José R. Lerma Valero

Plastics Injection Molding

Scientific Molding, Recommendations, and Best Practices

HANSER

Lerma Valero

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José R. Lerma Valero

September 2019

Preface

This manual has been created thinking of plastics injection molding technicians as well as processing engineers and quality and design engineers.

The book was initially born as a small procedure guide for the company where I was working, for fine-tuning injection machines with the aim of creating a logical, safe, and optimized start-up method. Gradually, it grew and accumulated interesting information for the technicians, in my opinion, and it took shape until the final editing.

It was created for those who have ever needed a book to help and support them to understand the technology, materials, and thermoplastics injection process.

It is a book that helps identify the key points of the process and show, explore, and teach new tools to define more stable, robust, and consistent processes; a book with information, for example, such as the following:

- Clear explanations about the main key points of the thermoplastics injection molding process
- Glossaries with detailed explanations and easy-to-handle data tables
- Explanations about thermoplastics and their properties and behavior
- Support information to select material according to its further application
- Support information to determine the most suitable machine to use
- Real case examples, problems, analysis, and solutions
- Scientific injection molding explanations of tools, calculations, and portability
- Examples of defects and failures, their causes and possible solutions
- Easy and clear explanations for injection process optimization
- General processing recommendations

I hope that this book can be a tool for consulting and support during the professional life of the reader.

I also aim to encourage technicians toward a cultural change in both the analysis of problems and the parameterization and definition of robust plastics injection molding processes, where the transition from the empirical method toward the scientific method can be made using appropriate methodologies.

José R. Lerma Valero

September 2019

About the Author

José R. Lerma Valero was born in Barcelona, Catalonia, in 1962; he is married and has a son. He obtained a superior degree in mechanics, with specialty in molds, and studied business management. He started his professional life as a trainee in a small injection molding factory.

José R. Lerma has dedicated close to 40 years of his professional life to the world of thermoplastics. Most of this professional life in plastics injection factories has been dedicated to producing parts for the automotive sector, producing both technical and aesthetic parts, painted, with chrome plating, etc. The functions and responsibilities he carried out in these injection plants have been of all kinds; for example, Processing Engineer, Technical Department Manager, Maintenance Manager, Production Manager, and Plant Manager.

Currently, and for almost 12 years, he is the Technical Manager for Spain and Portugal in Biesterfeld Ibérica SLU, leader in polymer distribution in Europe, with a portfolio of materials from the world's leading manufacturers.

José R. Lerma has been collaborating for more than 15 years with different technical centers in Spain as a leader of different seminars all related to plastics and the transformation of plastics, having trained hundreds of technicians in this technology.

In 2013 he published the book "Advanced Manual of Thermoplastics Transformation" in the Spanish language, with great success among plastics injection technicians.

It should also be noted that for six years he has developed and taught a specific seminar about scientific injection molding methodology in Spain, Portugal, and some Latin-American countries quite successfully.

All this accumulated background of experience in real day-to-day cases in factories as well as the training received and the experience of providing training in seminars to technicians is reflected and shared in this book.

Contents

Part 1

Plastics

CHAPTER 1

Polymers

Polymers are molecules very common in our environment. They may be natural or synthetic. We can find them in our food (starches, proteins), our clothing (cotton, polyester, silk, nylon, etc.), our homes (wood, paint), and even in our body (proteins, DNA). A polymer is a macromolecule with a high molecular weight. Its name comes from the Greek and we can roughly translate it as “many parts”.

Since polymers are substances with high molecular weight, they have a large size. This size is achieved by the repeated binding of small molecules called monomers. The binding is done in sequence: one unit after the other, like a chain where each unit is a link. The number of links (or monomers) indicates the degree of polymerization.

A common molecule (such as water) has a molecular weight of 18 grams/mol. This means that 6.06×10^{23} water molecules weigh 18 grams (1 mol). In the case of hexane, a solvent, it has a molecular weight of 86 g/mol. In comparison, for example, the molecular weight of UHMW PE (ultra high molecular weight polyethylene) can be 4,000,000 g/mol, or that of rubber can reach 1,000,000 g/mol. That is, 6.06×10^{23} rubber molecules weigh 1 ton. These data can give us an idea of the difference between small molecules and polymers.

Polymers have a heterogeneous molecular weight. When we speak of the molecular weight of polymers, we are talking about average amounts (see Section 1.5).

1.1 Plastics

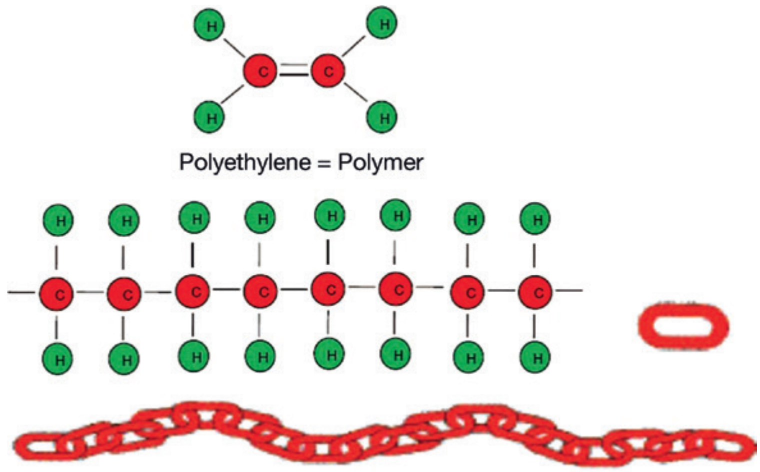
All plastics are composed of large molecules bound together by strong link forces. All plastics are characterized by high molecular weights.

Plastics are obtained by polymerization. Through this process, a number of molecules or monomers are linked by reactions to produce a large molecule or polymer (macromolecule).

We can imagine a plastic like a ball of wool made up of many individual threads.

Monomers are chemical compounds in which the carbon atoms are linked by a double bond.

Figure 1.1 Example: ethylene monomer (molecule)



The carbon double bond (C =) allows the linking of molecules and the creation of polymers. The carbon atom is one of the few that can link itself through its double bonds.

When polymerized, these double bonds are broken and form bonds in two directions, forming the macromolecule. In the simplest cases they are joined one after the other like the links of a chain or a necklace.

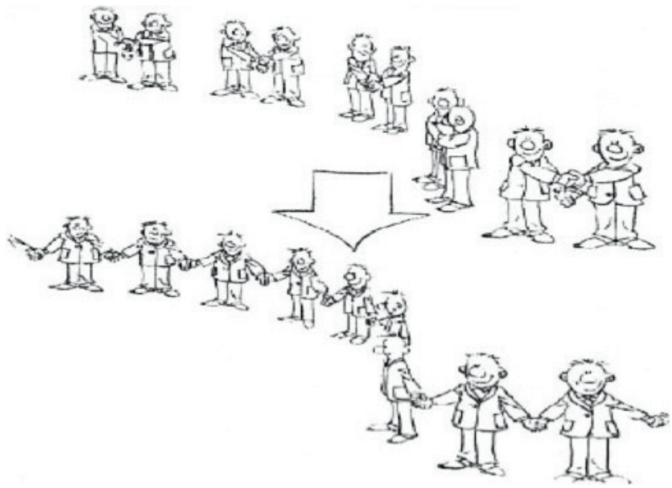
1.2 Molecular Bonds

Atoms of monomer molecules are linked by atomic bonds called covalent bonds. These bonds are forces holding two atoms together. Two atoms may be linked by single, double, or triple bonds.

Besides the bonding forces between atoms, there are bonding forces between molecules. These forces are called intermolecular forces. They attract the adjacent molecule with a certain intensity.

These forces provide and determine properties such as strength. To consider strength, we can use an analogous image: we can imagine a zipper, which provides strength to a fabric. The zipper hooks would be the intermolecular forces. Only if we pull very strongly do hooks come loose. However, these intermolecular forces are weaker than covalent bonding forces or atomic bonds.

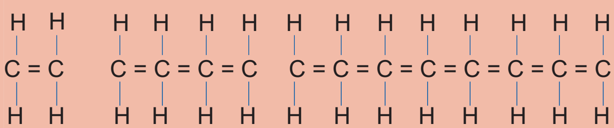
Intermolecular forces are sensitive to the energy applied by heat. The higher the temperature, the more the molecules move; molecules begin to vibrate and intermolecular forces decrease. Above a certain temperature, those forces disappear and the molecules can move freely and easily slide against each other. However, the covalent bonds between atoms are much more resistant and their destruction requires much higher temperatures.



Unlike intermolecular bonds, if the heat energy is high enough, covalent bonds or bonds between atoms do not form again when the temperature decreases: the molecule remains destroyed.

Hydrocarbons

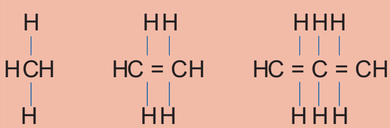
Hydrocarbons are **organic compounds** consisting only of **carbon** and **hydrogen** atoms. Their molecular structure consists of a framework of carbon atoms to which hydrogen atoms are attached.



- C_2H_4 ethylene
- C_4H_8 butene
- C_6H_{12} hexene
- C_8H_{16} octene

Properties change depending on the molecular structure:

GAS → SEMI-SOLID



CH_4 C_2H_6 C_3H_8 ... C_4H_{10} ... C_5H_{12} ... $C_{16}H_{34}$

METHANE ETHANE PROPANE ... BUTANE ... PENTANE ... PARAFFIN