INJECTION MOULDING OF PLASTIC COMPONENTS

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A Guide to Efficiency, Fault Diagnosis and Cure

John Bown

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A Guide to Efficiency, Fault Diagnosis and Cure

This book is dedicated to my dear wife, Hazel, who cajoled, bullied, and encouraged me at all times into completing the script and on whose support I rely so much.

Preface

Much has been written about the injection moulding of plastics, both in books and in articles. Nearly all manufacturers of raw materials have produced brochures on the subject, explaining the peculiarities of their products, and there are treatises ranging from a simple learning script to highly complicated mathematical analyses. In this context, why should another book be necessary?

There are, in the United Kingdom, perhaps one hundred companies engaged in large scale injection moulding, but there are also many hundreds of firms who operate on a very small scale, some with one or two machines only. It has been my privilege, over the last ten years or more, to meet many people who are interested in the subject. Some have been moulders, some mould makers; others have been machinery manufacturers and there have been many whose interest has been solely as users of moulded components. All have agreed that the injection moulding of plastics is an intriguing subject of absorbing interest. The degree of complexity has been likened to the moves of a knight in three-dimensional chess!

To these people I offer my sincere thanks for all the help they have given me in increasing my understanding of the injection moulding of plastics. This book is an attempt to place on record some of the things I have learned in twenty-five years of study of the subject. It is not intended as a guide to enable an engineer to build a machine nor for a fitter to mend one. The intention has been to make an analytical study to try and understand why things go wrong.

It has been wisely said that accidents do not happen: they are caused. Sometimes by ignorance, occasionally by stupidity. It is the same with injection moulding. Troubles and faults are not accidental; they occur because someone or something has caused them. In this book, some of the causes are examined and discussed with a view to banishing some of the ignorance. Stupidity cannot so easily be catered for!

I have found in the past that some of the writings on injection moulding have been very erudite and full of mathematical discussions but they have often failed to make concrete suggestions that could be understood at shop-floor level (not that shop-floor level is, in these days, by any means 'low'). In this book there is some mathematics, simple, let it be said, and reduced to terms that all should understand. Mathematical purists may scorn this simple approach, but I have found that presenting the facts in this way has enabled those who, like me, are not mathematical geniuses, to have a new understanding of the subject. It enables some definite, concrete proposals to

be made. That these proposals work in practice can hardly be disputed and, in fact, where they have been tried out it has been possible to improve performance in astonishing ways.

In an industry where there is increasing need for efficiency, any means which will help to remove causes of waste must be welcomed. Some measures such as spending money on cleaning or putting extra effort into keeping records are probably unpalatable and other ideas may never have been attempted because of the consequences of failure. This book is offered with these things in mind. If it also helps those who are just beginning their study of the technology of injection moulding that will, indeed, be a bonus.

I express my grateful thanks to all who, knowingly or not, have assisted in the preparation of this book. Some, whose work I have quoted or called on, I have credited in the text. To my good friends, John R. White and John E. Nightingale, I give special thanks for all their help.

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GKN Windsor Limited, for permission to use Fig. 2.8.

Sandretto Plastics Machinery Limited, for permission to use Fig. 2.9.

Contents

1

Introduction

Wherever one cares to look around in the home, the office, the factory, in industry, agriculture, horticulture or, in fact, in all aspects of modern life, one sees plastic injection mouldings. Their applications are numberless and, for the most part, their performance is unexampled. But they all have to be produced from granular or powdered plastic by a quite complicated process, and although the process is designed for mass production, all along the line there are difficulties. Each moulding should be exactly like every other moulding produced from a particular mould, but in order to ensure that this is the case many problems have to be overcome. This book is an attempt to approach the subject of the injection moulding of plastics in an analytical manner, to consider the problems that are encountered, and to discover their causes. Having done this, the method by which they may be overcome will be worked out from the basic principles of the process.

A close study of any common household article which is made from plastic by injection moulding—say a jug or basin, an electrical plug and socket, a radio cabinet or a vacuum cleaner case—will reveal many areas where problems can occur. Glossy surfaces must be unblemished, white items must not be contaminated with black specks (nor black articles with white specks), and handles must be smooth and edges not sharp enough to cause injury to the user. The design and production of the article must be such that no untimely breakdown occurs and it must be suitable for its purpose. Such matters present a challenge to the practical moulder, to whom a large section of this book is addressed.

In meeting this challenge it has to be remembered that a business cannot function unless it is financially viable and produces a useful return on the amount of capital employed. Because the process is 'capital intensive', requiring more capital per person employed than do many industries, the financial aspects of injection moulding have not been forgotten. With the increasing interest by the 'shop floor' workers in the proper running of a company, it does not seem out of place in a book which is, after all, aimed

primarily at the technical side of the business, to devote a chapter to the financial aspects of injection moulding.

Health and safety at work are assuming an increasingly important role, and this has not been neglected in the book. Although the chapter which deals with this is primarily concerned with housekeeping and efficiency, the relationship between health, safety and efficiency cannot be too strongly emphasized. Unfortunately, it has to be admitted that the injection moulding industry is not among the best so far as housekeeping and cleanliness are concerned and it may be opportune to take a self-analytical look at this subject and to see what the effects of poor housekeeping are likely to be.

Plastic injection moulding is a process which depends for its success on the proper functioning of a *machine* which is operating with *material* and producing the shapes required by means of a *mould.* Each of these three elements is important and the interdependence of machine, material and mould will become more apparent as the work proceeds. In order thoroughly to understand the functions of each it is necessary to know the jargon of the business. Just as every industry from pottery to ironfounding has its own language, so injection moulding has words, phrases and terminology that would not be readily understood, or may have a different meaning, outside the context of the injection moulding shop. Studying some of these terms will therefore be the first consideration, making sure that, so far as is possible, terms are defined in as concise and unambiguous a manner as possible. Reference should be made to British Standard 1755: Glossary of Terms Used in the Plastics Industry for any further information, but the terms used and defined in this book are those which, by experience, have been found to be in most common use among many people, at all levels of technology, who work in the industry. Many glossaries are placed in an appendix at the end of a book. Because of the importance of knowing the language this glossary is included in the introductory chapter and is in two sections: (1) Glossary and definitions of terms; and (2) faults in injection moulded components.

Glossary and definition of terms

Accumulator	A device for storing hydraulic fluid under pressure.
Appearance surface	The surface of a moulding which will be seen and which therefore has to present a suitable appearance.
Back-flow stop valve	A non-return valve on the tip of the screw which prevents fluid plastic from passing backwards along the screw flights when injecting.
Backing plate	A supporting plate in the mould carrying the cavity blocks (*see also* Bolster).
Balance tray	A tray under the mould on to which the moulding falls during automatic cycling and which then operates the switch to close the mould and so causes

	the re-cycling starter to operate to re-start the cycle. Used instead of a pause timer and as a mould-safety device.
Barrel	*See* Cylinder.
Bolster	A block of metal (usually steel) for carrying cavity blocks in an injection mould. Also called a 'chase'.
Carrot	*See* Sprue.
Cartridge heater	An electrical resistance heater in the form of a cartridge for inserting into a nozzle or a section of a mould.
Cavity	The hollow space in the mould where the plastic is formed to shape.
Cavity register	Angled faces on parts of the mould which match when the mould is closed and so ensure correct alignment of the parts.
Check ring	A ring type of non-return valve on the tip of the screw which prevents fluid plastic from passing backwards along the screw flights when injecting.
Compound	A mixture of plastic polymer and additives which has been fused by heating and then granulated or otherwise prepared for feeding to a moulding machine.
Compression ratio	The ratio of the volume of one flight of a screw (i.e., one complete revolution) at the feed end to that at the discharge end.
Copolymer	A polymer made by polymerizing together two or more different monomers.
Core and core pin	The solid part of the mould which gives the inside shape to the moulding.
Cuff heater	*See* Heater band.
Cylinder	The cylindrical part of the plasticizing unit of an injection moulding machine.
Cycle time	*See* Moulding cycle.
Daylight	The working distance between the fixed and moving platens of an injection moulding machine.
Decompression zone	In a vented barrel, the decompression zone comes in between the first and second compression zones and allows venting of volatiles without escape of plastic (*see* Vented barrel).
Degating	Separating the mouldings from the runner system.
Depolymerization	*See* Polymerization.
Dice cut	Material for processing in the shape of cubes of approximately 2–3 mm in size.
Dowel pins	Guide pins of hardened steel which hold one part of a mould in the correct position relative to the other

part or parts. The guide pins fit closely into bushes made of hardened steel.

Draft — The taper on parts of a mould designed to allow easy extraction of the moulding from the mould.

Draft angle — The angle of the taper from the vertical (i.e., from the direction of mould opening).

Ejector pin — A steel rod which moves forward as the mould opens, pushing the moulding from the mould.

Ejector plate — A plate in the mould which carries the ejector pins.

Ejector system — A device fitted to the moving platen of the machine for operating the moulding ejectors. It may be operated mechanically (including springs), hydraulically, pneumatically or electrically.

Extended nozzle — An extension of the cylinder nozzle which penetrates into the mould and shortens, or obviates the need for, a sprue bush.

Flash mould — A *horizontal* flash mould has the mating surfaces at right-angles to the direction of opening of the mould.

A *vertical* flash mould or positive mould has the mating surfaces in line with the direction of opening (*see* Fig. 5.2).

Flow moulding — A method of injection moulding in which the screw continues to rotate during injection, thus enabling larger shot weights to be obtained than would normally result. The injection rate is much slower than in normal operation and the process is generally applicable to the moulding of thick sections.

Gate — A restriction between the channel conveying material to the cavity and the cavity itself. For types of gate *see* Chapter 5.

Heater band — An electrical resistance heater in the form of a cuff which encircles the cylinder or nozzle.

Impression — A mould cavity. Moulds may be designated single-impression or 2-, 3-, 4- etc. or multi-impression.

Injection moulding — The process whereby a quantity of plastic material in solid or granular form is heated and softened in one part of the machine and then forced under pressure into a mould where it is cooled and hardened (or heated and cured in the case of thermosetting materials) and retains the shape imparted to it.

Injection pressure — The pressure exerted on the material in the cylinder by the ram or screw during injection. Injection

	pressure = line pressure × intensification ratio (q.v.).
Insert	A piece of material such as a screw or a stud placed in the mould before injection takes place and around part of which the plastic is moulded so that the insert becomes an integral part of the component.
Intensification ratio	The ratio of the injection pressure to the pressure of the hydraulic fluid (line pressure). It is numerically equal to the area of the hydraulic cylinder which actuates the screw or plunger divided by the area of the plunger itself.
Jig cooling	Cooling a moulding, after removal from the mould, in a jig which prevents it from changing shape.
Land	Narrow rims in a mould where parts of the mould 'mate' together. Also, the parallel parts of a gate.
Lift	A moulding, or set of mouldings, produced in one cycle of the machine.
Limit switch	A switch set at the limit of movement of part of the machine which controls the electrical power supply either to stop further movement of that part or to initiate a further part of the moulding cycle.
Line pressure	The hydraulic pressure in the supply pipes (or lines) to the part of the machine being used.
Locking force	The force exerted in the locking mechanism of the machine which keeps the mould closed during injection.
Locking mechanism	A hydraulic cylinder or toggle mechanism which is designed to close the mould and to keep it in the closed position during injection.
Masterbatch	A concentrated mixture of pigment, filler, antistatic agent, lubricant or other additive, and a base polymer (e.g., polyethylene, polypropylene, etc.) This is added by the moulder, as required, to the moulding material to give the concentration necessary to produce the colour or other quality desired.
Monomer	A chemical compound consisting of simple molecules which can be made to join together by a process called polymerization to produce a polymer which is composed of much more complex molecules and is the basic material from which plastics are made.
Mould	A hollow form or cavity into which molten plastic material is forced to give the shape of the required