Investigations on the Performance Characteristics of GMAW Power Sources

Rohith Joseph, M. Salai Selva Rani^, K. Devakumaran*, P. R. Venkateswaran*#,
JJ College of Engineering and Technology, Tiruchirappalli
^Sastra University, Thanjavur
*Welding Research Institute, Bharat Heavy Electricals Limited, Tiruchirappalli
prveswaran@bheltry.co.in#, devakumaran@bheltry.co.in
corresponding author

ABSTRACT

Performance evaluation of the transistorized and invertor type GMAW power source under various modes of operations as continuous, pulsed and dual pulse is discussed in this paper. The performance of the power source has been evaluated with respect to the variation of current and voltage under different wire feed rates. The data is analyzed for identification of optimum working range of current and voltage with reference to less spatter, porosity and good weld bead appearance. Based on the results, the choice of the GMAW power sources for different applications is established. This study provides wider scope for introduction of automation of welding.

Keywords: GMAW, dual pulse, transistorized, inverters and power source characteristics.

1.0 INTRODUCTION

Power Source construction plays an important role in deciding the weld performance and quality [1, 2]. In GMAW process, this assumes greater significance because the wire feed unit integrated with GMAW power source [1]. The schematic diagram of the GMAW process setup has been shown in **Fig. 1.** In general, welding power sources can be classified based on construction into different types as thyristor, transistorised and inverter type power sources. They differ in the mode of operation and their ability to differentially generate the output. Due to ease of control, faster response and waveform control options, the transistorized and inverter type of power sources used widely for GMAW process. They also provide for better control of spatter and more energy transfer efficiency to the work piece. In case of transistorized power sources, construction is based on an in-phase regulator utilising paralleled connected banks of small power transistors serving as variable load resistors. Whereas, Inverter technology transform input signal to high speed operating frequency pulses using transistor switches [2]. Operating at high frequencies gives direct benefits in the form of portability, lesser weight, arc stability, faster response times, energy efficient and reduced running cost. Indirect benefits are in form of reduction in labour and transportation cost. However, realisation of these benefits can be derived only when the power sources are operated at optimum range of welding parameters [1-3]. If the welding parameters are not optimized, then it will give rise to many quality problems like improper bead profile, porosity, undercut, etc., Hence, investigation into the behaviour of welding power sources to determine the range of operational values of arc voltage and welding current is therefore of importance.

Establishing the optimal parameter range of arc voltage and welding current of Transistorized and Inverter types of GMAW power sources is carried out in this paper. Wire Feed rate is considered as the reference parameter against which the effect of arc voltage and welding current are studied. The paper is divided into the following sections: Section 2 describes the experimental setup followed by Section 3 which details the results and inferences from a conventional GMAW power source. Section 4 discusses the investigations from P – GMAW followed by Section 5 on DP – GMAW process. In all these modes of processes, both transistorized and inverter type welding power sources are considered for evaluation. The results are correlated and the summary is inferred in the conclusion.

2.0 EXPERIMENTAL SETUP

Transistorised and Inverter types of GMAW power sources are considered for present investigation. Both the power sources are able to operate at three different modes of operations as conventional GMAW (GMAW), pulsed current GMAW (P-GMAW) and, dual pulse GMAW (DP-GMAW) under synergic mode of operating condition. Schematic diagram of GMAW set up has been shown in **Fig.1**.

To carry out the performance characteristics of both the power sources, weld bead deposition on 12 mm thick low carbon steel plate is considered for experimentation. The welding conditions used are listed in **Table 1.**

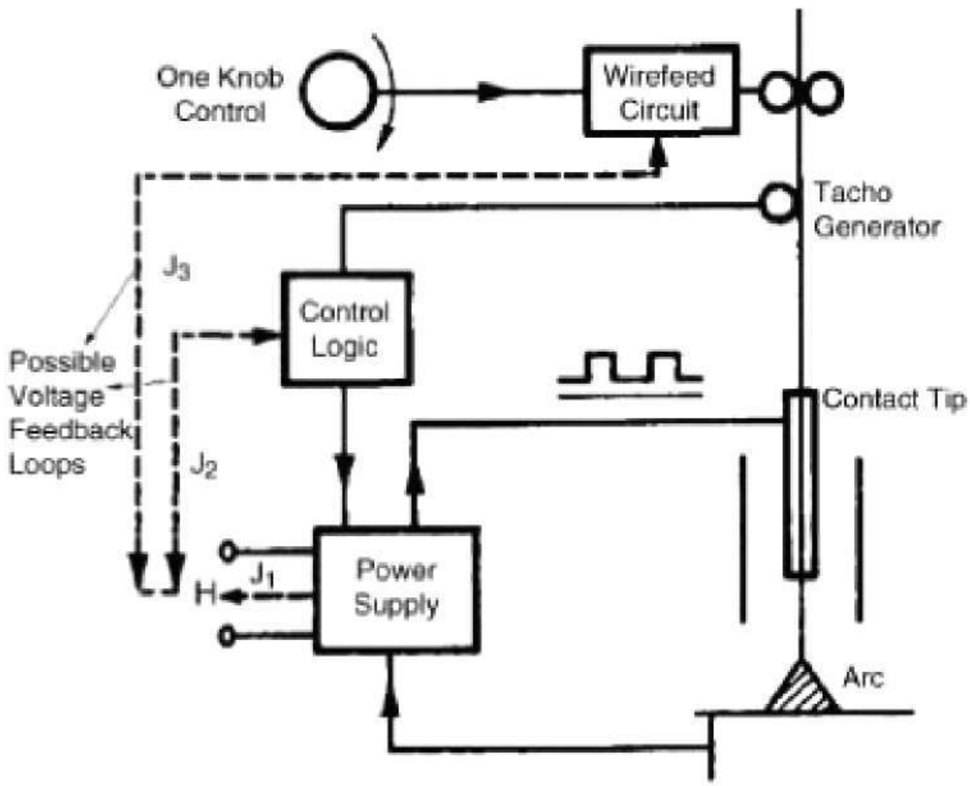


Fig 1. Schematic diagram of GMAW setup

Table 1 : GMA welding conditions used to study the various power source characteristics

Control mode	**Synergic Mode On**
Electrode Diameter & Specification	1.2 mm & AWS/SFA 5.18ER-70S-6
Weld Bead Length	450-500mm
Shielding Gas	80%Ar+20%CO_2
Gas Flow Rate	18l/min
Distance Between Nozzle to Work Piece	14-15mm
Polarity	Direct Current Electrode Positive (DCEP)

The current is defined as welding current (I) in non-pulse GMAW and as mean current (Im) in Pulsed GMAW (P – GMAW) and Dual Pulse GMAW (DP-GMAW). During welding, the current and voltage were measured with the help of a digital meter having a least count of 0.1. To maintain reliability in the study for power source characteristics of different welding processes, experiments were carried out on three to four welds by recording 40 to 50 readings for each welding parameter and results are plotted statistically. However, the highest working range of the power source is not considered because at those current values, excessive heat and spatter makes the weld deposition practically impossible.

3.0 PERFORMANCE OF CONVENTIONAL GMAW POWER SOURCES

The GMA welding power source is subjected to varying wire feed rates in the operating arc voltage (V) and welding current (I) region. The resulting V- I characteristics are observed in case of transistorized type GMAW power source is shown in **Fig. 2 (a).**

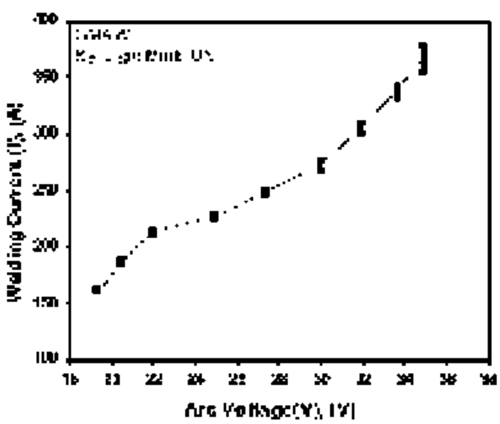


Fig. 2(a) V – I Characteristics

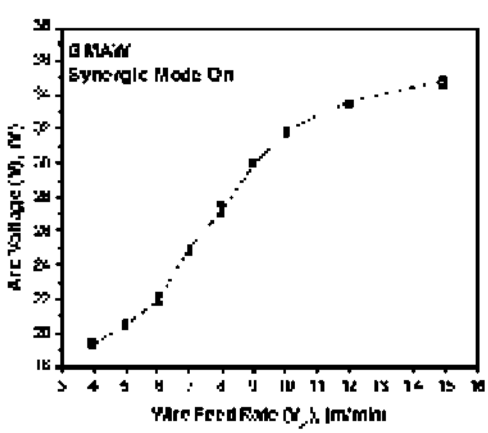


Fig. 2(b) WFR VS Arc Voltage

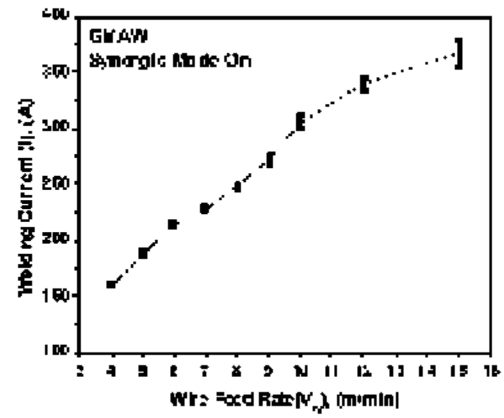


Fig. 2(c) WFR VS Welding current

Fig.2 : Output characteristics of Transistor type conventional GMAW power source.

The results show that beyond values of arc voltage and welding current of 24V and 230A respectively, there exist larger variations in the rated values of parameters. The threshold for this change in behavior is the transition in the type of transfer from globular to spray mode. The transition is largely identified by a change in the slope of the curve. As this transition happens, the values of rated parameters tend to deviate significantly. Such behaviour happens in case of transistorized GMAW because; the system may not restore arc length to set reference voltage by automatically modifying the burn off rate. The result of such deviation is the deterioration in weld quality as can be seen in **Figs. 3(a-f)**.

The effect of varying Wire Feed Rate (WFR) on arc voltage and welding current values are detailed in **Fig. 2(b)** and **Fig. 2(c)** respectively. From **Fig. 2 (b)**, two important conclusions are drawn: one, the input voltage from power source is proportional to WFR till 30V and then changes in WFR are minimal. Second, irrespective of the WFR, the deviations in the voltage settings are insignificant inferring that the voltage supplied is fully transferred for the WFR without much loss. In other words, a constant voltage characteristic with constant WFR ensures self-regulation of arc leading to better control of arc and metal transfer behavior.

It is also reported that in general, the WFR influences the welding current more than the welding voltage [2, 4]. From the **Fig. 2(c)** it is observed that, until the value of the rated current at 250A, there are no oscillations in the current to maintain a constant wire feed rate. But, the WFR greater than 9m/min, the current settings deviate up to 11% to maintain a self-regulation of arc. These deviations are primarily due to nonlinear relationship between welding current and resistance

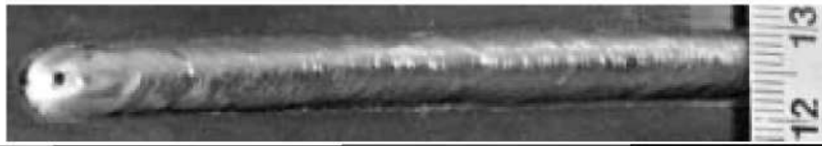
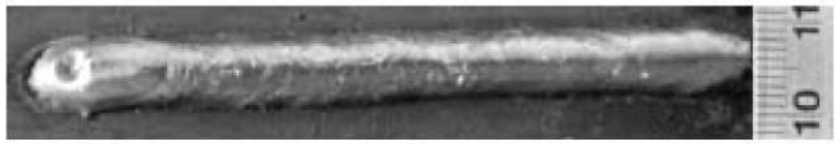
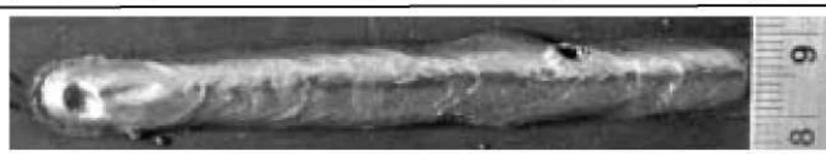
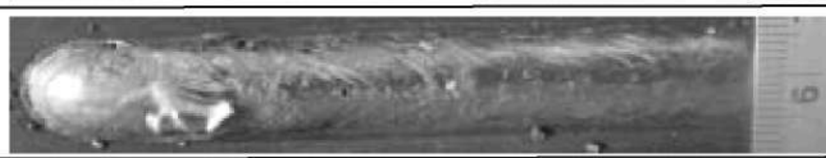
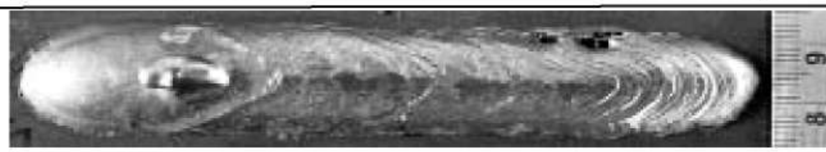
Fig. No.	WFR, m/min	Conventional GMAW process in Transistorised Power Source
3 (a)	4	
3 (b)	5	
3 (c)	6	
3 (d)	7	
3 (e)	8	
3 (f)	9	

Fig 3 : Surface appearance of weld bead using of Transistorized power source.

melting of wire results in changes in the weld quality as in **Fig. 3 (f)**. Thus, it is understood that the increase in wire feed rate brings with itself a large variation in the welding current resulting in defects. It is also verified from **Fig. 3** that at increased WFR, larger changes in the current settings create more of spatter and porosity. Due to transition current threshold, higher WFR witness larger variations in welding current resulting in higher occurrences of porosity and spatter. Hence, it may be prudent to operate the transistorized GMAW power source for arc voltage and WFR less than 30V and 9m/min respectively.

To explore into the requirement of higher WFR with spray mode metal transfer, the use of an inverter type GMAW power source is explored. It is verified from **Fig. 4** that higher current and voltage parameters do not fluctuate unreasonably at all levels of operating regions.

A more or less stable arc voltage and welding current is identified as the reason for the good results of the weld as in **Fig. 5**.

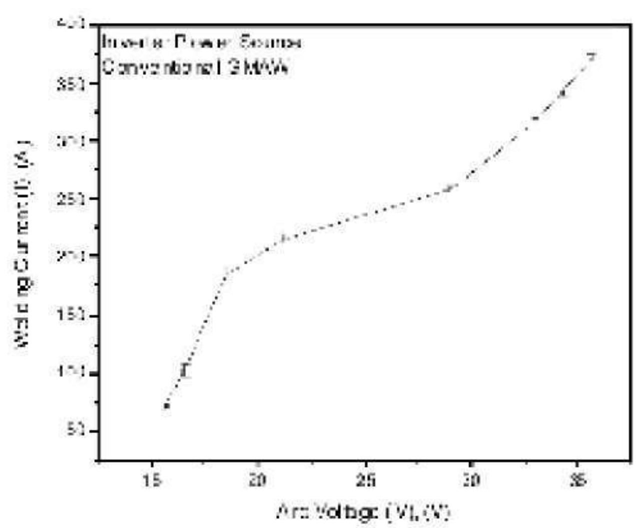


Fig. 4(a) V – I characteristics

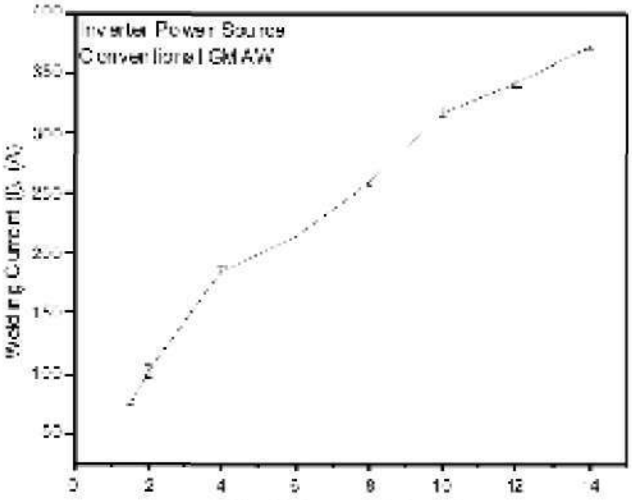


Fig. 4(b) WFR VS Welding Current

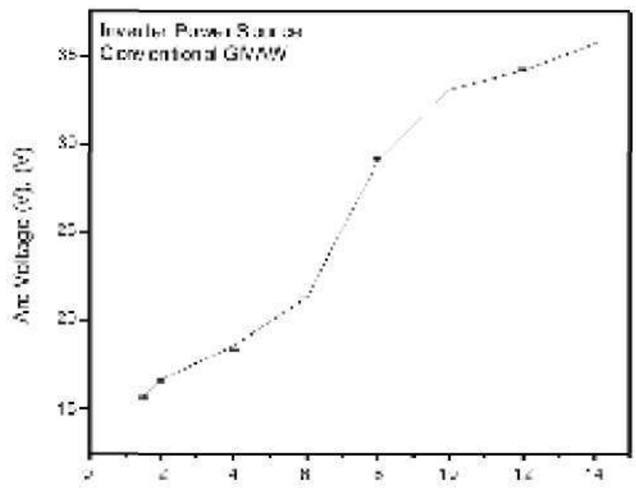


Fig. 4(c) WFR VS Arc Voltage

Fig. 4 : Output characteristics of Invertor type conventional GMAW power

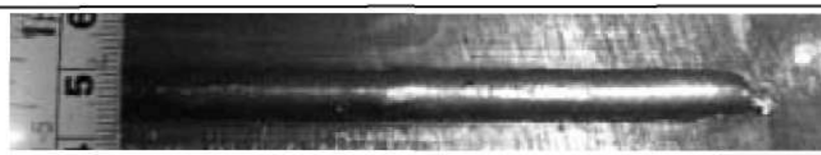
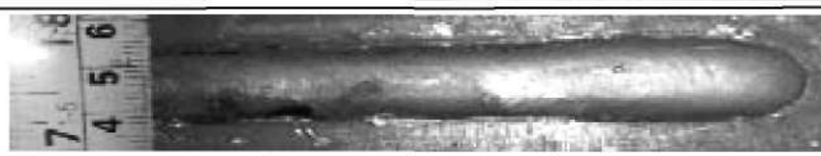
Fig. No.	WFR, m/min	Conventional GMAW process in Invertor Power Source
5 (a)	3	
5 (b)	5	
5 (c)	8	
5 (d)	10	

Fig 5 : Surface appearance of weld bead using of Inverter type power source.

It is observed from the V- I characteristics of **Fig. 4(a)** that there is a significant change in the relation between arc voltage and welding current dictated by the transition current threshold. Beyond the threshold, the V-I curve is steeper and initiates stable spray mode of metal transfer. Such behaviour happens in case of invertor type GMAW is microprocessor or microcontroller replaces traditional hard-wired systems for controlling, sequencing and timing of operations to achieve optimum output. In addition, modern days, the principle used for invertor type GMAW power source is convertor with high frequency transformer decoupling and three phase input without intermediate rectification [2]. Due to this principle the process efficiency of invertor type power source increased. This is also play the important role for obtaining good quality bead appearance. Based on the above, it infers that, the use of inverter type GMAW power source gives better arc length regulation control than transistorized GMAW power source. This is in agreement to the earlier literature shows that, the inverter type GMAW power source generate fewer spatters than thyristor type GMAW power source [2, 5].

4.0 PERFORMANCE OF P- GMAW POWER SOURCES

The pulsed current GMAW (P-GMAW) process has gathered a wide acceptance in weld fabrication of various ferrous and non-ferrous metals giving rise to improved weld quality. This is primarily because in P-GMAW process there is a distinct possibility of precisely controlled arc and metal transfer behaviour than that is available with the conventional GMAW process [6, 7, 8]. However, the wide acceptance of the process in fabrication is largely handicapped due to the criticality in the selection of pulse parameters [5, 7, 8]. In addition, in the modern day P-GMAW power sources the option of varying the pulse parameters to achieve the desired quality is not available with the user. It is often found that, different power source manufactures produce various combinations of pulse waveforms to meet desired quality of weld joint [7, 8]. But, proper utilization of pulse parameters in so many applications is not well defined with respect to the output characteristics of different type of P-GMAW power sources.

During welding the response to WFR, V and Im of transistorized P-GMAW power source has been shown in **Figures 6(a)** through **6(c)**. It is observed that, clear note of transition current does not appear **(Fig. 6 (a-c))**. This is because of the range of welding parameters used in P-GMAW always supposed to give spray mode of metal transfer at peak current (Ip) of the process.

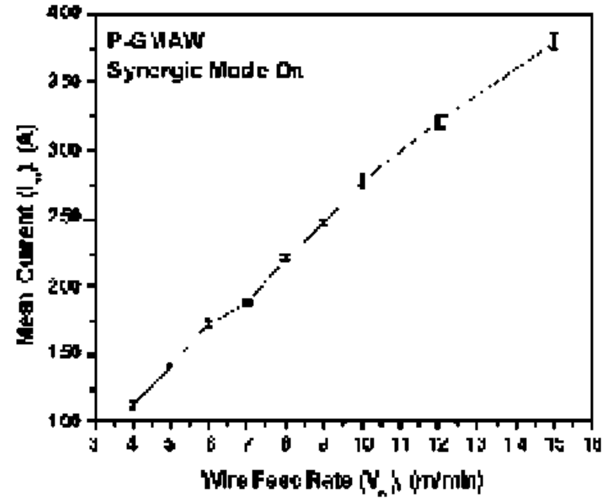


Fig. 6(b)WFR VS Arc Voltage

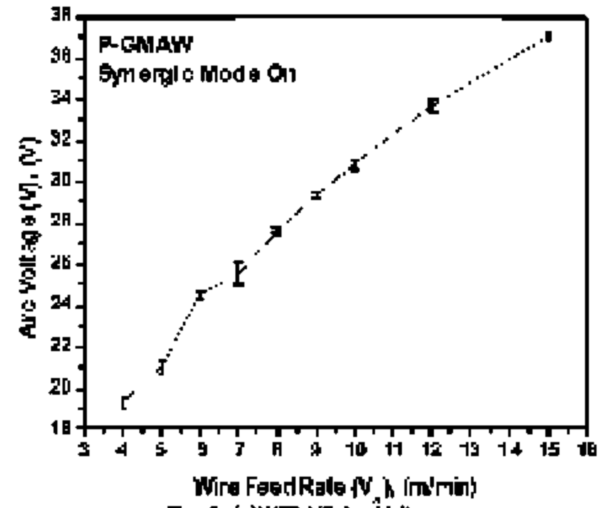


Fig. 6. (c)WFR VS Arc Voltage

Fig. 6 : Output characteristics of Transistor type P-GMAW power source.

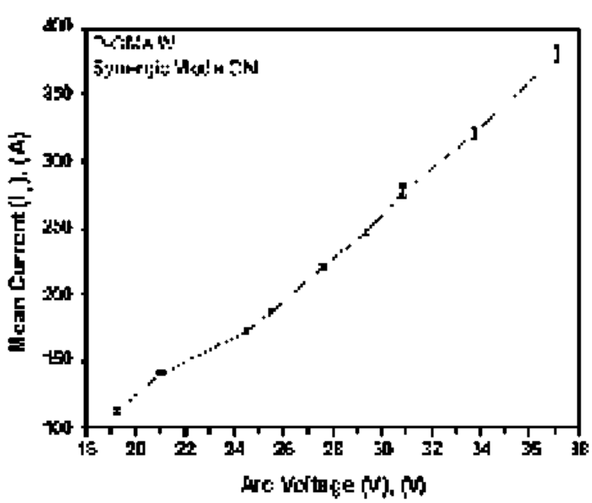


Fig. 6(a) V – I characteristics

Further, it is observed that, V-Im characteristics of transistorized P-GMAW shows insignificant deviation from the rated values than V-I characteristics of GMAW **(Fig. 2)**. However, the effect of deviation from the rated values is severe even for lower variations of V and Im. This could be verified from **Fig. 7(c, d and f)** which sees rampant porosity which in between them has a variation of only 0.2% difference in deviation.

Such a bead performance in P-GMAW primarily due to the fluctuation in arcing because of pulsed current. Therefore, it is inferred that, the precision control of weld bead quality in transistorized P-GMAW process under synergic mode of operation is critical.

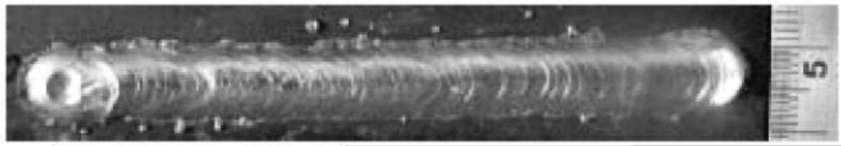
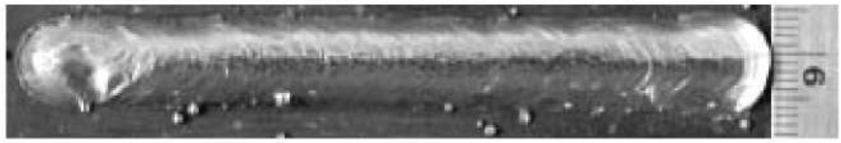
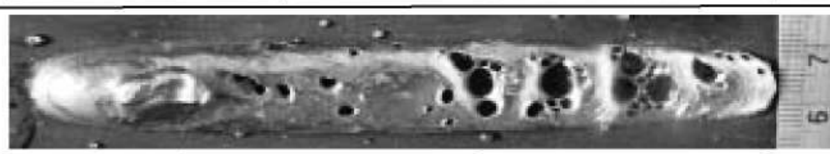
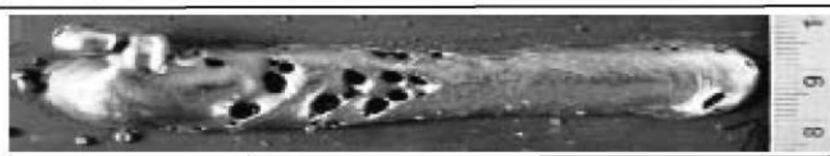
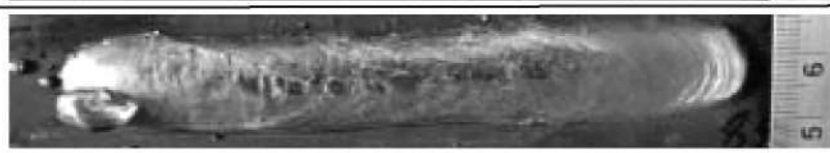
Fig. No.	WFR, m/min	P-GMAW in Transistorised Power Source
7 (a)	4	
7 (b)	5	
7 (c)	6	
7 (d)	7	
7 (e)	8	
7 (f)	9	

Fig 7 : Surface appearance of weld bead using of Transistorized power source

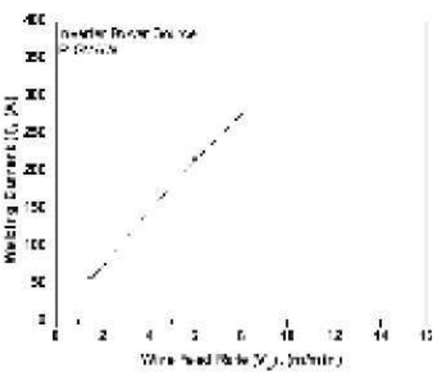


Fig 8(a) V – I characteristics

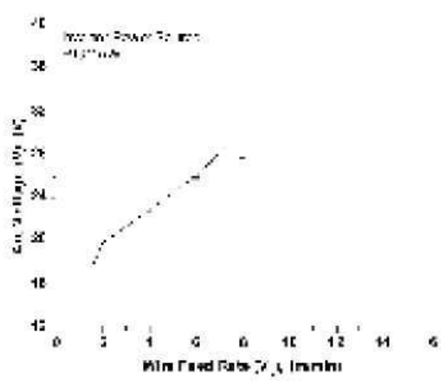


Fig. 8(b)WFR VS Arc Voltage

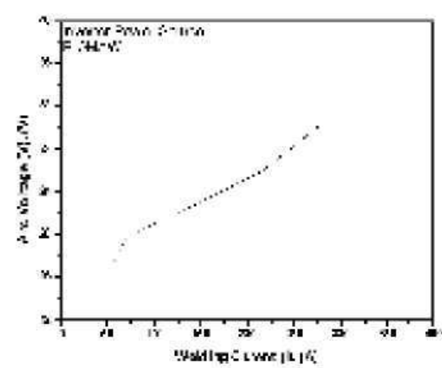


Fig. 8.(c)WFR VS Arc Voltage

Fig. 8 : Output characteristics of Invertor type P- GMAW power source.

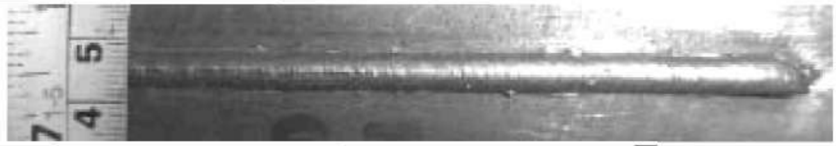
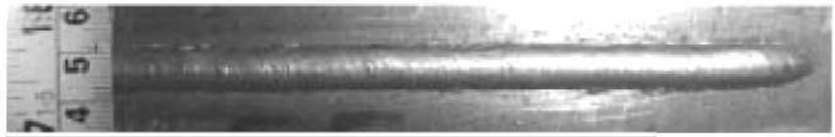
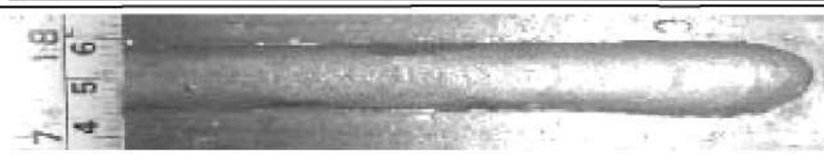
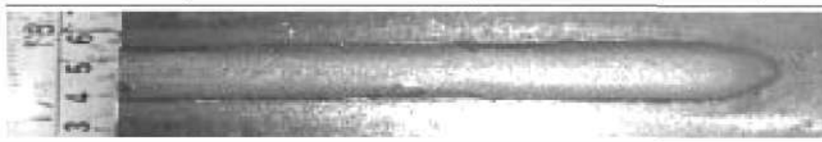
Fig. No.	WFR, m/min	P-GMAW in Invertor Power Source
9 (a)	3	
9 (b)	5	
9 (c)	8	
9 (d)	10	

Fig 9 : Surface appearance of weld bead using of Inverter P-GMAW power source.

The WFR, V and Im relationships of inverter type P-GMAW are shown in **Fig. 8 (a-c)** and its influence on weld bead appearance is shown in **Fig. 9 (a-d)**. In the line of earlier observation on performance characteristics of GMAW **(Fig. 3)** here also it is observed that, inverter type P-GMAW shows stable output characteristics and good weld bead appearance than that of the transistorized type P-GMAW.

Moreover, the energy transfer efficiency of invertor type power source is comparatively more than that of transistorized type power source [2]. Thus, in the line of earlier here also it is concluded that pulse waveform produced by inverter type GMAW power source gives stable arcing characteristics.

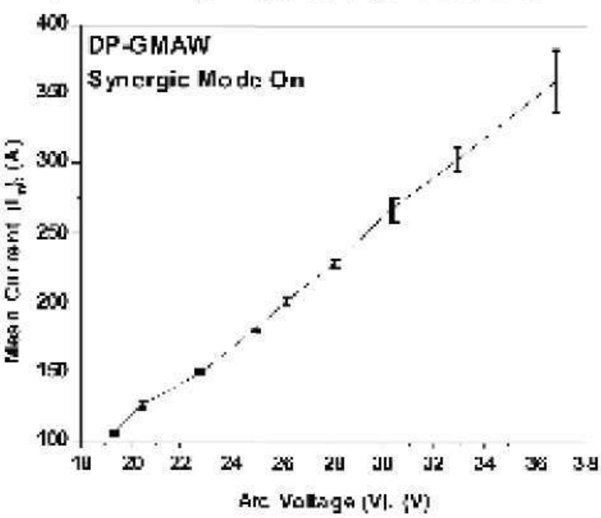


Fig. 10 (a)V – I characteristics

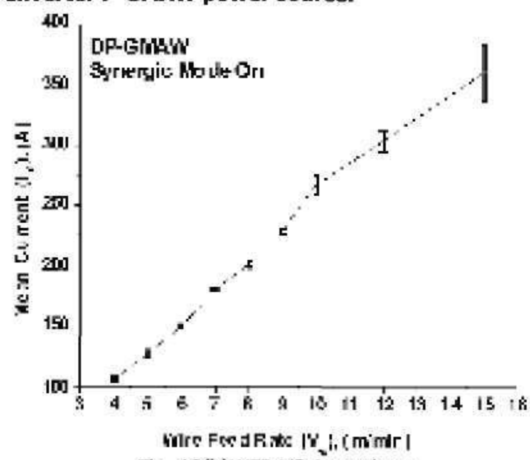


Fig. 10(b)WFR VS Arc Voltage

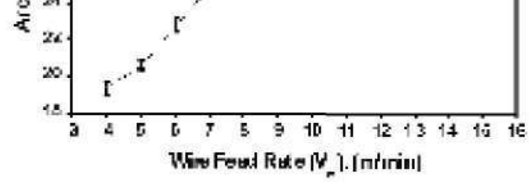


Fig. 10 (c)WFR VS Arc Voltage

Fig. 10 : Output characteristics of Transistor type DP-GMAW Power source.

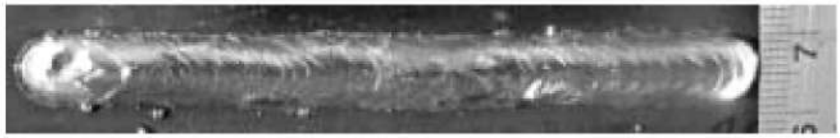
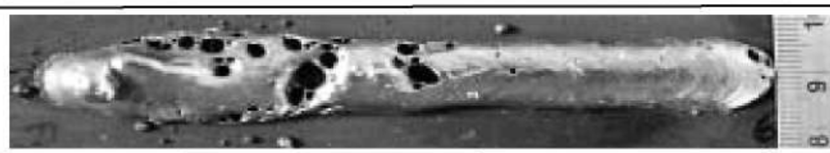
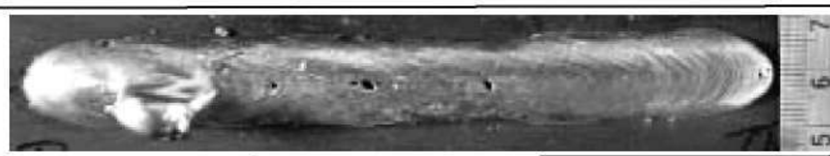
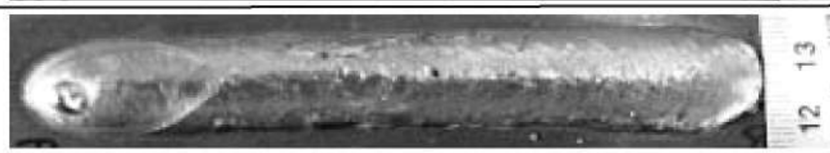
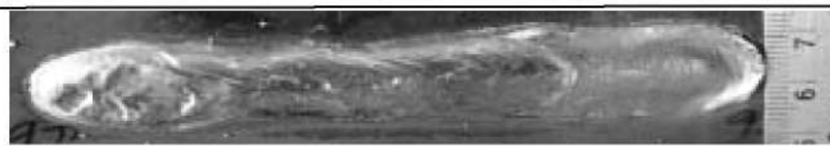
Fig. No.	WFR, m/min	DP-GMAW in Transistorised Power Source
11 (a)	4	
11 (b)	5	
11 (c)	6	
11 (d)	7	
11 (e)	8	
11 (f)	9	

Fig 11 : Surface appearance of weld bead using of Transistorized power source

5.0 PERFORMANCE OF DP- GMAW POWER SOURCES

The dual-pulsed GMAW (DP-GMAW) technique is a variation of the pulsed GMAW technique, in which the pulsing current aimed to metal transfer control is overlapped by a thermal pulsation, which in turn means pool control (similar to pulsed GTAW) [9]. Dual Pulse provides an interesting insight into the behavior of power source in GMA welding. Since pulsing significantly improves the quality of the weld with respect to the parameters, dual pulse actually needs careful calibration of the welding parameters as it deteriorates porosity in weld beads when there is a change in set parameters.

The WFR, V and Im relationships of the transistorized and Inverter type DP-GMAW are illustrated in Figures 10 and Figure 12 respectively. It is observed that, DP mode of inverter type shows less deviation from the rated values than that of the transistor type. This is verified through experimentation as in **Fig. 11 and Fig. 13**. As can be observed from **Fig. 11** and **Fig. 13**, DP mode of transistorized GMAW power source operation, voltage changes VS WFR creates deterioration of porosity. This is more pronounced at higher wire feed rates. Hence, the operation of the power source is best suited when there are least variations in the operating parameters. This is also verified for the performance of the Inverter Power Source in DP mode. Thus, it is understood that, the Inverter Power Source delivers accurate values of rated values and provides almost zero deviation. The performance on weld bead for the rated parameters are thus near perfect performance as in **Fig. 13**.

The study reveals basic understanding of the GMAW process operating at different modes of operations as conventional GMAW, P-GMAW and DP-GMAW under synergic mode condition. The comprehensive understanding over the characteristics of the variation in welding parameters and their control may provide ease and confidence in more wide use of

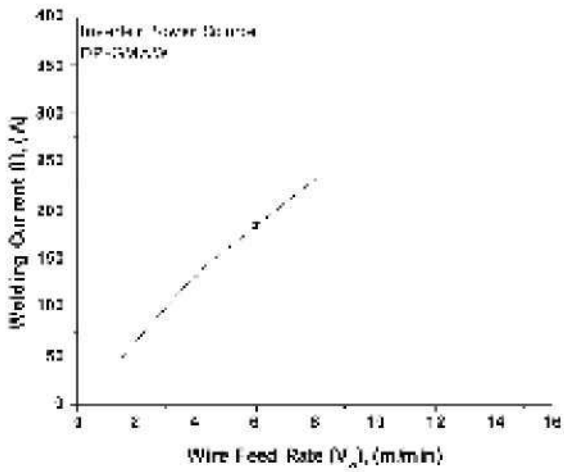


Fig. 12 (a) V – I characteristics

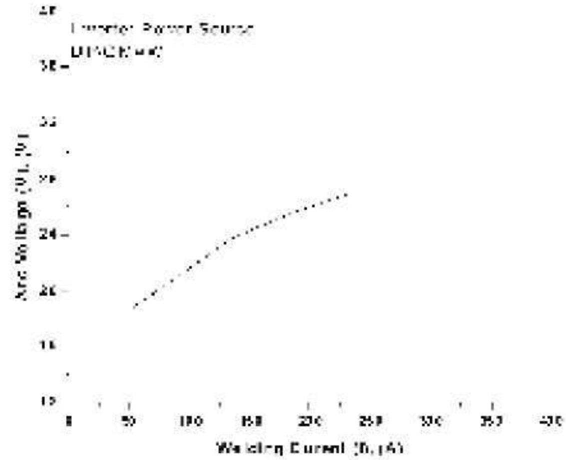


Fig. 12 (b) WFR VS Arc Voltage

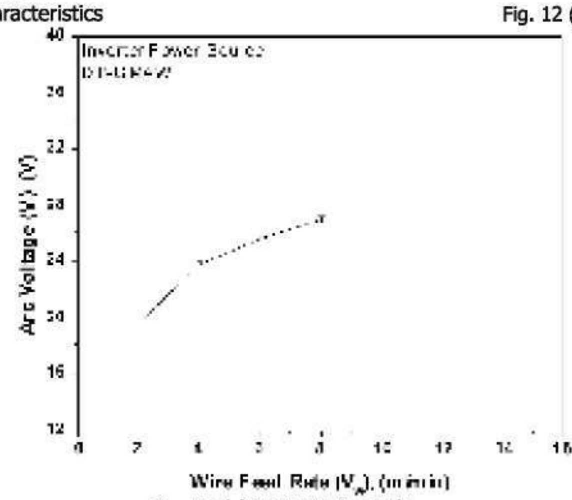


Fig. 12 (c) WFR VS Arc Voltage

Figs. 12 : Output characteristics of Inverter type DP-GMAW Power source.

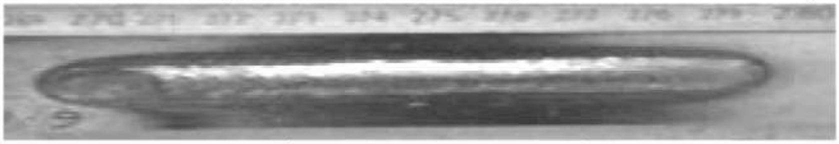
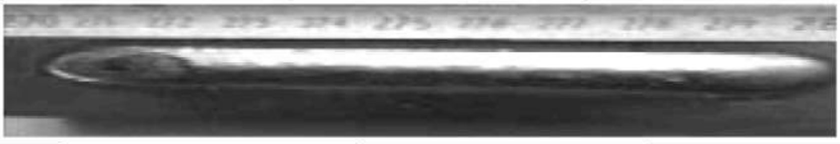
Fig. No.	WFR, m/min	DP-GMAW in Invertor Power Source
13 (a)	6	
13 (b)	7	
13 (c)	8	
13 (d)	9	

Fig 13 : Surface appearance of weld bead using of Inverter DP - GMAW power source.

GMAW to produce weld of desired quality especially, it is very much required in welding of high creep strength materials for boiler applications. An application example, tube to tube butt welding could be considered. If the welding parameters are not optimized, then it will give rise to many quality problems like profile mismatching, root pass identification etc. The present study includes only the dynamic characteristics of output parameters (V and I/Im) and its influence on weld bead quality. However, to establish the confident of inverter type GMAW process for various applications, the conversion efficiency, power per unit volume and power factor of the process should be studied further in details.

6.0 CONCLUSION

Experiments on performance characteristics of transistorized and invertor type GMAW welding power sources under various modes of operation as GMAW, P-GMAW and DP-GMAW were successfully carried out. From the results, the following conclusions are established:

1. It is observed that at a given WFR, the I/Im-V characteristics of transistorized and inverter type GMAW power source are significantly different from each other.
2. In all the cases of the GMAW, P-GMAW and DP-GMAW the machine setting of arc voltage and welding current differs from their operational display in the machine during welding especially the variations are more in case of transistorized GMAW power source.
3. It is concluded that the performance characteristics of inverter type GMAW power source comparatively stable than that of the transistorized GMAW power source.

REFERENCES

1) Quintino, L. and Alllum, C. J., [1984], "Pulsed GMAW: Interactions between process parameters, Part I", Welding and Metal Fabrication, Vol. 16(4), pp. 126-129.

2) Praveen, P., Yarlagadda, P. K. D. V. and Kang, M. J., [2005], "Advancements in pulse gas metal arc welding", Journal of Materials Processing Technology, Vol. 164–165, pp. 1113–1119.

3) K. Devakumaran N. Rajasekaran and P. K. Ghosh process characteristics of inverter type GMAW power source under static and dynamic operating conditions, Materials and manufacturing processes, Available online as a proof reading.

4) Arun Kumar Paul, Qualitative study of status of indigenous arc welding equipments in India, Indian Welding Journal, Vol. 44 No.3, July 2011, pp. 58 – 66.

5) John Norrish, Advanced Welding Processes – Technologies and Process Control, Wood head Publishing Limited, England, 2006

6) Palani, P. K. and Murugan, N., [2006], "Selection of parameters of pulsed current gas metal arc welding", Journal of Materials Processing Technology, Vol. 172, pp. 1–10.

7) Ghosh P. K., Dorn L, Devakumaran K, Hofmann F, Pulsed current gas metal arc welding under different shielding and pulse parameters: Part – I, Arc Welding Characteristics, ISIJ Int., Vol. 49(2), 2009, pp. 251 – 260

8) Ghosh P. K., Dorn L, Devakumaran K, Hofmann F, Pulsed current gas metal arc welding under different shielding and pulse parameters: Part – II, Arc Welding Characteristics, ISIJ Int., Vol. 49(2), 2009, pp. 261 – 269.

9) Celina Leal Mendes da Silva, Américo Scotti, The influence of double pulse on porosity formation in aluminum GMAW, Journal of Materials Processing Technology, Volume 171, Issue 3, February 2006, pp. 366 – 372.