Understanding

Product Design for Injection Molding

Herbert Rees

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Introduction to the Series

In order to keep up in today's world of rapidly changing technology we need to open our eyes and ears and, most importantly, our minds to new scientific ideas and methods, new engineering approaches and manufacturing technologies and new product design and applications. As students graduate from college and either pursue academic polymer research or start their careers in the plastics industry, they are exposed to problems, materials, instruments and machines that are unfamiliar to them. Similarly, many working scientists and engineers who change jobs must quickly get up to speed in their new environment.

To satisfy the needs of these "newcomers" to various fields of polymer science and plastics engineering, we have invited a number of scientists and engineers, who are experts in their fields and also good communicators, to write short, introductory books which let the reader "understand" the topic rather than to overwhelm him/her with a mass of facts and data. We have encouraged our authors to write the kind of book that can be read profitably by a beginner, such as a new company employee or a student, but also by someone familiar with the subject, who will gain new insights and a new perspective.

Over the years this series of **Understanding** books will provide a library of mini-tutorials on a variety of fundamental as well as technical subjects. Each book will serve as a rapid entry point or "short course" to a particular subject and we sincerely hope that the readers will reap immediate benefits when applying this knowledge to their research or work-related problems.

E.H. Immergut
Series Editor

Preface

During the more than 40 years the author has worked designing molds for plastics products, he has had many occasions to view and discuss product designs with their designers. Usually, the contact with the designer was established only *after* a purchase order for a mold had been placed to produce a certain product. In reviewing the supplied drawings, and occasionally models, many questions had to be answered before starting to design and build a practical mold, suitable for the plastic, for the requirements of the product, and for the planned production and mold life expectancy.

Many product designers have excellent ideas when coming up with new products and improvements to existing ones, but often they apply design principles similar to those they were familiar with and had used with other materials, such as steel, glass, and others. In discussions, the product designers often have been shown to lack even some of the most basic understanding of the principles of plastics molding and of the behavior of plastics, both during molding and after the product is finished.

The present book, **Understanding** Product Design for Injection Molding, is intended to give the product designer some guidelines and examples on how to proceed once the idea for a new product has been conceived, or the decision has been made to redesign an existing product already made from plastic or from a different material.

It should be pointed out that any design must always be based on straight common sense; the designer cannot be shown *how* to design or to "invent" a product, but, once the general idea of a target has condensed sufficiently, the designer is advised on what to consider to make a viable plastics product.

There is much preliminary work to be done—research into existing (similar and/or related) products, market analysis, cost estimating, safety assessment, etc.—before the designer should start sketching his or her idea. But at this point, the designer should understand what can be done with plastics, which processes to select, how to choose the proper materials, and how to design so that the product not only will work as expected but also can be made efficiently.

It is hoped that this book will help the practicing product designer, and any student in this field, to acquire the necessary background required. The author has deliberately kept the language simple and, rather than fill the book with many charts, he has preferred to direct the reader to sources: the suppliers of plastics and other products required for the contemplated design. Many charts and other relevant documentation have the habit of becoming obsolete soon after they are issued, and it is better to get the latest data from the source.

Herbert Rees
Orangeville, Ontario

Contents

Introduction

This book is intended to acquaint the aspiring product designer with some of the basic rules and practices with which he or she should be familiar before attempting any product design.

Completely new designs are rare, although they may be necessary for truly new inventions (patented or not) which have no precedent, not even in similar fields. By definition, there can be no precedent for "new;" therefore, there can be more than one way to design and build a new product.

After deciding on a possible, practical, and acceptable target design, there are two paths open to the designer. The old way is to first experiment, with product and test prototypes, and then proceed with the necessary strength calculation and graphic delineation of the new design so that it can be produced—and perform—safely. The modern way, after a suitable design has been selected, is to use the preliminary drawings for stress and flow analyses; changes which then appear necessary are made before the final drawings are completed.

Today, most so-called "new" designs are really "improvements" of existing products or are based on similar, not necessarily related, products in other fields. (Note that patents are worded ". . . this invention describes an improvement of. . . .") It is common practice and highly recommended that, prior to any attempt to redesign or to simply copy an existing product, the designer should gather as many similar and related products as possible that are already on the market and study them carefully to determine which "good" features to retain and which "bad" features to avoid in the "new" product. This philosophy applies to any product, whether a simple handle or a complicated mechanism.

Most importantly, the designer must be aware of and consider possible alternatives when designing any product, and then answer all relevant questions before proceeding. The designer is responsible for ensuring that the product fulfills all expectations, both in performance and in appearance, *and that it can be produced economically*.

In the following chapters, the author highlighted many of the questions and decisions a designer will face while designing any product. Unfortunately, there are no rules for explaining or teaching "common sense"—the basic requirement for any design, whether for a consumer product or for a machine. The main principle is that the designer must understand where problems will and can arise, and that he or she will learn where to find the answers to such problems.

1 Plastic Product Design

Why design a product made of (any) plastic? Usually, the reason to design products made of plastic is either to create new products, never made before, or to create something similar to existing old products but which is better, more appealing to the user, or more economical to produce.

Typical examples of new products include compact disks (CDs) and enclosures for CDs, etc. There are many examples of old products which could be, or need to be, redesigned for the following reasons:

1. Different appearance (shape) and more sales appeal (decorations, colors). Typical examples include kitchenware, containers, cutlery (some previously made from plastics or other materials such as glass, wood, metal, paper, etc.).
2. Improved performance so that products last longer, are easier to use, and are easier to handle. For certain applications, some physical properties of plastics may be more suitable, such as corrosion and scratch resistance, proof against shattering, and lighter weight. Typical examples are eyeglass and contact lenses, and protective eye wear.
3. Weight (and cost) reduction of products previously made from plastics. Typically, weight reduction is most important in products used in the packaging industry and in the automotive and aircraft industries, where lower weights can result in significant fuel economy and allow greater payloads. Cost reduction, always important, is achieved by both reducing material costs and shortening molding cycles, while improving the product quality.
4. Changes in materials, for any of the above reasons. Typical examples are vials and bottles (from glass); hinges (from metal); floppy computer disk enclosures (from paper); hardware, such as knobs and tool handles (from wood); toys (from metal, paper, or cloth); automotive, aircraft, and naval parts (from cast zinc or aluminum, sheet steel, wood, or glass); and enclosures for electronic equipment (from wood or metal).

5. Reduction of the number of product components, usually achieved by combining functions. Typical examples include box and cover assemblies joined with "live hinges," the use of self-tapping screws to eliminate nuts, and staking of molded plastic bosses instead of metal rivets or screws.
6. Faster or easier assembly. A typical example is snap fit instead of screw assembly.

2 Making a New Product

How does a designer begin to make the contemplated new or redesigned product? First, the designer must decide which type of plastic to use for the contemplated product. Then, he or she must select the best method for processing the plastic to create the finished product.

2.1 Choosing the Proper Plastic

There are many thousands of plastics, each with specific chemical and physical characteristics which will affect the performance of the product. There can be vast differences in processing these plastics. First, the designer must choose between two basic types of plastic, *thermosets* and *thermoplastics*.

With thermosets, the raw material (resin) is "cured" under high pressure inside a *heated* mold. The chemistry of the resulting product is *different* from that of the original resin, and it cannot be recycled. A cured thermoset product (or any scrap) cannot be ground up to be reused, except perhaps as an *inert filler* for some other products. However, thermoset products inherently resist higher temperatures than most other plastics, and they have certain better physical, electrical, and chemical properties, as well.

Most thermosets are molded with the compression or transfer molding process (tires, dinnerware, electrical components, etc.). Some products, usually smaller ones, can be made using the injection molding process in specially adapted or modified injection molding machines. Some thermosets are used as liquids, applied to sheets or mats of glass and other fibers, and then cured under (relatively low) pressure and heat. (Examples are plywood, particle board, fiberglass structures, etc.)

With thermoplastics, the raw material must be heated before it is injected into a *cooled* mold. The resin does not change (or only minimally changes) its chemistry during the heating, molding, and cooling processes. Products (and any scrap) can be ground up and the material, in most cases, reused as if it were virgin material. Other processing methods are also possible, as discussed below.

A large variety of thermoplastics are molded using the injection molding process. Some products, such as disks for (analogue) music records, are molded in compression or in injection-compression molds, while (digital) compact disks are injection molded.

2.2 Selecting the Best Processing Method

Today, there are a number of different plastic processing methods, and new methods are developed frequently:

- Molding (compression, transfer, injection, injection-compression),
- extruding (structural shapes, tubing, sheet),
- extrusion blowing ("blow molding" or "bottle-blow molding"),
- injection blowing,
- stretch blowing (one- or two-step),
- expandable bead molding,
- reaction injection molding,
- structural foam molding,
- thermoforming,
- rotational molding, and
- lost-core molding (an area of injection molding).

Many of today's plastics may be suitable for only one or for just a few of the above-listed processing methods.

The type of product contemplated will play a large role in determining the method of manufacturing. The following discussion will describe some of the advantages and disadvantages of the various methods.

2.2.1 Molding

Processing under this category includes compression, transfer, or injection molding of thermosets or thermoplastics.

Advantages:

- Suitable for any size product, from those weighing fractions of a gram to large pallets and containers weighing 40 kg and more,

- excellent surface definition,
- good accuracy,
- good repetitiveness,
- high productivity, and
- product finishing usually is not required after molding.

Disadvantage:

- High mold and machine cost.

This book will be concerned mostly with designing products for injection molding, but, before continuing, we should consider some of the other plastic processing methods used.

2.2.2 Extruding

Extruding may only be performed with some thermoplastics. Typical products include endless tubing for food, industrial, agricultural, and medical use; garden hose; sewer and water pipe; structural profiles; sheet; and film. Extrusions can be rigid or flexible.

Advantages:

- Suitable for practically any size product, but limited by available equipment size,
- fair accuracy,
- good repetitiveness,
- high productivity, and
- low-cost tooling.

Disadvantage:

- Limited application as a final product.

2.2.3 Extrusion Blowing

extrusion blowing, which is suitable only for some thermoplastics, cut lengths hot extruded tubing, called *parisons*, are automatically transferred from an extruder to one or several cooled blow molds (blow cavities), where they are blown into the final shape.