Effects Of Plasma Arc Welding On Various Materials & It's Modeling: A Review

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Abstract

Plasma arc welding (PAW) uses non consumable tungsten electrode and arc is formed between electrode and workpiece.Shielding gas can be separated from plasma arc by placing the electrode within the body of the torch. Among different welding processes, plasma welding has various advantages like non-contact, high welding quality, narrow heat-affected zone, deep penetration etc which makes it superior to the commonly used processes. Plasma welding has broad range of applications in different engineering field. This present research work provides an overview of the effects of plasma arc welding and its various parameters on different materials. The heat transfer during plasma arc welding to the work piece has significant effect upon the weld material quality. This research work also reviews the heat transfer modeling of plasma arc welding that had been developed by researchers for prediction of better weld geometry and weld quality.

Keywords: Plasma Arc Welding, Process Parameters, Modeling, Materials

1. Introduction

Welding may be defined as joining of two similar or dissimilar materials with the help of fusion or pressure or by both of them. Due to availability of electric current and continuous challenging situation in industries, modern engineering demands the development of welding with an accelerating rate. [1]. Because of high gas velocity and heat input, PAW can operate in the keyhole mode. Compared with electron beam and laser welding, keyhole PAW has different advantages such as cost effectiveness, lower shrinkage and distortion,hence it is widely used in manufacturing structures with medium thickness. However, the keyhole establishment and sustainment during the initial stage of PAW process, i.e., the keyholing process, has a critical effect on the process stability and the weld quality. Thus, modelling and simulating of the keyholing process and its influence on fluid flow and heat transfer in keyhole PAW process is of great significance to completely understand the process mechanism [2].

The conventional and commercially used welding processes are listed in Table 1. The possible welding processes for different materials are listed in this table [3]. Table 2 shows main advantages and limitations of PAW process. In the PAW process, transferred arc and non transferred arc modes are used. In the transferred arc, the arc is carried from electrode to the work piece. In the non transferred arc system the arc is generated & established between the electrode and the orifice of the nozzle [3].

Table 1. Master Chart of Welding and Joining Processes [3]

Material	SMAW	SAW	GMAW	FCAW	GTAW	PAW	ESW	EGW	RW	FRW	EBW
Carbon Steel	√	√	√	√	√		√	√	√	√	√
Low Alloy Steel	√	√	√	√	√		√		√	√	√
Stainless Steel	√	√	√	√	√		√		√	√	√
Cast Iron	√	√	√	√							
Nickel and Alloys	√	√	√		√	√	√		√		
Aluminum and Alloys	√		√		√	√	√	√	√	√	√
Titanium and Alloys			√		√	√			√	√	√
Copper and Alloys			√		√	√				√	√
Magnesium and Alloys			√		√				√	√	√

Table 2. Advantages & Limitations of PAW [3]

	Advantages of PAW process	Limitations of PAW
1	Concentration of energy is higher, resulting in: High welding speed Low current is required to produce sound weld Low shrinkage and distortion is observed with PAW process. Adjustment of welding variables may control depth of penetration. Minimum distortion is observed for materials with high thickness with keyhole technique	Very small tolerance for different joint misalignment.
2	Stability of arc can be improved.	For practical application, automatic PAW is more preferred than manual PAW.
3	Arc column has greater directional stability.	Regular inspection and maintenance is required for the constricting nozzle
4	High depth-to-width ratio can be obtained which results in less distortion.	
5	Fixturing cost may be reduced.	

2. Review Of Keyhole Plasma Arc Welding

Fig. 1 is a schematic sketch of keyhole PAW process. In this process, the high-temperature and high-velocity plasma arc strikes on work piece, melts metal, creates a molten pool and finally penetrates through the pool . Due to generation of huge amount of heat at a very narrow zone a complete keyhole may form. After the formation of complete key hole some efflux plasma may exit at the back side of the work piece. So, by detecting efflux plasma keyhole signal may be obtained [5]. Fig. 2 shows development of quasi keyhole process in time sequence. When the current changes from base to peak current, depth of weld pool and partial keyhole increases.

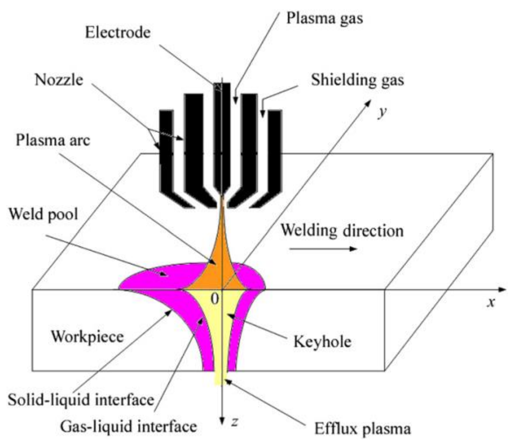

FIG 1. Schematic of keyhole PAW process [4]

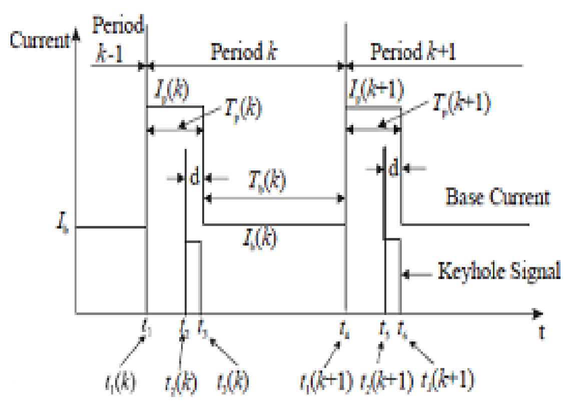

FIG 2. Dynamic development in quasi keyhole process in time sequence[6]

Fig. 3 shows evolution of keyhole with distribution of temperature and flow of molten metal flow at the transverse cross-section of weld pool. The keyhole interface is represented by purple line, and velocity of molten metal is represented by blue arrow & the symmetrical temperature field is shown in right side. It may be easily figure out that keyhole continues to increase both in depth and in width with time, which also promotes the molten metal flow [4].

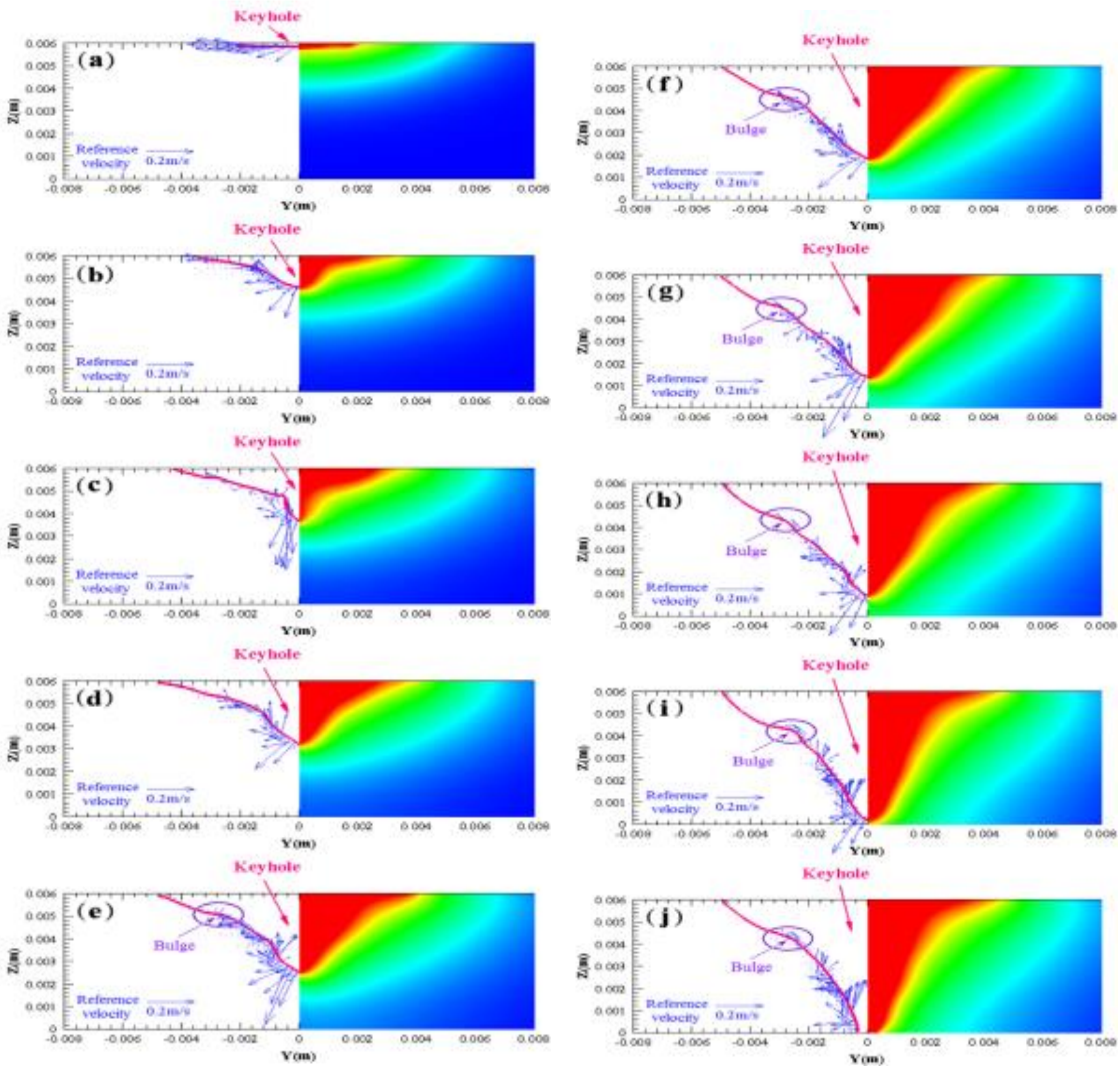

FIG 3. Keyhole evolution with temperature distribution[4]

Fig. 4 shows the procedure for stationary keyhole PAW process simulation. It shows the main calculating procedure for fluid flow and heat transfer phenomena. For solution purpose calculation is divided into two types of grid system. Finer grid is applied for the weld zone and the nearby area. The coarser grid is applied for the region which is away from the weld zone. Numerical simulation was applied for stationary plasma arc welding of ferrous alloy based work piece [7]. Fig. 5 represents variation of grain size, hardness and tensile strength of different steel. From the point of view of weld quality characteristics it may be noticed that AISI 304L has better mechanical properties such as strength and hardness compared to other steels. On the other hand, the grain size & hardness of welded zone of AISI 321 is the smallest & plasma arc welded AISI 316L has attained lowest tensile strength among the other samples [8]. Fig. 6 shows contrast between experimental figure and calculated image of the fusion zone at the cross-section of PAW weld. For both tests calculated geometry matches well with the experimental images, i.e. difference between calculated data & experimental result is very less [4].

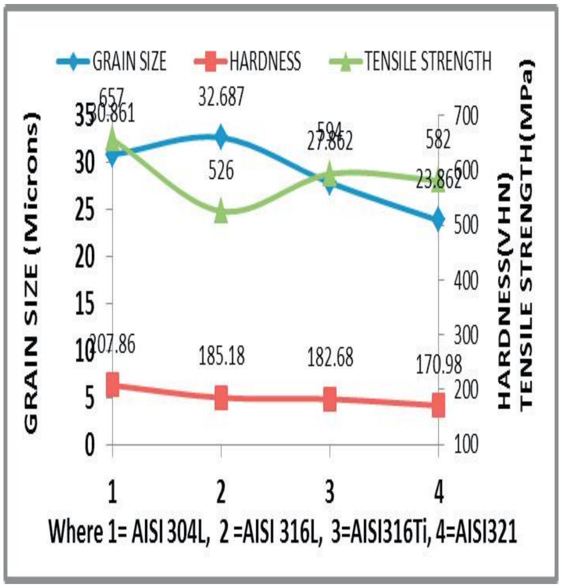

FIG 5. Variation of mechanical properties in plasma arc welded steels [8]

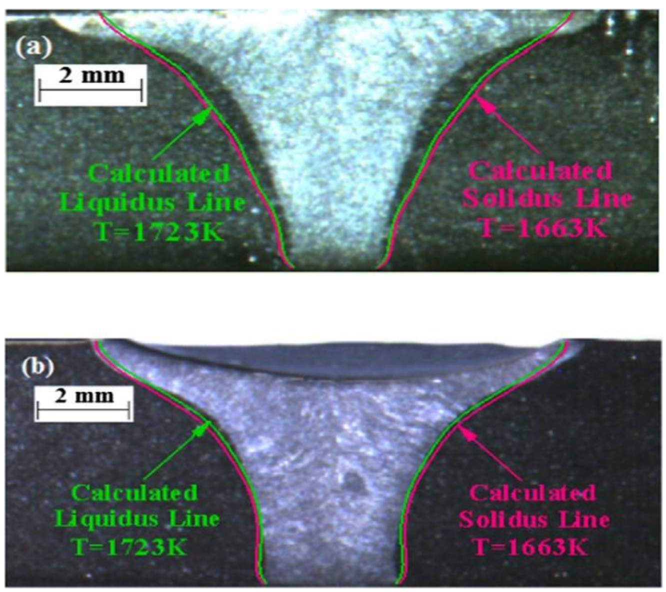

FIG 6. Fusion zone at the transverse cross-section of PAW weld [4]

3. Future Prospects of Plasma Arc Welding

Research and development activities for future applications are carried out for different ferrous and non ferrous metals which till date cannot be welded well. The manufacturing of the devices for research work and different industry applications may generate difficult problems in the joining of materials. For the time being, the solutions based on different welding processes become more popular and noteworthy contribution for the progress of science and industry has been figured out. With the help of keyhole plasma arc welding process continuous deposition of alloying material may be assured.

4. Conclusion

Present review work describes plasma arc welding process. Effect of PAW on various mechanical properties of different stainless steel has been presented. Procedure for stationary keyhole PAW process simulation developed by researchers for prediction of better weld geometry and weld quality is presented in this review work. For different plasma arc welded steels, variation of mechanical properties has been presented.It has been found for same PAW input parameters AISI 304L has the highest hardness and tensile strength.

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