JOINING

UNDERSTANDING
THE
BASICS

Edited
by
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Preface

This book is a rather brief introduction to industrial joining processes. The intent was to take an extensive amount of technical information on the individual joining processes and boil it down to provide a readable resource on joining. The majority of the information in this book was extracted from the *ASM Handbook* series. The book covers all of the major welding processes; brazing and soldering; mechanical fastening; and adhesive bonding.

Welding is a process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. No other technique is as widely used as welding to join metals and alloys efficiently and to add value to their products. Most of the familiar objects in modern society, from buildings and bridges, to vehicles, computers, and medical devices, could not be produced without the use of welding.

Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering them. Arc welding and oxyfuel welding were among the first processes to develop late in the century, and resistance welding followed soon after. Welding technology advanced quickly during the early 20th century as World War I and World War II drove the demand for reliable and inexpensive joining methods. Following the wars, several modern welding techniques were developed, including manual methods like shielded metal arc welding, now one of the most popular welding methods; as well as semiautomatic and automatic processes such as gas metal arc welding, submerged arc welding, flux-cored arc welding and electroslag welding. Developments continued with the invention of laser beam welding and electron beam welding in the latter half of the century. Today, the science continues to advance. Robot welding is becoming more commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of
weld quality and properties. Welding today is applied to a wide range of materials and products, using such advanced technologies as lasers and plasma arcs.

After an introduction to the various joining processes (Chapter 1), the next five chapters address different welding processes. It is estimated that 90% of all industrial welding is done by arc welding. The arc welding processes covered in Chapter 2 include shielded metal arc welding, flux-cored arc welding, submerged arc welding, gas metal arc welding, gas tungsten arc welding, plasma arc welding, plasma-MIG welding, and electroslag welding and electrogas welding.

Resistance welding is a group of processes in which the heat for welding is generated by the resistance to the flow of an electrical current through the parts being joined. It is most commonly used to weld two overlapping sheets or plates that may have different thicknesses. Specific resistance welding processes covered in Chapter 3 include resistance spot welding, resistance seam welding, projection welding, flash welding, and upset welding.

The other fusion welding processes that were not covered in Chapters 2 and 3 are covered in Chapter 4. These include oxyfuel gas welding, oxy-acetylene braze welding, stud welding (stud arc welding and capacitor discharge stud welding), high-frequency induction welding, electron beam welding, laser beam welding, and thermit welding.

Some of the metallurgical variables in fusion welding are reviewed in Chapter 5. These include energy intensity, heat flow, weld pool solidification, solid-state transformations after solidification, residual stresses and distortion, distortion control, welding discontinuities, weld cracking, fatigue strength of weldments, and inspection of welded joints.

Solid-state welding processes (Chapter 6) are those that produce coalescence of the faying surfaces at temperatures below the melting point of the base metal being joined without the addition of brazing or solder filler metal. Pressure may or may not be applied. These processes involve either the use of deformation or of diffusion and limited deformation in order to produce high-quality joints between both similar and dissimilar materials. Specific solid-state welding processes include: diffusion bonding, forge welding, roll welding, coextrusion welding, cold welding, friction welding and friction stir welding, explosive welding, and ultrasonic welding.

Brazing and soldering processes, covered in Chapter 7, use a molten filler metal to wet the mating surfaces of a joint, with or without the aid of a fluxing agent, leading to the formation of a metallurgical bond between the filler and the respective components. Solders usually react to form intermetallic phases, that is, compounds of the constituent elements that have different atomic arrangements from the elements in solid form. By contrast, most brazes form solid solutions, which are mixtures of the constituents on an atomic scale. Joining processes of this type are defined as
soldering if the filler melts below 450 °C (840 °F) and as brazing if it melts above this temperature.

A mechanical fastener is a hardware device that mechanically joins or affixes two or more objects together. The concept of the screw was described by the Greek mathematician Archytas of Tarentum (428-350 BC). Mechanical fastening is the subject of Chapter 8. One unique feature of mechanical fastening is that the joint can either be permanent (e.g., riveting) or temporary (e.g., screws). Many types of fasteners and fastening systems have been developed for specific requirements, such as high strength, easy maintenance, corrosion resistance, reliability at high or low temperatures, or low material and manufacturing costs. Fastener types discussed include threaded fasteners (bolts and screws), pin and collar fasteners, rivets, blind fasteners, and miscellaneous fastening methods such as stitching, stapling, snap fits, and integral fasteners.

An adhesive (Chapter 9) is a polymeric mixture in a liquid or semiliquid state that adheres or bonds items together. Adhesives may come from either natural or synthetic sources. The types of materials that can be bonded are vast but they are especially useful for bonding thin materials. Adhesives cure (harden) by either evaporating a solvent or by chemical reactions that occur between two or more constituents. Adhesives are advantageous for joining thin or dissimilar materials, minimizing weight, and when a vibration dampening joint is needed.

While adhesive bonding is often thought of as a relatively new technology, the oldest known adhesive, dated to approximately 200,000 BC, is from spear stone flakes glued to a wood with birch-bark-tar, which was found in central Italy. The use of compound glues to attach stone spears into wood dates back to round 70,000 BC. Evidence for this has been found in Sibudu Cave, South Africa and the compound glues used were made from plant gum and red ochre. The Tyrolean Iceman had weapons fixed together with the aid of glue.

A number of materials and material combinations are difficult to join, either because of their individual chemical compositions or because of large differences in physical properties between the two materials being joined. In any dissimilar joining process high temperatures, differences in the coefficients of thermal expansion (CTEs) are a major consideration. In Chapter 10, a number of these situations are covered: welding of dissimilar metal combinations; joining of plastics by mechanical fastening, solvent and adhesive bonding, and welding; joining of thermoset and thermoplastic composite materials by mechanical fastening, adhesive bonding, and for thermoplastic composites, welding; the making of glass-to-metal seals; and joining of oxide and nonoxide ceramics to themselves and to metals by solid-state processes and by brazing.

This book is intended for those wishing to learn more about the technology of joining of materials. It would be useful to almost anyone who is
interested in or deals with joining, including designers, structural engineers, material and process engineers, manufacturing engineers, managers, and students and faculty. It is brief enough to serve as a first text on joining that can later be supplemented by more advanced texts.

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