3. COMMON JOINING PROBLEMS

Just as materials selection criteria are aimed at satisfying engineering requirements by avoiding failure in both production and service, so the selection implementation of a joining process must meet the engineering requirements for system, both in the course of the joining process and throughout the subsequent service life of the assembled components.

3.1 JOINING SIMILAR MATERIALS

The parameters of the joining process must be selected to ensure that the joint fulfils the engineering requirements. Successful engineering processes have a working window for the process parameters, within which acceptable performance can be assured for the system. In the assembly of engineering components, this working window may include a heating and cooling cycle required to cure an epoxy bond or braze a vacuum component. It may also involve the application of a critical pressure, as in diffusion bonding, or the maintenance of a controlled atmosphere, as in many welding processes. In every case, these process parameters must take account of dimensional accuracy in the location of the components prior to bonding and during the bonding process. If the processing parameters are allowed to fall outside this specified working window, then undesirable consequences may include dimensional distortions, imperfectly bonded components, excessive residual stresses and severe contamination of the bonded region.

Since the joint is a region of heterogeneity, many problems associated with the performance of the joint in service can be traced to the various sources of heterogeneity. Changes in microstructure-which occur in the heat affected zone (HAZ) that borders a weld-give rise to differences in chemical potential and corrosion susceptibility. They also change the local mechanical properties: either a reduction in the yield strength, and hence increased susceptibility to dynamic (mechanical) fatigue, or an increase in the hardness, and associated susceptibility to brittle failure.

Loading a bolted joint generates a complex system of local stresses and stress concentrations. These can be compensated by efficient stress transfer to spread the load and reduce the local stress concentration with the help of a compliant gasket. Residual stresses (for example, thermal shrinkage stresses or the stresses associated with solvent evaporation from an adhesive joint) may overload the joint to the point of failure, even in the absence of an applied load.

Dimensional mismatch may be accommodated by a filler whose performance in service depends on the constraints exerted by the assembled components. Most joints will be less than perfect, and will contain some defects in the form of inclusions, microcracks, pores and imperfectly bonded regions. The size, position and elastic compliance of these defects (compare a pore with a hard inclusion) frequently are major factors determining the final performance of the assembled components.

3.2. JOINTS BETWEEN DISSIMILAR MATERIALS

A joint between dissimilar materials is commonly accompanied by mismatch in the mechanical, physical and chemical properties of the components which have been joined. A mismatch in the elastic modulus of the two materials will give rise to localized shear stresses when the joint is loaded in tension (as noted in Fig. 2.1), and may lead to mechanical failure.

Chemical reactivity between the components may lead to undesirable interface reactions and the products of these reactions are often brittle. Reactions accompanied by a volume change generate local stresses, and the mechanical integrity of the joint will be threatened. If the phases present in the components to be joined have significantly different chemical potentials, then differences in electrochemical potential may lead to localized corrosion in the presence of a suitable electrolyte. Thermal expansion mismatch is a major concern in the bonding of brittle materials, especially those which are required to withstand thermal shock or repeated temperature cycles (thermal fatigue). Borosilicate glass tubing (Pyrex is a trade name) can be successfully joined to stainless steel, but only by bonding through a series of graded glass compositions. These provide a transition region over which the expansion coefficient is monotonically changed in controlled steps. The stainless steel must also be welded to a low-expansion nickel alloy tube (the common trade name is Kovar). The Kovar alloy is then bonded to a metal-wetting glass of matched expansion coefficient to minimize the elastic modulus mismatch at the interface. The result is a complex, but successful, graded seal (Fig. 3.1).

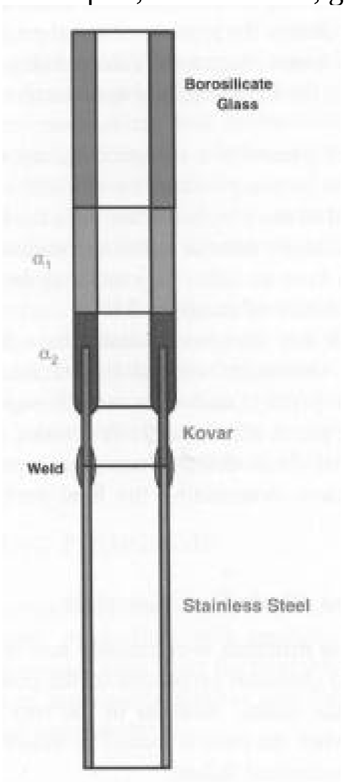

Fig. 3.1
A graded glass seal between stainless steel and borosilicate glass makes use of a low thermal expansion coefficient alloy (Kovar) and intermediate glass compositions in order to "grade" the residual thermal stresses.