

Training in

Injection Molding

2nd Edition

HANSER

Michaeli / Greif / Kretschmar / Ehrig
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A Text- and Workbook

2nd Edition

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Foreword

Training in Injection Molding is a text- and workbook for technicians employed in the plastics industry. The original German language edition, *Technologie des Spritzgießens*, was prepared at the request of three cooperating organizations: the Federal Republic of Germany, the German Federal Association of Employers in the Chemical Industry (BAV Chemie) and the German Chemical Workers Union (IG Chemie). The writing of the book was contracted by them to the Institute of Plastics Processing (Institut für Kunststoffverarbeitung—IKV) at the Technical University of Aachen.

The book is intended as a sequel to *Training in Plastics Technology* by Walter Michaeli, Leo Wolters, Helmut Greif and Franz-Josef Vossebürger also of the Institut für Kunststoffverarbeitung.

The text focuses on many very important practical aspects of injection molding not (usually) found in treatments of injection molding intended for American engineering students. This includes the design of machine clamping units and hydraulic systems as well as the interaction of the plasticating and mold sections of the machine. Engineering students as well as technicians will find many sections of this book worthy of serious study.

It is hoped that this book will find use in educational programs taught both within industry and in schools dedicated to this purpose.

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Publisher's Note: Professor White edited the manuscript for the first edition of this book and adapted it for training courses of plastics technicians in the United States and in other countries where English is spoken. His effort is gratefully acknowledged.

Preface

Injection molding is the most important method in the field of plastics processing in terms of the number of machines operating, the value of the products and the number of individuals involved. This text- and workbook provides an introduction to this processing method.

Lessons

Training in Injection Molding is divided into educational units which can be described as lessons. Each lesson covers a distinct subject area. The individual lessons are arranged in such a way that they can be tackled by the student in a meaningful educational sequence, namely in a step-by-step manner.

Key Questions

The *key questions* at the beginning of each lesson are intended to help the student approach the subject matter with certain questions in mind. The student should be able to answer these questions after working through the lesson.

Prerequisite Knowledge

It is not necessary to study the lessons in any particular sequence. Each lesson is therefore preceded by a list of other lessons or sections which are important for understanding the new material.

Review Questions

The review questions at the end of each chapter test the knowledge acquired. The student selects an answer from among the choices provided and enters it in the blank space within the sentence (_____). The answers can be checked against the lists of correct answers at the end of the book. If the chosen answer is incorrect, the student should review the corresponding subject matter.

An Example: The Compact Disk (CD)

In order to give the explanations in this book a more concrete form and to clarify the relationship between lessons, we have chosen a familiar molding, the Compact Disk, to serve as an example. On the one hand, the production of this plastics molding puts special demands on the technology employed. But on the other hand, the widespread distribution of the CD would not be possible without this special production technology. The CD thus represents a typical high-quality plastics product. It recurs in many of the lessons, providing answers to various questions regarding the choice of the right plastics material for a particular molding or the possibilities of recycling, for example.

Appendices

The appendices provide the interested reader with supplementary material regarding plastics. The reader can derive information on additional technical literature from the list of selected literature. The glossary is intended to contribute to a consistent understanding of the terms used in the book. It can be used as a brief lexicon.

Acknowledgments

This book has been a collaborative effort. We would especially like to thank Werner Okon for the preparation of the figures. Special thanks also to the translators Randall T. Wert and Elmar Tremmel who did a perfect job.

The authors hope you will enjoy learning and working with this book.

*Walter Michaeli
Helmut Greif
Gernot Kretzschmar
Frank Ehrig*

Contents

Introduction	Injection Molding – An Ideal Manufacturing Method	1
Lesson 1	Basic Principles of Plastics	5
	1.1 Classification and Identification of Polymeric Materials (Plastics and Elastomers).	6
	1.2 Deformation Characteristics of Plastics	8
	1.3 Molding Compounds and Shaping Methods	11
	1.4 Plastics Melts	12
	Review Questions	18
Lesson 2	The Injection Molding Machine	19
	2.1 Classification of Injection Molding Machines	20
	2.2 Structural Units of Injection Molding Machines	24
	2.3 Special Injection Molding Processes	26
	Review Questions	30
Lesson 3	The Plasticating and Injection Unit.	31
	3.1 Tasks of the Plasticating and Injection Unit	32
	3.2 Plasticating	35
	3.3 Injection.	37
	Review Questions	40
Lesson 4	The Mold.	41
	4.1 Tasks and Modes of Operation.	42
	4.2 Gating and Runner System	43
	4.3 Cavity	47
	4.4 Heating/Cooling Systems	49
	4.5 Ejection System.	50
	Review Questions	54
Lesson 5	The Clamping Unit	55
	5.1 Function and Structure	56
	5.2 Mechanical Clamping Units.	57
	5.3 Hydraulic Clamping Units.	59
	Review Questions	62

Lesson 6	Drive System and Controls	63
	6.1 Drive System	64
	6.2 Controls	67
	Review Questions	68
Lesson 7	The Injection Molding Process	69
	7.1 Phases of an Injection Molding Cycle.	70
	7.2 Start	72
	7.3 Injection Phase	74
	7.4 Holding Pressure Phase	77
	7.5 Cooling Phase	80
	7.6 Feed Phase.	82
	7.7 Removal from the Mold	83
	Review Questions	86
Lesson 8	Mold Design	87
	8.1 Tasks and Specifications of Injection Molding Tools	88
	8.2 The Designer's Tasks	88
	8.3 Mold Layout	90
	Review Questions	98
Lesson 9	Quality Assurance in Injection Molding	99
	9.1 Quality	100
	9.2 Quality Assurance	101
	9.3 Quality Management	102
	9.4 Integrated Management Systems	108
	Review Questions	110
Lesson 10	Recycling of Plastics Waste	111
	10.1 Reutilization of Plastics	112
	10.2 Recycling of Production Waste	115
	10.3 Recycling of Industrial and Domestic Plastics Waste	116
	Review Questions	118
Appendix I	The Modern Injection Molding Company	119
	I.1 Structure of an Injection Molding Company.	120
	I.2 Order Processing Organization within an Injection Molding Company	121
	I.3 Specifications for Injection Molding Companies	122
Appendix II	Occupational Safety Around Injection Molding Machines	125
	II.1 European Regulations	126
	II.2 U.S. Regulations.	130
Appendix III	Selected Literature	135
Appendix IV	Glossary of Injection Molding Technology	139
	Answers to Review Questions	149

Introduction

Injection Molding – An Ideal Manufacturing Method

Key Questions What is injection molding?
What is injection molding used for?
What are the main characteristics of an injection molding machine?

Contents Injection Molding – A Young Production Method
Injection Molding – A Discontinuous Single-Stage Process
Injection Molding – The Injection Molding Machine and Mold

Injection Molding – A Young Production Method

*the most important
processing method
for plastics*

In comparison to the classic methods of metal fabrication and processing (such as milling, drilling, turning, etc.), injection molding represents a manufacturing method which is still young. However, injection molding has already become the most important method in plastics processing technology.

plunger machines

The early injection molding machines were plunger machines. The plastic was melted in a heated cylinder and injected into the mold by the plunger. This type of machine is no longer found, except in research laboratories, for making very small quantities of experimental articles. Plunger machines are not discussed in this book.

screw principle

Most modern injection molding machines operate on the screw principle. The molding compound is melted by band heaters and the frictional heat produced by the rotating screw. In the injection operation, the rotation of the screw is stopped and the screw begins to function as a plunger. The screw must therefore fulfill the functions of conveyance, mixing, and injection. Separate plasticating screws and injection plungers are often used in the processing of elastomers.

thermoplastics

Thermoplastics represent the most important group of plastics to be processed in injection molding. Typical injection-molded parts made from thermoplastics include automobile hubcaps and bumpers, gears in kitchen appliances, screw-on caps and lids, bottle crates, printer cartridges, and ball-point pens. Even the Compact Disk (CD) is produced from polycarbonate (PC) by the injection molding method.

elastomers

Another important materials group are the cross-linked polymers, such as elastomers and thermosets. Typical elastomer molded parts manufactured by injection molding include bellows, shock-absorbing components in automobiles, seals, and molded tubes.

thermosets

Thermosets consist of densely crosslinked polymers, that can also be processed by injection molding. Thus produced articles are used in boats, in the automotive field and in the electrical industry (insulation). Thermoset moldings find particular application, where their non-conductive properties and heat-resistance are essential. Injection molding provides a cost-effective mass-production process of articles for the electrical industry.

Injection Molding – A Discontinuous Single-Stage Process

*primary processing
method*

Injection molding, as a primary processing method, is particularly well suited for the mass-production of molded articles, because the conversion of the raw material into a finished product usually requires just a single operation. Little or no finishing is required, and even complicated geometries can be produced in a single operation.

It is an ideal production process with the proviso, that large batches are produced, because the injection molding tool is usually made for a single article only.

ideal production process

It is typical within the context of primary processing technology, that each mold is unique. Molds are therefore very expensive in comparison to most forming tools and dies used in metals fabrication, because they are not universally employable.

expensive molds

The process for molding thermoplastics proceeds as follows:

production process

- The material is fed into the hopper on the machine.
- Within the heated cylinder, the material is conveyed, melted, and mixed thoroughly by the rotating screw.
- The molten molding compound (melt) is then injected into the mold under high pressure.
- The melt cools within the heat-balanced mold and thus gains the inherent stability needed for its removal.
- The article is now removed from the mold, and a new injection molding cycle can begin.

Parts produced by injection molding display a very high degree of dimensional accuracy—for example, to $1/100$ mm ($4 \cdot 10^{-4}$ in). Even greater accuracy is possible in special applications.

high degree of accuracy

With the Compact Disk, information is stored in minute pits formed in the surface. These pits, produced as direct reproductions by the injection molding process, are only a few microns wide and deep.

CD

Injection Molding – The Injection Molding Machine and Mold

Two main components are required for injection molding:

main components

- The injection molding machine
- The mold

The injection molding machine is in turn divided into the

injection molding machine

- Plasticating (plastification) unit and the injection unit
- Clamping unit

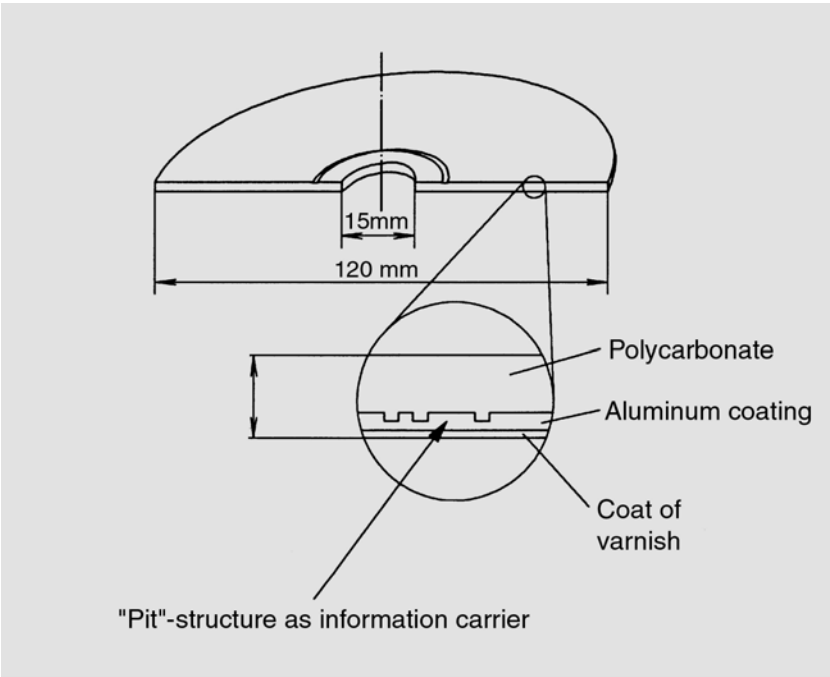
- Controls (hydraulics, electrical system)

mold Different molds are needed for different injection-molded articles. It is therefore necessary to replace the entire mold in order to produce a different part from the one currently being made.

profitable production Production of certain articles (e.g., household appliances, certain automotive subassemblies, CDs) would not be profitable at all without the means, of producing them from plastics by injection molding.

special features When articles hitherto produced from classic materials (such as wood or metal) are to be made by the injection molding process, it is advisable, to give serious consideration to the special properties of plastics materials, as well as the more salient points of injection molding as a production method. This plastics-oriented procedure requires an understanding of the basic principles of the manufacturing and production processes involved, and also of the plastics material's behaviour. The book provides a comprehensive overview of the principles involved in injection molding.

CD For that purpose, we follow a modern plastics article (a Compact Disk) from the starting material to the form, in which it will ultimately be used. The possibilities for recycling will also be explained. As a high-tech product, the CD is particularly well suited to serve as an example of modern plastics processing and injection molding technology. The diagram shows a CD and its dimensions.



Lesson 1

Basic Principles of Plastics

Key Questions

- What types of polymeric materials (plastics and elastomers) are there?
- How do they behave under the influence of heat?
- How does melt viscosity vary with temperature?
- Which plastics are used in injection molding?

Contents

- 1.1 Classification and Identification of Polymeric Materials (Plastics and Elastomers)
- 1.2 Deformation Characteristics of Plastics
- 1.3 Molding Compounds and Shaping Methods
- 1.4 Plastics Melts

Review Questions