,20,21,22,23,31], high alloy steel [10], duplex stainless steel [11] but less popular for non-ferrous material like magnesium alloy [9] and copper [30] . Nakahara, S., and Y. Okinaka says that mechanical properties of copper are influenced by Hydrogen. Three situations in which the properties of copper are known to be affected by hydrogen are (1) thermal charging, (2) cathodic charging and (3) electroless copper plating.

In this paper author suggest that to reduce the hydrogen sickness risk we have to use more refined copper such as oxygen free high conductivity (OFHC) copper [24]. Keene, B. J survey the experimentally determined values of surface tension for pure metal [25]. Munitz, A investigate the weld microstructure between the stainless tube and copper tube using TIG and electron beam welding and found differences in composition in different part of weld zone due to the short solidification time [26]. ASME specialty Handbook “copper and copper alloys” byJ. R. Davis gives the vital information regarding all the types of processes on copper and its alloys and many more [27]. Liming, Liu et al. work on the lap joint by TIG welding between dissimilar magnesium and copper material using Fe as inter layer and results says that Cu and Fe diffused into each other while obvious interface existed between iron plate and magnesium [28]. Lin et al. investigate the mechanical properties of pure copper using FSW and TIG welding and results proves that mechanical properties of pure metal using TIG are better than the base metal and lower than the properties regarding FSW [29]. Segletes et al. regeister the patent regarding the A-TIG welding of copper alloys for generator component in which they get the full penetration at least 5mm using flux without edge preparation and without preheating.The activated flux comprises 20-50% by Weight of at least one of SiO2, TiO2, Cr203 and a halide [30].

V. EXPERIMENTAL SETUP

To carry out the experiments,Welding setup is shown in figure 5.1. LORCH TIG T-pro series machine setup is used for welding. Argon is used as a shielding gas. In my experiments author use a pure oxygen free copper (Cu 99.98%), Grade ASTM B152 Gr. C10200 with 6 mm thickness and refer ASME sec IIB; specification SB-152 in which composition are fit in grade C10200. ASTM standard for this material is ASTM B152/B152M ; ASTM B170 ; ASTM B224. According to the physical property; this material has specification of H00 (Cold rolled temper-eight hard). [31,32,33,34]

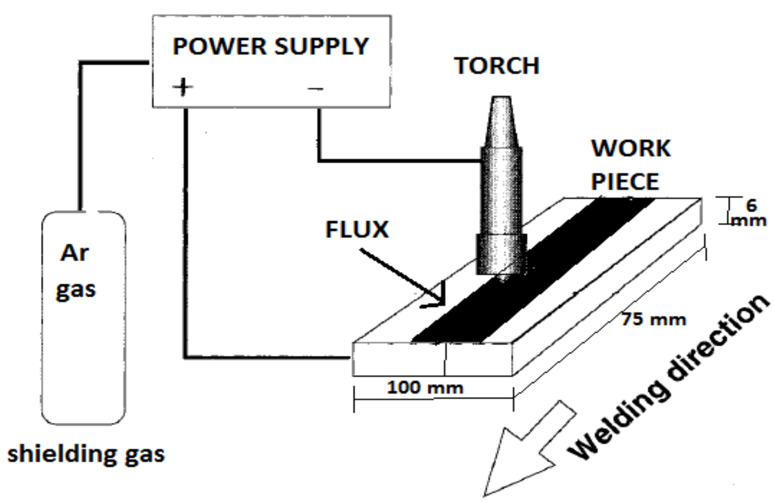

Figure 5.1 TIG Welding Setup

VI. EXPERIMENTATION

To check the feasibility of A-TIG welding for copper material first we start with oxide-based fluxes. Using various parameters with oxide fluxes trial run carried out and Various parameters which are taken for the test are shown in the table 1. Here we use 50 mm^3 volume of flux for all the trial test.Flux applying technique is shown in Figure 6.1.

Sr. No.	**Current A**	**Voltage V**	**Speed cm/min**	**Flow rate l/min**	**Flux**
1)	200	9-11	8	15	Tio2
2)	230	9-11	8	15	Sio2
3)	250	9-11	8	15	Sio2
4)	250	9-11	8	15	No Flux
5)	250	9-11	4	15	Tio2 + Mgcl2
6)	180	9-11	4	15	Sio2 + Mgcl2
7)	250	9-11	4 (Weaving)	18	Sio2 + Mgcl2
8)	250	9-11	4	18	Sio2 + Mgcl2

Table1. Trial test parameters table

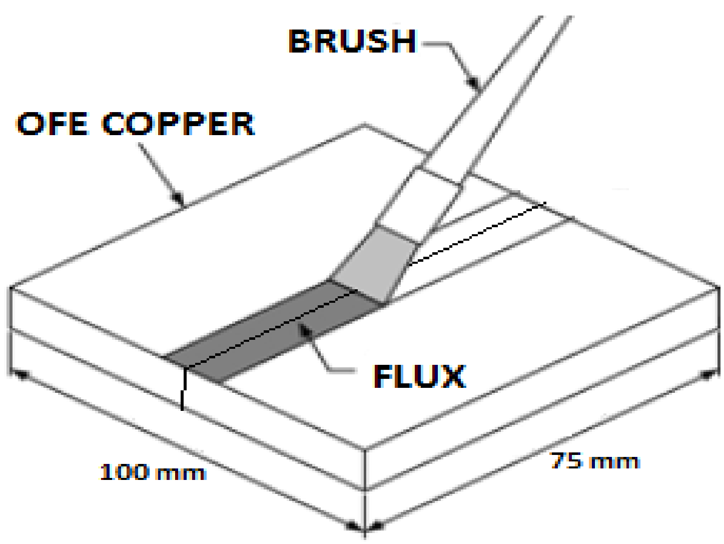

Figure 6.1 Flux applying technique in Trial test

VII. RESULTS AND DISCUSSION

After welding in samples of test 1 to 3,we found solidification crack and lack of penetration. Now we go for trial 4 without flux with maximum current and no crack or surface defects observes but we did not get the full penetration as shown in Figure 6.2. .

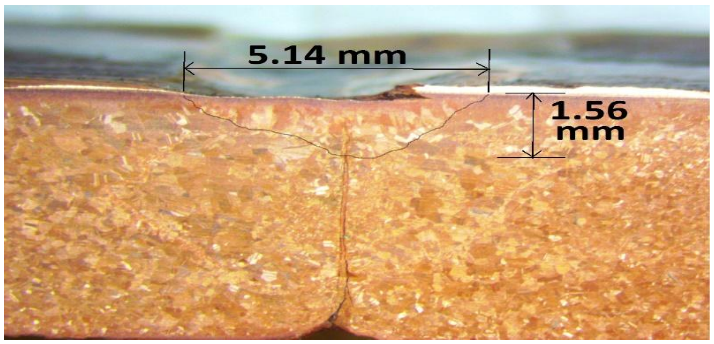

Figure 6.2Weld profile of No flux sample (using Ar gas)

After that we try mixture of oxide and halides for trial run 5 & 6 using various parameters but again same errors come in picture and we did not get the results as required then we go with weaving concept in 7^{th} run but it also did not give the required results. Lastly, we apply the thick layer of flux on the all the sides of weld joint edges with maximum current and gas flow rate but again very poor result is observed.

The main Reasons for the poor performance are the high thermal conductivity and high heat dissipation of copper material and the flux applying technique. The technique which we use in this trial test is work as an insulator for the base metal to arc. So, the flux insulates the arc and restrict the arc to reach at the metal effectively. So, the proper heat input is not there due to which the lack of penetration and solidification cracks are observed. From this trial test we can say that that we have to increase the heat input from arc to base metal so the proper fusion takes place and full penetration achieved.

VIII. CONCLUSION

1. Lack of penetration and solidification cracks are mainly due to the high thermal conductivity and high heat dissipation of base metal.

2. Various single components oxides and mixtures of oxides and halides are used as a flux in ratio of 1:2 to enhance the penetration but these fluxes work as an insulator which restrict the arc on the surface of the base metal.

3. From the trial test we can say that welding parameters are not sufficient to break the flux to penetrate in the metal so that we have to increase the heat input.

REFERENCES

1. Heiple, C. R., and J. R. Roper. "Effect of selenium on GTAW fusion zone geometry." *Welding journal* 60.8 (1981): 143.
2. Heiple, C. R., and P. Burgardt. "Effects of SO2 shielding gas additions on GTA weld shape." *Welding journal* 64.6 (1985): 159-162.
3. Mills KC, Keene BJ. Factors affecting variable weld penetration. Int Mater Rev1990;35:185–216,
4. Mills KC, Keene BJ, Brooks RF, Shirali A. Marangoni effects in welding. Phi-los Trans R Soc A Math Phys Eng Sci 1998;356:911–25,

5. Tanaka M, Terasaki H, Fujii H, Ushio M, Narita R, Kobayashi K. Anode heat transfer in TIG welding and its effect on the cross-sectional area of weld penetration. Weld Int 2006;20:268–74
6. Modenesi PJ, Apolinário ER, Pereira IM. TIG welding with single-component fluxes. J Mater Process Technol 2000;99:260–5,
7. Tanaka M, Shimizu T, Terasaki T, Ushio M, Koshiishi F, Terasaki H,et al. Effects of activating flux on arc phenomena in gas tungstenarc welding. Sci Technol Weld Join 2000;5:397–402
8. Lu S, Fujii H, Sugiyama H, Tanaka M, Nogi K. Weld penetration and Marangoni convection with oxide fluxes in GTA welding. Mater Trans 2002;43:2926–31
9. Marya M, Edwards GR. Chloride contributions in flux-assisted GTA weldingof magnesium alloys. Weld J 2002:291–8.
10. Niagaj J. The use of activating fluxes for the welding of high-alloy steels by A-TIG method. Weld Int 2003;17:257–61,
11. Ames N, Frye C. Use of PE-GTAW to control microstructure in duplex stainless steels. Proceedings of the engineering conference 2005;8:96–101
12. Lowke JJ, Tanaka M, Ushio M. Mechanisms giving increased weld depth due to a flux. J Phys D Appl Phys 2005;38:3438–45
13. Luciano de Azevedo AG, Ferraresi VA, Farias JP. Ferritic stainless steel welding with the A-TIG process. Weld Int 2010;24:571–8
14. Huang H-Y. Research on the activating flux gas tungsten arc welding and plasma arc welding for stainless steel. Met Mater Int 2010;16:819–25,
15. Tseng K-H, Chuang K-J. Application of iron-based powders in tungsten inert gas welding for 17Cr–10Ni–2Mo alloys. Powder Technol 2012;228:36–46,
16. Sambherao PAB. Use of activated flux for increasing penetration in austenitic stainless steel while performing GTAW. Int J Emerg Technol Adv Eng2013;3:520–4.
17. Nayee SG, Badheka VJ. Effect of oxide-based fluxes on mechanical and metallurgical properties of dissimilar activating flux assisted-tungsten inert gas welds. J Manuf Process 2014;16:137–43
18. Howse DS, Lucas W. An investigation into arc constriction by active fluxes for tungsten inert gas welding. Sci Technol Weld Join 2000;5:189–93,
19. Lu S, Fujii H, Sugiyama H, Tanaka M, Nogi K. Effects of oxygen addi-tions to argon shielding gas on GTA weld shape. ISIJ Int 2003;43:1590–5,
20. Lu S, Fujii H, Nogi K. Marangoni convection and weld shape variations in Ar–O2 and Ar–CO2 shielded GTA welding. Mater Sci Eng A 2004;380:290–7,
21. Lu S, Fujii H, Nogi K. Marangoni convection in weld pool in CO2-Ar-shielded gas thermal arc welding. Metall Mater Trans A 2004;35:2861–7,
22. Huang H-Y. Effects of shielding gas composition and activating flux on GTAW weld ments. Mater Des 2009;30:2404–9,
23. Huang HY. Argon–hydrogen shielding gas mixtures for activating flux-assisted gas tungsten arc welding. Metall Mater Trans A Phys Metall MaterSci 2010;41:2829–35
24. Nakahara, S., and Y. Okinaka. "The hydrogen effect in copper." Materials Science and Engineering: A 101 (1988): 227-230.
25. Keene, B. J. "Review of data for the surface tension of pure metals." International Materials Reviews 38.4 (1993): 157-192.
26. Munitz, A. "Metastable liquid phase separation in tungsten inert gas and electron beam copper/stainless-steel welds." Journal of materials science 30.11 (1995): 2901-2910.
27. Davis, Joseph R., ed. *Copper and copper alloys*. ASM international, 2001.

28. Liming, Liu, Wang Shengxi, and Zhao Limin. "Study on the dissimilar magnesium alloy and copper lap joint by TIG welding." Materials Science and Engineering: A 476.1 (2008): 206-209.

29. Lin, Jau-Wen, Hsi-Cherng Chang, and Ming-Hsiu Wu. "Comparison of mechanical properties of pure copper welded using friction stir welding and tungsten inert gas welding." Journal of Manufacturing Processes 16.2 (2014): 296-304.

30. Segletes, David S., and Dennis R. Amos. "A-TIG welding of copper alloys for generator components." U.S. Patent Application No. 11/703,472.

31. Sándor, Tamás, and János Dobránszky. "Comparison of penetration profiles of different TIG process." (2009): 1-16.

32. ASME Sec II-B_2013;SB-152

33. ASTM B152/B152M

34. ASTM B170

35. ASTM B224

36. ASME Section IX_2013

ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to COE Weldingand personally to Dr. G H Upadhyay, Mr. Ragesh Baterywala Siras well as all COE Welding staff who gave me the golden opportunity to do this wonderfull research. During this Research I came to know about so many new things I am really thankfull to them.Secondly I would also like to thak my parents and friends who helped me a lot in my research.

AUTHORS

First Author – SipaiGulamhushenAnvarbhai, PG Student, Department of Mechanical engineering, L D College of Engineering Ahmedabad.

Email:gasipai9055@yahoo.in

Second Author – Dr. Komal G Dave, Associate Professor, Department of Mechanical engineering, L D College of Engineering Ahmedabad.

Email:dave_komal@yahoo.co.in