Handbook of Pultrusion Technology

Raymond W. Meyer, B. S. Ch. E.,

Chapman and Hall
New York London

First published 1985
by Chapman and Hall
29 West 35th St. New York, NY 10001

Published in Great Britain by
Chapman and Hall Ltd
11 New Fetter Lane, London EC4P 4EE

Library of Congress Cataloging in Publication Data

Meyer, Raymond W., 1918–
Pultrusion technology handbook.

Bibliography: p.
Includes index.
1. Pultrusion. I. Title.
TP1175.P84M49 1985 668.4'94 85-3828

ISBN 978-1-4684-7766-5 ISBN 978-1-4684-7764-1 (eBook)
DOI 10.1007/978-1-4684-7764-1

Table of Contents

Chapter 1:	General Information	1
	Description of Pultrusion Composite	1
	Description of Pultrusion Process	3
	Description of Pultrusion Machine	3
	History of the Pultrusion Process	7
	Pultrusion Markets	7
Chapter 2:	Pultrusion Part Design	13
	FRP Mechanical Property Design Criteria	13
	Structural Shapes	20
	Hollow Shapes	23
	Pultrusion Part Standard Tolerances	23
	Fabrication Techniques	28
	Mechanical Fasteners	32
	Adhesive Bonding	32
	Pultruded Product Case Histories	38
Chapter 3:	Pultrusion Die Design	41
	Introduction	41
	Pultrusion Die Design Suggestions	42
	Specific Pultrusion Die Design Criteria	42
	Special Pultrusion Die Considerations	50
Chapter 4:	FRP Raw Materials	51
	Introduction	51
	Unsaturated Polyester Resins	51

	Other Resins	60
	Thermoplastic Additives	62
	Inorganic Fillers	64
	Fibrous Reinforcements	76
	Organic Peroxides	84
	Internal Release Agents	87
	Pigments	88
	Additives	90
	Surfacing Mats and Veils	91
Chapter 5:	Formulations and Preparation	94
	Introduction	94
	Preparing Resin Mixes	94
	In Process Testing	95
	Published Formulations	96
Chapter 6:	Pultrusion Machines	101
	Introduction	101
	Brenner Pultrusion Machine	102
	Goldsworthy Machines	105
	Martin Hydraulics Machines	110
	Mec-Pro Corporation Machines	112
	Pultrusion Technology Machines	115
	Gatto Machinery Development Corp. Machines	118
	Morrison Molded Fiber Glass Company Machines	120
Chapter 7:	Pultrusion Machine Operation	124
	Introduction	124
	Calculating Glass Reinforcement Requirements	124
	Pultrusion Machine Start-up	132
	Pultrusion Resin System Comparison	134
	Pultruded Flat Sheets	135
Annotated Bibliography		142

Appendix A: Annotated Bibliography Authors Index By Item Numbers 161
Appendix B: Glossary 163
Appendix C: Pultrusion Product Trade Names 168
Appendix D: List of trade Names 171
Appendix E: Manufacturers Addresses 173
Appendix F: List of Professional Organizations 177

Index 179

Foreword

We have needed this book for some time. There is a very wide spectrum of management personnel, engineers in continuing education, specifiers, designers, graduate students—not to omit investors—who need this material as an intensive short course and reference work permanently at hand.

Even in recession conditions the pultruded product business has grown by double-digit percentages, and this level of demand will continue as the U. S. infrastructure is renovated. Demand has stirred competition, in turn leading to product refinement. This technology development is taking place in materials, such as processable epoxy systems; in exotic but reliable production systems; and in mold/part complexity.

The *Handbook of Pultrusion Technology* is essential to orient us in the fundamentals. The substance in Ray Meyer's treatment of this RP process is not available in any other compilation.

Joseph S. McDermott, Manager
Reinforced Plastics/Composites Institute
The Society of the Plastics Industry, Inc.

Preface

Since my retirement five years ago I have had several opportunities to review my files and draft reports on pultrusion, especially for overseas clients. This book resulted from organizing and updating these reports and filling in some of the gaps in my information.

Basic design information for fiberglass reinforced plastics (FRP) products in general and pultruded products in particular have not been readily available. Mold design data are very difficult to locate. Raw materials information traditionally flows directly from the manufacturer to the pultruder. Several misapplications of information, in the past, have resulted in problem areas. It is with the intent of partially overcoming some of these deficiencies that this volume has been prepared.

Raymond W. Meyer
Tallmadge, Ohio
January, 1985

Acknowledgments

There were many contributors who helped in supplying the data in this book. I would like particularly to thank the following: J. Albert Rolston; Ivan Brenner of I. G. Brenner Co., Henry Green of Martin Hydraulics; Jeff Martin of Pultrusion Technology Inc.; David Breck of Goldsworthy Engineering; Ernest Preiato of Gatto Machinery Development; C. W. Bass of Mec-Pro; David Evans of Creative Pultrusions; J. D. Tickle and Nell Campbell of Morrison Molded Fiber Glass; T. S. McQuarrie of Koppers; Ron Rumpler and Sean McMullen of Owens-Corning Fiberglas; Tom Surrant and Tom Pflieger of CertainTeed; A. H. Horner of Silmar; Mike Kallaur of Freeman Chemical; John Dockum of PPG Industries; Bob Talbot and Jack Mitrey of Ashland Chemical, and many others.

General Information

Description of Pultrusion Composite

A pultrusion composite consists of reinforcing materials, a laminating resin that binds the composite together, possibly a surfacing mat to improve the composite surface appearance, chemical resistance and weather resistance, and a variety of ancillary materials such as pigments to impart color, accelerators to cure the laminating resin, internal release agents, inert fillers, etc. The reinforcing materials normally used are fiberglass continuous strand mats and continuous fiberglass rovings. In many foreign countries continuous strand mat is not available and low solubility chopped strand mats must be used instead. The laminating resin may be an unsaturated polyester resin, a vinyl ester resin, or an epoxy resin, but approximately 90% of all pultruded products currently use polyester resins. Figure 1.1 shows an exploded view of one type of pultrusion composite containing both continuous strand mat and roving reinforcements. This construction should be balanced (same composition above horizontal centerline as below) to prevent the cured part from twisting and warping. Unbalanced construction profiles sometimes are made for specific design reasons. Some pultruded products contain only roving as the reinforcement. These are known as rod or bar stock.

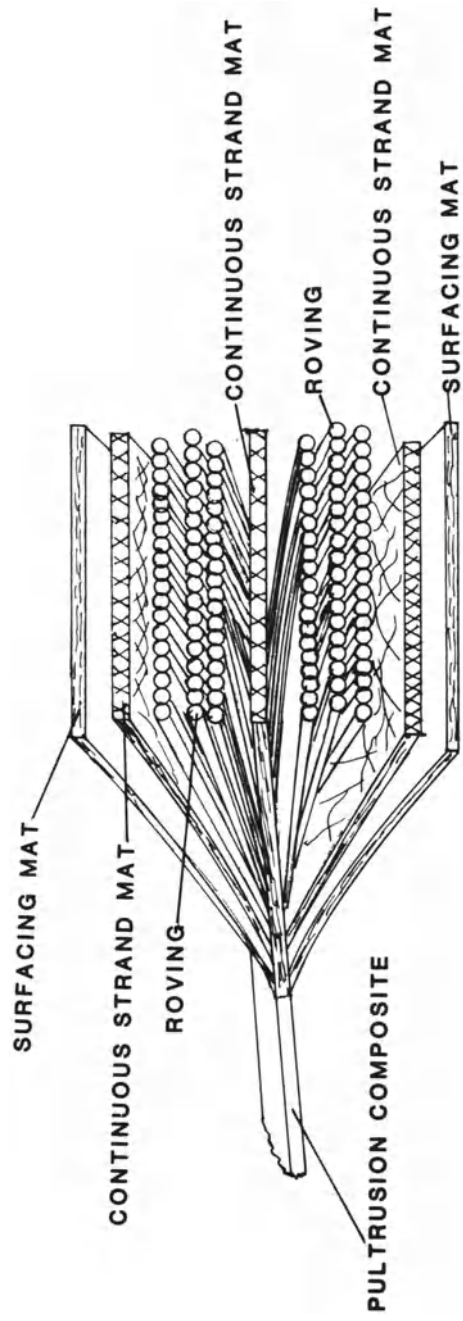

Figure 1.1 Exploded View of Pultruded Composite

Description of Pultrusion Process

The pultrusion process generally consists of pulling continuous rovings and/or continuous glass mats through a resin bath or impregnator and then into preforming fixtures where the section is partially shaped and excess resin and/or air are removed, and then into heated dies where the section is cured continuously.

Description of Pultrusion Machine

The basic pultrusion machine consists of the following elements as shown in Figure 1.2:

1. creel
2. resin wet-out tank
3. forming dies
4. heated matched metal die
5. puller or driving mechanism
6. cut off saw

For hollow shapes a mandrell is installed ahead of the resin tank and the mandrel extends through the forming die section as shown in Figure 1.3.[47*]

Creel

The creel for continuous rovings generally consists merely of bookcase-type shelves for inside pull packages with ceramic eyes located immediately above the center pull roving packages, and at convenient intervals to lead the rovings to the resin mix tank. In setting up the pultrusion process one must be careful to insure that the rovings do not scrape across one another as this will generate considerable static and cause "fuzz balls" to build up in the resin mix tank, raising its viscosity. Metal bookshelves are best since they can be grounded to dissipate some of the static charge. An alternative to using ceramic guide eyes and a more foolproof system is to guide the rovings

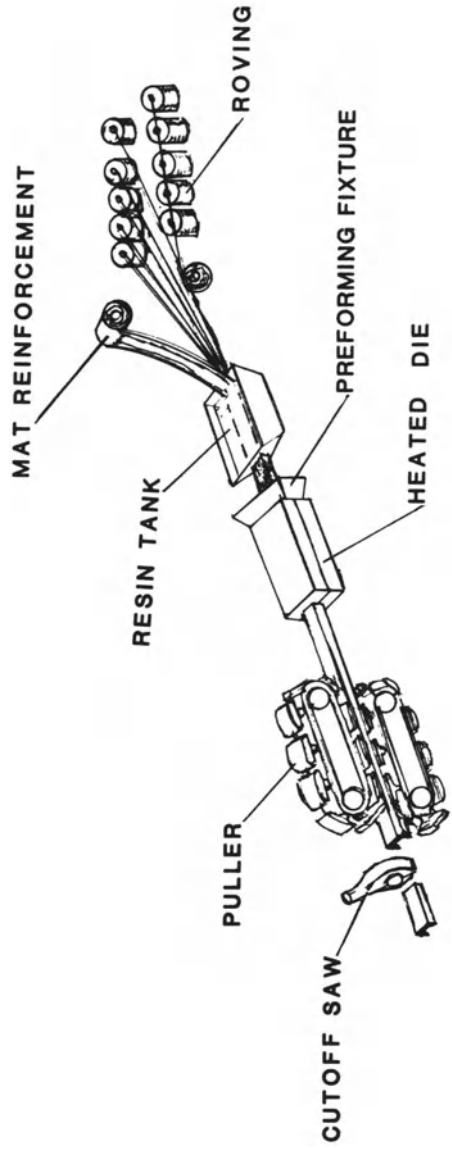

Figure 1.2 Typical Pultrusion Process

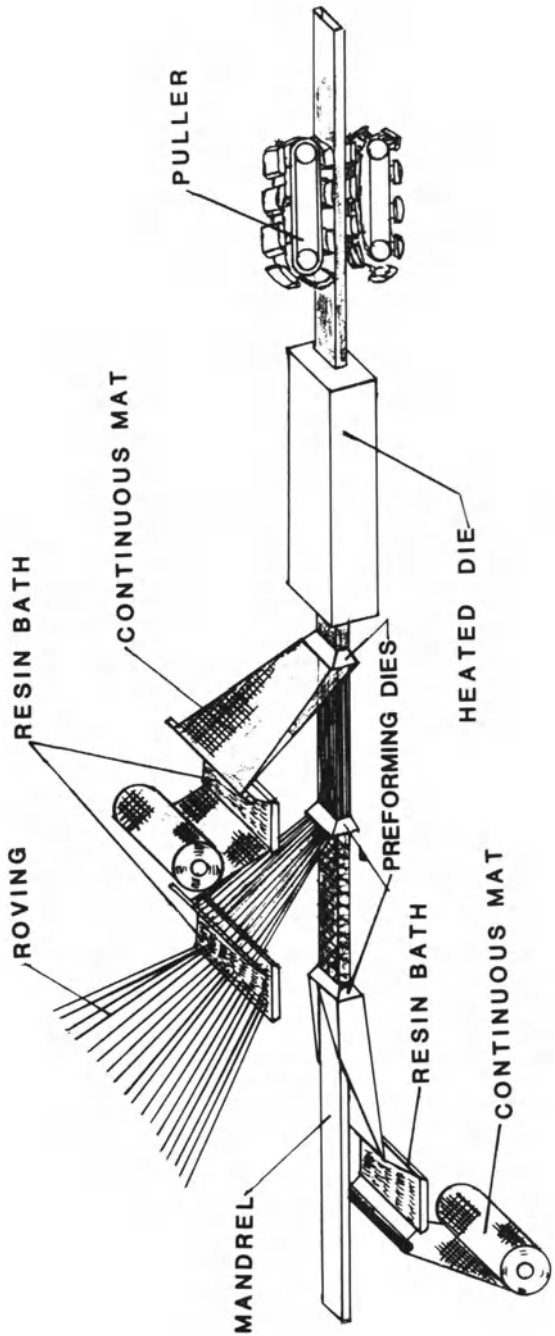

Figure 1.3 Typical Hollow Pultrusion Process

from the creel to the wet-out tank in vinyl tubes. This prevents much of the problems of the rovings crossing one another.

Resin Wet-out Tank

The resin bath or wet-out tank generally is a sheet metal or aluminum trough containing rolls that force the reinforcement under the surface of the resin mix. Most good wet-out tanks contain a set of rolls or slots at the exit end which can be adjusted to strip off much of the excess resin mix from the reinforcement. A comb or grid plate generally is provided at the entrance and exit ends of the resin bath to keep the rovings in horizontal alignment as they pass through the tank. The tank should have a drain plug for emptying the mix.

Preforming Fixtures

Preforming fixtures consolidate the reinforcements and move them closer to the final shape provided by the die. They may be constructed of flourocarbon or ultrahigh molecular weight polyethylene since these are easy to fabricate and to clean, or of chrome-plated steel for longer wear on high production runs.

Heated Dies

The chrome-plated matched metal die may be heated by electrical cartridges, by strip heaters, or by hot oil. Thin sections generally are best heated by conductive heat. The cure of unidirectional thick sections can be speeded up and made more uniform by using both radio frequency (RF) radiation and conductive heat. For RF cure it is necessary to have a short section of the mold constructed of a material that is transparent to RF radiation such as Teflon™ or to support the wet rovings on each side of the RF station with grilles or guide members.

Pulling Section

The pulling section can be either a pair of continuous caterpillar belts containing pads that engage the pultrusions, a double set

of cylinders with pad pullers that can be synchronized for a continuous pull, or a single cylinder for an intermittent pull.

Cut-off Saw

A conventional cut-off saw is used with an abrasive or a continuous rim diamond wheel and sometimes a coolant spray. In addition to cooling the cut-off wheel and improving the appearance of the cut-off section the coolant spray minimizes dust. Cut-off saws will cut on either the forward or return stroke. The saw carriage is clamped to the pultrusion product during the actual sawing operation.

History of the Pultrusion Process

Probably the first pultrusion machine was in operation in Polygon Plastics (Martin, 1983). The initial pultrusion patent in the United States was issued in 1951.[2] In the early 1950s pultrusion machines for the production of simple solid rod stock were in operation at several plants. Most of these machines were designed and built in-house and most were the intermittant pull type.

In the mid-1950s, continuous pull machines were available.[3] By the late 1950s pultruded structural shapes were being produced. In 1970 approximately 20 pultruders made 10 million pounds of composite in the United States.

The inclusion of structural shapes gave a good impetus to the pultrusion business and by 1976 40 captive and custom pultruders shipped 40 million pounds of composite (broken down by markets in Table 1.1).

Pultrusion Markets

The initial products made by the pultrusion process went into the recreational/sporting goods market (fishing rods) and into the electrical market (transformer spacer sticks). In the early

Table 1.1 An Estimate of Pultruded Composite Markets In Recent Years

Market Area	1976 M Pounds	1976 %	1981 M Pounds	1981 %	1983 M Pounds	1983 %
Electrical/Electronic	15,000	37.5	19,800	36.0	21,000	33.3
Corrosion Resistant	3,100	7.7	14,300	26.0	16,000	25.5
Consumer/Recreation	15,500	38.8	12,900	23.5	14,000	22.2
Construction	1,800	4.4	2,900	5.2	5,000	7.9
Land Transportation	2,500	6.3	4,300	7.8	5,000	7.9
Miscellaneous	2,100	5.3	800	1.5	2,000	3.2
Total	40,000	100	55,000	100	63,000	100

Source: Data Courtesy Pultrusion Technology, Inc.

stages the electrical market dominated the pultrusion business with most of the captive pultruders being in this area. As new pultruders entered the market the quantity of applications for pultruded products increased. The market breakdown for the years 1976, 1981, and 1983 are shown in Table 1.1.

The consumer/recreational and electrical markets dominated the pultrusion business in 1976. The electrical market has continued to expand. The list below contains a breakdown of the electrical applications. This is again the largest user of fiberglass reinforced plastics (FRP) pultruded shapes. It is followed by a similar breakdown for the consumer/recreational market uses. Both areas have increased their output but not at the same rate as other market areas so that their proportional share of the total market declined very slightly. During the period 1976–1981 the corrosion resistant market expanded at a faster rate than any of the other areas so that by 1981 it was in second place in volume of products shipped being surpassed only by the electrical market.

Electrical Applications for Pultruded Shapes

1. Transformer air duct spacer sticks
2. Pole line hardware
3. Ladders
4. Bus bar supports
5. Motor top sticks
6. Cable support trays
7. U-shaped motor stator wedges
8. Service truck booms
9. Switch actuators
10. Fuse tubes

Consumer/Recreational Applications For Pultruded Shapes

1. Fishing rods
2. Sail battens
3. Tent poles
4. CB antennas
5. Skate boards
6. Tool handles
7. Ski poles
8. Hockey sticks
9. Fence posts
10. Bike flags
11. Paddle shafts
12. Bows and Arrows
13. Crossbows
14. Golf shafts

15. Flag poles
16. Pole vault poles
17. Xylophone bars
18. Umbrella shafts
19. Snowmobile track stiffeners

While up to now the electrical and consumer/recreational markets have dominated the pultrusion business, the fastest growing segment today is the corrosion resistant market shown below.

Corrosion Resistant Uses Of Pultruded Shapes

1. Bridges and platforms
2. Floor gratings
3. Hand rails
4. Ladder cages
5. Pipe supports
6. Stairs
7. Structural supports
8. Pipes and tubes
9. Weir plates
10. Slide guides
11. Sucker rods for oil wells
12. Internal tank supports
13. Demister blades
14. Structural shapes
15. Wet scrubbers for power industry
16. Cable support trays

The transportation market for pultruded shapes, as shown below has been disappointingly small to date, but there is considerable development work involved in this area and if some of these developments mature into products this area could take sudden spurts in the future. One of these developments involves the pultrusion of a B-staged product which is then molded in matched metal molds.[69]

Transportation Uses Of Pultruded Shapes

1. Lading bars in trucks and railcars
2. Kick plates
3. Trailer jamb posts
4. Subway contact rail covers
5. Bus luggage racks
6. Seating
7. Flat sheets for refrigerated trucks
8. Leaf springs

Construction Uses For Pultruded Shapes

This area is much more developed in Europe than in the United States.

1. Portable work platforms
2. Sign posts
3. Lamp posts
4. Roof trim (Europe)
5. Gutters
6. Glazing systems (Europe)
7. Green house structures
8. Building panel sections
9. Sign support posts
10. Signs
11. Highway delineator markers

Miscellaneous Uses For Pultruded Shapes

Several of these uses in the agricultural field are due to the chemical resistance of pultruded shapes when they come into contact with fertilizers, farm wastes, etc.

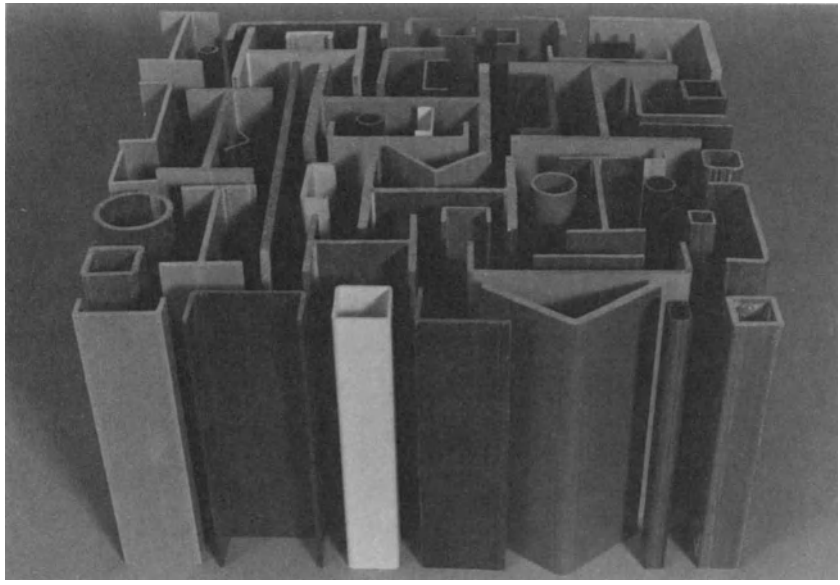

Figure 1.4 Short Sections of Structural Pultruded Parts and Hollow Parts *(Courtesy Creative Pultrusions, Inc.)*

1. Heat shields on Xerox copiers
2. Slats for hog pens
3. Farm wagons
4. Pallets in food processing plants

Figure 1.4 is a view of short sections of structural pultruded parts, hollow round, square, and rectangular pultruded parts and several pultruded flat sheets.

References

Goldworthy, B. "The Continuous Extrusion of RP." In: *Proceedings*, SPI 91L RPD Conference, Chicago, IL, Feb. 3–5, 1954, Section 13.

Howald, A. M., and Meyer, L. S. U.S. Patent 2, 571, 717, "Shaft For Fishing Rod" (Oct. 16, 1951).

Martin, J. *Plastics Products Design Handbook.* Part B, Chapter 3: "Pultrusion." Marcel Dekker, New York, 1983, p. 38.

"Pultrusion Processing: New Technology that Borders on the Exotic." *Plas. Mach. & Equip.* (Apr. 1980): 30–38.