31.7 Diffusion Bonding

Diffusion bonding, or **diffusion welding** (DFW), is a process in which the strength of the joint results primarily from diffusion (movement of atoms across the interface) and secondarily from plastic deformation of the faying surfaces. This process requires temperatures of about 0.5 T_m (where T_m is the melting point of the metal, on the absolute scale) in order to have a sufficiently high diffusion rate between the parts being joined (see also Sections 1.7 and 1.8).

The interface in diffusion welding has essentially the same physical and mechanical properties as the base metal; its strength depends on (a) pressure, (b) temperature, (c) time of contact, and (d) cleanliness of the faying surfaces. These requirements can be relaxed by using a filler metal at the interface. Depending on the materials joined, brittle intermetallic compounds may form at the interface, which may be avoided by first electroplating the surfaces with suitable metal alloys. In diffusion bonding, pressure may be applied by dead weights, a press, differential gas pressure, or the thermal expansion of the parts to be joined. The parts usually are heated in a furnace or by electrical resistance. High-pressure autoclaves also are used for bonding complex parts.

Although DFW was developed in the 1970s as a modern welding technology, the principle of diffusion bonding dates back centuries when goldsmiths bonded gold over copper, to create a product called **filled gold**. First, a thin layer of gold foil is placed over copper, and pressure is applied by a weight on top of the foil. The assembly is then placed in a furnace and left until a strong bond is developed, hence the process is also called *hot-pressure welding* (HPW).

Diffusion bonding generally is most suitable for joining dissimilar metals, and is also used for reactive metals (such as titanium, beryllium, zirconium, and refractory metal alloys) and for composite materials such as metal-matrix composites (Section 9.5). Diffusion bonding is an important mechanism of sintering in powder metallurgy (Section 17.4). Because diffusion involves migration of the atoms across the joint, DFW is slower than other welding processes.

Although diffusion welding is used for fabricating complex parts in low quantities for the aerospace, nuclear, and electronics industries, it has been automated to make it suitable and economical for moderate-volume production as well. Unless highly

automated, considerable operator training and skill are required. Equipment cost is related approximately to the diffusion-bonded area, and is in the range of \$3–\$6/mm^2.

EXAMPLE 31.4 Diffusion-bonding Applications

Diffusion bonding is especially suitable for such metals as titanium and the superalloys used in military aircraft. Design possibilities allow the conservation of expensive strategic materials and the reduction of manufacturing costs. The military aircraft illustrated in Fig. 31.17 has more than 100 diffusion-bonded parts, some of which are shown.

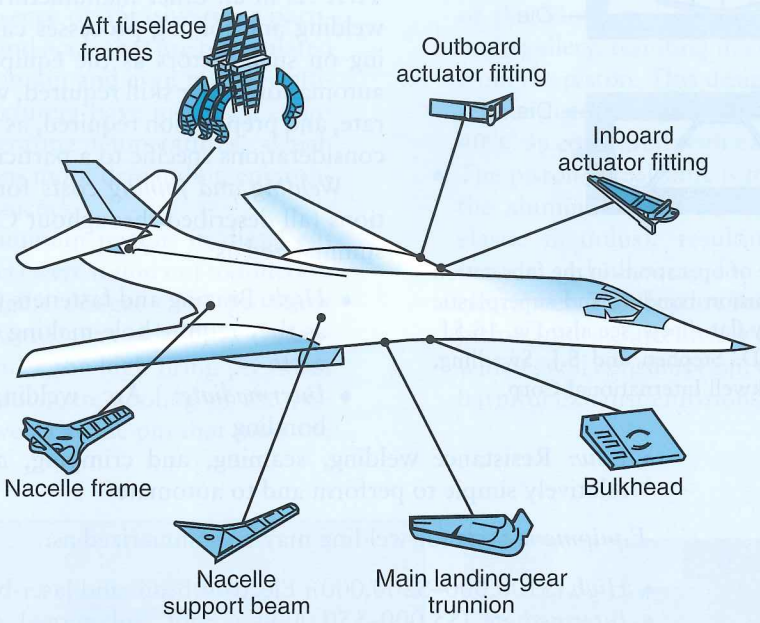

FIGURE 31.17 Aerospace diffusion-bonding applications.