STUDY ON THE PROPERTIES AND USES OF POLYVINYL CHLORIDE, POLYSTYRENE AND CELLULOSE ACETATE IN THE MANUFACTURE OF MASS-PRODUCED ITEMS

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Abstract: The object of the study is the analysis of representative properties of polyvinyl chloride, polystyrene and cellulose acetate in the manufacture of mass-produced items in various fields – the automotive industry, the food industry, constructions, the electronics and home appliance industry, the toy industry, the optical industry, etc.

1. INTRODUCTION

Polyvinyl chloride (PVC), polystyrene (PS) and cellulose acetate (CA) are three thermoplastic technopolymers which are frequently used in the manufacture of mass-produced items in various fields - the automotive industry, the food industry, constructions, the electronics and home appliance industry, the toy industry, the optical industry, etc. [1,2,3,4]. Their main properties which make them suitable for the use in these fields are:

- they have good mechanical resistance (PVC, PAS and AC);
- good electrical insulators;
- shock resistant materials (PAS, plasticized PVC);
- resistant to various chemical agents;
- wear and abrasion resistant materials (PVC);
- can be coloured;
- they are easily processed;
- they have a nice surface.

2. POLYVINYL CHLORIDE (PVC)

PVC is obtained through the bulk, emulsion or suspension polymerisation of vinyl chloride. Currently, PVC is manufactured and distributed in three forms: rigid PVC, semi-rigid PVC and plasticized PVC.

2.1 RIGID POLYVINYL CHLORIDE

It is a cheap material with a price of less than €2/kg [2]. It comes either in the form of a white or variously coloured translucent powder or granules. The main properties of rigid polyvinyl chloride are:

- it has excellent rigidity up to 70-85˚C (close to the vitrification temperature)
- abrasion – resistant material,
- it has no shock resistance at temperatures under -10˚C,
- products can be used up to 60-70˚C in the absence of mechanical solicitations,
- it is a hard material,
- it is a good electrical insulator,
- it has good resistance to acids, bases, alcohols, gasoline, oil, Diesel fuel up to 60˚C,
- it can be used in the manufacture of items that come into contact with food products,

- it has no resistance to esters, ketones, ethers, carbon tetrachloride,
- it has good dimensional stability,
- it does not ignite easily, it softens at first, and then it is eventually charred emitting a sour odour of hydrochloric acid,
- it burns with a green flame in the presence of copper (PVC-insulated electrical cable),
- its current solvents are cyclohexanone and tetrahydrofuran,
- it can be hot gas welded at 230˚C using high frequency currents, ultrasounds or abrasion.

The most frequently used technologies for PVC processing are calendering, extrusion and injection.

Fields of use:

- construction: partition walls, window profiles, fittings, connecting pipes, holders, pipes, lines, etc.,
- electronic industry: sockets, insulating parts, cases,
- food industry: mineral water plastic bottles, packaging,
- photographic industry,
- chemical industry: corrosion-resistant materials,
- cosmetic and pharmaceutical industry.

2.2 PLASTICIZED POLYVINYL CHLORIDE

Plasticized PVC takes either the form of translucent powder or transparent or variously coloured granules with a maximum humidity of 0.3%. All of its properties depend on the quantity and the type of the plasticizer. Plasticizers reduce the intermolecular connecting forces and modify the rigidity of the end product, resulting in a product with increased elasticity. Esters are the most frequently used plasticizers. The amount of plasticizers used can reach 25-30% for electric cable insulators or flexible hoses [6].

The main properties of plasticized PVC are:

- the rigidity and the hardness of the objects decreases with the increase in the amount of plasticizer,
- the brittleness of a part is influenced by the amount of plasticizer used (parts with a higher percentage of plasticizer are more shock-resistant than parts with a lower amount of plasticizer),
- a higher percentage of plasticizer leads to better elasticity,
- it is a flexible, soft material,
- it is a good electrical insulator,
- it is sensitive to the action of atmospheric factors and sunlight,
- it can be used for manufacturing food packaging if the plasticizer is not harmful in contact with food,
- when burning it emits a chlorine odour,
- it has good resistance to weak acids and bases,
- it has no resistance to strong acids and bases, alcohols, esters, ketones, ethers, benzene, gasoline.

It is processed through injection, extrusion, calendering, welding and pressing.

Fields of use:

- automotive industry: connecting pipes, seals, protective elements, buffer elements, gaskets, electric cable protection,
- stationery, computers: cases, keyboards,

- electronic industry: plugs, various telephone and radio components, insulating parts,
- toys industry: tyres, tracks, transmissions, belts,
- light industry: shoe heels and soles,
- various types of calendered sheets which can later be thermoformed or coated in order to obtain tablecloths, raincoats, tarpaulins,
- extruded products: garden hoses, furniture gaskets, electrical wire and cable protections.

Table 1 comparatively shows a few properties of rigid and plasticized PVC.

Table 1. Properties of rigid and plasticized PVC

Properties	Units	Rigid PVC	Plasticized PVC
Density	g/cm³	1.38-1.40	0.3
Water absorption until saturation	%	0.1	1.3-1.7
Breakage resistance	MPa	45-60	10-20
Elongation at break	%	20-70	200-500
Flexural resistance	MPa	70-80	
Modulus of elasticity at traction	MPa	2200-3000	
Modulus of elasticity at flexion	MPa	2000	
Shock resistance at 23°C	kJ/m²	4-7	
Shock resistance at -30°C	kJ/m²	240	
Processing temperature	°C	160-170	140-170
Vitrification temperature	°C	75-85	-40/-10
Temperature interval of continuous resistance	°C	60	-35/+70
Contraction at formation	%	0.1-0.5	
Thermal expansion	cm/cm/°C	0.00007	0.8-3

Advantages of rigid PVC: good rigidity up to 70˚C, good dimensional stability, it is self-extinguishing, resistant to chemical agents, can be used for manufacturing items which come into contact with food products.

Disadvantages of rigid PVC: brittle at low temperatures, sensitive to UV radiation.

Advantages of plasticized PVC: remains elastic even at low temperatures.

Disadvantages of plasticized PVC: lower resistance to chemical agents than rigid PVC.

3. POLYSTYRENE

Polystyrene is obtained through the bulk or suspension polymerisation of styrene. Polystyrene can have the following forms: crystalline polystyrene (PS), shock-resistant polystyrene (PAS), expanded polystyrene (EPS), acrylonitrile butadiene styrene (ABS). PS takes the form of transparent or vividly coloured, cubical or cylindrical granules. PAS, EPS and ABS are opaque materials.

3.1 CRYSTALLINE POLYSTYRENE (PS)

It is a thermoplastic material, also known as standard polystyrene, with a price of less than €2/kg. It has the following properties:

- it has similar transparency to glass,
- it is tasteless and inodorous,
- PS products can be used at temperatures of max. 70˚C,
- not resistant to mechanical solicitations,
- fragile and brittle,
- hard, rigid material with good dimensional stability,

- good electrical insulator,
- it can be electrostatically charged and it attracts dust,
- it has a greater permeability to gases than polyolefins,
- weak resistance to UV radiation,
- in time, due to the accumulation of internal tensions, it cracks and becomes brittle,
- good resistance to acids, bases, alcohols and oils,
- weak resistance to fuels, esters and ketones.

Fields of use: household items, stationery, electronics and electronic hardware industry, telecommunications, toys, thermoformed packaging, audio tapes, medical technology items, etc.

3.2 SHOCK-RESISTANT POLYSTYRENE (PAS)

It is a cheap material with a price of less than €2/kg. PAS was designed and manufactured in order to eliminate the biggest disadvantage of PS, i.e. poor shock-resistance. It is obtained by modifying polystyrene with an elastomer (butadiene rubber). The disadvantage of PAS is that it is no longer transparent. It takes the form of opaque, coloured granules. It has the following properties:

- opaque and shock-resistant material,
- better resistance to mechanical solicitations than PS,
- good electrical insulator,
- maintains its stability under the action of weak acids and bases, but it is unstable in the presence of esters, ketones, ethers and gasoline,
- it burns slowly with a yellow flame.

It can be processed through injection, extrusion and thermoforming [5]. The best welding techniques for PAS are friction welding and ultrasonic welding. Its gluing can be done by using toluene, chloroform, methylene chloride or epoxy resins. PAS products can be vacuum metallized with aluminium and they can undergo a flexographic, serigraphic or offset printing process.

Fields of use:

- electronics and electronic hardware industry: computer cases, monitor cases, cassette recorders, audio systems,
- household items: refrigerators, mixers, coffee makers,
- packaging,
- bathroom items: hairbrush mounts, combs,
- toys.

Table 2 comparatively shows a few properties of PS, PAS, EPS and ABS.

Table 2. Properties of PS, PAS, EPS and ABS

Properties	Units	PS	PAS	EPS	ABS
Density	g/cm³	1.04-1.05	1.03-1.04	0.02-0.06	1.03-1.08
Water absorption until saturation	%	maximum 0.1			0.45
Cristallinity index	%	0	0		0
Light transmission	%	90	-		-
Breakage resistance	MPa	41-60	27-30	0.15-0.45	40-55
Elongation at break	%	2-3	35-50		20-60
Flexural resistance	MPa	75-110	50-60	0.2-0.5	70-80
Modulus of elasticity at traction	MPa	3300	2200	1-2.5	2000-2800
Modulus of elasticity at flexion	MPa	3450	2000		2500

Shock-resistance at 23°C	kJ/m²	5-13	35-110		60
Shock-resistance at -30°C	kJ/m²	5-13	20-50		30
Melting point	°C	180-280	180-280		210-280
Vitrification temperature	°C	90	90		105-115
Temperature interval of continuous resistance	°C	+70	+70	+70	+80
Contraction at formation	%	0.4-0.6	0.5-0.7		0.4-0.6

Advantages of PS: it is a rigid material, it has good dimensional stability, good behaviour when in contact with food products, good electrical insulator, it is transparent and its contraction at formation is low.

Disadvantages of PS: it is a brittle material, weak shock-resistance, it can be electrostatically charged and it is non-resistant to gasoline.

Advantages of PAS: better shock-resistance than PS.

Disadvantages of PAS: it is more rigid than PS, opaque and difficult to weld.

Advantages of EPS: it is very light, excellent thermal insulator, and it is easily glued.

Disadvantages of EPS: somewhat rigid and inflammable.

Advantages of ABS: good shock-resistance and dimensional stability, it has a hard, wear-resistant surface, unlimited colouring possibilities, and it can be easily formed.

Disadvantages of ABS: opaque, it can be electrostatically charged.

4. CELLULOSE ACETATE (CA)

Compared to polystyrene or polyvinyl chloride, cellulose acetate is a more expensive material having a price of €3-5/kg.

It is obtained as a result of the chemical reaction between cellulose and acetic acid or acetic anhydride in the presence of sulphuric acid. It takes the form of transparent or variously coloured cyllindrical granules. The granules contain plasticizers. It is a shiny material which is pleasant to touch. It is suitable for injecting on metallic inserts, and CA products can be used at temperatures up to 60-85°C.

The main properties of CA are:

- it is an amorphous, transparent material,
- it has good dimensional stability even in humid environments,
- it has great mechanical resistance due to its amount of plasticizers,
- its mechanical properties are not influences by humidity,
- very low sensitivity to dust,
- good electrical insulator,
- deformation-resistant at high temperatures,
- remarkable acoustic inertia,
- it burns slowly, it emits black smoke, the ashes are dark brown,
- its flame is green and forms sparks, it softens and drips, emitting a strong acetic acid odour,
- it is soluble in acetone and acetic acid,
- must be stabilized against UV radiation,
- can come into contact with food products,
- resistant to gasoline, oil, salt water, alcohol.

CA is processed through injection, extrusion and thermoforming. CA products can be painted, vacuum metallized and can undergo a serigraphic process.

Fields of use:

- automotive industry: steering wheels, decorative elements, knobs,

- optical industry: eyeglasses frames, lenses,
- toolboxes: screwdriver and pliers handles,
- furniture industry: chairs, drawers, cabinets, door handles,
- transparent packaging,
- household items: cutlery handles, scissors handles,
- electronic equipment: television cases, radios, telephone accessories,
- stationery: compasses, fountain pens, triangles and rulers,
- cosmetic products: toothbrushes, combs, lipstick tubes, hairbrush handles,
- toys.

Table 3 shows a few properties of CA.

Table 3. Properties of AC

Properties	Units	CA
Density	g/cm³	1.26
Refractive index		1.51
Water absorption until saturation	%	3.8
Breakage resistance	MPa	25-50
Elongation at break	%	3-70
Modulus of elasticity at traction	MPa	1400
Flexural resistance	MPa	35
Shock-resistance at 23°C	kJ/m²	It doesn't break
Vitrification temperature	°C	100-130
Temperature interval of continuous resistance	°C	100

Advantages of CA: it is as transparent as glass, it is shock-resistant, it is easily processed and pleasant to touch.
Disadvantages of CA: behaves poorly in bad weather and it is sensitive to humidity.

5. CONCLUSIONS

This study has taken into consideration the properties and fields of use of PVC, PS and CA. It can be observed that the use of the three technopolymers in various technical fields is a consequence of their main physical, mechanical, thermal and electrical properties.

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