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Analysis of Film Types for Packaging Processes

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Abstract: *This article presents a structured analysis of film types. The types of chemical and physical properties are considered. The need for packaging was analyzed and the factors influencing the choice of film for the needs of the consumers were also studied. An overview and comparative analysis of the three main types of film are presented*

The aim of the paper is to be analyzed the different film types for the needs of packaging machines.

Keywords: *packaging, film type, process, automation.*

1. Need for packaging

The packaging covers a large proportion of the most advanced industries globally. The wide range of uses has an impact on consumers' daily lives worldwide. People's daily choices depend on how the packages produced and marketed are designed. Packaging helps consumers to make decisions, choose what to eat, how to take care of their health, how they look, what they choose to buy.

The rapidly evolving consumer community is forcing packaging manufacturers to meet the growing demands for quality and convenience. In addition to consumer requirements, there are many other factors that influence the way that manufacturers of goods, products, packaging carry out their current business practices and future projects. One of the major problems affecting the future vision of European packaging is the increasing pressure to deliver packaging solutions from eco-friendly materials. In the combination of tightening European legislation, climate change and increasing environmental awareness of the consumer, it is becoming a major driving force for the packaging industry. The requirements of the European Union on the recycling of packaging materials urge governments to work closely with producers, retailers, to help deal with stringent rules [1, 2, 3, 4, 5, 6, 7].

The aim of the presented paper is to be analyzed the film types for packaging processes.

2. Comparative characteristics of types of packaging film

The two main film types for the packaging industry are stretch film and polyethylene film.

2.1. Stretch film

Stretch film is a commonly used term for multilayer elastic polyethylene film produced by the so-called "CAST" film extrusion technology. Linear Low-Density PolyEthylene (LLDPE) is the main material for the production of the extensible film- stretch film.

Thanks to the modern production lines and state of the art technologies, as well as the use of raw materials supplied by renowned manufacturers, the film is with very high quality.

Application: Stretch film is mainly used to pack and protect products ranging from palletized loads to individual items of large or small overall size. Due to its low thickness and high durability, it guarantees the stability of a load of packaging products. There are different types of stretch film on the market from different manufacturers [1, 2, 7].

Machine-extensible Stretch Film - it is used to pack and protect products ranging from pallet-packed loads to individual large-sized items. Designed for packaging goods by using packaging machines.

Super Power and Power Stretch Film - this type of stretch film is designed to pack and protect products by using packaging machines, the thickness of the produced film is from 10 up to 35 micrometers.

Standard Stretch Film - designed to pack and protect products by using packaging machines.

Pre-Stretched Film - produced by pre-stretching the stretch film to a certain thickness. The pre-stretched film has many advantages over traditional stretch film:

- Allows the consumption of film to be reduced during pallet packaging and thus to reduce the cost per unit;
- High tension of the prestressed film is achieved with only one stretch, which results in the stability of the load during transportation;
- Less effort is required to stretch the film, which has a positive effect on the efficiency of the packaging;
- Reducing the consumption of film has a positive impact on the environment due to the reduced amount of waste.

2.2. Polyethylene

PolyEthylene is the most common type of plastic (PE). The annual production of polyethylene exceeds 85 million metric tons. The main application of polyethylene is in the packaging industry is for the production of plastic bags, envelopes, film, polyethylene containers, bottles and more. There are many different types of polyethylene, most of them have the chemical formula $(C_2H_4)_nH_2$.

The physical properties of Polyethylene are the thermoplastic polymer that is composed of long hydrocarbon chains. Depending on the molecular weight and crystallinity, a characteristic melting point may be observed. The temperature at which a melting point can be observed varies greatly between different types of polyethylene. For the most common brands of low-density polyethylene (LDPE), the melting point is between 105 and 110° C. In high-density polyethylene (HDPE), the melting point is observed between 120-130° C. [1, 2, 4, 7,]

The chemical characteristics, most of the low, medium and high-density polyethylene brands (LDPE, MDPE and HDPE) have excellent chemical resistance, which means they do not react when reacted with strong acids or bases. In addition, polyethylene is also resistant to light oxidants. Polyethylene burns slowly, with a blue flame, releasing the odor of paraffin. When the polyethylene is removed from the heat source, combustion continues to form a melt. Polyethylene does not melt at room temperature and can usually be dissolved in aromatic hydrocarbons toluene or xylene, at elevated temperatures or in chlorinated diluents such as trichloroethane or trichlorobenzene.

Polyethylene can be divided into several groups, depending on its density and branching. Its mechanical properties depend mainly on the branching of its micromolecular chain, its crystal structure, and its molecular weight. By volume sold, the most commonly used types are - HDLE, LLDPE, and LDPE.

Ultra High Molecular Weight Polyethylene (UHMWPE) - its molecular weight is usually between 3-6 million, making it an extremely solid and durable material. It is used for making bottles, machine parts of engineering plastics, bearings, gears, safety edges, etc. Also, it is used in the production of implants.

High-Density Polyethylene (HDPE) – characterized by a density equal to or greater than 0.941 g/cm^3. There is less branched-chain followed by lower tensile levels. It is used in the packaging industry - garbage bags, plastic pipes, etc. More than 30 % of toys worldwide are manufactured by HDPE. It holds the largest market share among other brands of polyethylene - over 30%. Over 30 million tons of high-density polyethylene are produced and sold annually.

Polyethylene Medium Density (MDPE) - characterized by a density range of 0.926-0.940 g/cm^3. Medium-density polyethylene has exceptional shock strength and overall improved mechanical properties. It is more difficult to cling to HDPE. It is mainly used for the production of gas pipes, fittings, reinforced bags and cases, bottle caps, heat shrink film.

Low-density linear polyethylene (LLDPE) is a linear polymer with an extremely high number of short and long chains composed of copolymerization of ethylene with short-chain alpha-olefins. Its density is in the range of 0.915-0.925 g/cm^3. Linear polyethylene has a higher tensile strength than LDPE. It is also superior to low-density polyethylene in all other mechanical properties such as impact strength, tensile strength, adhesion and more. It is used for the production of thin films, for bags and formats. LLDPE produces cable ducts, buckets, toys, pipes, etc. It is widely used in the production of the stretch film due to its excellent mechanical properties and high elasticity. It accounts for 20% of the global polyethylene market.

Low density polyethylene (LDPE) - characterized by density of 0.910-0.940 g/cm3. It has a high number of short and long chains and does not form a crystalline structure. There is a lower tensile strength compared to other types of polyethylene and higher plasticity. It is used for making both polyethylene films and solid containers. It is most commonly used to make polyethylene film packages. It holds about 25% market share compared to other types of polyethylene. Figure 1 shows a LDPE granules [1, 2, 4, 5, 7,].

Fig. 1. LDPE granules

2.3. Thermo-shrink film

Thermo-shrinkable polyolefin films are polyethylene or polypropylene-based materials. Polyolefins are polymers containing only carbon and hydrogen, in which there are long-CCC carbon chains that make the basic skeleton of the polymer chains themselves. It can be said that polyolefins are polymeric hydrocarbons.

Polyolefins are a very important industrial group of polymers. The production of polyethylene and polypropylene accounts for about 80% by weight of all synthetic polymers produced. These polymers have very good useful properties, the monomers for their production are obtained directly from crude oil and their polymerization is not a major technical problem.

Polyethylene or polyethylene. Industrial symbol (PE). The polyethylene is flexible, waxy, transparent, and thermoplastic. It loses elasticity under the influence of sunlight and moisture. Polyethylene synthesis is an example of radical polymerization. PE films are characterized by low water vapor permeability, they easily pass organic vapors, and they are not resistant to hydrocarbons and their chlorine derivatives. They are resistant to acidic, alkaline and saline solutions, as well as to low temperatures.

• PE-HD (High-Density PE, PE-HD) it has high-density polyethylene. It is obtained by low-pressure polymerization. It is stiffer than PE-LD, and has higher mechanical strength, higher melting point (125° C), higher gas barrier and higher chemical resistance, shows greater brittleness at higher temperatures. Lower temperatures, less transparent (milky white). The most popular commercial varieties of PE-HD are PE 80 and PE 100. Density - 0.94-0.96 g/cm³.

• LLDPE (Linear Low-Density PE) - linear low-density PE (short, unbranched chains are formed by copolymerization of ethene with longer chain alkenes). Density - 0.915-0.935 g/cm³.

Polypropylene. Industrial symbol (PP). It is a polymer of the polyolefin group consisting of the units of the formula [CH_2CH (CH_3)]. It results from the polymerization of low-pressure propylene. Polypropylene is one of the two most used plastics, next to polyethylene. Elements made of this material are usually marked with the PP symbol. Polypropylene is a thermoplastic hydrocarbon polymer, i.e. it can liquefy under the influence of increasing temperature and again harden after lowering it without altering its chemical properties. PP is obtained by the polymerization of propene (commonly known as propylene, $CH_2 = CHCH_3$), which is obtained from oil. Today, most of the polypropylene is produced in the Ziegler-Nata in the gas phase process using catalysts of organometallic compounds suspended on special substrates.

PP is the lowest density plastic material among widely used polymers. It exhibits high chemical resistance, especially at room temperature, at which it is almost completely resistant to acids, alkalis, salts, and organic solvents. At this temperature, it is attacked only by strong oxidizing agents such as evaporation of sulfur or nitric acid, bleaching bases and non-polar liquids (benzene, carbon tetrachloride, methyl chloride). Prolonged contact with copper also has a destructive effect on PP, which is why brass fittings should be used for permanent PP-copper connections [1, 2, 4, 6, 7,].

Polyvinyl chloride. Industrial symbol (PVC). Polyethylene chloride, polychloroethylene (PVC, PVC) - plastics resulting from the polymerization of the monomer - vinyl chloride. It is a competitive material for polyolefins for the production of shrink film is polyvinyl chloride. Due to its large poorer mechanical properties and problems with waste processing, the sale of PVC film in developed countries is significantly reduced.

It has thermoplastic properties, is characterized by high mechanical strength and is resistant to many solvents.

Shrink films can be divided into a few types:

- Single-layer extruded from one or a mixture of granules;
- Multilayer formed by several layers of similar or different polymers to obtain special properties of the finished product;
- Mono-axial - one-direction shrinking oriented (longitudinal or transverse) ;
- Biaxial - oriented in both directions.

In order to compare the properties of different materials, is recommended to use standardized test methods (ASTM):

- Optical properties:
    - Clarity - the percentage of image distortion viewed through the material, the higher the value, the cleaner the image;
    - Gloss - reflecting light from the surface, the higher the value, the shinier the film surface;
    - Fog - the amount of fog seen through the product film, the higher the value, the less expressed.

- Mechanical properties:
    - Flexibility - at low temperatures informs us about the possibility of film working;
    - Module - a measure of film hardness (larger modulus means greater hardness);
    - Coefficient of friction between two layers of the film;
    - Impact strength (higher value means greater resistance);
    - Tensile strength - film sensitivity to tear (longitudinal and transverse);
    - Stretching (extension) - what extent the film will stretch before tearing;
    - The strength of the seal is a measure of the resistance to tearing of the weld;
    - Tear propagation - allows to evaluate the tendency of the material to tear after cutting;
    - Tension is a measure of the force exerted by a film during shrinkage on a packaged product;
    - Free shrinkage is the percentage of film shrinkage in percent.

- Physicochemical properties:
    - Water permeability [MVTR] - an important food packaging measure it shows the film's ability for not wetting the packaging;
    - Oxygen permeability [OTR] - an important measure in food packaging that informs us about the ability of the foil to limit the delivery of oxygen to the packaging.

3. Advantages and disadvantages of film types.

As advantages can be considered the following:

- very easy to seal and shrink (low requirements to the packaging machine)
- low shrinkage temperature
- fast shrink

Polyolefin shrink films can be made from pure granules or mixtures of various intermediates. The additives allow for the obtaining of specific properties of the foil. And so:

- Polyethylene (PE) enables welding and increases the mechanical resistance of the film;
- Polypropylene (PP) provides high hardness, high temperature resistance and excellent optical properties;
- Ethylene vinyl acetate (EVA) copolymer strengthens film, improves weldability and shrinkage;
- Ethyl vinyl alcohol (EVOH) improves the oxygen barrier;
- Polyamide (PA) increases tear resistance and provides a gas barrier.

As disadvantages can be considered:

- Poor sealing strength;
- The need to use thicker films of POF due to its low puncture and tear resistance;
- Not adapted to operate fast machines due to the strength and highly corrosive vapors causing machine corrosion.

4. Conclusion

The comparative analysis of film types for packaging processes was made due to choosing the appropriate film type for the packaging machine. The chosen type of film is a polyolefin. It is the most used film because of its low weight, low cost and versatility. Polyolefin shrink films do not have chlorine, so they do not produce hydrogen chloride. The polyolefin heat-shrinkable sheet has no plasticizers, so the temperature is not an influencing factor. The polyolefin can be stored over a wide range of temperatures and does not harden and soften in different media such as PVC shrink film. The choice is made on the basis of its characteristics.

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Анализ типов пленки для упаковочных процессов

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Резюме: *В этой статье представлен структурный анализ типов фильмов. Рассмотрены виды химических и физических свойств. Потребность в упаковке была проанализирована, а также факторы, влияющие на выбор пленки для нужд потребителей. Обзор и сравнительный анализ трех основных типов фильмов представлены*

Цель статьи - проанализировать различные типы пленки для нужд упаковочных машин.

Ключевые слова: *упаковка, тип пленки, процесс, автоматизация.*