DESIGNING with PLASTICS and COMPOSITES

A HANDBOOK

Donald V. Rosato David P. DiMattia
Dominick V. Rosato

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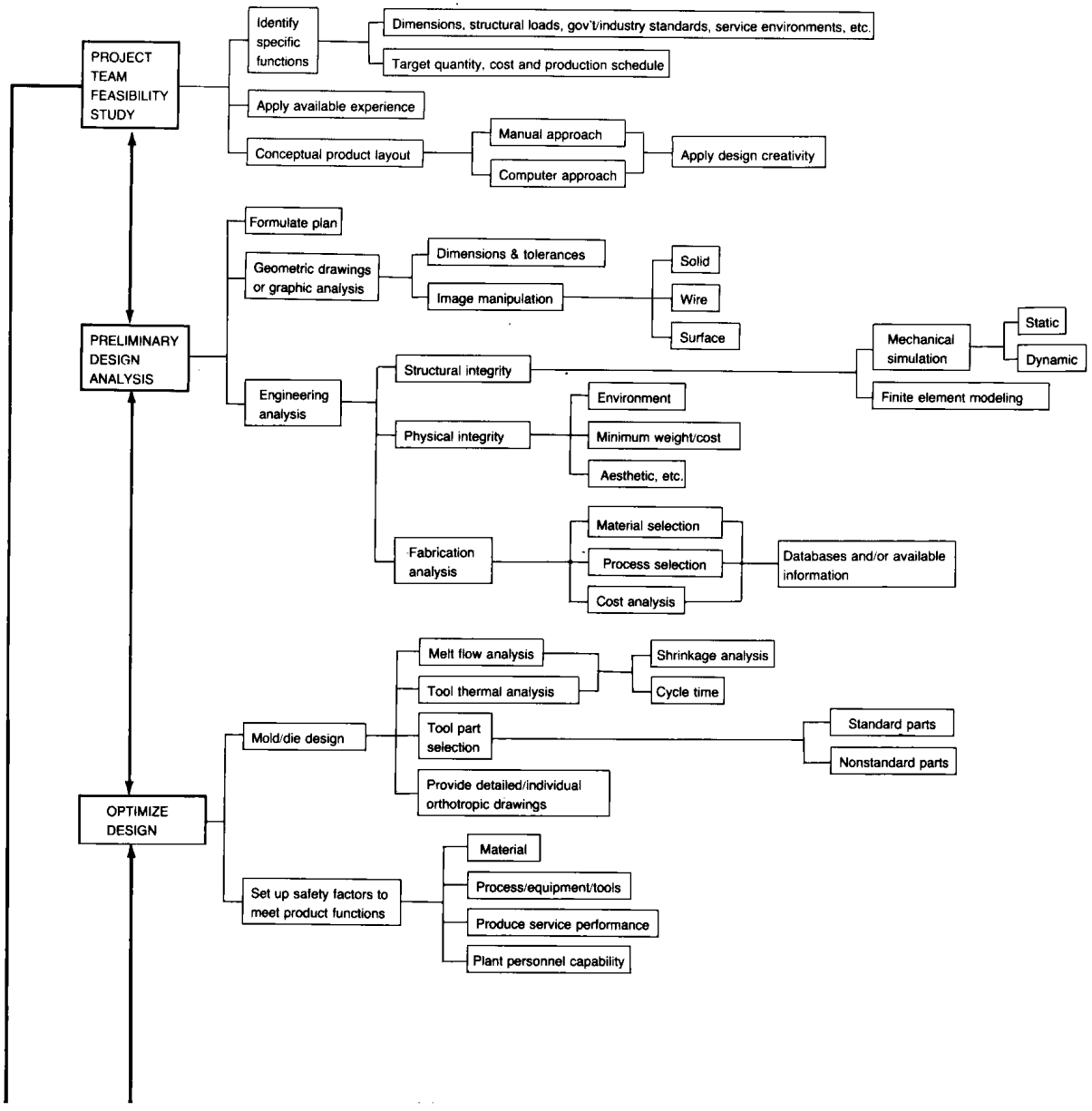
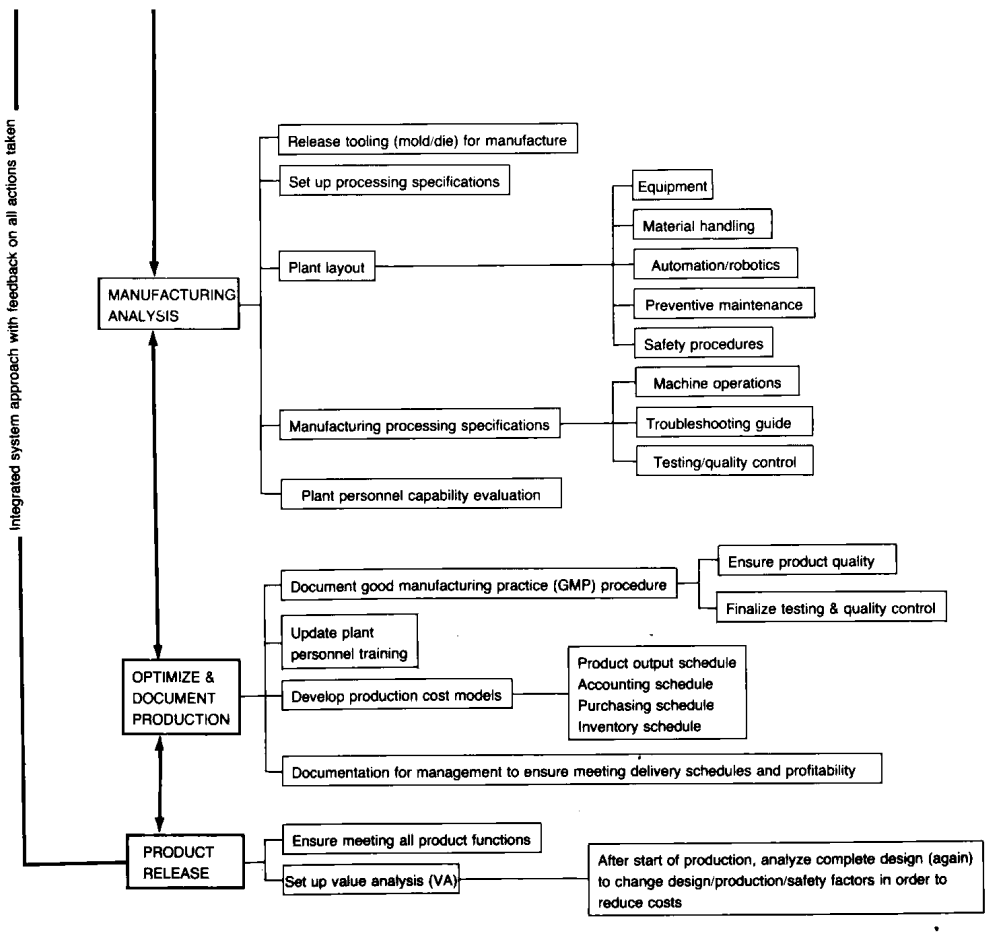

PROJECT TEAM FEASIBILITY STUDY
Identify specific functions
Dimensions, structural loads, gov't/industry standards, service environments, etc.
Target quantity, cost and production schedule
Apply available experience
Conceptual product layout
Manual approach
Computer approach
Apply design creativity
PRELIMINARY DESIGN ANALYSIS
Formulate plan
Geometric drawings or graphic analysis
Dimensions & tolerances
Image manipulation
Solid
Wire
Surface
Engineering analysis
Structural integrity
Mechanical simulation
Static
Dynamic
Finite element modeling
Physical integrity
Environment
Minimum weight/cost
Aesthetic, etc.
Fabrication analysis
Material selection
Process selection
Cost analysis
Databases and/or available information
OPTIMIZE DESIGN
Mold/die design
Melt flow analysis
Tool thermal analysis
Shrinkage analysis
Cycle time
Tool part selection
Standard parts
Nonstandard parts
Provide detailed/individual orthotropic drawings
Set up safety factors to meet product functions
Material
Process/equipment/tools
Produce service performance
Plant personnel capability


Integrated system approach with feedback on all actions taken
MANUFACTURING ANALYSIS
Release tooling (mold/die) for manufacture
Set up processing specifications
Plant layout
Equipment
Material handling
Automation/robotics
Preventive maintenance
Safety procedures
Manufacturing processing specifications
Machine operations
Troubleshooting guide
Testing/quality control
Plant personnel capability evaluation
OPTIMIZE & DOCUMENT PRODUCTION
Document good manufacturing practice (GMP) procedure
Ensure product quality
Finalize testing & quality control
Update plant personnel training
Develop production cost models
Product output schedule
Accounting schedule
Purchasing schedule
Inventory schedule
Documentation for management to ensure meeting delivery schedules and profitability
PRODUCT RELEASE
Ensure meeting all product functions
Set up value analysis (VA)
After start of production, analyze complete design (again) to change design/production/safety factors in order to reduce costs

Preface

For some time there has been a strong need in the plastic and related industries for a detailed, practical book on designing with plastics and composites (reinforced plastics). This one-source book meets this criterion by clearly explaining all aspects of designing with plastics, as can be seen from the Table of Contents and Index. It provides information on what is ahead as well as today's technology. It explains how to interrelate the process of meeting design performance requirements with that of selecting the proper plastic and manufacturing process to make a product at the lowest cost. This book has been prepared with an awareness that its usefulness will depend greatly upon its simplicity. The overall guiding premise has therefore been to provide all essential information. Each chapter is organized to best present a methodology for designing with plastics and composites.

This book will prove useful to all types of industrial designers, whether in engineering or involved in products, molds, dies or equipment, and to people in new-product ventures, research and development, marketing, purchasing, and management who are involved with such different products as appliances, the building industry, autos, boats, electronics, furniture, medical, recreation, space vehicles, and others. In this handbook the basic essentials of the properties and processing behaviors of plastics are presented in a single source intended to be one the user will want to keep within easy reach.

Once a product's purpose and service requirements have been established, its successful design and manufacture to meet zero-defects production requires knowledge of 1) the plastic materials from which it is to be made, their nature, and the ways in which processing may affect their properties; 2) the processing methods available for its manufacture; and 3) how to evaluate its properties and apply effective quality control.

This reference handbook has been designed to be useful to those using plastics as well as those still contemplating their use. To this end the presentations are comprehensive yet simplified, so that the specialist in a specific field will obtain useful information. The cross-comparisons and interrelations of design facts and figures are extensive, to ensure ease in understanding the behavior of plastics and composites.

Designing depends on being able to analyze many diverse, already existing products such as those reviewed in this handbook. One important reason for studying these designs is that this shows how many diverse topics cooperate synergistically to enhance designers' skills.

Design is interdisciplinary. It calls for the ability to recognize situations in which certain techniques may be used and to develop problem-solving methods to fit specific design situations. Many different examples of problems are thus presented within this handbook, concerning many products.

With plastics, to a greater extent than with other materials, the opportunity exists to optimize design by focusing on a material's composition, its structural orientation during processing, and other factors described throughout this handbook. Analyses are made of problems that can occur and how to eliminate them or how to take corrective action. This book is intended to provide practical guidelines to designers using plastics or composites.

Throughout this handbook, examples that relate to basic strengths of materials are given so as to highlight their influence in different designs. The information to the designer includes the behavior of plastics under extreme performance conditions, relates these behaviors to design principles, and provides important information on design parameters as they interrelate with plastic materials, processing characteristics, and the performance of products.

As materials to be fabricated, plastics provide practical, unlimited benefits to the design of products. Unfortunately, as with other materials, such as steel, wood, glass, aluminum, and titanium, no one plastic has all the best traits, so that sometimes selecting a material requires compromising. Successfully applying their advantages and understanding their limitations, as reviewed in this handbook, will allow designers to produce useful, profitable products.

There is a wide variation in the types of properties among the fifteen thousand materials commercially available worldwide that are classified as plastics or composites. In general, however, most plastics can be processed into different shapes and sizes. If so required, they can have intricate shapes held to tight tolerances and be made by processes suitable for either limited or mass production. The costs of plastics range from relatively low to extremely expensive, enough to make a plastic appear to be too costly for a given product. However, studying the processing method could result in meeting low product-cost requirements. This handbook thus provides the designer with useful information on the different processing methods as they relate to meeting design and cost requirements.

Plastics vitally concern almost everyone worldwide. They occupy an important part of the research, development, design, production, sales, and consumer efforts in diverse industries. As reviewed later, for over a century plastics have been used successfully, in such applications as for packaging, housewares, medicine, marine, aerospace, hydrospace, transportation, biological, appliance, building, and recreation. The significant improvements that have been made in plastic materials, processing, and applications thus far will no doubt be overshadowed by future improvements.

Because their broad range of properties makes plastics unique, they are adaptable to different products and markets. With plastics, one can decide on practically any requirement and find for it a processable plastic, whereas other materials have comparatively narrow capabilities. It is nevertheless important to recognize that there are tremendous variations in the properties and performance of plastics. This handbook shows that there is a practical, easy approach to designing with plastics.

One of the major aims of this book is to help develop the designer's ability to analyze problems, a most important skill. Although engineering mechanics is based on only a few basic understandable principles, these principles are needed to provide a means to solve many problems relating to present-day design and analysis. This book emphasizes both understanding and applying these principles, so that the designer will have a firm basis for utilizing the principles.

It is essential to reemphasize the point made in the text that all data presented on plastic properties are to be used only as guides. Obtain the latest, most complete data from material suppliers and data banks from the various sources referenced throughout this handbook.

The information presented herein may be covered by United States or foreign patents. No authorization to utilize these patents is either given or implied; they are discussed as information only. Likewise, the use of general descriptive names, proprietary names, trade names, and commercial designations and the like in no way implies that they may be used freely. They are often legally protected by registered trademarks or some other format even if they are not designated as such in this book. Finally, although the information presented is useful data that can be studied or analyzed that are believed to be true and accurate, neither the authors, contributors, nor publisher can accept any legal responsibility for errors, omissions, or similar factors.

In preparing this handbook extensive use was made of the personal industrial and teaching experiences of the authors, going back to 1939, as well as worldwide information from industry and trade associations on materials, equipment, and the like, published books, articles, reports, conferences, and so on, as is evident in the references given at the end of the book.

In the preparation of this handbook the authors have been assisted and encouraged by many friends and international business associates. Special acknowledgment must be made to the many different authors cited, including many different material suppliers. All have, whether directly or indirectly, contributed to advancing the state of the art in designing with plastics.

Contents

Chapter 1

FUNDAMENTALS OF DESIGNING WITH PLASTICS AND COMPOSITES

There is a practical, easy approach to designing with plastics and composites (see Figs. 1-1 to 1-3) that is basically no different than designing with other materials: steel, aluminum, titanium, copper, brass, wood, concrete, and so forth. This book provides useful and necessary information on how to comprehend plastics' and composites' extreme range of properties, structural responses, product-performance characteristics, part shapes, manufacturing processes, and their influence on product performance, the simplifying of designs, as guides on selecting plastics and processes as well as on how to keep up-to-date on important information and understand the economics of designing with plastics [1–200].*

Many different products can be designed using plastics and composites. They will take low to extremely high loads and operate in widely different environments, from highly corrosive ones to those involving electrical insulation. They challenge the designer with a combination of often unfamiliar and unique advantages, and limitations. By understanding the many different structures and properties as well as the design and fabrication capabilities, the designer can meet this challenge as demonstrated by the existence of the many different products made from plastics. They exist in all types of applications—underground, underwater, in the atmosphere, in outer space, in the office, and in the home.

Although plastics and composites may appear to some observers to be new, because the industry has an unlimited capacity to produce new plastics to meet new performance and processing requirements, plastics and composites have been used in no-load to extremely high-load situations for over a century. The ever-evolving technology does not mean that plastics and composites will automatically replace other materials. Each material (plastics, metals, wood, aluminum, and so forth) will, basically, be used in favorable cost-to-performance situations. As of the early 1980s, more plastics were used worldwide on a volumetric basis than any other materials except wood and concrete. Before the end of this century there will be on a weight basis more plastics used than the others, except wood and concrete.

*All references are listed in the References section in the back of the book.

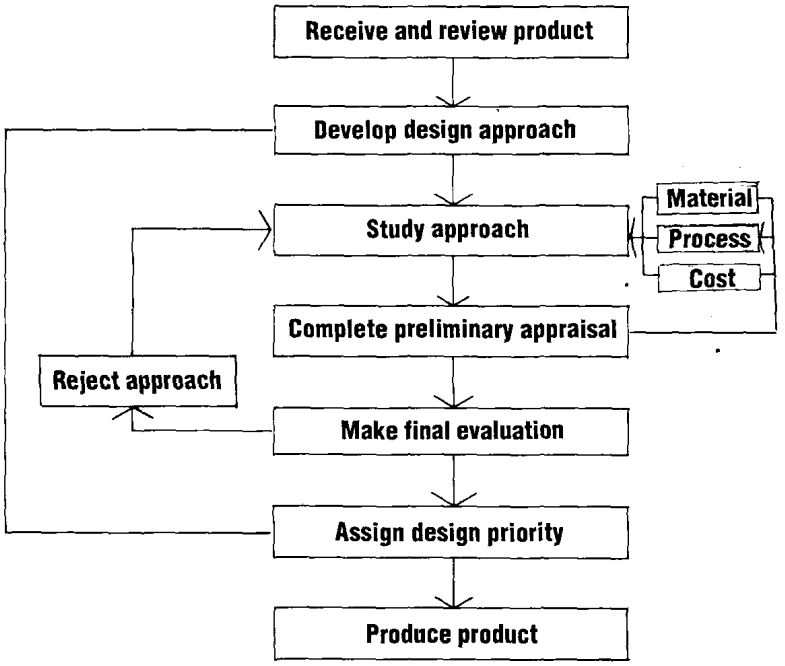


Figure 1-1. To be effective, the evaluation of new product ideas should proceed according to a logical step-to-step process, as shown.

With plastics and composites, to a greater extent than with other materials, an opportunity exists to optimize design by focusing on a material's composition and orientation as well as its structural-member geometry. There are also important interrelationships among shape, material selection (including reinforced plastics, elastomers, foams, and so forth), the consolidation of parts, manufacturing selection, and other factors that provide low cost-to-performance products. For the many applications that require only minimal mechanical performance, shaping through processing techniques can help overcome limitations such as low stiffness with commodity (lower cost) plastics. And when extremely high performance is required, reinforced plastics (RP), composites, and other engineering plastics are available. In this book the term *plastics* also refers to composites.

All processes fit into an overall scheme that requires the interaction and proper control of different operations. The *F*ollow *All O*pportunities (FALLO) approach shown in Figure 1-2 can be used in any process by including the "blocks" that pertain to the fabricated product's requirements. (See Chapters 7 and 8 regarding basic processing and auxiliary—upstream and downstream—equipment.)

The FALLO approach has been used by many processors to produce parts at the lowest cost. Computer programs featuring this type of layout are available (see Chapter 10). The FALLO approach makes one aware that many steps are involved in processing, all of which must be coordinated. The specific process (injection, extrusion, blowmolding, thermoforming and so forth) is an important part of the overall scheme and should not be problematic. The process depends on several interrelated factors, such as designing a part to meet performance and manufacturing requirements at the lowest cost, specifying the plastics, and specifying the manufacturing process. To do so basically requires designing a tool (mold, die, and so forth) around the part, putting the proper-performance fabricating process around the tool, then setting up the necessary auxiliary equipment to interface in the complete fabricating line, and, finally, setting up completely integrated

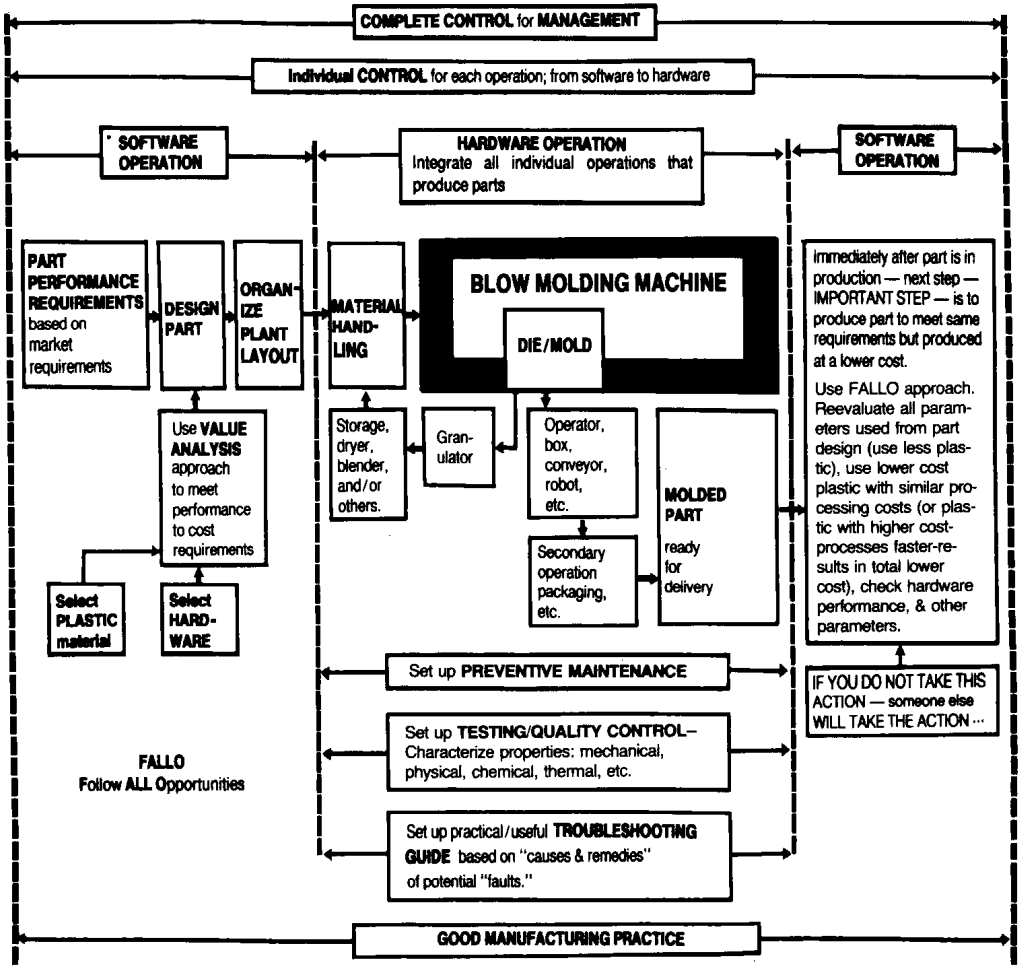


Figure 1-2. The example shown here for the complete blow-molding fabrication operation is also applicable to the other processes. This diagram shows the FALLO approach.