INVESTIGATIONS INTO TIG ARC EFFICIENCY

By
S. R. Gupta, P. C. Gupta and S. N. Dubey
Department of Mechanical & Industrial Engineering,
University of Roorkee, Roorkee

ABSTRACT

Experimental investigations have been carried out to study the influence of various welding variables on arc efficiency in TIG (GTA) process using water cooled copper block as work piece. Heat collected by the water flowing through the hollow block, has been used to calculate the arc efficiencies. It has been shown that the welding current, arc length and electrode polarity have appreciable influence on the arc efficiencies over the entire range of investigations. Gas flow rate and torch angle also influence efficiency significantly but only under certain conditions.

INTRODUCTION

One of the major concerns to the welding engineer has been the effect which the heat of welding has on the mechanical properties and structure of materials to be joined. The heat input to the work piece during welding depends upon the arc efficiency.

The distribution of arc energy changes with the variation in welding parameters. Thus the quantity of heat entering the base metal depends upon the welding parameters. An accurate prediction of this quantity is needed to predict the metallurgical response and thus mechanical properties of the weldments [1].

Since the heat input from the arc is a basic boundary condition for any analytical method, an accurate knowledge of the fraction of the energy of the arc transferred to a workpiece is essential. This fraction is known as the welding arc efficiency and can be defined as the ratio of the total energy which enters the plate or sections being welded per unit length to the total energy input of the arc over the same length [1,2].

Heat is dissipated from the arc by conduction, convention and radiation. Conduction through the electrode is significant in the case of GTA welding. Further, heat is also lost from electrode by evaporation and radiation. Heat is convected by gas flow in the arc column, some being transferred to workpiece and some being lost. There are radiation losses from the arc and from the work piece too. In consumable electrode welding process the heat absorbed by the electrode is transferred to the workpiece, while in non-consumable GTA welding the heat absorbed by the electrode is relatively lower than that of consumable electrode welding processes [3-7]. Ghent et al [6] measured the heat radiated, convected and conducted from arc column together with heat radiated from the electrode and weld pool by means of a cooling coil surrounding the arc and found that about one third of the column energy was emitted radially. Further, arc efficiency decreases with increasing arc power. Wilkinson and Milner [8] obtained an approximately constant efficiency over the same power range. It is suggested that the heat input to the workpiece i.e. process efficiency can be improved with the addition of hot wire and narrow gap technique [9].

It has been reported that a decreasing percentage of total heat enters the plate with increasing current level when using either argon or helium as shielding gas. This indicates that heat losses from the arc column increase more rapidly with current level than the percentage of the total heat which enters the base metal. It has also been observed that the effect of current on the arc efficiency is more critical in argon than in the helium [1].

The weld material apparently has no effect on the measured arc efficiency over a wide range of arc conditions. The TIG process exhibits a nearly constant level of arc efficiency with welding speed except at the slowest travel speed where a slight decrease is observed [10]. However, Niles et al [1] have reported that a decrease in the travel speed produces a decrease in the process efficiency. The arc efficiency essentially remains constant with any change in tip vertex angle.

Giedt et al [2] investigated the influence of duty cycle on arc efficiency. This duty cycle differs from conventional duty cycle term and is defined as the ratio of pulse time to cycle time. For pulsed TIG, the arc efficiency remains relatively constant for the changes in duty cycle and average current.

In the present work, investigations have been carried out with the help of water cooled copper block and the heat transferred to the block was collected through flowing water in a calorimetric setup. The TIG arc efficiency was measured, based on the ratio of heat collected in the calorimetric setup and the total arc heat i.e. energy input.

EXPERIMENTAL PROCEDURE

A water cooled work piece and a calorimetric setup was fabricated for experimentation so that heat collected by the work piece may be measured.

Stainless steel sheet of thickness 1 mm was used to fabricate a calorimeter of dimension 450x400x250 mm. Stainless steel was used because of its corrosion resistance and lower thermal conductivity. Water flowing through the copper box was collected in this calorimeter during the course of experimentation. A 25 mm thick thermocol was pasted as an insulator on all the sides of calorimeter. Water cooled welding torch was mounted on a clamping device to obtain a constant arc length. Argon was used as shielding gas. Before starting the experiments, the welding variables were adjusted and then arc was struck with the help of a carbon electrode between the copper box and 4 mm tungsten electrode. Simultaneously, water was made to flow through copper box into the calorimeter. After 120 seconds, arc was extinguished and water flow was stopped. Subsequently, the temperature of the water collected in the calorimeter, was measured. height of the water was also measured to calculate the mass flow rate. For each set, three observations were taken and average values have been recorded.

The welding variables were selected as follows :

(i) **For Electrode Negative :**

Current - 50 to 300 A (with a gap of 50 A)

Gas flow rate - 6 to 15 lit min^{-1} (with a gap of 3 lit min^{-1})

Arc length - 10 & 15 to 24 mm (with a gap of 3 mm)

Torch angle - 0 to 40° (with a gap of 20°)

(ii) **For Electrode Positive :**

Current - 30 to 70 A (with a gap of 20 A)

Gas Flow rate - 6 to 15 lit min^{-1} (with a gap of 3 lit min^{-1})

Arc length - 10 & 15 to 24 mm (with a gap of 3 mm)

Torch angle - 0 to 40° (with a gap of 20°)

Beyond 70 A current, it was not possible to do experimentation as electrode tip was getting damaged very soon and electrode was also overheated with positive polarity.

RESULTS

Influence of welding current

Figs. 1 and 2 show the influence of welding current on arc efficiency at different torch angles. From these figures it can be observed that the arc efficiency decreases with the increase in welding current for different torch angles as well as for both the polarities.

Influence of arc length

The arc efficiency decreases with the increase in the arc length for both the polarities. However, it has been observed that the arc efficiencies are lower with the positive polarity as compared to negative polarity over the entire range of arc lengths. **Fig. 3** shows the representative case where the comparison of arc efficiencies is given at different arc lengths for both the polarities at 50 A current for zero torch angle.

Influence of torch angle

Torch angle upto 20° from vertical axis does not seem to have appreciable influence on the arc efficiency with the increasing current for electrode negative. However, arc effi-

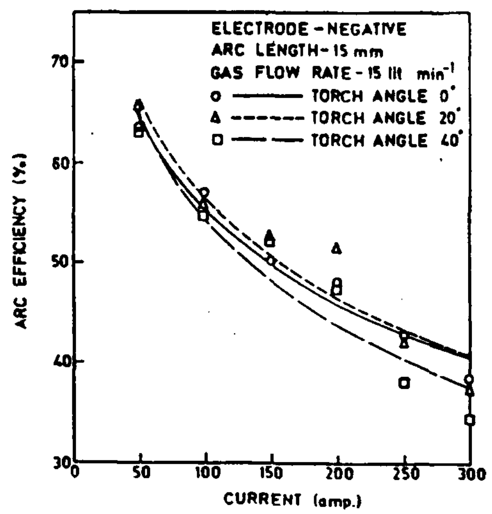

Fig. 1 : Arc Efficiency Vs Current at Electrode Negative

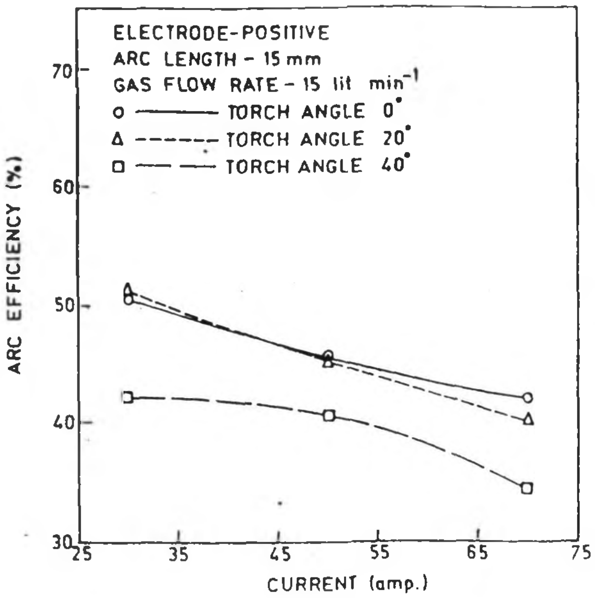

Fig. 2 : Arc Efficiency Vs Current at Electrode Positive

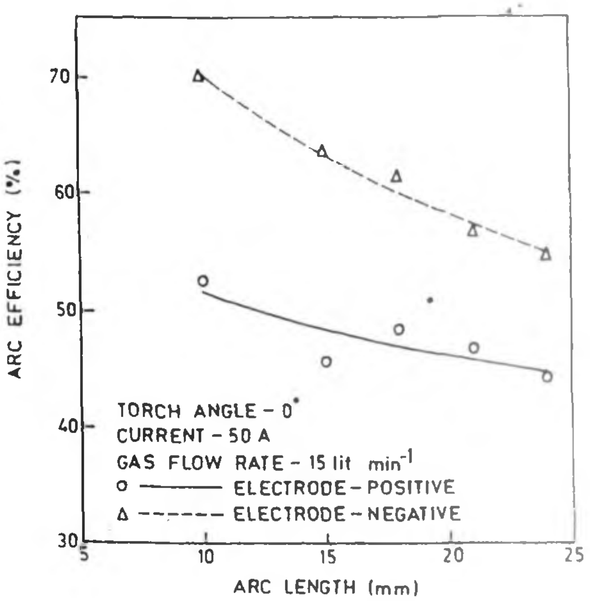

Fig. 3 : Arc Efficiency Vs Arc Length at both Polarities

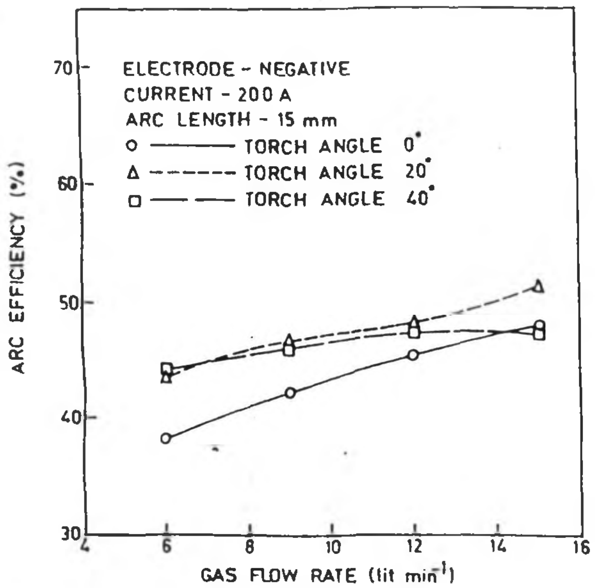

Fig. 4 : Arc Efficiency Vs Gas Flow Rate at 200A Current

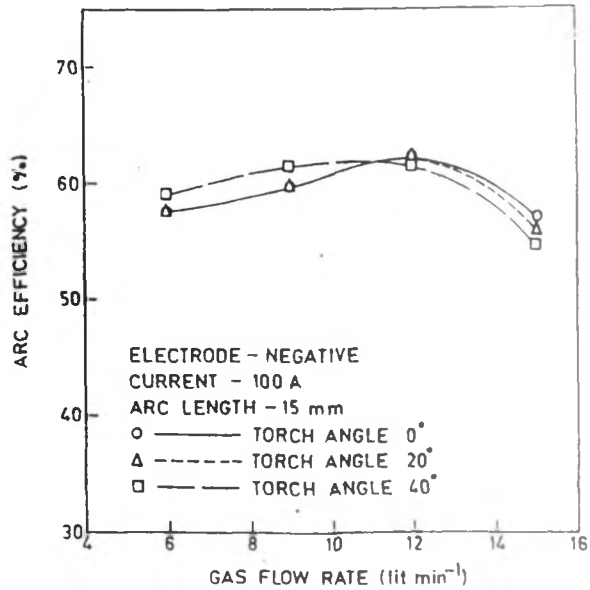

Fig. 5 : Arc Efficiency Vs Gas Flow Rate 100A Current

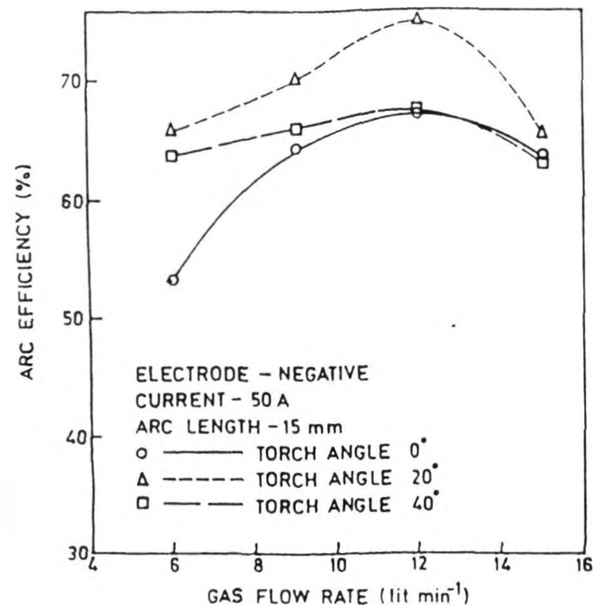

Fig. 6 : Arc Efficie· ·y Vs Gas Flow Rate at 50A Current

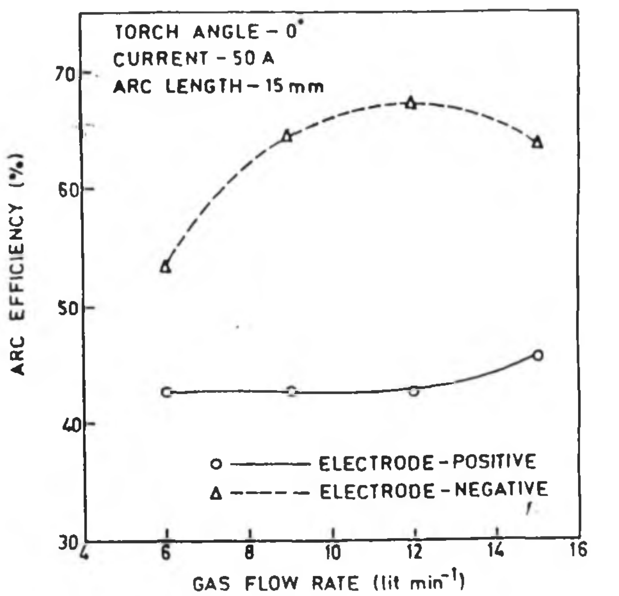

Fig. 7 : Arc Efficiency Vs Gas Flow Rate at both Polarities

ciency goes down by reasonable amount with electrode positive if torch angle is increased to 40° (Fig. 2).

Torch angle may influence the efficiencies if either gas flow rate is changed or arc length is varied in both the polarities, but no definite trend has been obtained with torch angle.

Influence of gas flow rate

Fig. 4 depicts the influence of gas flow rate on arc efficiency for electrode negative at 200 A. The efficiency generally increases with the increase in gas flow rate for all torch angles. However, for 100 and 50 A current levels (**Figs. 5 and 6**) efficiency increases with increase in the gas flow rate but beyond 12 lit min^{-1} flow rate, the efficiency suddenly decreases for all the three torch angles.

For electrode positive, at 50 A current level, the efficiencies are found to have no definite trend with gas flow rate except for 20° torch angle, where it first increases with the increase in gas flow rate and then decreases.

It has been observed that normally efficiencies are higher for low current levels (except for gas flow rate of 6 lit min^{-1}) over the entire range of investigation of gas flow rate with negative polarity.

Influence of electrode polarity

As stated earlier the electrode polarity appreciably influences the arc efficiency and negative electrode polarity invariably leads to relatively higher efficiencies than the positive polarity (**Figs. 3 and 7**). With positive polarity, except for current variation where the efficiency decreases with the increase in current, no definite or appreciable influence is noticed on arc efficiency with the variation of either arc length or gas flow rate.

DISCUSSIONS

The decrease in the arc efficiency with increase in welding current is due to the increased losses from the arc envelope owing to the fact that as current increases, the temperature isotherms are widened perpendicular to the axis of arc resulting in larger arc cross section and consequently larger surface losing heat to the atmosphere.

Similarly, with the increase in arc length the total heat conducting surface increases resulting in higher arc energy losse to the atmosphere thus reducing arc efficiency with increase in arc length while other conditions remaining the same.

Again, when the torch angle of arc is increased, keeping the vertical distance between the electrode tip and the work piece constant, the effective arc length is increased resulting in larger surface area losing higher arc energy into the atmosphere and hence reducing arc efficiency.

When the gas flow rate is low the shielding of the arc is not effective and external gases are partly mixed in the arc atmosphere. These gases conduct away heat from arc envelope at a faster rate due to their higher thermal conductivity, leading to higher arc energy losses and hence lower arc efficiency.

With increasing flow rate, the fraction of external gases involved in arc atmosphere reduces, thus increasing the arc efficiency. Once a flow rate which provides effective shielding is reached, any increase in flow rate, increasing the velocity of gas (as the area of cross-section of nozzle is same) will increase the cooling of arc envelope, resulting in higher losses and hence decrease in the arc efficiency.

The optimum flow rate needed to give effective shielding increases with the increase in current and that is why no reduction in arc efficiency is found, even up to gas flow rate of 15 lit min^{-1}, when the arc current is 200 A. It is expected that a further increase of gas flow rate is likely to bring down the arc efficiency.

CONCLUSIONS

The arc efficiency decreases with the increase in welding current and arc length for both positive and negative polarities. There is no definite trend of variation of arc efficiency with gas flow rate, however, it influences the efficiency appreciably in some cases depending upon the welding parameters. Torch angle also influences the arc efficiency but again no definite trend could be observed except for the variation of current where 40° torch angle generally reduces the efficiency. Positive polarity invariably leads to appreciably lower efficiency as compared to negative polarity.

REFERENCES

1. Weld Thermal Efficiency of the GTAW Process, Welding Journal, Vol. 54(1), 1975, pp 28s to 32a.
2. Giedt, W.H., et al, GTA Welding Efficiency : Calorimetric and Temperature Field Measurement, Welding Journal, Vol. 68(1), 1989, pp 28s to 32s.
3. Lancaster, J.F., Physics of Welding. Pergamon Press, U.K., 1984.
4. Lancaster, J.F., Energy Distribution in Argon-Shielded Welding Arcs, British Welding Journal Vol. 1(8), 1954, pp 412 to 426.
5. Apps, R.L. and Milner, D.R., Heat Flow in Argon-Arc Welding. British Welding Journal, Vol. 2(9), 1955, pp 475 to 485.
6. Ghent, H.W., et al, Arc Efficiency in TIG Welds, Proceedings of Conference on Arc Physics and Weld Pool Behaviour, The Welding Institute, Cambridge, 1979.
7. Morris, A.D., and Gore, W.C., Analysis of the Direct Current Arc. Welding Journal Vol. 35(3), 1956, pp 153s to 160s.
8. Wilkinson, J.B., Milner, D.R., Heat Transfer From Arc. British Welding Journal, Vol. 7(2), 1960, pp 115 to 128.
9. Anon, Improving the Capabilities of the TIG Processes, Welding and Metal Fabrication, July, 1992, PP 34 to 36.
10. Fuerschbach, P.W. and Knorovsky, G.A., A study of Melting Efficiency in Plasma Arc and Gas Tungsten Arc Welding, Welding Journal, Vol 70(11), 1991, pp 287s to 297s.

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Regards,

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