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Arc Plasmas for Joining, Cutting and Surfacing

Robert L. O'Brien

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COMMITTEE FOREWORD

Almost fifteen years have passed since the introduction of the use of a constricted arc torch for cutting materials such as aluminum and stainless steel. During this period, a background of information has developed at so fast a rate that it is difficult to prepare an up to date report. However, it is well to summarize the available data at this time and to present it so that additional information can be added as it develops. Efforts to control the heat intensity of the inert gas arc have resulted in techniques which constrict the arc. Most of the techniques for constricting the arc consist of passing the arc through a water-cooled copper orifice which collimates the arc and increases the energy density in the arc stream. The term "plasma arc" has been used to describe the family of metal-working processes which utilize the constricted arc.

This report covering the plasma arc processes includes a discussion of the general characteristics, the electrical and equipment requirements with operating parameters and a description of typical process applications. The information is basic, yet shows the practical importance of the specific parameters which are encountered. The range of applications is wide and generally in the alloy field with unique uses which make the process ideal for certain problem areas. This field will undoubtedly grow in its applications over the coming years and a review of the technology at the present time is appropriate.

Clarence E. Jackson, Member
WRC Interpretive Reports Committee

Arc Plasmas for Joining, Cutting and Surfacing

by R. L. O'Brien

Introduction

Definition of Plasma

A plasma is a gas which has been heated to a condition where it is at least partially ionized and is, therefore, capable of conducting electric current. When an arc is established through the gaseous column separating two electrodes, some of the gas molecules in the column become ionized. The ionized zone, or plasma stream, consists of positively charged atoms of the arc gas, an essentially equal number of electrons, and neutral atoms or molecules. The electrical conductivity of a plasma stream varies with the degree of ionization but for argon plasma it is about 0.05% that of copper. More comprehensive discussions of plasma physics may be found in the literature.[1, 2]

A plasma exists during any arc occurrence. In nature, the air that is ionized by a lightning bolt constitutes a plasma. The same ionization phenomenon occurs in welding arcs, carbon arc lights and arc furnaces. In recent years, however, the expression "plasma arc" has become associated with those processes employing a constricted arc. Arc constriction is brought about by forcing the arc to pass through a small nozzle or opening as it passes from the electrode to the workpiece.

Initial ionization in plasma arc torches is brought about by superimposing a high-frequency spark or high voltage pulse between the electrodes, or by use of a probe (retract starting). Arc heat and ionization are then maintained by the resistance heating effect of current passing through the gas.

In addition to the formation of plasma in an arc, a gas can be maintained at its ionization point by induction or capacitance methods.[3] An induction plasma generator heats gas by inductively coupling high-frequency power (30 MHz and below) into a gas stream that has been made conductive by spark discharge. In the capacitance method microwave power (1000 MHz) is utilized to heat gas in a discharge between a central electrode and a surrounding coaxial tube. Such devices are used for special chemical reactions and for testing specimens in high temperature gas atmospheres; since they are not used commercially for metalworking, they are mentioned here only as a point of interest.

Scope

This report discusses plasma arc processes used for welding, cutting and surfacing metals. Equipment used for each of the processes is described and practical applications are presented with operating conditions.

History of Plasma Arcs

One of the earliest plasma arc systems was a gas vortex stabilized device introduced by Schonherr[4] in 1909. In this unit, gas was blown tangentially into a tube through which an arc was struck. The centrifugal force of the gas stabilized the arc along the axis of the tube by creating a low pressure axial core. Arcs up to several meters in length could be produced, and the system proved useful for arc studies.

Gerdien and Lotz[5] built a water vortex arc stabilizing device in 1922. In this device, shown

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