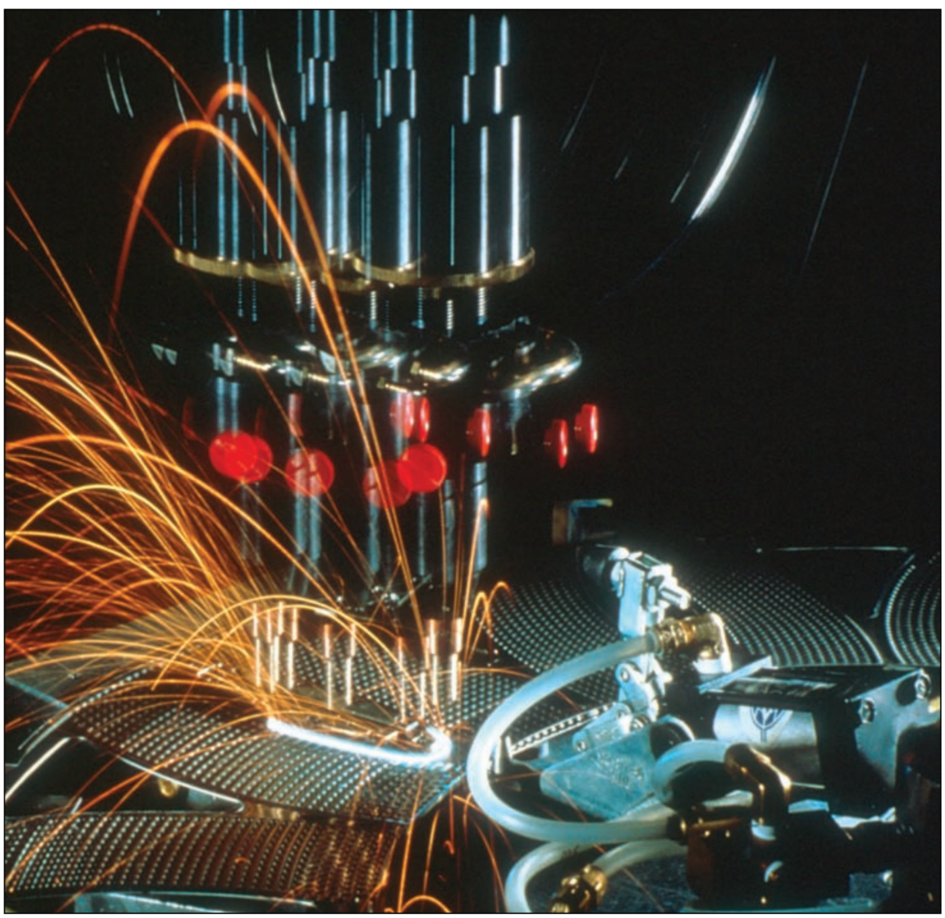
CHAPTER 2

PHYSICS OF WELDING AND CUTTING



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INTRODUCTION

The physics of welding deals with the phenomena associated with welding processes and the formation of weld bonds. This chapter discusses two types of welds, fusion welds and solid-state welds. These are commonly differentiated by the physics of the metallic bonding mechanism.

The chapter includes a discussion of the physics of energy sources—electrical, chemical, focused-beam, mechanical, and solid-state—and energy transfer as they relate to the various welding processes. Also discussed are the physical phenomena of the electric arc, metal transfer, melting rates, the properties of metals and shielding gases, and the manner in which these and myriad associated phenomena contribute to successful (or unsuccessful) welds.

The information in this chapter is applicable to many thermal cutting and spraying processes, as they are closely allied with welding processes and involve the same phenomena for the purposes of cutting or removing material, cladding, and surfacing. Considering that the International System of Units (SI) is customarily employed in this discipline, this chapter uses SI units exclusively.

FUSION AND SOLID-STATE WELDING

The physics of weld bonds and the associated welding processes differ markedly with respect to fusion welds and solid-state welds and are best considered separately. Fusion welds are created by the coalescence of molten base metals mixed with molten filler metals (if a filler metal is used). Metals must be heated to the melting point for fusion welds to be produced. Solid-state welds are produced at temperatures below the melting temperature and are created by either the macroscopic or microscopic coalescence of the materials in the solid state.

FUSION WELDS

Fusion welding processes must produce sufficient heat to achieve melting. Heat for melting is either developed at the intended weld joint or applied to the intended joint from an external source. In some processes, pressure is applied to force the materials into close contact. An example of a means of developing heat at the weld joint is the passing of current through the electrical contact resistance between the contacting surfaces of the materials to be welded (resistance welding). Electrical discharges between surfaces can also be utilized to develop heat for joining (flash welding). A common characteristic of these welding processes is that the entire weld is usually produced at one time, either at a spot or along an entire joint.

Most fusion welding processes apply heat from an external source to the weld joint to produce the weld bond. Heat is transported from the heat source to the joint by conduction, convection, and radiation. Almost every imaginable high energy density heat source has been adapted at one time or another for fusion welding.

Sources of externally developed heat include electron beams, laser beams, exothermic chemical reactions (used in oxyfuel gas welding and thermite welding), and electric arcs. Fusion welding processes that apply heat from external sources are usually identified according to the type of heat source employed. Electric arcs, the most widely used heat source, are the basis for the various arc welding processes. The following are the most