Joining Technology

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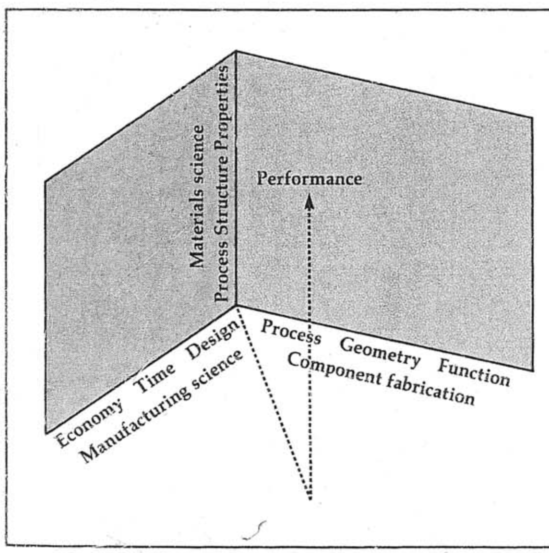
Virtually every manufactured product contains joints; either to assemble similar materials into a more complex shape or to attach dissimilar materials to create a composite product incorporating different materials properties. The latter trend is creating ever increasing problems in joining technology, many of which welding engineers are unprepared to solve today.

The quality of a manufactured product is directly related to the quality of the joints. The remark, "something won't fail unless it has been welded" holds some truth, in that joints usually are located in the most highly stressed regions of the component. A disproportionately large number of component failures are related to the welded joints. For this reason, a basic rule of design requires that the number of joints be minimized. By combining increasingly diverse materials, this rule is being violated at an increasing rate.

In predicting future trends in joining technology, it is convenient to differentiate between traditional materials and advanced materials. The properties and functions of traditional materials are well known; therefore, improved performance can be best achieved by reducing the cost and increasing the quality of the joining process. It is commonly believed that this can be accomplished through automation and enhanced quality-control procedures. However, it is becoming increasingly apparent that automation of a process that is not under control merely produces scrap more quickly. Automation of welding and other joining processes is not the key to improved production of traditional materials; this can only be achieved by improved understanding of the process, which will require a more thorough education of the workforce. Few engineers or designers have any formal education in joining technology. This situation will change during the next decade in "successful" manufacturing companies that devote an expanding fraction of their budget to educate the manufacturing workforce.



As a process, joining lies at the interface between materials science and manufacturing. Materials science, manufacturing science, and fabrication contribute to product performance. Many of the advanced materials being developed today will never by used in large volumes because of inattention to component fabrication and manufacturing science. Without geometry or shape, which produces function, the properties of the material are useless and unless the shape and properties can be obtained economically, the product has limited utility.

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In the fabrication of heavy structures, such as in the shipbuilding, construction, and pressure-vessel industries, arc welding will continue to dominate due to its flexibility and cost-effectiveness. Automation will increase steadily, driven as much by a shortage of skilled labor as by new technologies. The most successful automation technologies will be simple and inexpensive rather than the high-technology, high cost-approaches which are so popular among welding researchers — it simply makes no sense to incorporate a $50,000 sensor on a $10,000 welding arc unless one is working with materials of an extremely critical nature.

A revolution in arc-welding power-supply technology will occur due to the use of new inverter-controlled machines. However, adoption of this new technology will be slowed by the lack of knowledge of how to apply it. Eventually, pulsed-current and current-waveshaped technology will improve the quality and reliability of both arc welds and resistance welds, but there will be many false starts and much building of empirical-models building before the capabilities of these new power supplies are used to their full extent.

Whether a material or process is traditional or advanced depends on the industry considered. For example, welding structural aluminum cannot be considered new in the aerospace industry, yet, it is an advanced application in automotive production. For example, the change to a space-frame automobile design will remove the structural redundancy afforded by current

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designs; thus, new joining processes will be required to overcome the limited quality of resistance welding. Brazing as well as laser, magnetically impelled arc butt (MIAB), or conventional arc welding processes are candidates to handle the fabrication requirements of new automobile structural components.

The cost of many advanced materials is so high, and their properties so specialized, that they will only be used where they are essential. Consequently, products will contain more joints, a greater number of which will join dissimilar materials. Few traditional joining processes are practical in this situation; new part designs and joining processes will be required. Adhesives can always be used, but joint properties often place severe limitations on part design or function. Brazing will be considered increasingly, especially to join ceramics and metal-matrix composites. Low-temperature metallic bonding using transient-liquid-phase technology will be extended to many more alloy systems. In this process, a component of the brazing material or solder diffuses into the base material resulting in isothermal solidification of the filler material.

In the jet turbine engine industry, superplastic forming/diffusion bonding (SPF/DB) will be used more effectively in new designs than in the past. "Blisk," or bladed disk, technology, in which a lightweight SPF/DB vane is friction welded directly to the disk will remove significant weight from both the engine and the airframe.

Microwave bonding ceramics will be developed, but it is too early to predict how prevalent this technology will become. Ultra-high-brightness lasers already have shown their usefulness in hole drilling; however, successful application to thick-section welding or cutting has not been demonstrated. Variations of the plasma-arc welding process also may provide new capabilities for arc welding advanced materials.

For every new material developed, joining processes must be restudied or developed to use the material effectively. Use of new materials will be limited by the capability to exploit the joining processes, rather than by the ability to design or produce such materials.

Based on today's trends, the joining engineer of the next decade will be faced with the task of developing processes for new materials in much shorter lead times. Components will be smaller; structures will be more three-dimensional with less redundancy, requiring greater reliability; and more dissimilar materials combinations will be required. ■