ARC EFFICIENCY DURING PULSE TIG WELDING OF ALUMINIUM AND MILD STEEL

S. R. Gupta* and T.D.S. Vamsidhar**

*Professor **Graduate student

Welding Research Laboratory
Department of Mechanical and Industrial Engineering
University of Roorkee, Roorkee, India

ABSTRACT

To study the influence of welding parameters on arc efficiency during pulse TIG welding of aluminiurn and mild steel, the heat loss through radiation was collected from a coil placed around the arc and the heat loss from torch was measured through the water employed for its cooling. 'The investigations revealed that the welding parameters and material of the work piece have definite influence on TIG arc efficiency. Higher efficiencies are associated with the welding of aluminium as compared to that of mild steel.

INTRODUCTION

In a fusion butt weld a molten pool is maintained across the abutting edges to be joined and moved along the seam to complete a weld. The source of heat for the pool is the power dissipated in the immediate area of the arc. Of this only a part enters the weld pool, the remainder being dissipated in the arc column and at the electrode. From the heat entering the weld pool, some is lost by conduction to the metal plates and some lost by radiation or convection from the pool. Only the heat used in melting the weld bead is usefully utilised. It is obvious that a fraction of energy dissipated from the arc enters into the work piece and remaining is lost in conduction, radiation and convection. Hence the idea of arc efficiency comes into existence. Arc efficiency is defined as the ratio of total energy that enters into the work piece to the total energy input to the welding arc [1,2].

To find out the arc efficiency a simple calorimeter is used to measure losses, which occur during welding for a unit length of weld [3].

Arc efficiency values have usually been determined by requiring an agreement between the predicted and measured temperature histories near the molten zone for a depth or width of the molten zone. Published values vary from 21 to 80%. This large range has generated interest in the development of methods for measuring the energy transferred during welding rather than determining this from welding temperatures [4,5].

The above relationship is important since most heat transfer expressions derived for predicting weld temperature distribution and cooling rates depend upon the insertion of an efficiency term for their solution. If the transfer efficiency of total energy input is not considered, the energy term does not represent the actual energy entering the plate which results into wrong estimation of heating and cooling behaviour and hence metallurgical response will not result in desired mechanical properties [6].

Fuerschbach et.al. [7] defined the ratio of peak current time to the cycle time as duty cycle and found that the arc efficiency remains relatively constant for large changes in the duty cycle which correspond to substantial change in the peak current levels. Therefore, arc efficiency seems to be independent of duty cycle as well as average current. Further, it has also been reported that for continuous current welds with the increasing welding

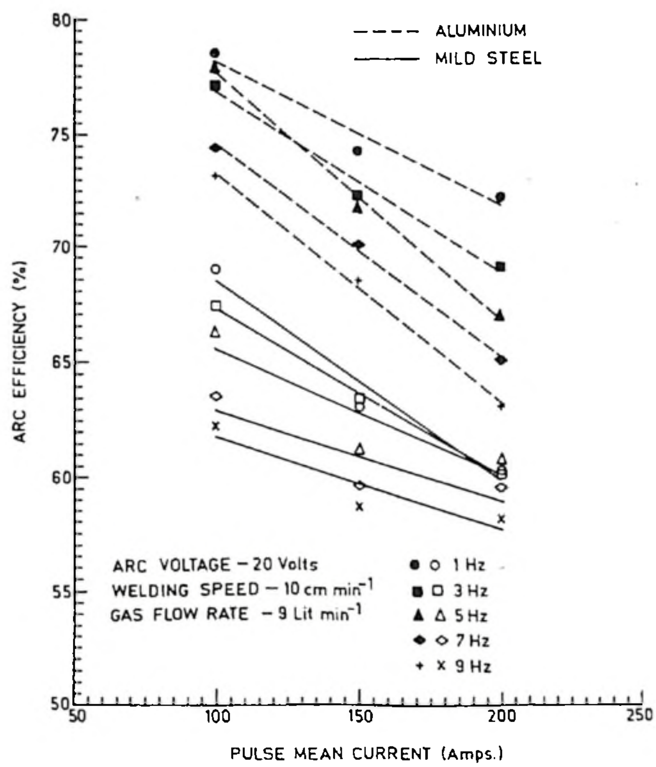

Fig.1: Influence of pulse mean current on arc efficiency for various pulse frequencies for welding of aluminium and mild steel

speeds, TIG process exhibits a nearly constant level of arc efficiency with the exception of very slow travel speeds where a slight decrease is observed.

Experiments were carried out to study the influence of power input on the arc efficiency and it has been reported that the efficiency remains almost constant over a wide range of power inputs [8]. Further, the tip vertex angle of the electrode does not bring in any appreciable change in arc efficiency [9].

EXPERIMENTAL PROCEDURE

During welding for evaluating pulsed TIG arc efficiencies, the heat lost by radiation and part of convective losses were collected through copper coil placed around the arc and cathode heat loss through the water flowing for cooling of TIG torch i.e. the tungsten electrode. The water-cooled copper coil was clamped firmly on the torch.

The water flowing through the cooling coil and the torch were collected separately in different calorimeters to determine the heat collected as losses.

Aluminium and mild steel were taken as work pieces for welding during the investigations to determine the influence of nature of work piece material on arc efficiencies. Welding was carried out both on properly cleaned aluminium and mild steel plates, which were clamped on the worktable. An electrode EWTh2 of 4 mm was used. Two observations were made for each set of parameters and average was taken for calculation of arc efficiency.

The welding variables were selected as follows :

Electrode Polarity	**Negative**
Back-ground Current	60-160 A
Pulse Current	140-240 A
Pulse Frequency	1-9 Hz
Gas Flow Rate	6,9,12,15 Lit min^{-1}
Arc Voltage	20,23,27,30 Welding
Speed	10,15,20, 25cm min^{-1}

For calculating the arc efficiency, heat input i.e. the actual amount of heat going to the work piece was calculated by substracting the heat losses (i) to cool the tungsten electrode and torch, described as conduction loss and (ii) the amount of heat carried by the water flowing through copper cooling coil collected in calorimeter described as radiation and a part of convection losses from energy input to the arc.

The ratio of the heat input to the work piece calculated as above to the energy input to the arc was taken as arc efficiency.

Arc efficiencies have been calculated assuming the major heat losses through radiation and from the electrode, which is cathode. Other heat losses such as heat lost through flow of shielding gas (convective losses) etc. are assumed to be negligible though they are bound to exist and may sometimes be substantial. It is expected that some part of convective heat will be absorbed by the water flowing through copper coil.

RESULTS

Figure 1 gives the influence of pulse mean current on arc efficiency as a representative case. From the figure it can be observed that the arc efficiency decreases with the increase in mean current at all the observed frequencies for both aluminium and mild steel as work pieces. However, efficiencies associated while welding of aluminium are higher than those obtained with mild steel.

Similar to the influence of mean current, the arc efficiency decreases, if either the base current is increased or the pulse current is increased. This can be observed in figures 2 and 3.

Figure 4 depicts the influence of arc voltage on the arc efficiency. From the figure, it can be observed that the arc efficiency decreases with the increase in the arc voltage i.e. arc length. This trend remains unchanged for both mild steel and aluminium, even if pulse frequency is changed.

Figure 5 gives the influence of pulse frequency on arc efficiencies. The arc efficiency decreases with the increase in the pulse frequency. This trend remains unchanged if arc voltage is changed for the welding of both the selected materials as work piece. However, similar to the influence of mean current the efficiencies associated while welding of aluminium are higher as compared to those, which are obtained with the mild steel.

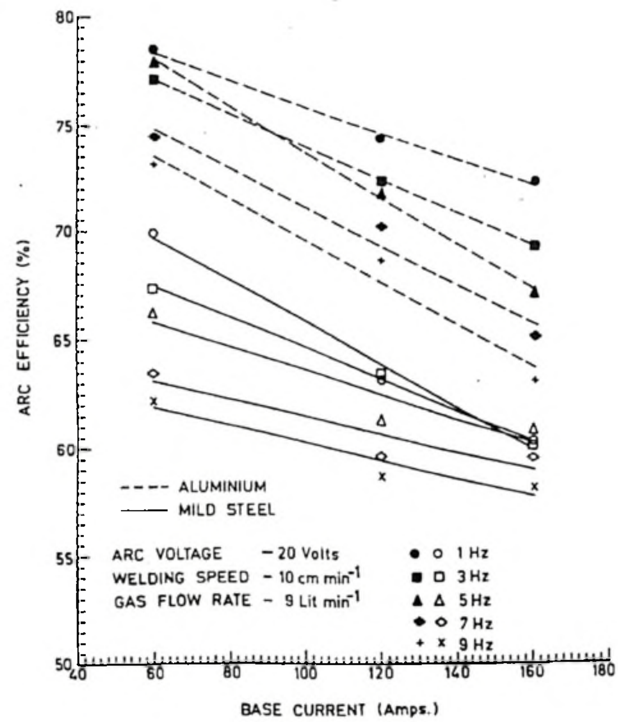

Fig.2: Influence of base current on arc efficiency for various pulse frequencies for welding of aluminium and mild steel.

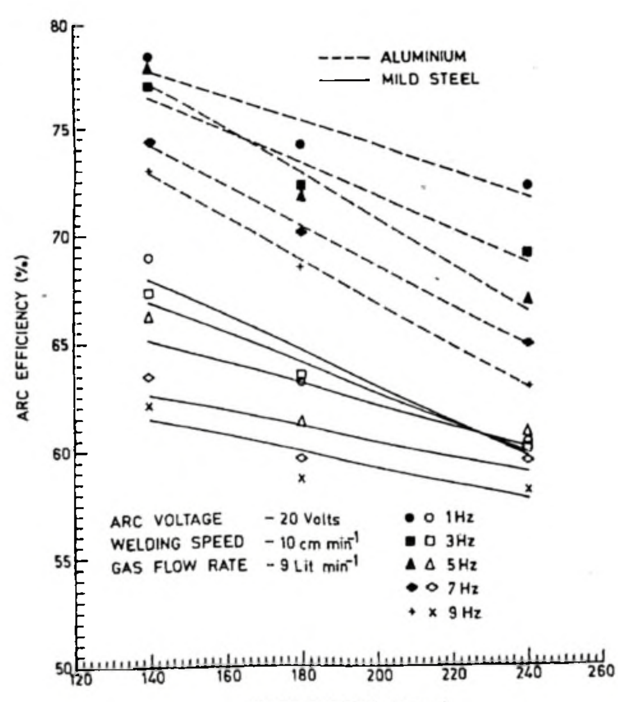

Fig.3: Influence of pulse current on arc efficiency for various pulse frequencies for welding of aluminium and mild steel.

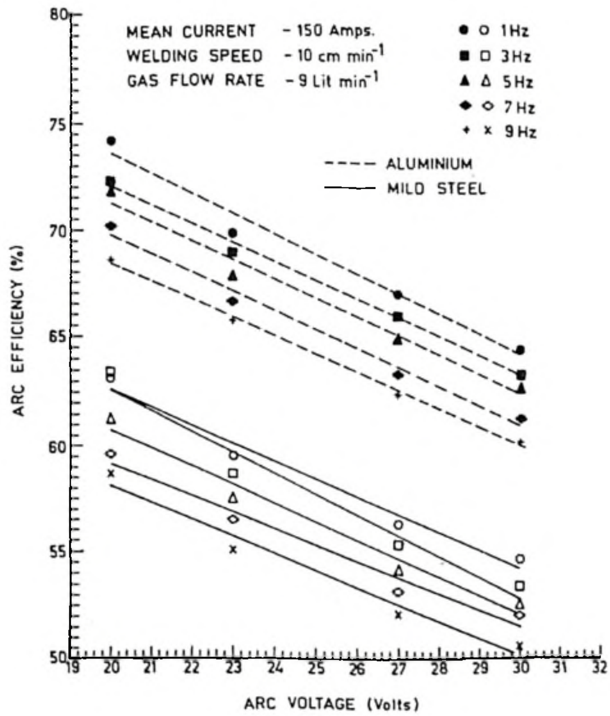

Fig.4: Influence of arc voltage on arc efficiency for various pulse frequencies for welding of aluminium and mild steel.

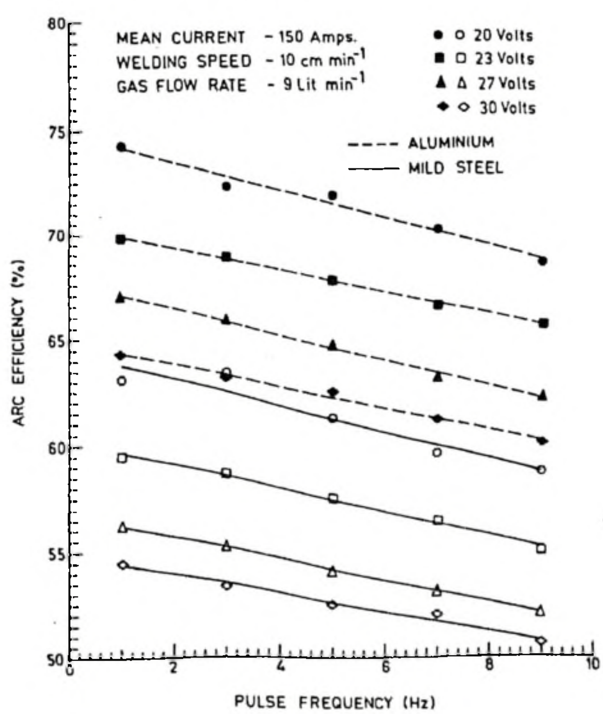

Fig.5: Influence of pulse frequency on arc efficiency for arc volatges frequencies for welding of aluminium and mild steel.

Figure 6 gives the influence of welding speed on arc efficiency at 150 amperes mean current for different pulse frequencies. From the figure, it can be observed that the arc efficiency increases with the increase in welding speed while welding both aluminium and mild steel. However, again the arc efficiencies associated with aluminium welding are higher as compared to the welding of mild steel. This trend remains unaffected with the variation of pulse frequency.

The variation of arc efficiency with the argon gas flow rate has been depicted in figure 7. For 150 amperes mean current, it is observed that the arc efficiency increases generally up to 12 Lit min^{-1} of gas flow rate and then decreases with the increase in gas flow rate i.e. 15 Lit min^{-1}. This variation practically remains unaffected with change in pulse frequency.

DISCUSSION

The reduction in the arc efficiency with the increase in the mean current can be attributed to the constant arc length. When the current is increased then with argon gas shielding the arc isotherms widen which in turn lead to increased arc surface area and thus more radiation and convection losses. Further the increased current will increase the resistive heating of the tungsten electrode which leads to higher heat losses through electrode which is collected through the torch cooling water. The combined effect of above two phenomena leads to reduced fraction of heat going to the work piece resulting in reduced efficiencies.

If either the pulse current or the base current is increased then ultimately the mean current will increase which leads to increased heat losses thus reduced arc efficiency.

Increase in the arc voltage i.e. arc gap increases the arc length, which will increase the conical surface of the arc area and thus higher heat losses to the atmosphere will occur through radiation and convection. This will again result into reduced efficiencies.

With the increase in pulse frequency, the pulsation effect increases, causing turbulence in the gases surrounding the arc, which may probably take higher fraction of convection heat thus causing increased heat losses and so reduced efficiencies.

With the change in the welding speed it has been reported that the arc efficiency remains unaffected. However, in the present investigations it has been found that the arc efficiency increases with the increase in the travel speed. Perhaps this may be due to the reason that at slower travel speed the work piece has already attained a certain temperature due to conduction of heat and thus the heat absorbing capacity of the material is reduced. If the travel speed is increased then the heat from the area already welded, which is transmitted to the next point through conduction is reduced and the heat absorbing capacity of the new point where the arc is concentrated increases. This may increase the arc efficiency.

The smaller gas flow rates around 6 Lit min^{-1} may not be sufficient to provide proper shielding to the arc and

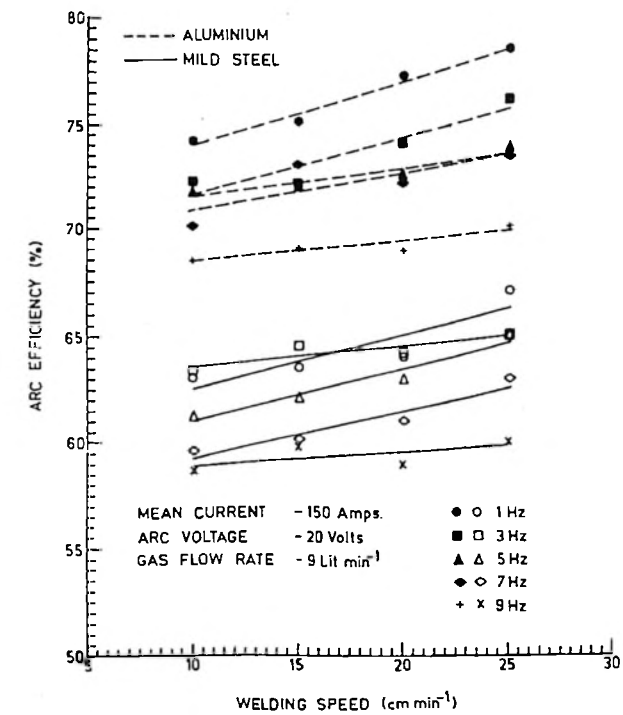

Fig.6: Influence of welding speed on arc efficiency for various pulse frequencies for welding of aluminium and mild steel.

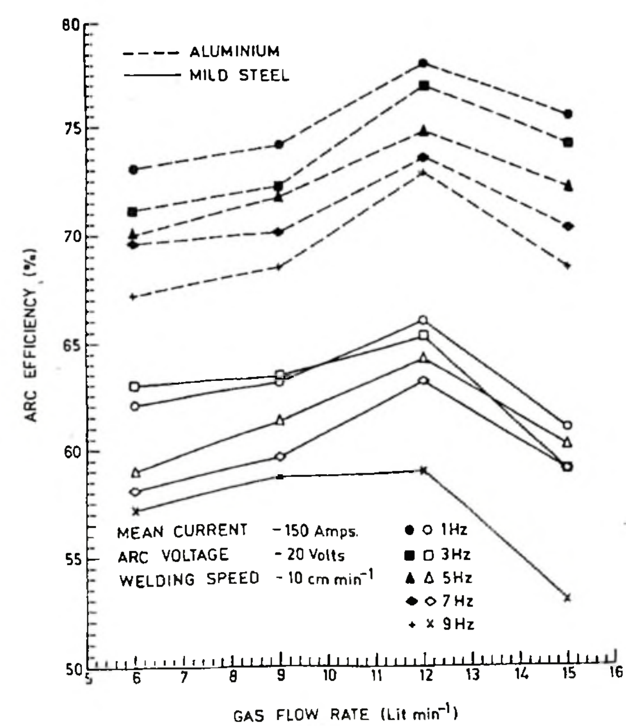

Fig.7: Influence of gas flow rate on arc efficiency for various pulse frequencies for welding of aluminium and mild steel.

also the formation of proper plasma envelope. This will yield higher heat losses and thus lower efficiencies. As soon as gas flow rates are increased, proper shielding envelope is obtained which will reduce the heat losses due to radiation because of lower thermal conductivity of argon. However, beyond a particular gas flow rate the turbulence may start and it may lead again to improper shielding and disturbed arc envelope leading to higher heat losses resulting into reduction in the arc efficiency.

For the similar welding parameters, the arc efficiency associated with aluminium is higher as compared to the value obtained while welding of mild steel. Although it has been reported that the heat losses from the surface of the work piece will be dependent on brightness of the surface, but that may be valid for high melting temperature metals. In case of aluminium the melting temperature is very low and thermal conductivity is very high as compared to mild steel. So the heat absorbed will be relatively higher in case of aluminium as compared to mild steel inspite of the fact that aluminium is having bright surface. This may be the reason for higher efficiencies with aluminium as compared to the mild steel as work piece during welding.

CONCLUSIONS

The arc efficiency decreases with the increase in mean current, pulse current, base current, pulse frequency and arc voltage i.e. arc length during welding of both mild steel and aluminium. With the gas flow rate, efficiency increases up to certain level and then slightly decreases. With the increase in the welding speed, generally the arc efficiencies are found to increase. Higher efficiencies are obtained while pulsed TIG welding of aluminium as compared to mild steel for similar set of parameters.

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