

Power density and welding process

In this chapter, energy density and temperature associated with different welding processes have been presented. Further, the influence of energy density on the performance parameters of the weld joints has also been described.

Keywords: Power density, temperature of heat source, heat input, distortion, mechanical properties

4.1 Introduction

Fusion welding processes can be looked into on the basis of range of energy density which they can apply for melting the faying surfaces of base metal for joining. Heat required for fusion of faying surfaces of components being welded comes from different sources in different fusion welding processes (gas, arc and high energy beam). Each type of heat source has capability to supply heat at different energy densities (kW/mm^2). Even for a given arc power (arc current I X arc voltage V), different welding processes provide heat at different energy densities due to the fact that it is applied over different areas on the surface of base metal in case of different processes. Energy density (kW/mm^2) is directly governed by the area over which heat is applied by a particular process besides welding parameters. Power density in ascending order from gas welding to arc welding to energy beam based welding processes is shown in table 4.1. Typical values of energy densities and approximate maximum temperature generated during welding by different processes are shown in Table 4.1.

Table 4.1 Heat intensity and maximum temperature related with different welding processes

| Sr. No. | Welding process | Heat density (W/cm^2) | Temperature ($^{\circ}\text{C}$) |
|---------|---------------------------|----------------------------------|------------------------------------|
| 1 | Gas welding | $10^2 - 10^3$ | 2500-3500 |
| 2 | Shielded meta arc welding | 10^4 | >6000 |
| | Gas metal arc welding | 10^5 | 8000-10000 |
| 3 | Plasma arc welding | 10^6 | 15000-30000 |
| 4 | Electron beam welding | $10^7 - 10^8$ | 20,000-30000 |
| 5 | Laser beam welding | $>10^8$ | >30,000 |

4.2 Effect of power density

Energy density associated with a particular welding process directly affects amount of heat required to be supplied for fusion of the faying surfaces. An increase in power density decreases the heat input required for melting and welding of work pieces because it decreases time over which heat is to be applied during welding for melting. The decrease in heat application time in turn lowers the amount of heat dissipated away from the faying surfaces to the base metal so the most of the heat applied on the faying surfaces is used for their fusion only. However, it is important to note that heat required for melting the unit quantity of a given metal is constant and is a property of material. Heat for melting comprises sensible heat and latent heat. Latent heat for steel is 2 kJ/mm^3 .

Fusion welding processes are based on localized melting using high-density heat energy. To ensure melting of base metal in short time it is necessary that energy density of welding process is high enough (Fig. 4.1). Time to melt the base metal is found inversely proportional to the power density of heat source i.e. power of (arc or flame) / area of work piece over which it is applied (W/cm^2). Lower the energy density of heat source greater will be the heat input needed for fusion of faying surface welding as a large amount of heat is dissipated to colder base material of work piece away from the faying surface by thermal conduction (Fig. 4.2).

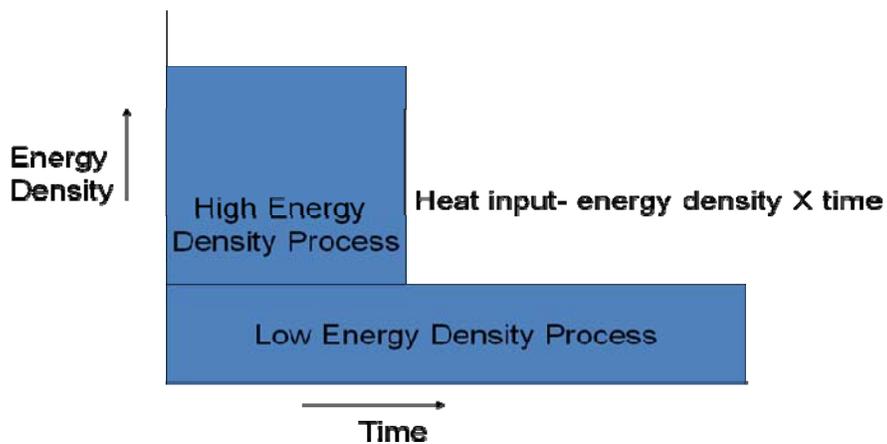


Fig. 4.1 Effect of energy density and time on energy input

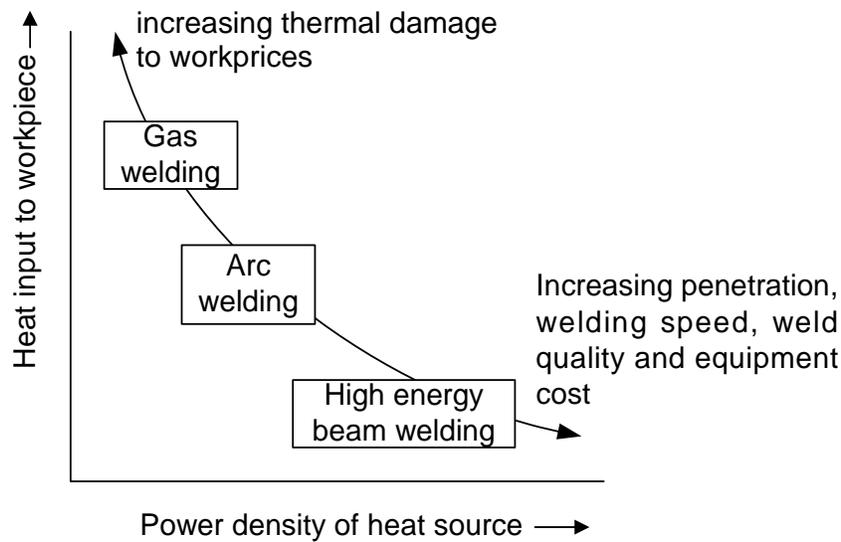


Fig. 4.2 Effect of power density of heat source on heat input required for welding [Kou S, 2003]

4.3 Need of optimum power density of welding process

As stated, low power density processes need higher heat input than high power density processes. Neither too low nor too high heat input is considered good for developing a sound weld joint. As low heat input can lead to lack of penetration and poor fusion of faying surfaces during welding while excessive heat input may cause damage to the base metal in terms of distortion, softening of HAZ and reduced mechanical properties (Fig. 4.3). High heat input has been reported to lower the tensile strength of many aluminium alloys of commercial importance due to thermal softening of HAZ and development of undesirable metallurgical properties of the weldment (Fig. 4.4). Moreover, use of high power density offers many advantages such as deep penetration, high welding speed and improved quality of welding joints. Welding process (where melting is required) should have power density approximately $10(\text{W}/\text{mm}^2)$. Vaporization of metal takes place at about $10,000\text{W}/\text{mm}^2$ power-density. Processes (electron and laser beam) with such high energy density are used in controlled removal of metal for shaping of difficult to machine metals. Welding processes with power density in ascending order are shown in Fig. 4.5.

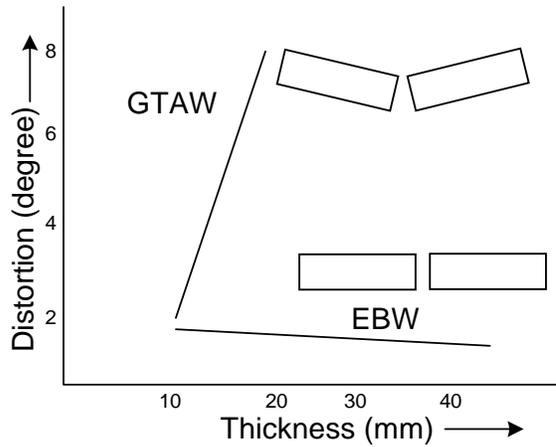


Fig. 4.3 Effect of welding process on angular distortion of weld joint as a function of plate thickness[Kou S, 2003]

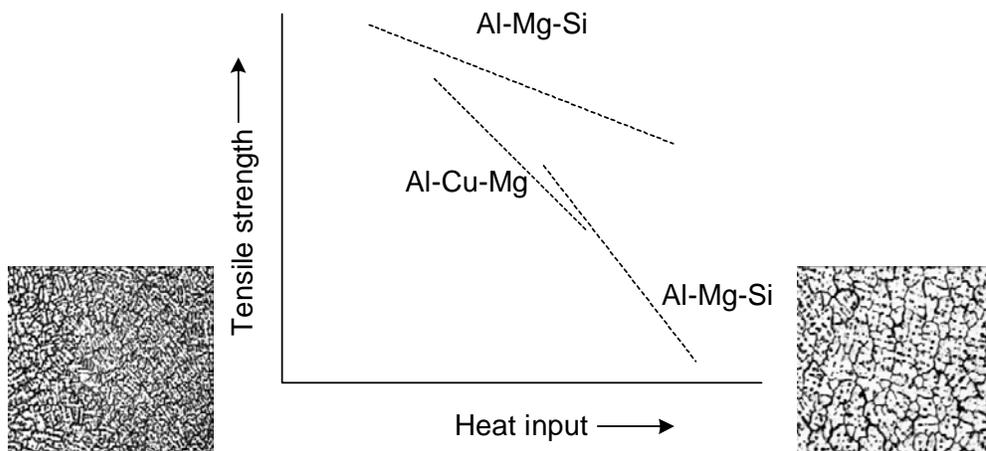


Fig. 4.4 Schematic diagram showing effect of heat input on tensile strength of aluminium alloy weld joints (magnification of micrograph in figure is 200 X) [Kou S, 2003]

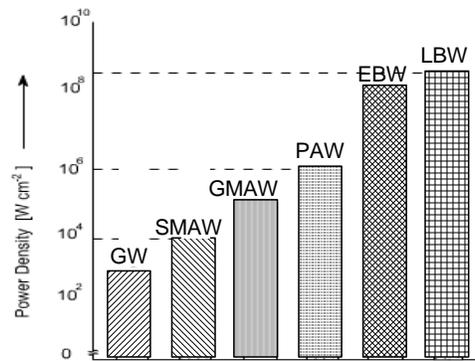


Fig. 4.5 Power densities of different welding processes

References and books for further reading

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