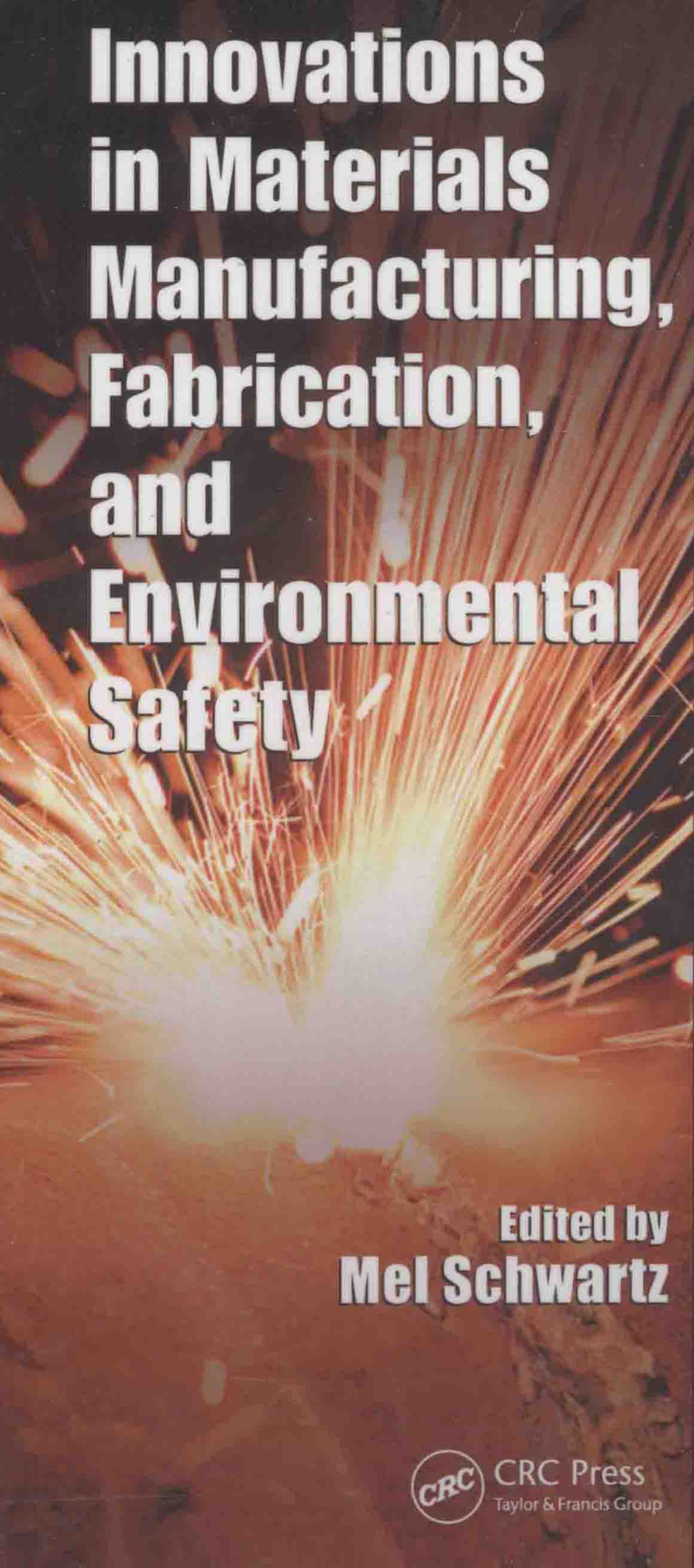
Innovations in Materials Manufacturing, Fabrication, and Environmental Safety



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To my family whose free-flowing love and encouragement have endured for 40 years of my book publishing career.

Preface

Throughout industries, pressure for change now comes from all directions—technical, financial, environmental, political, and social. The roadmap for new and developing processes, technologies, and materials provides a vision that shows company-by-company efforts aren't enough—implementing such a vision requires extensive value/chain collaboration and public/private partnerships. To ensure success in a highly competitive environment, the government must be part of the business strategy, especially long-term funding of research and development. Technical societies could also be a prime mover and act as a catalyst/facilitator at times.

In the research and development of new materials or variations of new processes, the word "innovation" for the scientist means something altogether different from the interpretation by the general public. According to Margaret W. Hunt, editor of *Advanced Materials & Processes* magazine, "Innovation is really a state of mind, a fundamental attitude of willingness to try new and sometimes radically different approaches to problems." This is the state of mind of the engineers who help drive the innovations that prime the U.S. economy. No one can predict the wonders that will become commonplace in the future, but it is safe to predict that they will be based on unseen developments.

For the general public, innovation brings to mind such products as cell phones and laptop computers, not advanced materials and process technologies. However, the inventors of these devices know that without advanced materials, joining methods, processing, and testing technologies, clunky telephones and typewriters would still be the norm, not to mention heavy and inefficient automobiles. These innovations that save money and reduce costs are often hidden from the ultimate consumer, who might not realize that the improved mileage in a new car is partially due to a metal diecast or molded plastic part that weighs less, that better safety is provided by stronger steel, and that new coating methods make the car look better and last longer. These things are invisible and the engineers who design and develop them often do not receive the credit they deserve.

A roadmap that was created in 1998 to identify the robotics and intelligent machine (RIM) goals by the year 2020 is now in place. This national initiative called for focusing and strengthening research in intelligent systems to strengthen the entire industry—currently U.S. companies lead the world in sensory devices and algorithms. Intelligent machines are advanced sensory devices to collect information about their environment and use sophisticated algorithms to respond to the information. This RIM science will benefit industry and society.

Intelligent machines can provide value to companies in all segments of manufacturing. An important question to ask is: What can RIM help you do better? For example, the high-value consumer electronics manufacturers want intelligent production systems that can rapidly and easily accommodate new product lines; they want intelligent systems to ensure the manufacturability of a product line and autonomously reprogram themselves when a new design is introduced. The welding industry wants an intelligent machine that will result in a repeatable, high-quality, structurally reliable weldment.

Many of the manufacturing processes described in this book can, and likely will, benefit from the incorporation of an intelligent machine into the processing and fabrication cycle. For example, a project at the Idaho National Engineering & Environmental Laboratory (INEEL) currently involves intelligent welding machines that incorporate both knowledge of welding physics and empirical learning capabilities. Currently, welding is considered as an industrial art based on a welder's manual skills or very simple duplication of these skills by an automatic (but dumb) machine. A typical approach to a machine control problem is to have a central body of intelligence (and control) in the machine. However, researchers at INEEL have developed a conceptual design of a machine using distributed learning and intelligence. The design is loosely based on biological models of social insects. For example, in an ant colony each ant functions according to local rules of behavior. Thus methods of learning and behavior modification have been developed that ensure global stability and optimization of the total machine. Researchers believe a qualitative understanding of the relationships between local costs and global subcosts can be used to develop future models for a welding process, as well as in more traditional control systems for welding processes.

In this 21st century, there are numerous challenges that are being overcome and in some instances have been overcome. Increased emphasis has been put on new materials, new fuels and propulsion technologies, advanced manufacturing, and predictive engineering that will put tremendous demands on our educational infrastructure and necessitate changes in curricula. Various industrial learning centers have been actively engaged during the past 10 years with design-oriented and engineering schools, industry scientists and engineers who work with materials, and advanced processes in activities including seminars, workshops, forums, and national conferences.

The initiatives mentioned here require steadfast commitment to long-term research and development, advocacy, and communication. Individual and corporate participation is, of course, critical.

This book will discuss environmental issues and safety in regard to processes and processing. In fact, all products manufactured need energy for material and production. Professor Timothy G. Gutowski, Faculty of Mechanical Energy at MIT, has received a grant from the National Science Foundation (NSF) to conduct research into the energy use of manufacturing processes of materials. "Manufacturing processes can be thought of as products with a huge energy appetite," Gutowski says. "These processes contribute to global warming, but are not visible to the public, unlike gas-guzzling SUVs or images of melting polar ice caps." Many people are not aware of the energy requirement for a lot of manufacturing processes, claims Gutowski. For example, the whole of the Western composites industry should be concerned. Upcoming economies such as China, India, Korea, and Malaysia are rapidly developing composite technologies and production processing.

Composites and energy could well be the criteria for future success in public transport. The subject of composites and energy is strongly related to population growth, mobility, and transport systems. Countries that have new economies are less hindered by rules, regulations, laws, and standards, and they are able to start from a different playing field. These countries have the best of both worlds—their own low cost of manufacturing and a highly educated population, and the loan of the often rusted technology know-how from Western countries. Southeast Asia is going to be in strong competition with the Western world. This should be a major concern to industry in the future. However, being different may be the only way the Western world of industries can sustain, by being one step ahead of the rest of the world and focus on what is the most important area for future growth and development; that is, resin transfer molding (RTM) composites and energy.

Speaking about energy, fresh research out of Yale University concludes that the energy required to produce nickel-containing, austenitic stainless steel from scrap is less than a third of the energy used to produce stainless steel from virgin sources. As an additional environmental bonus, recycling produces just 30% of the CO_2 emissions. Already one of the most recycled materials in the world, stainless steel could, theoretically, be made entirely from scrap if there weren't serious limitations on the availability of this material. Ironically, one of the main benefits of the material—its durability—limits its recycling potential: stainless steel structures and products tend to last a long, long time.

Current recycling operations reduce primary energy use by about 33% and CO_2 by 32% compared with production from virgin sources alone. But if stainless steel were to be produced solely from scrap (a merely hypothetical scenario), about 67% of the energy could be saved and CO_2 emissions cut by 70%.

"It confirms common sense," says Barbara Reck, a research associate at the School of Forestry and Environmental Studies at Yale. "The biggest energy use is in the mining and smelting phase, and you don't have to go through this phase using scrap. But now calculations have shown this systematically and the hypothesis has been confirmed." These findings have implications for the thousands of end-users of nickel-containing stainless steels.

In today's environmentally conscientious marketplace, customers want assurance that the products they buy will not contribute to climate change. They prefer to contribute to a sustainable world. Today products are advertised as being made of materials that have been validated, by one association or another, as safe for the environment. For example, in Northbrook, Illinois, a U.S.-based Crate and Barrel reports that its sofas have wood frames "certified by the Sustainable Forestry Initiative" and that they are "guaranteed for life." What's more, its cushions are "created with revolutionary, bio-based materials that are environmentally renewable." The advertisement concludes: "Sustainability is a beautiful thing."

The same can be said of products made of nickel-containing stainless steel. It is one of the world's most recycled materials. Austenitic stainless steel products are all around us. Our kitchen appliances and sinks are made of it, we cook our meals in it, we eat our meals with it, the material has been available for less than 100 years, and is increasingly recycled. More than 80% of all products made of austenitic stainless steel are recycled at the end of their useful life. That has significance for the environment and sustainability. It means less energy is needed and less CO_2 emitted in the manufacture of austenitic stainless steel than in the past, when virgin material was all that was available. As more scrap becomes available, the need for virgin material declines and the carbon footprint left by a ton of austenitic stainless steel becomes smaller. The production of austenitic stainless steel is more sustainable than ever.

Fabricators and original equipment manufacturers (OEMs) must address health, safety, and environmental concerns. Infusion processing technologies especially must maintain a safe workplace including periodic training, adherence to detailed handling procedures, maintenance of current toxicity information, use of protective equipment (gloves, aprons, dust-control systems, and respirators), and development of company monitoring policies. Both suppliers and OEMs are working to reduce emissions of highly volatile organic compounds (VOCs) by reformulating resins and prepregs (pre-impregnated) and switching to water-dispensable cleaning agents.

So where does all this lead? Advances in materials technology and the convergence of materials, information, and miniaturization will drive less resource intensity, more complexity, and smart products. Older, established technologies will continue sidewise development into new markets and applications. Innovations such as nanotechnologies, portable energy sources, multifuel products, miniaturization, and customizable intelligent materials will grow.

But how do we cope with these challenges and the opportunities that result?

We put the spotlight on innovation of new and exciting processing techniques, methods, and fabrication technologies developing the next business models, not only on new products, processes, and services within your own company. Identify novel segments and geographies, quickly spot new competitors and partners, and establish global positions quickly through acquisitions, alliances, and licensing. In addition, we must manage strategic risk—not just operational risk or political risk. Speed, flexibility, market knowledge, effective alliances and acquisitions, and innovation will be critical success factors required to win in an environment driven by these mega trends.

In conclusion, we have before us opportunities and huge challenges. They are coming at us simultaneously ... we have no option to take them in sequence. We must play two hands.

Mel Schwartz

Editor

Mel Schwartz has degrees in metallurgy and engineering management and has studied law, metallurgical engineering, and education. His professional experience extends over 51 years serving as a metallurgist in the U.S. Bureau of Mines; metallurgist and producibility engineer, U.S. Chemical Corps; technical manufacturing manager, chief R&D Lab, research manufacturing engineering, and senior staff engineer, Martin-Marietta Corporation for 16 years; program director, manager and director of manufacturing for R&D, and chief metals researcher, Rohr Corp for 8 years; staff engineer and specification specialist, chief metals and metals processes, and manager of manufacturing technology, Sikorsky Aircraft for 21 years. While retired Mel has been a consultant for many industrial and commercial companies including Intel and Foster Wheeler, and was former editor for *SAMPE Journal of Advanced Materials.*

Mel's professional awards and honors include Inventor Achievement Awards and Inventor of the Year at Martin-Marietta; C. Adams Award & Lecture and R.D. Thomas Memorial Award from AWS; first recipient of the G. Lubin Award and an elected Fellow from SAMPE; an elected Fellow and Engineer of the Year in CT from ASM; and Jud Hall Award from SME.

Mel's other professional activities involve his appointment to ASM Technical Committees (Joining, Composites and Technical Books; Ceramics); manuscript board of review, *Journal of Metals Engineering* as peer reviewer; the Institute of Metals as peer reviewer as well as *Welding Journal;* U.S. Leader of IIW (International Institute of Welding) Commission I (Brazing & Related Processes) for 20 years and leader of IIW Commission IV (Electron Beam/Laser and Other Specialized Processes) for 18 years.

Mel's considerable patent activity has resulted in the issuance of five patents, especially aluminum dip brazing paste commercially sold as Alumibraze.

Mel has authored 17 books and over 100 technical papers and articles. Internationally known as a lecturer in Europe, the Far East and Canada, Mel has taught in U.S. colleges (San Diego State, Yale University), ASM Institutes, McGraw-Hill Seminars, and in-house company courses.

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Contents

1

Plasma Brazing

Dr.- Ing. Carolin Radscheit

CONTENTS

Why Plasma Brazing?

In the last 20 years, the weight of vehicles has been steadily increasing. This tendency can be applied to all makes and models of vehicles. The Volkswagen Golf I automobile was made from 1974 until 1983 and weighed only 870 kg, whereas the Golf 5 that started production in 2004 weighed about 1200 kg. This increase in weight is largely due to two factors:

- The increase in components concerning the safety of the occupants and the environment, for example, curtain and side airbags, antilock braking systems, belt tensioners, catalytic converters, and so on.
- The increase in components that increased driving comfort: electric windows, electrically operated sunroofs, power steering, air conditioning, and so on. For example, a maximum of five electric motors and control units were installed in the Golf 3 (from November 1991 until May 1997), whereas the Golf 5 possesses 25–30 such units with optimal equipment.

Parallel to this development, the construction of vehicles was changed so that safety could be provided through stable passenger compartments and consequently, the thickness of the body sheet metal was reduced. Most body panels today are thinner than 1.0 mm. Galvanization provides corrosion protection, which helps maintain the vehicle, its value, and enables the vehicle manufacturer, Volkswagen, to offer guarantees against rust perforation.

Another development was the influence of joining techniques in body construction. Previous welding procedures have caused spattering on galvanized metal, and if the sheet metal is thin, there is a danger that it will be burn-through. As a result, new or modified joining methods were needed and required development.

Several brazing methods have been examined and developments have produced several new techniques. Three of these methods appear to have promise; however, the third method is the most applicable and is covered in this chapter.

The first process that was examined was laser beam brazing, which is suited for producing visually demanding and completely splatter-free seams. Therefore, this process has been used for outer surface joints, the boot lid (trunk) or hatch, and roof/side panel joints in autos. However, this process depends on maintaining small gaps ($g < 1.0$ mm), and can only be used in automated applications and also requires safety measures specific to laser beams.

The second method that was examined was MIG brazing (gas metal brazing), a metal inert gas process in which a copper-containing filler metal was used as a brazing material and is well suited for joining thin galvanized sheet metal. This process or ability to fill gaps well is especially advantageous when used with robots. However, this process is not splatter free and consequently has limited use for outer body surfaces. The splatter must be removed by grinding.

The third method and the subject of this chapter is plasma brazing, which offers an excellent compromise between the previous two modern brazing methods. Plasma brazing is very well suited for joining thin galvanized sheet metal, produces a narrow, visually appealing, and completely splatter-free seams and therefore has been used primarily on the outer body surfaces of autos. Plasma brazing can be performed manually as well as robotically and requires the same safety precautions as inert gas shielded welding.

How Plasma Brazing Works

A schematic diagram of the plasma brazing torch is shown in Figure 1.1. A plasma brazing machine consists of a plasma torch, a power source, a filler material wire feed, gas feed and, if required, a seam guide sensor, Figure 1.2. Plasma brazing is the equivalent of plasma welding with nonconducting filler wire. Just as with other welding and brazing processes with a side-feed