TEACHING POLYMER PROCESSING IN A MECHANICAL ENGINNERING UNDERGRADUATION COURSE

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Abstract. *Polymers have been largely used to produce goods due to their main properties like: low weight, low electric permeability, corrosion resistance, and above all due to their low cost to be molded in almost any shape. While polymers synthesis is a chemistry issue, for polymer processing it is necessary machines and tools, which are mechanical issues. A brief profile of the Brazilian Plastic Processing Industry and the job opportunities for mechanical engineers will be presented. The contents of the course will be presented, followed by a discussion about the field in which mechanical engineers can work and the contribution that could be given by this course in each of these fields.*

Keywords*: polymer processing course, plastics processing course, polymer processing for mechanical engineers*

1. INTRODUCTION

This work presents the experience in teaching polymer processing in Universidade Federal do Rio de Janeiro (UFRJ). A discussion about the opportunities for mechanical engineering in polymer processing industry is also presented.

In the second sections the profile of the polymer processing industry is presented. The amount of plastic processed the sectors that use polymer processing and the percentage of companies that uses each polymer processing techniques are presented.

The knowledge and skills necessary for a mechanical engineer of work in polymer processing industry, is presented in the third section.

The structure of the polymer processing course of the mechanical engineering of the UFRJ is presented in section four.

Finally there is a conclusion and the references used in the course.

2. A BRIEF PROFILE OF THE BRAZILIAN POLYMER PROCESSING INDUSTRY

According to Plastics Europe (2009), the total production of plastics were 1, 5 million of tones in 1950 and 245 million of tones in 2008. Although this great increase in plastics production, the distribution of this production by regions or countries are not even. Latin America produce only 4% of the total while other countries in similar development stage such as China and Middle East produce 15% and 8% respectively. The Per Capita Consumption of plastic in NAFTA and in East Europe countries were around 100 kilograms in 2005 in Latin America it was 21 kilograms. On the other hand, the consumption per capita estimated for 2015 will be around 138 kilograms and 32 kilograms respectively. Although the increase in per capita consumption expected for Latin America in this period of time was 52% while in the increase for NAFTA and East Europe was 38%, the amount of the plastic per capita consumption is very low. Therefore there is room for the increase o plastic consumption in Latin America following the growth of the economy. It means increase of the number of companies and the increase of the number of jobs for engineers in the plastics, tolling and machine sectors.

In Brazil it was observed a grows of 64, 59% in the number of companies from 2000 to 2008 and a growth of 65, 22% of employees in this sector. The amount of plastics processed in 2009 was 5.194 millions of tons and the R$ 35,90 billions of turnover.

The percentage of processed plastics market by the main industrial sectors are: food (17,5%), building (15,6%) and package (14,5%). Taking into account that in food sector the plastics are used for package, it can be considerer that the actual share of plastics processed for package is 32 %. This trend can be confirmed by the segmentation of the processed plastics market. The molding processes most frequently used are: extrusion 57%, injection molding 19%, blow molding 16%, rotomolding 1% and others 7%. Although thermoforming was not mentioned in this study, this process is frequently used for package, and therefore it probably has the great share of the percentage of others 7 %.

The share of companies by number of employees shows that 88% of the companies has up to 50 employees. Only 0,05% has 1000 employees or more and 6,27% of the companies do not have any employees. Based on these numbers, it can be said that small companies are dominant in the plastic processing sector.

3. MECHANICAL ENGINNERS IN PLASTIC PROCESSING INDUSTRY

There are several opportunities for mechanical engineers in plastic processing companies. For low cost and efficient performance of a plastic product it is necessary: adequate choice of material, good design, efficient tool, efficient machine and efficient process control. Apart from choice of material, that is a chemistry issue, all other items need mechanical knowledge.

For a good design it is necessary a product designer to: create the shape, chose the color, type of surfaces and so one. It will be done with the assistance of a chemical engineer to select the type of plastic and a mechanical engineer to verify by means of simulations structural strength of the product.

The tools for plastic processing are usually made of one or more metallic parts and they usually have a feed of plastics system and a cooling system for thermoplastics, or heat a system for thermo rigid polymers. For a efficient tool design it is necessary several knowledge of mechanical engineer such as:

- Fluid dynamics (rheology) for tool filling;
- Solid mechanics for strength analysis;
- Heat transfer for cooling;
- Machine design for special tools where actuators and mechanisms can be found,
- Manufacturing processes to produce the tool itself.

Therefore, tools design is made by mechanical engineers.

The machines for polymer processing are formed by the following systems: heating, melting, polymer transfer, for tool holding and/or tool moving, and for product extraction. These systems must be chosen by a mechanical engineer before to start a manufacturing product line. During the production periodical maintenance is required for this line and it is also a mechanical engineer issue.

The machine systems must be controlled to have an efficient process and to obtain products with the expected quality. Once more, the mechanical engineer knowledge is necessary to set-up these systems.

Frequently a particular polymer processing area is part of a manufacturing chain where they need to be interacting with robots, transport systems, assembly and packaging equipments. The project, the section of equipments and the set-up of the manufacturing chain are also a mechanical engineer issue.

In the previous section it was presented that 88% of the polymer processing companies are small with 50 or less employees. This type of company can not afford to have several specialized engineers to deal with all aspects of the manufacturing system. While a large company can afford different engineers for maintenance, control, tooling, materials, handling and so one, a small company must have one or two engineers to deal with all those issues. In this case, the engineer must have a broad knowledge back ground and skills to let him perform the different tasks on demand. The courses attended by mechanical engineer students give them the necessary back ground to be the most suitable professional to work in a polymer processing company.

A course to improve the mechanical engineer formation to work in this type of company was created in Federal University of Rio de Janeiro, named “Fabricação de Produdos com Polímeros”. This name was chosen to show that it is a manufacturing and not a material or chemical course.

This course was created to give knowledge about polymers properties, rheology, and processing techniques to permit mechanical engineers make tools design and to manage a polymer processing plant. For this the mechanical engineer must be capable of to identify the products defects, understand the causes of the defects and to take actions to avoid them. In many cases, the problems may be solved in more than one way, by doing changes in processing parameters, doing modifications in tools, doing small changes in the product design or selecting different material.

4. “FABRICAÇÃO DE PRODUTOS COM POLIMEROS” COURSE

To prepare engineers for polymer processing companies is the aim of this course. It is divided in two parts: Polymers and Polymer Processing Technology. In polymers part it is presented the characteristics of the polymers, their maim properties, their mechanisms of degradation and the most used types of additives, fillings and reinforcing agents. In the second part it is presented the main polymer processing techniques and exploring the influence on the characteristics of the molded products caused by the following the aspects: machine, tools and process parameter.

4.1. Part I - Polymers

This part of the course was meant to give basic knowledge about polymers to the students to make them capable to understand how the polymers behave in use and in molding process. It is divided in:

The polymer:

- Types of chemical bonding in the polymers;
- Monomers and copolymers;
- Molecular weigh;
- Cross linking;
- Crystallinity;
- The chemical structure

Polymers properties:

- Stress x strain behavior;
- Thermal transitions;
- Hardness;
- Impact strength;
- Thermal properties (thermal expansion, thermal conductivity, specific heat)
- Introduction to rheology.

Polymers stability:

- Thermal degradation;
- Oxidative degradation;
- Flammability.

The main functions or the polymers addictives:

- UV absorbers;
- Plasticizers;
- Flame retardants;
- Fillers;
- Pigments and dyes.

Guide lines for polymers selection.

The knowledge about the items above mentioned are also important to select a polymer for a particular product and to solve problems of quality of the product or problems caused by the processing technique.

4.2. Part II – Polymers processing techniques.

In this part the most frequent used polymer processing techniques are presented. The machine, tool, processing parameters and main problems and solutions are presented for each processing technique.

- Compression;
- Molding of Composite (fibers-polymer);
- Extrusion (solid, tubes and films);
- Thermal forming;
- Blow molding;
- Rotational Molding;
- Injection.

The most important techniques are extrusion and injection molding because they are the most used, the cost products molded by these techniques are low due to automation and high rate of productions. Frequently extruded products are used as input material for other processes as thermoforming and blow molding. Injection molding is highly used because the time to mold the parts is lower than the other processes and when the products are extracted from the tool ready to be used. The injection molding is far more complex that the other processing techniques, and therefore, more time are consumed to teach it than to teach other processes.

4.3. Literature recommended for the course.

One of the greatest difficulties to prepare this course is to find a appropriate literature. The most suitable book for this course is Blass (1984), which has been written for the mechanical engineer course of Federal University of Santa Catarina. Although polymers structures, polymers properties and new technologies for polymer processing are not included in this book, the basic knowledge about polymer and processing technology are there. Each topics of the course have been prepared using specific literature. The main books are listed in the item references.

An adequate literature for introduction to polymers, their characteristics and structure is Mano (1985). There is possible to learn about monomers, copolymers, molecular weight, and several forms to classify polymers.

For polymer selection, Mano (1991) is a good reference where tables and graphs with properties of the most frequently used polymers. Shackelford (1992) is also a relevant literature for polymers characteristics and properties.

An introduction to rheology can be found in Manrich (2005). The theory of rheology and its use in extrusion and injection of thermoplastics are clearly presented in this book.

For the second part of the course, where processing techniques are presented, it is recommended Blass (1988) as a general literature and specific literature for most processes. Although the techniques are not presented in Blass (1888) in a up to date technology, this book is still an important reference to learn the maim polymer processing techniques. A few examples of literature for a particular process are: Menges, G., Mohren, P (1993), Michaeli, W. (1984), Rees, H (1995), Sidney Levy, P.E., (1981) and'Throne, J.L. (1996).

5. CONCLUSION

The course of polymer processing in mechanical engineer course of UFRJ was presented in this work.

It was presented a brief profile of the polymer processing industry showing the rate of each plastic consumption, rate of most used molding processes and rate of companies by number of employees.

A discussion about the ways in which mechanical engineers can work in polymer industry has been undertaken. The attributions of the mechanical engineers in polymers companies are presented. Mechanical engineers are the first choice to work in polymer processing companies due to the large number of knowledge in different fields that are necessary for a engineer work in the different sections of the companies.

The knowledge about polymer properties and polymer processing given during this course, makes the mechanical engineer capable to design tools and to take care of a polymer processing plant.

The structure and subjects of the course of polymer processing of the UFRJ was presented.
Finally, it was presented the main literature in which the course was based.

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