Dănuț Ionel SAVU **Sorin Vasile SAVU**

HEATED TOOL AND ELECTROFUSION WELDING OF POLYMERS

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Prof. Dr. Eng. Ion CIUPITU
Assoc. Prof. Dr. Eng. Gheorghe VADUVOIU

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I. Savu, Sorin Vasile

62

To our children,

ARIANNE & ANDREI.

Foreword

”Heated Tool and Electrofusion Welding of Polymers” aims to be a practical instrument for the specialists in the field of welding, as well as for the students in the university classes and in different training classes.
The theme of the discussion is actual, large number of application in water and gas supplying, in automotive industry and other is often met.
The presented data cover the main information regarding the welding process of polymers: description of the base materials, principle of the processes, description of the processes, equipment, technology, testing of the welds, potential material imperfections inside welds and the main information on the health and safety to apply during welding process. The information is mainly practical one, but partly pure theoretical information is given, as well. Because of that the book is similar to a course for the specialists involved in fabrication of polymer constructions, but the students who try to discover the field of the polymers welding they can find important theoretical information on the polymers, on the characteristics of the welding process and on the influences of different phenomena on the technological parameters.
The book is also a personal achievement that I owe our father who has always wanted his two children to excel in everything we have set out to do.

Drobeta Turnu Severin, October 2013

Danuț Ionel SAVU
Sorin Vasile SAVU

Chapter 1

MATERIALS TECHNOLOGY OF PLASTICS

1.1 Generals

Polymers are a large class of materials consisting of many small molecules (called *monomers*) that can be linked together to form long chains, thus they are known as *macromolecules*(term introduced by H. Staudinger in 1920's). A typical polymer may include tens of thousands of monomers. Because of their large size, polymers are classified as macromolecules. Polymers occur naturally in the form of proteins, cellulose(plants), starch(food) and natural rubber. Engineering polymers, however, are usually synthetic polymers.

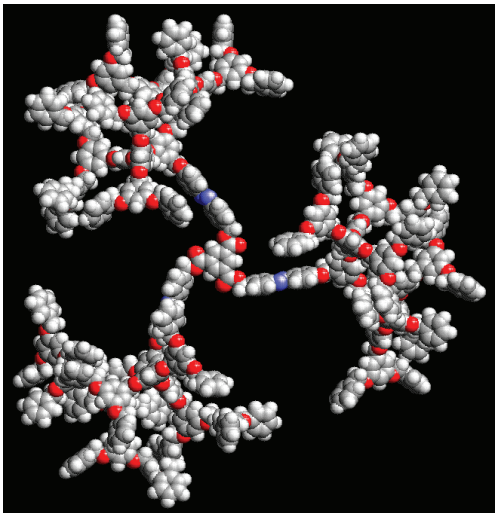


Fig. 1.1 Molecular chains

1.1.1 Definitions

Polymer – Large molecule consisting of a number of repeating units with molecularweight typically several thousand or higher.
Repeating unit – The fundamental recurring unit of a polymer.
Monomer – The smaller molecule(s) that are used to prepare a polymer.
Oligomer – A molecule consisting of reaction of several repeat units of a monomer but not large enough to be consider a polymer.
Single repeat unit: MONOMER
Many repeat units: POLYMER
Degree of polymerization – The number of the repeating units

1.1.2 Application of polymers

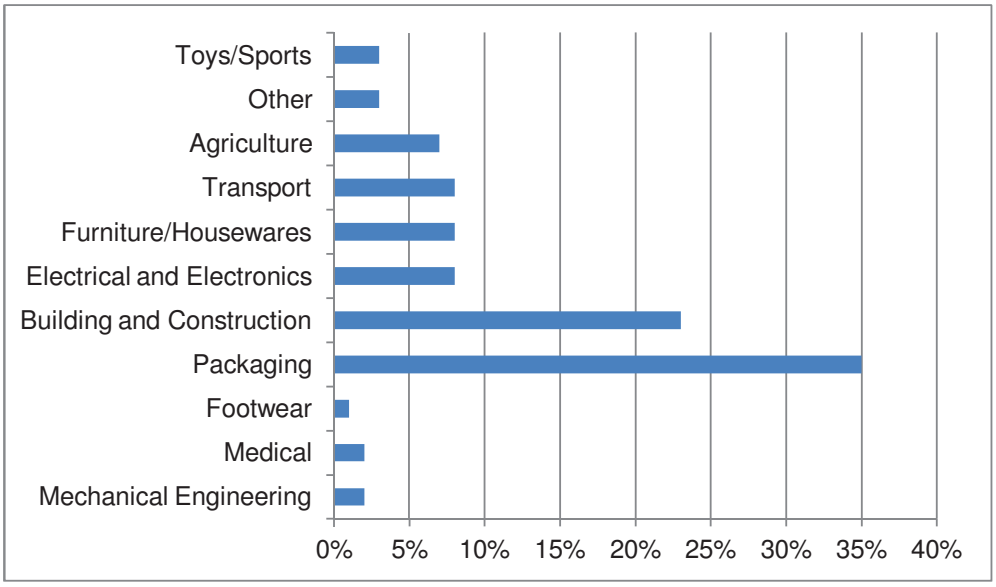


Fig. 1.2 Application of polymers
INCPEN, Towards greener households, June 2001

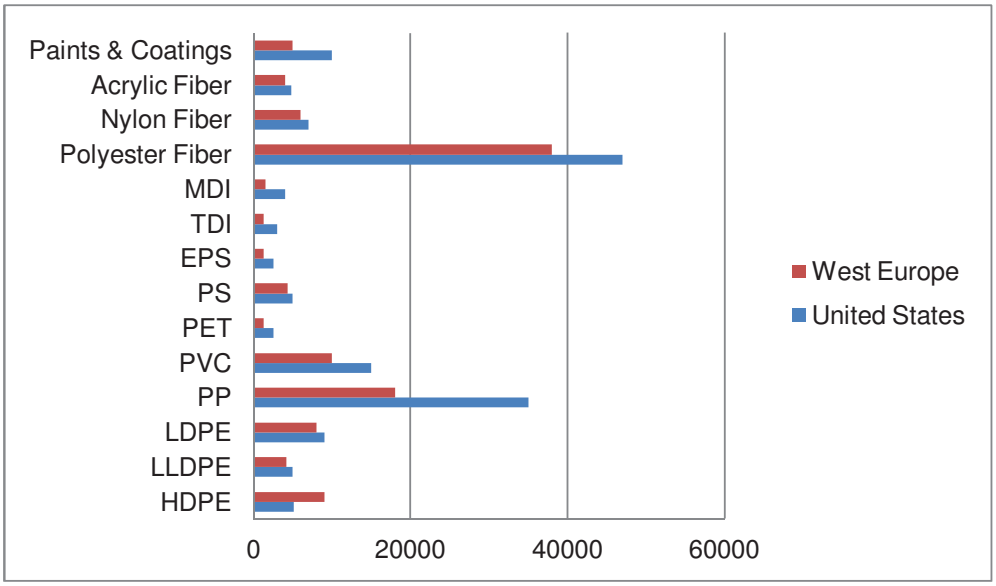


Fig. 1.3 Market of polymers

1.1.3 Nomenclature of polymers

1.1.3.1 Nomenclature Based on monomer source

The addition polymer is often named according to the monomer that was used to form it: poly(vinyl chloride) PVC is made from vinyl chloride -CH_2-CH(Cl)-:

- If " X " is a single word the name of polymer is written out directly: -CH_2-CH(Ph)-, Poly-X
- If " X " consists of two or more words parentheses should be used: poly (vinyl acetate) -CH_2-CH($OCOCH_3$)-

1.1.3.2 Based on polymer structure

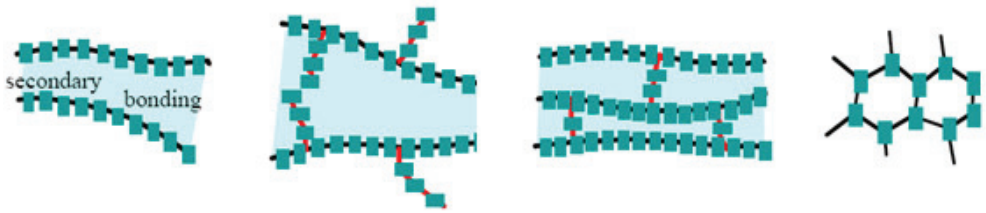
The most common method for condensation polymers since the polymercontains different functional groups than the monomer

PC = Polycarbonat
PPE = Polyphenylether
SMA = Styrol-Maleinsäureanhydrid
ABS = Acrylnitril-Butadien-Styrol
PMMA = Polymethylmethacrylat
PS = Polystyrol
SAN = Styrol-Acrylnitril-Copolymere
PVC = Polyvinylchlorid
PET = Polyethylenterephthalat (PETP)
PBT = Polybutylenterephthalat (PBTP)
PA = Polyamid
POM = Polyoxymethylen
RF-PP = Resorcin-Formaldehyd-Polypropylen
PE-UHMW = Polyethylen-ultra high molecular weight
PP = Polypropylen
PE-HD = Polyethylen hoher Dichte (High Density)
PE-LD = Polyethylen niedriger Dichte (Low Density)

1.2 Classification of polymers

1.2.1 Classification by chain structure

- Linear chains:a polymer consisting of a single continuous chain of repeat units
- Branched chains:a polymer that includes side chains of repeat units connecting onto the main chain of repeat units
- Hyper branched polymer consist of a constitutional repeating unit including a branching groups
- Cross linked polymer: a polymer that includes interconnections between chains
- Network polymer: a cross linked polymer that includes numerous interconnections between chains.



a. b. c. d.

Fig. 1.4 Network polymer

1.2.2 Classification by Thermal Behavior

From the thermal behavior point of view, there are three general groups of polymer materials:

- Elastomers
- Thermoplastics
- Thermosets

1.2.2.1 Elastomers

Elastomers are polymers possessing high elasticity - may be reversibly stretched at high degree. Elastomers consist of long lightly cross-linked molecules.
Common elastomers are:

- Polyisoprene (natural rubber)
- Butyl
- Nitrile
- Neoprene
- Ethylene-Propylene
- Hypalon
- Silicone

Elastomers may be strengthened by **vulcanization** process (heat treatment in presence of chemical agents). Vulcanization results in

increase of cross-linking of the molecules. Vulcanized elastomers are elastic for small deformations.

1.2.2.2 Thermoplastics

Thermoplastics are polymers, which soften (becomes pliable and plastic) and melt when heated. In the melted conditions thermoplastics may be formed by various methods (injection molding, extrusion, Thermoforming). No new cross-links form (no chemical curing) when a thermoplastic cools and harden. Thermoplastics may be reprocessed (re-melt) many times. Molecules of most of thermoplastics combine long polymer chains alternating with monomer units. Thermoplastic materials may contain filler materials in form of powder or fibers, providing improvement of specific material properties (strength, stiffness, lubricity, color etc.). Thermoplastic groups:

- **Polyolefines**: Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), Polypropylene (PP).
- **Styrenics**: Polysterene (PS), Acrylonitrile-Butadiene-Styrene (ABS), Styrene-Acrylonitrile (SAN), Styrene/Acrylic (S/A), Styrene-Maleic Anhydride (SMA).
- **Vinyls**: Polyvinyl Chloride (PVC), Chlorinated Polyvinyl Chloride (CPVC).
- **Acrylics**: Polymethylmethacrylate (PMMA), Polyvinilchloride-Acrylic Blend (PVC/MA).
- **Fluoropolymers**: Polychlorotrifluoroethylene (CTFE), Polytetrafluoroethylene (PTFE), Polyvinylidene Fluoride (PVDF).
- **Polyesters**: Polyethylene Terephtalate (PET), Polyester PETG (PETG), Polybutylene Terephtalate (PBT), Polyarilate (PAR), Liquid Crystal Polyester (LCP).
- **Polyamides (Nylons)**: Nylon 6 (N6), Nylon 66 (N66), Nylon 11 (N11), Nylon 12 (N12), Polyphtalamide (PPA), Polyamide-imide (PAI).
- **Polyimides**: Polyimide (PI), Polyetherimide (PEI).
- **Polyethers**: Polyacetal (POM), Polycarbonate (PC), Polyphenylene Oxide Blend (PPO), Polyaryletherketone (PAEK), Polyetheretherketone.