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Research Paper

"Engineering Thermoplastic Materials Poly (Bis-Phenol-A-Carbonate) for Industrial Utility"

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Abstract

Polycarbonates are studied for impact strength over a temperature range of -275-+250°F. They have excellent thermal stability and retention of physical properties and can be used continuously at temperature upto 250°F under load. Polycarbonates have high resistance to creep or cold flow. They are all self extinguishing under conditions set by ASTM, D635 and have high resistance and stability in water and in most acids. Typical properties of polycarbonate mouldings are studied at 73°F in table 4. Also, glass reinforced and unreinforced flame retardant properties of polycarbonate are highlighted.

Introduction

Polycarbonates are esters of carbonic acid. Polycarbonates are produced by poly-condensation of bis-phenol-A with phosgene. Due to toxicity hazards of phosgene, research is directed at safer methods eliminating handling of phosgene in the manufacturing operations.

Polycarbonate is an amorphous thermoplastic material with a Tg of 150°C. The material itself is as clear as glass and shows exceptionally high impact strength. Other outstanding feature of this material is its almost rheological behaviour which means that the viscosity of the material is not influenced by the shear rate.

The combination of transparency, heat and high impact strength makes polycarbonate the number one material for moulded application in volume. [1]

Engineering plastics that are able to replace metal, play an important role in achieving desired requirements. Since these engineering plastics are available in a variety of chemical compositions and can in addition, be modified by reinforcement with a variety of fiber materials as well as fillers or by forming polymer alloys, it is easy to design a suitable plastic material for a given appliance.

Furthermore, super-engineering plastics, which are characterized by combining much higher heat distortion temperature with excellent mechanical strength, are being applied to mechanical and structural components and parts of appliances as well as to electronic components.

In this paper, the engineering plastics and super-engineering plastics being applied to industrial automation and audio-visual appliances in India are outlined.

Personal office automation appliances are becoming more popular, highly efficient desk-top workstations and multiple use office appliances are becoming more common. Networking a variety of appliances for more efficient utilization of information and effectiveness of operation is rapidly progressing. It is certain that more and more industrial automation appliances are going to be used.

Engineering plastics are playing a major role in India's effort to make smaller, lighter weight office automation and audio-visual appliances.

There will be sharp increase in word processors and personal computers with the advent of a multifunctional personal computer anticipated for the near future.

Although the major improvement of such office automation appliances will be by speeding up the processor and increasing the capacity of the memory, there are also improvements to be made in making them lighter, thinner, shorter, and smaller.

The most important contribution toward size reduction will be made by the use of PC.

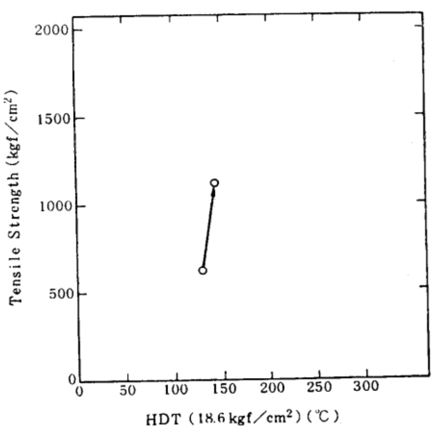
The considerations in applying PC to industrial automation appliances are as follows:

1.Reduction of weight. Utilization of PC for structural materials, such as housing and chassis and making mechanical components such as gears, sprockets, pulley, etc.

2.Miniaturization and thin patterns. The production of multiple lamination and thin parttern, e.g. printed circuit boards and electronic components for surface mounting technology. [2]

Poly (bis-phenol-A-Carbonate) has an advantage in that they are able to replace metals. Polycarbonate (PC), is mass – produced and have year by year become more important as industrial materials. In the development of PC it is natural that much attention is given to the improvement of its heat-resistance so that they could be able to replace metal. As a result, the so-called super-engineering PC, which is defined as the ones having an UL temperature index of more than 1500C, appeared one after another.

There is also composite PC material that becomes competitive with metal by means of reinforcement by glass fiber (GF) and carbon Fiber (CF). This is because the tensile strength, rigidity, HDT and dimensional stability are markedly improved by the reinforcements. Fig.1 shows the HDT versus tensile strength relationship in GF – reinforced PC. It is clear from this figure that the reinforcement effect by GF is outstanding for both properties.



The technology of making a polymer alloy is progressing and it has become possible to mix different polymers homogenously in order to produce a number of modified plastics (polymer alloys) that have a wide spectrum of improved properties, for instance, improvement of impact resistance.

Polycarbonate (PC) is one of the most versatile engineering plastics for office automation and audiovisual appliances. Because of its small molding shrinkage, it is suitable for parts and components that are required to have high shaping precision.

In office automation appliances, GF-reinforced PC is used for the chassis of large printers and the housing of lap-top personal computers. PC/ABS alloy is used for the housing of large computers. Further, the reinforced PC is applied for the inner-structural parts of a facsimile machine and plain paper copiers. It is well known that reinforced PC is a very popular material for optical parts and components.

PC compound is applied for the mechanical chassis or cylinder chassis which consist of all plastic materials combining camera and VTR. Further, the core material of gears of a VTR is made from PC, which contributes to the decrease in the noise.

In the rigid packaging area, research and development will focus on coextrusion blow-molding and combinations of polymers to achieve improved physical properties for plastic bottles.

Foamable resins have emerged as an important polycarbonate growth area. One foamable polycarbonate resin is available that improves flow without sacrificing its other properties. Better surface appearance and greater density reduction in molded parts are claimed compared to standard foamable polycarbonate. The resin which holds a flammability rating of UL-94 V-0, can be used extended flow lengths.

Polycarbonate foams with glass contents of 10 and 20 percent, respectively, produce parts with solid integral skins, cellular core, and sufficient strength to enable their use in structural applications. Both have UL – 94 V-0. flammability ratings. Low mold charcterstics, electrical nonconductivity, and good thermal insulation make the resins suitable for business machines, automotive parts and the injection molding of large parts.

A thin wall polycarbonate foamable resin is on the market that improved material cost savings, improved cycle times enhanced flow and better surface appearance compared to traditional quarter – inch structural foam. The resin meets UL-V-0 requirements at 0.157 inches has a tensile strength of 7300 psi, a flexural modulus of 406,000 psi, and a heat distortion temperature of 270° F at 264 psi.[3]

The amorphous polycarbonates have a broad, gradual softening range as the polymer goes from a solid to a melt. Biaxial heat orientation is therefore not necessary to produce full physical strength and clarity. They will not lose their clarity through wide temperature use or turn milky white due to high temperature stress relief, as will biaxially oriented film. Low water absorption levels and 89-percent light transmission are among the films other advantages.

Other applications include food packaging, cosmetic and liquor cartons, decorative wrap, wall covering, labels, solar-window films, and hot stamping substrates.

10% aluminum flake filled polycarbonate blend, was introduced that provides 99.99% shielding effectiveness against electromagnetic interference (EMI), eliminating the need for secondary processing.

Polycarbonates are amorphous engineering thermoplastics characterized by a combination of toughness, transparency, dimensional stability, and heat and flame resistance. Creep resistance is excellent throughout a broad temperature range and is improved by a factor of two to three with glass reinforcement. Insulating and other electrical characteristics are excellent and almost unchanged by temperature and humidity. One exception is arc resistance, which is lower than that of many other plastics.

They are soluble in chlorinated hydrocarbons and attacked by most aromatics solvents, esters and ketones. Special grades are used for blow-molding, weather and UV-resistance, and EMI and RFI shielding. [4]

Properties

Toughness

Polycarbonates yield rather than shatter under high impacts because of their high impacts because of their high ductility. Notched Izod valued when critical part thickness is more than 0,140 to 0,160 in, or at -100F are 2 to 3 ft – lb per in of notch. A clean break occurs. Below critical thickness, notched bars elongate and required high impact to produce ductile failure.

In both cases, the material retains its toughness when unnotched and cannot be broken, even by the 60 ft lb capacity of the testing machine. A properly designed polycarbonate part, when at temperatures below-10 0F, is far more impact resistant than many polymers at room temperature.

Dimension Stability

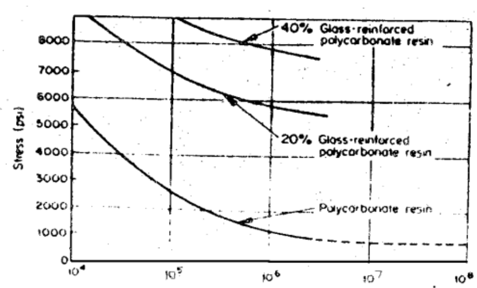
Exposure to boiling water will not cause polycarbonate dimensions to change more than 0.001 in per in. Changes in humidity do not affect dimensions at all.

Within the design limits described in Table 1, polycarbonates do not significantly change in dimension under load due to creep or cold flow. A 2000 psi static load, deflection of polycarbonate remains stable at about 45 mils (on a standard 8½ in. ASTM bar) for more than 1000 hours. Glass-reinforced polycarbonate stabilizes at under 20 mils at 4000 psi stress load.

Table 1: Allowable Working Stress for Polycarbonate Sheet

Service and Loading Conditions	Max Working Stress psi Tension	Compression
Intermittent Load 73 ^{0}F …………………	4000	6000
Intermittent Load 125 ^{0}F …………………	4000	6000
Intermittent Load 212 ^{0}F …………………	3000	3000
Steady Load 73 ^{0}F …………………	2000	2000
Oscillation or Vibration	1000	1000

Continuous oscillating loads should be kept at 1000 Psi maximum. Higher loads may cause failure due to fatigue, Fig. 2. Intermittent oscillating loads can be much higher, depending on the number of desired cycles.



Chemical Resistance.

Polycarbonates are soluble in chlorinated hydrocarbons. Most aromatic solvents, esters and ketones will attack polycarbonates, resulting in crazing and possibly cracking. The extent of damage depends on time of exposure, stress on the part and temperature,

Polycarbonates are generally unaffected by greases, oils and acids. Room temperature water has no effect, but continuous boiling water exposure causes hydrolysis or breakdown, resulting, in gradual em-brittlement.

Solvents such as methylene chloride can be used to bond polycarbonate parts together. Resultant bond strengths are essentially as strong as the parent material. [5]

Electrical Properties:

Polycarbonates are excellent electrical insulators over a wide range of temperature and humidity conditions. They also have good self-extinguishing characteristics.

Applications

Applications of polycarbonate resin include injection molded items such as electrical connectors, Air conditioner housings, filter bowls, portable tool housing, small appliances, beverage dispensers, camera parts, pumps impellers, safety helmets, high centrifuge tubes and automotive trim clips. Film and sheet are available for graphic arts substrates, packaging, formed aircraft ducts and food handling trays. [6]

Fabrication

Polycarbonates are commonly fabricated by Injection molding, extrusion, blow molding, solvent casting (films) and vacuum forming. Stock. shapes are readily machined, cold Punched, sawed, and cut with steel rule dies. Parts may be hot or cold staked, or friction and hot gas welded.

Joining: Ultrasonic bonding, solvent or adhesive cementing, thermal bonding, and mechanical fastening can be used with polycarbonates.

Decoration: Polycarbonates, accept decorative finishes readily. Because of their transparency, second surface decoration can be done. Hot stamping, printing, painting, vacuum metallizing, electroplating and flame spraying are used. Care must be taken in selecting coatings to avoid solvents which may attack the polycarbonate part.

Design

Tolerances: Because of low shrinkage, low crystallinity and dimensional stability close tolerances can be held on poly. carbonate parts as molded. A tracheal tolerance is 0.002 in. per in.; however, tolerances to 0.0005 in. Per in. are possible.

Part Design: Maximum practical section thickness for injection molding' is usually 0.375 in. Thinness of a part is limited by material flow length in the mold.

UL approval

UL (Underwriters Laboratories) performs various tests on products sold in the United States. One such test, UL94, is used to measure the resistance of plastics to a flame source. For polycarbonate, the test will normally result in a mark of V-0, V-1, V-2. V-0 is the most flame retardant and V-2 is the least flame retardant of the marks typically given to polycarbonate. If the material does not pass the test for V-0, V-1, or V-2; then the product is not UL approved. UL approval is given for a particular product at a measured thickness which is reported with the rating. Hence, saying that a given product is V-2 is insufficient information without also specifying at what thickness the rating is valid. UL approval is required for certain applications of polycarbona te.

CONDITION	94V-0	94V-1	94V-2
Maximum time any one specimen can burn after removal of 2nd application of flame	10 sec	30 sec	30 sec
Maximum glowing time permitted for any one sample after removal of 2nd application of flame	30 sec	60 sec	60 sec
Total flaming combustion time allowed (maximum) for the 10 flame applications	50 sec	250 sec	250 sec

Glass reinforced polycarbonate- 40% glass reinforced is studied and found ultimate in rigidity and dimensional stability. The flammability is rated 94V-1 at 1.47mm. Table - 2

Typical properties of Polycarbonate are obtained as per ASTM as below.

Table . 2

Properties Mechanical	ASTM	Unit	Glass Reinforced
Tensile Strength, Break	ASTM D 638	MPa	120
Tensile Elongation, Break	ASTM D 638	%	2
Tensile Modulus	ASTM D 638	MPa	10000
Flexural Modulus	ASTM D 790	MPa	10000
Hardness H358/30	-	MPa	145
Hardness, Rockwell	ASTM D 785	-	M93
Impact			
Charpy Impact. Notched	-	kJ/M^2	9
Izod Impact. Notched	ASTM D 256	J/m	100
Thermal			
Thermal Conductivity	ASTM C 177	$W/m\ ^0C$	0.22
Coeff. Of Linear Thermal Expansion. Flow	ASTM D 696	$m/m\ ^0C$	2×10^{-5}
Physical			
Specific Gravity	ASTM D 792	-	1.52
Water Absorption, 24hours	ASTM D 570	%	0.90
Mould Shrinkage, Flow	ASTM D 955	%	0.1-0.3
Electrical			
Volume Receptivity	ASTM D 257	Ohm-m	$>10^{15}$
Dielectric Strength, Shorttime 3.2 mm	ASTM D 149	kV/mm	20.0
Dielectric Constant. 50 Hz	ASTM D 150	-	3.40
Dielectric Constant, 1 MHz	ASTM D 150	-	3.40
Dissipation Factor, 50 Hz	ASTM D 150	-	0.0013
Dissipation Factor, 1 MHz	ASTM D 150	-	0.0067
Arc Resistance, Tungsten	ASTM D 495	Sec	59
Flame Characteristics			
Oxygen Index	ASTM D 2863	-	34
Flame	UL 94	-	V- 1 (1.47)

Unreinforced flame retardant polycarbonate with varying melt viscosity and having a flammability rating of 94V-0 at 3.05mm according to UL Table 3.

Typical properties of Polycarbonate are obtained as per ASTM as below.

Table . 3

Properties Mechanical	ASTM	Unit	Unreinforced Flame Retardant
Tensile Strength, Yield	ASTM D 638	MPa	60
Tensile Strength, Break	ASTM D 638	MPa	70
Tensile Elongation, Yield	ASTM D 638	%	7
Tensile Elongation, Break	ASTM D 638	%	120
Tensile Modulus	ASTM D 638	MPa	2300
Flexural Strength Yield	ASTM D 790	MPa	100
Flexural Modulus	ASTM D 790	MPa	2500
Hardness H358/30	-	MPa	95
Hardness, Rockwell	ASTM D 785	-	M70
Impact			
Charpy Impact. Notched	-	kJ/M^2	35
Izod Impact. Notched	ASTM D 256	J/m	700

Thermal			
Thermal Conductivity	ASTM C 177	W/m ^{0}C	0.20
Coeff. Of Linear Thermal Expansion. Flow	ASTM D 696	m/m ^{0}C	7 x 10^{-5}
Physical			
Specific Gravity	ASTM D 792	-	1.20
Water Absorption, 24hours	ASTM D 570	%	0.10
Mould Shrinkage, Flow	ASTM D 955	%	0.5-0.7
Electrical			
Volume Receptivity	ASTM D 257	Ohm-m	$>10^{15}$
Dielectric Strength, Shorttime 3.2 mm	ASTM D 149	kV/mm	17.0
Dielectric Constant. 50 Hz	ASTM D 150	-	3.00
Dielectric Constant, 1 MHz	ASTM D 150	-	2.90
Dissipation Factor, 50 Hz	ASTM D 150	-	0.0009
Dissipation Factor, 1 MHz	ASTM D 150	-	0.0100
Arc Resistance, Tungsten	ASTM D 495	Sec	120
Flame Characteristics			
Oxygen Index	ASTM D 2863	-	35
Flame	UL 94	-	V- 0 (3.05)

Table 4. Typical Properties of Polycarbonate Moldings at 73^{0}F

	ASTM TEST	VALUE
Mechanical		
Tensile Strength (Psi)	D638	9000 to 10500
Tensile Yield Strength (Psi)	D638	8000 to 9000
Flexural Strength (Psi)	D790	11000 to 13000
Compressive Strength (Psi)	D695	11000
Shear Strength (Psi)	D732	9200
Shear Yield Point (Psi)	D732	5400
Modulus of Rigidity (Psi)	------	116000
Modulus of Elasticity (Psi)	------	340000
Tensile Elongation (percent)	D638	50 to 100
Poisson's Ratio	------	0.08
Hardness, Rockwell	D785	M70, R118
Hardness, Share D	------	8%
Abrasion Resistance	D1044	
(mg loss per 1000 cycles)	------	7 to 11
Impact Strength, Izod,	D258	
1/8 –in. bar (ft-lb per in.)	------	12 to 16
Tensile Impact Strength (ft-lb per cu in.)	------	1000
Physical		
Specific Gravity	D792	1.20
Water Absorption, 24 hr.	D570	
Immersion (percent)	------	035
Color, Natural	------	Transperant
Light, Transmissions, 1/8-in. thick (percent)	------	75 to 89
Refractive Index at 25° C	------	1.586
Thermal		
Heat-Distrotion Temp (°F)	D648	
at 264 psi	------	265
at 65 psi	------	235
Thermal Conductivity (Btu-in/hr-sq-ft-deg F) ------	1.33	
Coefficient of Thermal Expansion	D696	
(per deg F)	------	3.9
Brittleness Temp (°F)	D746	-275
Flammability	D635	Self –ext.
Electrical		
Dielectric Constant	D150	
at 60 cps	------	3.17
at 10^4 cps	------	2.96
Power Factor	D150	
at 60 cps	------	0.0009
at 10^4cps	------	0.010
Volume Resistance (ohm-cm)	------	2.1 X 10^{10}
Arc Resistance (Sec)	D495	
Stainless-steel strip electrodes	------	10-11
Tungsten electrodes	------	120
Dielectric Strength, short time. ¼ in. (V / min)	------	400

Conclusion

The addition of glass fibers to polycarbonate significantly increases the tensile strength, flexural strength, flexural modulus, and heat deflection temperature of the polycarbonate while causing a decrease in the impact strength and tensile elongation. The greater the amount of glass fiber added to the polycarbonate, the greater the effect on each property will be.

Polycarbonate is naturally transparent, with the ability to transmit light nearly that of glass. It has high strength, toughness, heat resistance, and excellent dimensional and color stability. Flame retardants can be added to polycarbonate without significant loss of properties.

One of the biggest advantages of polycarbonate is its impact strength. Polycarbonate does have its disadvantages. It has only fair chemical resistance and is attacked by many organic solvents. It is also fairly expensive compared to other plastics.

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