CHAPTER 7

RESIDUAL STRESS AND DISTORTION

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INTRODUCTION

The types of residual stress that occur in welds and their respective distribution patterns are quite complex. This chapter presents an analysis of stress in single- and multiple-pass welds and examines the various factors that interact to increase or decrease the magnitude of stress in welds. As distortion in weldments is an important factor in their serviceability, the procedures used to predict distortion are also discussed here. In the final section, the various procedures used to reduce or control residual stress and distortion in welds are examined in detail.

Since most information published on this subject concerns welds produced with the arc welding processes, the discussions presented in this chapter almost exclusively address residual stress and distortion in welds fabricated with these processes. A limited amount of information is presented on residual stress in spot welded joints in titanium 8Al-1Mo-1V alloy.

FUNDAMENTALS

A weldment undergoes localized heating during most welding processes; therefore, the temperature distribution in the weldment is not uniform, and structural and metallurgical changes take place as the welding progresses along a joint. Typically, the weld metal and the heat-affected zone immediately adjacent to the weld are at temperatures substantially above that of the unaffected base metal. As the weld pool solidifies and shrinks, it begins to exert stress on the surrounding weld metal and heat-affected zones. When the weld metal first solidifies, it is hot and relatively weak; thus, it exerts little stress. As the weld cools to ambient temperature, however, the stress in the weld area increases and eventually reaches the yield point of the base metal and the heat-affected zone.

When a weld is made progressively, the portions of the weld that have already solidified resist the shrinkage of later portions of the weld bead. Consequently, the portions welded first are strained in tension in a direction longitudinal to the weld, that is, down the length of the weld bead, as shown in Figure 7.1.

In the case of butt joints, little motion of the weld is permitted in the transverse direction because of the preparation of the weld joint and the stiffening effect of underlying passes. Because of shrinkage in the weld, transverse residual stress is also present, as shown in Figure 7.1. For fillet welds, the shrinkage stress is tensile along the length and across the face of the weld, as shown in Figure 7.2.

Residual stress in weldments can have two major effects. It can produce distortion or cause premature failure, or both. Distortion is caused when the heated weld region contracts nonuniformly, causing shrinkage in one part of a weld to exert eccentric forces on the weld cross section. The weldment strains elastically in response to this stress. Detectable distortion occurs as a result of this nonuniform strain.

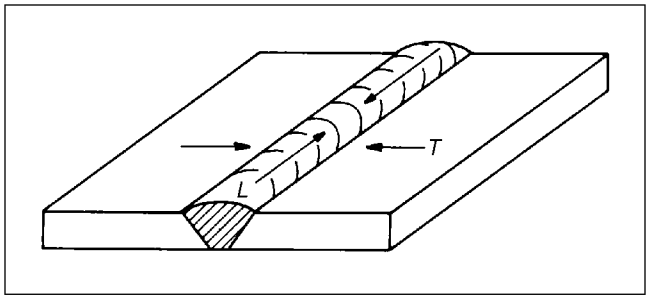

Figure 7.1—Longitudinal (*L*) and Transverse (*T*) Shrinkage Stress in a Butt Joint Weld