

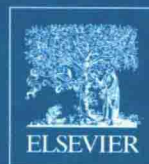
PDL HANDBOOK SERIES



Manufacturing Flexible Packaging

**Materials, Machinery,
and Techniques**

Thomas Dunn



Manufacturing Flexible Packaging

Materials, Machinery, and Techniques

Thomas Dunn



AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

William Andrew is an imprint of Elsevier



William Andrew is an imprint of Elsevier
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK
225 Wyman Street, Waltham, MA 02451, USA

First published 2014

Copyright © 2015 Elsevier Inc. All rights reserved

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangement with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-0-323-26436-5

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

For information on all William Andrew publications visit our website at store.elsevier.com

Printed and bound in the United States



Working together
to grow libraries in
developing countries

www.elsevier.com • www.bookaid.org

Manufacturing Flexible Packaging

Introduction

Efficient and profitable delivery of quality flexible packaging to the marketplace requires the design and manufacture of products that are both “fit-for-use” and “fit-to-make.” The engineering function for a flexible packaging operation must design products and processes that deal with both challenges. The alternative finds the company facing a stalemate in which “Manufacturing can’t make what Sales can sell” and “Sales can’t sell what Manufacturing can make.”

The scope of engineering knowledge inherent in designing “fit-for-use” and “fit-to-make” products is broad:

- Chemical engineering and chemistry: underlying principles of the resins, adhesives, inks, etc., that serve as the raw materials for the industry’s products and of the foods, pharmaceuticals, and other products packaged in them;
- Mechanical engineering: basics of both the equipment used to manufacture flexible packaging materials and the machines used by its customers to form and/or fill and/or seal that material;
- Materials science: principles explaining how flexible packaging materials respond to environmental forces during their manufacture and use.

Ideally, the engineering function company of a company takes on the characteristics of a “learning organization”...

...organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together [1].

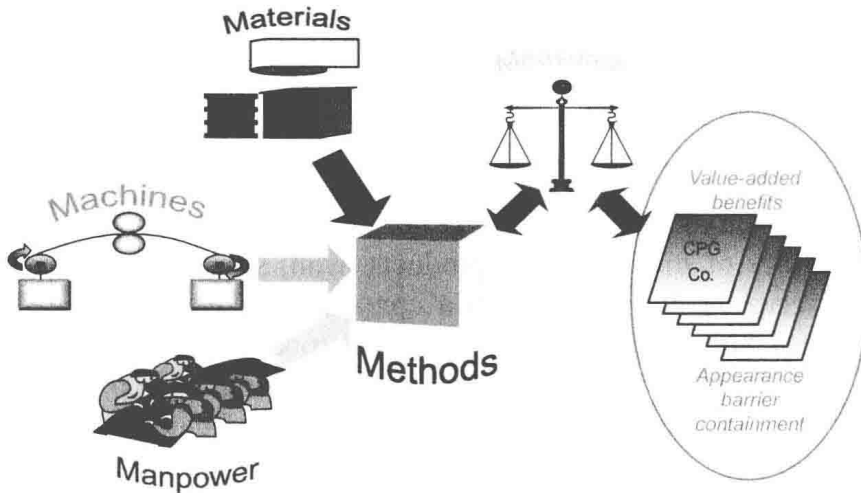
This book attempts to both introduce the engineering student or novice to basic manufacturing steps used to manufacture flexible packaging and suggest how to find and use additional learning resources. Effective participation in the industry requires continual learning. While the pace of change in the industry does not match those based in newer technologies, such as telecommunications and electronics, competitive advantage lies in early recognition and application of material and equipment innovations. Failure to do so leads to professional and organizational stagnation.

The book focuses on “fit-to-make” design challenges of flexible packaging manufacturing. It addresses various manufacturing processes individually, but the reader should appreciate that a great many flexible packages require multiple processes, carried out in sequence, to manufacture a fully functional fit-for-use product. Each process has an input material(s) to which it adds some value. That value-added material may well serve as the input to subsequent processes, and so on until a fit-for-use product is ready for market. The industry uses various “secondary quality characteristics” (Chapter 32) to measure interim and final products. Such test methods attempt to predict the ability of the final product to function successfully for its customer. The methods often provide the basis for contractual “specifications.”

Background

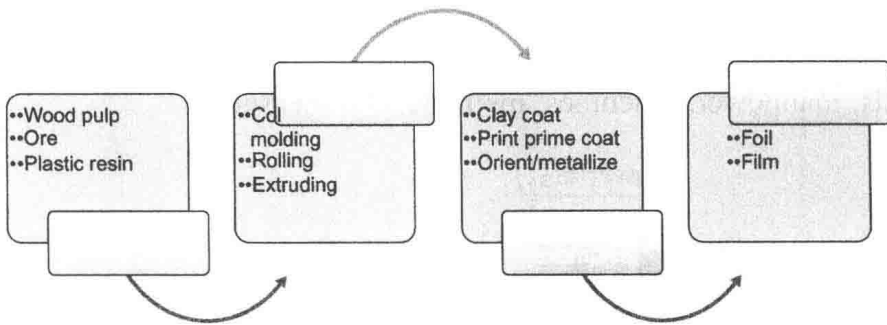
Flexible packaging manufacturing is part of the “converting” industry. The expression comes from the paper industry’s use of the term to describe secondary processes associated with a paper mill that “converted” the mill’s large rolls of paper into smaller products such as envelopes, bags, and sheets for writing or printing. This book approaches the industry as essentially a manufacturing process. Its physical inputs are rolls of paper, plastic film, and aluminum foil, various fluids such as inks and adhesives, and some plastic resins. Its outputs are functional packaging materials ready to contain various products. The

simple input/output model of a process is expanded by the “5Ms” model of manufacturing. Manufacturing requires materials, manpower, machines, methods, and measures.



The book is organized to present “methods” first (Chapters 1–9), then “machines” (Chapters 10–18), “materials” (Chapters 19–29), and finally measures (Chapters 30–32). The subject matter of each chapter could take up an entire academic term of study, but the objective here is to provide enough familiarity with the subject that its relationship to the others is appreciated and a deeper study of its details is possible.

The larger converting industry includes manufacturing processes to produce products other than flexible packaging such as paper and plastic bags, pressure-sensitive tapes and labels, articles fabricated from nonwoven fabrics, and decorative laminates. These all involve “web handling processes,” some basics of which Chapter 1 addresses. The book uses the terms “web,” “substrate,” and “roll stock” interchangeably. The below figure provides a very simplified summary of manufacturing processes for raw material roll stock used in flexible manufacturing. In depth, teaching resources exist for these raw materials processes. This book only considers raw material manufacturing in the context of how the converting industry uses them.



Much of the appeal of flexible packaging comes from the versatility of the industry's products, from simple plastic bags that serve as little more than a container to keep out dust, to complex "retort pouches" in which microbe-susceptible food is sterilized under intense heat and pressure and then preserved for years in a safe and suitable state. The application range of the industry's products results in large part from the ability to combine multiple materials in laminating processes (Chapters 4 and 5).¹ The term "structure" is used to describe the resultant material.

Reference

- [1] P. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization*, second ed., Doubleday, New York, NY, 1990, 413pp.

¹ Although such composite materials can provide a great deal of package functionality, their nature precludes simple recycling of their components into subsequent use in identical form.

Contents

Introduction	xiii
1 Basics of Web Processes	1
Web Tension	2
Web Winding	3
Cross-Web Variation	5
Web Dimensional Analysis	9
Industry Units of Measure	9
Web Length Estimation	11
Roll Rewind Designation	12
2 Rotogravure Printing	13
Gravure Process	14
Gravure Cylinders	14
Halftone Image Reproduction	16
Ink Metering	20
Gravure Process Innovation	22
Cylinder Cost and Cycle Time	23
Work Practices	24
Reference	25
3 Flexographic Printing	27
The Flexo Process	28
Numerical Color Space	28
Flexo Ink Metering	32
Flexo Halftone Printing (Process Printing)	33
Flexo Process Innovation	35
Reference	37

4	Adhesive Lamination	39
	Adhesive Laminating Process	41
	Adhesive Lamination Strength	43
	Other Coating Processes	44
	Adhesive Laminating Innovation	45
	Reference	47
5	Extrusion Lamination and Coating	49
	Extrusion Laminating Process	49
	Promoting Adhesion: Melt Curtain	52
	Promoting Adhesion: Substrate	54
	Extrusion Coating Process	55
	Extrusion Laminating Innovation	57
	References	59
6	Finishing and Slitting	61
	Communicating Slit Roll Requirements	61
	Slitting Options	65
	Rewind Options	65
	References	69
7	In-Line Processes	71
	Equipment Requirements	71
	Operational Considerations	73
	Availability	73
	Performance	74
	Quality	74
	Success Criteria	74
8	OEE Effectiveness	77
	Overall Equipment Effectiveness	79
	Availability	81
	Performance	81
	Quality	83
	OEE Calculation	83
	References	85

9	Efficiency and Cost Accounting	87
	Efficiency	88
	Material Waste	90
	Time Waste	92
	Cost Accounting	93
	Minimum Order Size	98
	References	101
10	Basics of Control Systems	103
	Distributed Control Systems	103
	Data Inputs	105
	Process Feedback	106
	Open-Loop Control System	106
	Closed-Loop Control System	107
	PID Controls	108
	References	110
11	Rotogravure Presses	111
	Press Components	111
	Ink Viscosity	113
	Electrostatic Assist	114
	Image Monitoring	114
12	Flexographic Presses	117
	Press Components	117
	Plate Cylinder Pressure	118
	Plates, Mounting Tape, and Plate Sleeves	120
	Drying Technology	121
	Reference	122
13	Adhesive Laminators	123
	Dry Bond Laminators	123
	Solventless Laminators	125
	Online Coating Measurement	125

14	Flexible Packaging Extrusion	
	Coating/Laminating Line	127
	Line Configuration	129
	Gauge Measurement and Control	129
15	Slitters	133
16	Preventative Maintenance versus Available Production Time	137
	Availability	137
	Preventative Maintenance	138
	Calibration	139
	Actual Operating Time	140
17	Setup/Cleanup versus Scheduled Production Time	143
	Performance	143
	Setup and Cleanup	143
	Decreased Speeds and Minor Stoppages	145
	Increased Speeds	146
18	Saleable Product versus Product Produced	149
	Quality	149
	Reference	154
19	Paper	155
	Paper Dimensioning	155
	Paper Grades	156
	Paper Coatings	158
	Paper for Flexible Packaging	159
	References	160
20	Foil	161
	Production	161
	Converting	163
	Commercial Trends	164
	References	165

21	Unoriented Plastic Films	167
	Flexible Films	167
	Cast	169
	Tubular	170
	General Film Property Effects	172
	References	175
22	Oriented Plastic Films	177
	Film Orientation	178
	Oriented Film Applications	180
	Cast (Tenter)	180
	Tubular (Bubble)	182
	Special Oriented Film Effects	183
	References	185
23	Bulk Polyolefin Resins	187
	Polymer Structure	187
	Functional Description	189
	Intrinsic Material Characteristics	190
	Value Provided	194
	Forms Used	195
	Reference	196
24	Specialty Sealant and Adhesive Resins and Additives	197
	Polymer Structure	198
	Alpha-Olefin Comonomers	199
	Additives	200
	Functional Advantages	201
	Ethylene Vinyl Acetate	202
	Ethylene Methyl Acrylate	202
	Ethylene Acrylic Acid	203
	Ionomer	203
	Alpha-Olefin Copolymers (LLDPE and mLLDPE)	204
25	Barrier Resins	207
	Barrier Kinetics	207

	Polyvinylidene Chloride	214
	Ethylene Vinyl Alcohol	215
	Nylon	216
	Coextrusion	216
	References	217
26	Inks	219
	Ink Vehicles	219
	Ink Pigments	221
	Ink Curing	222
	Ink Selection	223
	References	225
27	Overprint Varnishes and Coatings	227
	Overprint Varnish	227
	Coating Integrity	228
	Vacuum Deposition	229
	Reference	232
28	Adhesives	233
	Polyurethane Adhesives	234
	Acrylic-Based Adhesives	236
	Energy-Cured Adhesives	237
	References	238
29	Primers	239
	Polyethylene Imide Primers	239
	Ethylene Acrylic Acid Copolymer Primers	241
	Other Primers	242
	Primer Selection	242
	Reference	243
30	Conditioning	245
	Standard Conditioning	246
	Special Conditioning	247
	References	248

31	Intrinsic Material Properties	251
	Standards	253
	Intrinsic Property Influences	253
	Case Study: Intrinsic Property Influences	255
32	Secondary Quality Characteristics	259
	Containment Integrity Characteristics	264
	Protection/Preservation Characteristics	266
	Transportation Integrity Characteristics	272
	Communication Integrity Characteristics	274
	Flexible Packaging Material Specifications	274
	References	276
	Index	277

