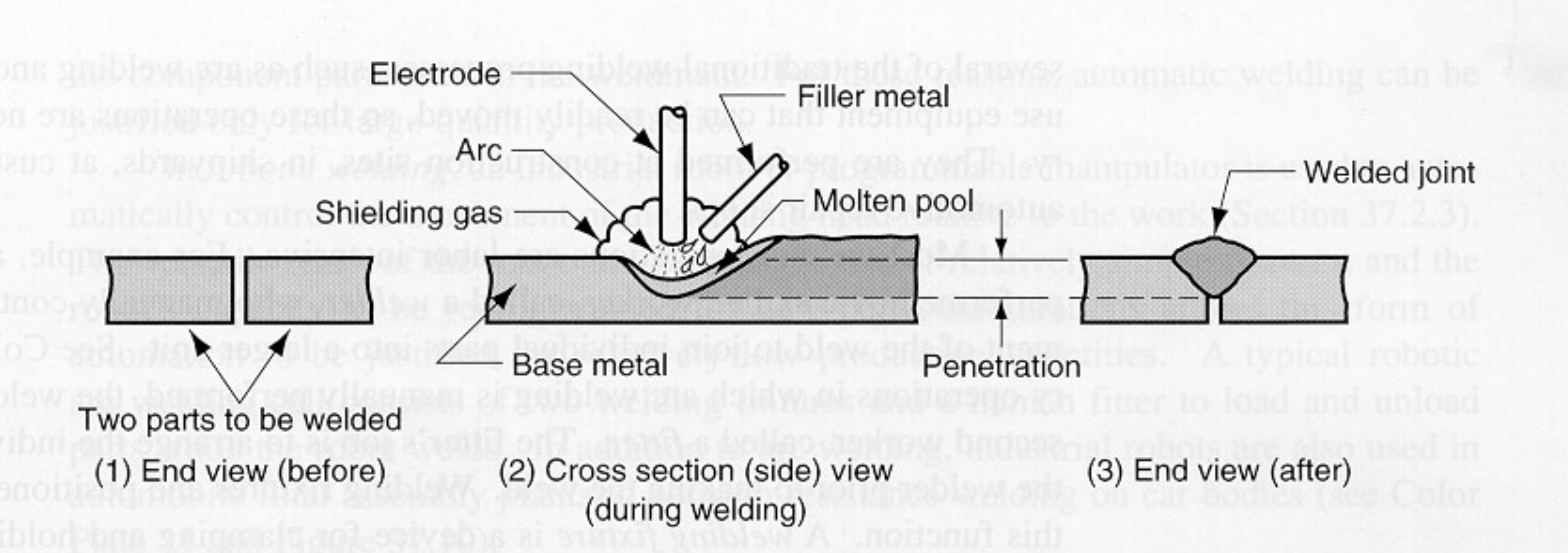
Basics of Welding Metallurgy

Module 3B

Welding Process

A concentrated heat source melts the material in the weld area; the molten area then solidifies, causing fusion, to join the pieces together

Sometimes a filler material is added to the molten pool to strengthen the weld



Welding Metallurgy

- The base metal(s) and filler metal mix together during melting, forming an alloy when they solidify

- The solidification of the metals can be considered as casting a small amount of metal in a metal mold

The Nature/types of Welding Processes

From a metallurgical viewpoint welding processes may be divided into two main categories: fusion-welding processes and solid-phase welding processes. In **fusion welding** the two edges or surfaces to be joined are heated to the melting point and, where necessary, molten **filler metal** is added to fill the joint gap. Such welds comprise three metallurgical zones; the **fusion zone**, the unmelted **heat-affected zone** (HAZ) adjacent to the fusion zone, and the unaffected **parent plate** (Fig. 2.1). **Solid-phase** welds, on the other hand, are made by bringing two clean, solid metal surfaces into sufficiently close contact for a metallic bond to be formed between them (Fig. 2.2). Whereas fusion welding necessarily requires part of the metal to be heated above the melting

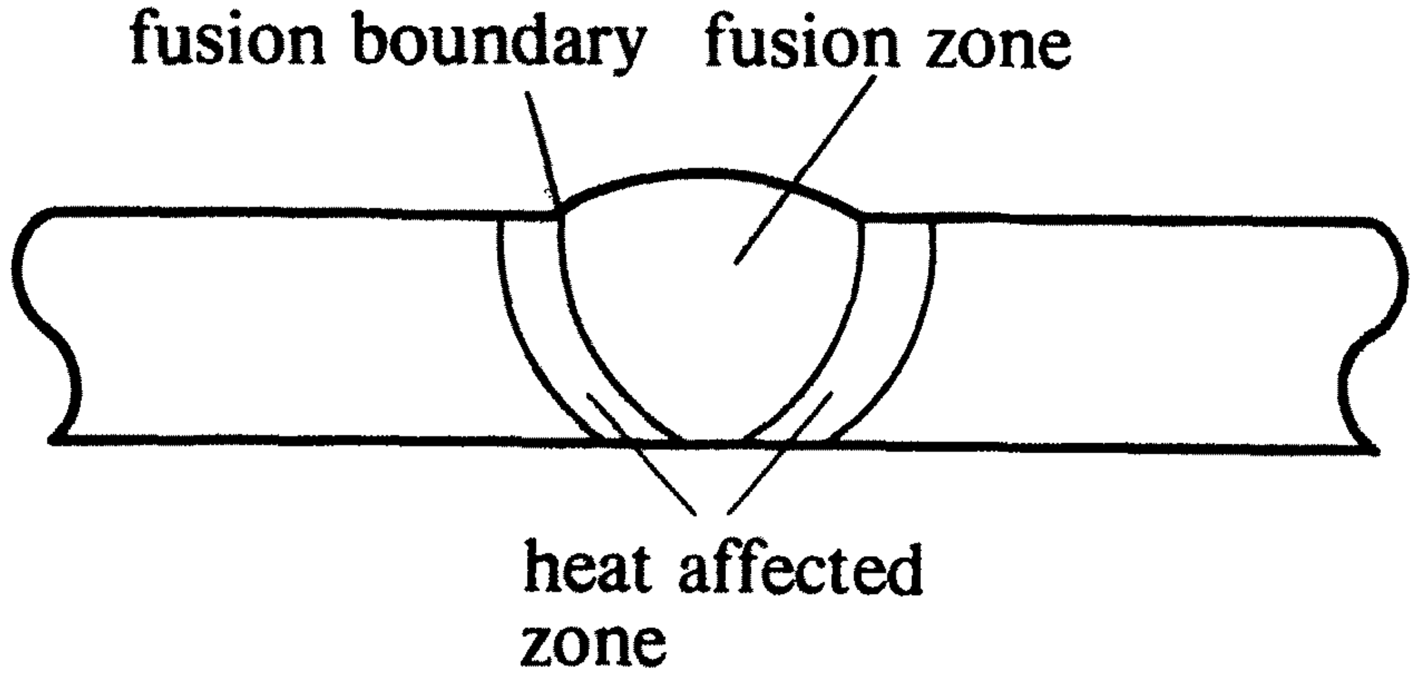


Figure 2.1 Fusion weld.

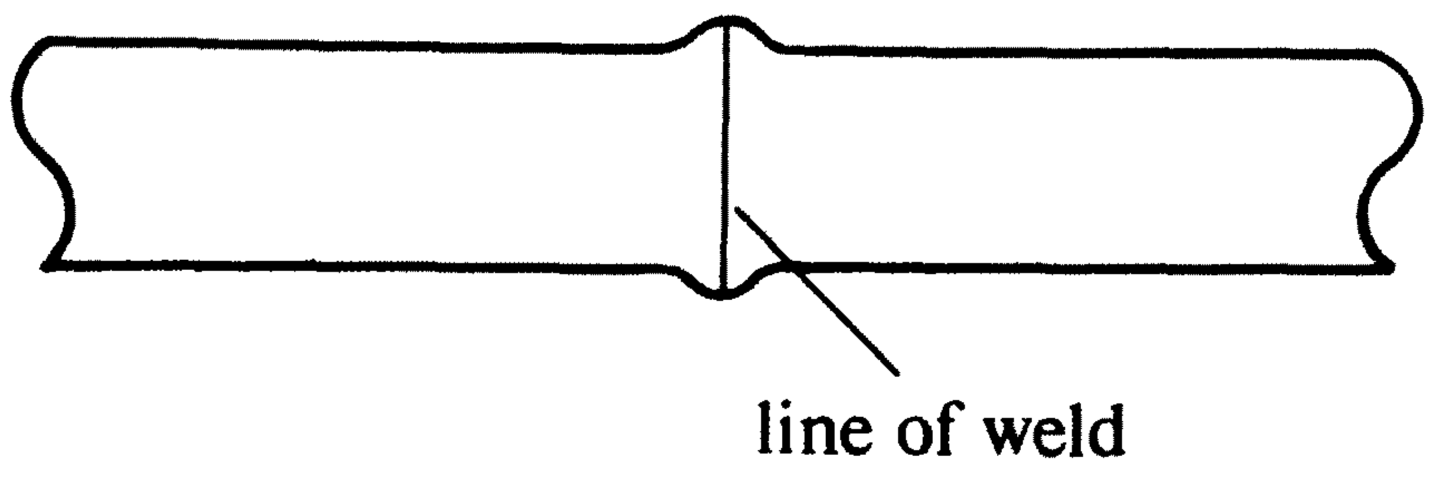
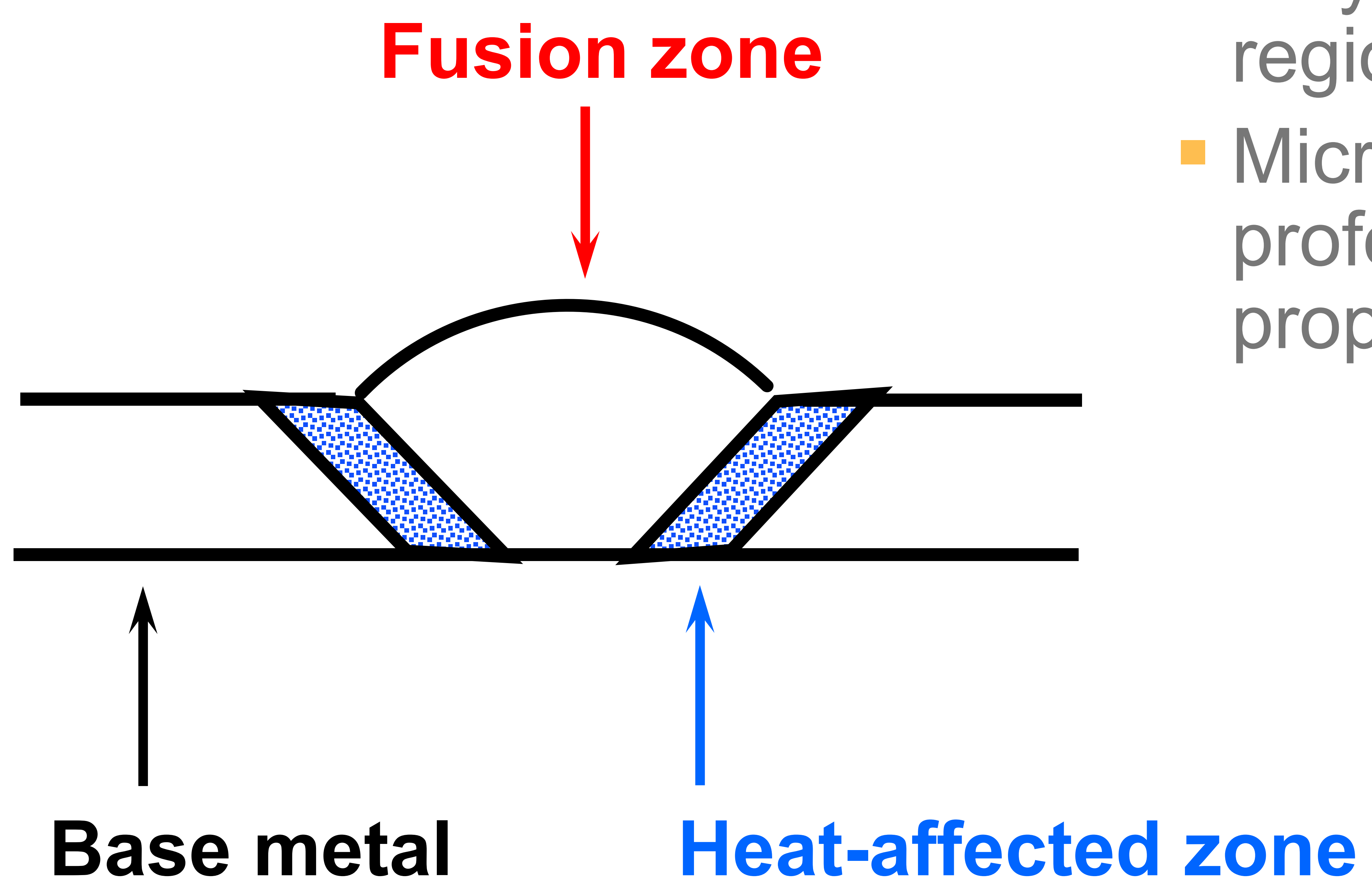


Figure 2.2 Solid phase weld.

point, solid-phase welding may be accomplished at temperatures as low as normal room temperature. Solid-phase welding will be considered in detail in

Region of the Fusion Weld

In fusion welding, a source of high-density heat energy raises the temperature of the surfaces enough to cause localized melting; if the heat density (power ÷ surface area) is too low, the heat is conducted away as fast as it is added and melting does not occur

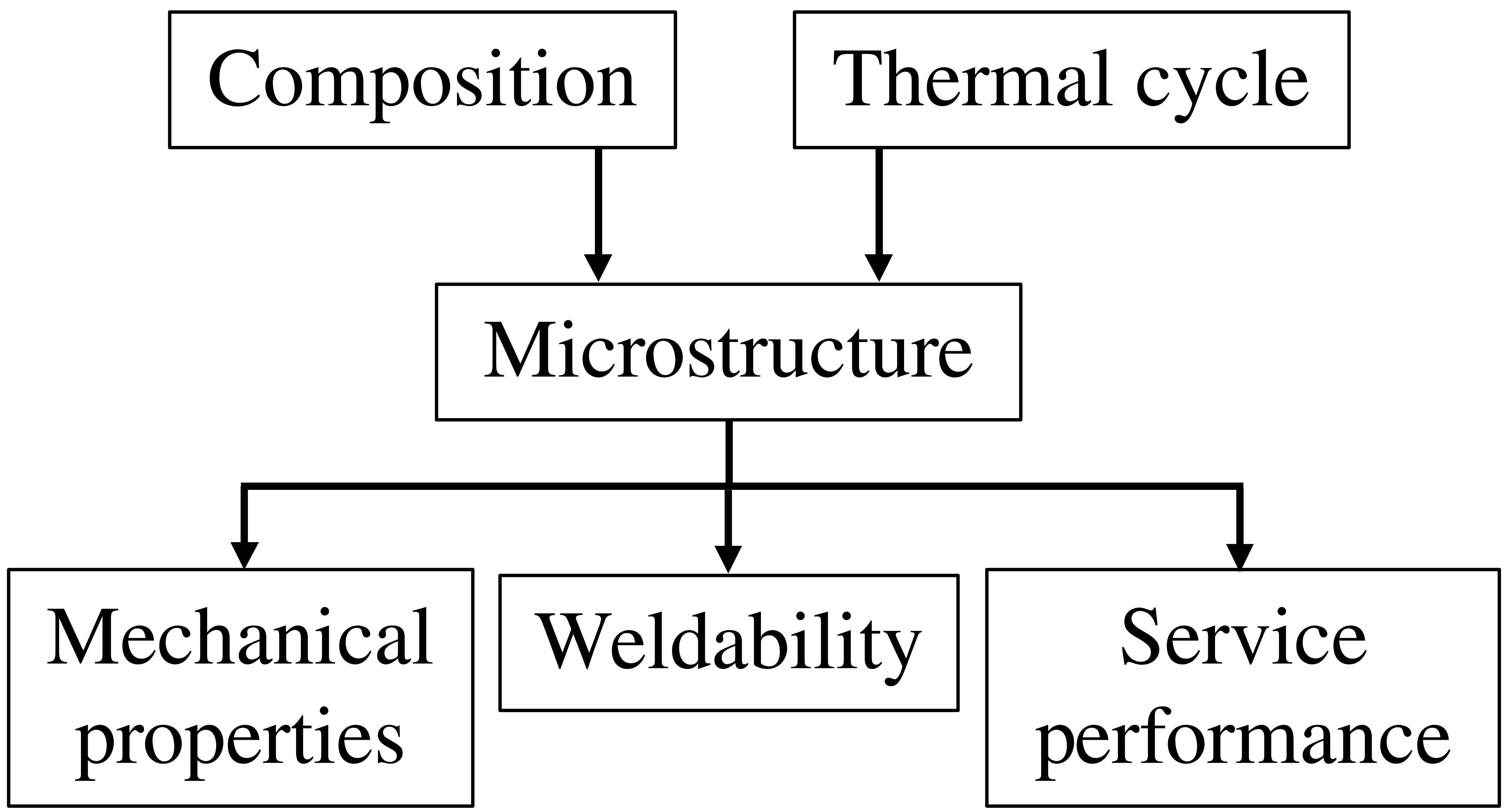


- The microstructure can vary from region to region in a weld
- Microstructure has a profound effect on weld properties

Welding Metallurgy

- Metallurgy of Welding addresses the topics of Welding Metallurgy and Weldability
- Welding Metallurgy describes a microcosm of metallurgical process occurring in and around a weld that influence the microstructure, properties and weldability of the material
- Due to rapid heating and cooling rates associates with most welding processes, metallurgical reaction often occur under transient, non-equilibrium conditions
- The Weldability can be used to describe both the ability to successfully fabricate a component using welding and the capacity for that component to perform adequately in its intended service environment
- The term Weldability also describes the behavior of welded structures after they are put into service

Microstructure and Properties



- Cooling rate and Chemical Composition affect the microstructure of the weld joints
- The mechanical properties (includes weldability and performance) of a weld joint depend on the microstructure produced by the welding

Metallurgical Processes

- Melting and solidification
- Nucleation and growth
- Phase transformations
- Segregation and diffusion
- Precipitation
- Recrystallization and grain growth
- Liquation mechanisms
- Embrittlement
- Thermal expansion, contraction, and residual stress

Why welding metallurgy is important

There are a number of metallurgical processes that control the microstructure and properties of welds. Melting and solidification are important processes, since they are the key to achieving acceptable joints in all fusion welding processes. Coupled with solidification are segregation and diffusion processes resulting in local compositional variations that influence both weldability and service performance.

Many metallurgical processes occur in the solid state, including phase transformations, precipitation reactions, recrystallization, grain growth, etc. The extent of these reactions may significantly alter the microstructure and properties of the weldment (weld metal and heat-affected zone (HAZ)) relative to the base metal. Many of these reactions, or complex combinations of reactions, can result in embrittlement, or cracking, of welds. This embrittlement can occur due to liquation, the presence of liquid films in an otherwise solid matrix, or in the solid state due to a loss in ductility.

Thermal expansion during heating and contraction during cooling can result in complex stress patterns in and around welds. These stresses can subsequently affect the microstructure and properties of the weldment and may promote cracking in regions where the tensile strain resulting from these stresses exceeds the ductility of the material.