ing, and solid-state bonding[1]. Generally, welding results in a large increase in grain size with a corresponding loss in strength and ductility and increase in transition temperature. Brazing severely limits service temperature because of remelting, base metal erosion, and incipient joint weakness.

Some of the problems associated with joints formed in the liquid state can be overcome by solid-state bonding. In this approach to joining, the bond is made by diffusion of atoms from one side of the interface to the other. In many instances, the resulting joint will have properties identical to the base materials. Examples of solid-state-bonding processes include roll bonding, coextrusion, resistance bonding, platen bonding, friction bonding, and gas-pressure bonding. Some work has been done in joining refractory metals by each of these processes[2–6]. This paper will deal with studies at Battelle-Columbus Laboratories on the application of the gas-pressure-bonding process to various refractory metal combinations.

Gas-Pressure-Bonding Process

Discussions of the gas-pressure-bonding process have been presented elsewhere in the literature[7,8]; however, a brief discussion is warranted at this time to provide the reader with sufficient background to understand some of the information which will follow.

The gas-pressure-bonding technique basically is an idealized hot pressing operation performed in a high-pressure, cold-wall autoclave in which the deforming force is applied by a high pressure of an inert gas at elevated temperature. Insulating material is located between the wire-wound resistance heater and the inside wall and closures of the autoclave to prevent appreciable heating of the cold-wall vessel. To prepare assemblies for bonding, the cleaned components are assembled into a thin metal container of the desired geometry which is then evacuated and sealed. The sealed assemblies are then placed in the heater inside the autoclave, and the temperature and pressure required for bonding are applied. At temperature the high gas pressure in the system is uniformly transmitted through the very plastic container walls from all directions to the bond interfaces. The components to be joined are thus locally deformed at contact points into complete contact and are solid-state bonded together by diffusion. The conditions required depend, of course, on the materials being processed; for refractory-metals temperatures of approximately 1600° C. and pressures between 10,000 and 30,000 psi are typical. The application of pressure and temperature can be programmed to accommodate the specific properties of particular metal combination.

Important Parametric Considerations

In solid-state bonding by the gas-pressure-bonding process, the following parameters are of importance: surface preparation, bonding temperature, pressure, and time. Surface preparation is the term used to describe the treatment employed to prepare the faying surfaces prior to bonding. This