NAN YA PC Engineering Plastics

Transparency · Impact Resistant · Heat Resistant · Insulation Properties · Self-extinguishing · Mechanical Properties

Introduction

Polycarbonate (PC) is one of the five major engineering plastics (PC,PBT, Nylon, POM, Modified PPE). Among the five engineering plastics, PC is an engineering plastic with balanced properties and few drawbacks. Applications of PC are vast. Currently, it is used primarily for electrical and mechanical purposes. One major advantage of PC is it has excellent transparent qualities, impact strengths and heat resistance.

NAN YA PC Engineering Plastics Characteristics

Among the engineering plastics, PC has the most characteristics and balanced properties. Primary characteristics are:

1. Excellent mechanical strength, especially in impact strength.
2. Excellent electricity insulation properties.
3. Retains excellent physical properties from low to high temperatures, applicable in wide ranges.
4. Excellent dimensional stability with minimal influences from temperature and moisture.
5. As it is a type of colorless and transparent material, it can be colored to make products with shiny colored surfaces.
6. Has self-extinguishing properties and flame retardant effects.

NAN YA PC APPLICATIONS

PC has the widest range of applications among the engineering plastics. As PC also has many physical characteristics, it has applications in electronics, electrical, automotive, mechanical and optical components. PC can also react with fluorocarbon resins, PBT, PET, ABS and other engineering plastics to change the qualities and is used in applications in various sectors and industries.

Industry	Applications	Required Characteristics
Electrical and Electronics	Reel shafts, connectors, circuit relays, lamp shades, computer components, telephone switches, terminal blocks, switches, tape recorders, end terminal machines, button bases, televisions, radios, recorders, and hairdryer casings, chassis, coffee makers, razors, refrigerators, audio systems, iron, egg boilers, gramophones, signal light convex lenses, boat lights, lights, safety lights, flashlights, signal light components, lightning rods, antenna insulation and casings, mobile phone casings, IC chassis, electrical stoves, CDs, chassis OA fan blades, LED casings, and machine casings.	Impact Resistant, Heat Resistant, Transparent, Dimensional Stability, Flame Retardant, Electrical Resistance, Lightweight
Automotive Industry	Heater fan,bumper,headlights,dashboards,taillights, meters, counters, oil covers,stir flow plates, track insulation handles, windshields, signal lights, wheel covers, optic fibers, insulation materials, windshields, external panels, and safety glass.	Impact Resistant, Heat Resistant, Weather Resistant, Lightweight
Precision Machinery	Camera components, microscopes, watches, projectors, flashlights, binoculars, motor appliance casings, motors, pressure plates, manometers, vending machines, nuts, screws, auto-adhesive machines, and printer components, photocopiers, register machines, calculator casings, computers, writing machines, memory disk drives, fax machines, and drawing equipment components, textile bobbins, video camera casings, signal lights, lamp shades, clock components, camera lenses, meter safety glass, and lamp casings.	Impact Resistant, Transparent, Dimensional Stability, Weather Resistant, , Electrical Resistance, Safety, Lightweight

PHYSICAL PROPERTIES

♦ Influence of Glass Fiber on PC Physical Properties and PC Characteristics

Glass fibers and ore fibers are excellent reinforcing materials for PC. But due to the low costs of glass fibers, most models on the market use glass fiber such as 30% glass fiber reinforced PC. The influences on PC characteristics are shown in Table 1.

♦ Excellent Mechanical Properties

PC has excellent mechanical properties. Among the five major engineering plastics, PC has the strongest impact strength. This characteristic allows PC to be used in products that require high impact strengths, such as motor powered tool casings, tool boxes, car door handles, lamp shades, and helmets, as shown in Table 2.

Table 1. Effect of Adding glass on the physical properties of PC (fiberglass 30%)

Property	Affect
Tensile strength	2-fold increase
Elastic modulus	3-fold increase
Heat distortion temperature	Increase 10℃
Thermal expansion coefficient	Reduced to 1/3
Molding shrinkage	Reduced to 1/6

As described above, the PC was added fiberglass improved a lot, more suitable for the production of high precision, requiring a higher strength of the molded article.

Table 2: Mechanical and Physical Properties of Ordinary Grade PC Engineering Plastic

Property		Test Method	Unit	Unit	
				NAN YA 5110 0% Glass Fiber	NAN YA 5210G6 30% Glass Fiber
Ordinary Grade Mechanical Properties	Specific Gravity		g/cm^3	1.2	1.43
	Moisture Absorption	ASTM D-570	%	0.24	0.20
	Tensile Strength	ASTM D-638	kg/cm^2	630	1,300
	Elongation	ASTM D-638	%	130	3-5
	Flexural Strength	ASTM D-790	kg/cm^2	950	1,600
	Flexural Modulus	ASTM D-790	kg/cm^2	23000	75,000
	IZOD Impact (Notched 1/8)	ASTM D-256	kg• cm/ cm	75	15
	Rockwell Hardness	ASTM D-785	---	M70	M90
	Taber Wear (CS-17)	----	$mg/10^3$ rpm	13	24
	Abrasion Index (on Steel)	ASTM D-1894	---	0.38	---

From the table, PC has excellent mechanical properties such as tensile strength, Flexural Strength and addition of glass fiber can reinforce most mechanical properties. For impact strength, pure PC is better and offers 75 Kg•cm/cm.

PHYSICAL PROPERTIES

♦ Excellent Electrical Resistance

PC has excellent electrical properties such as volume resistivity, dielectric strength and arc resistance. As shown in Table 3, the 30% glass fiber reinforced PC has dielectric strength of 18kv/mm, which is considered high among engineering plastics. As PC is a hydrophobic plastic, it has low water absorption and moisture has little influence over PC electrical properties.

♦ Excellent Thermal Properties, Wide Range of Working Temperatures

According to ASTM D 746-57T test methods, the PC brittle temperature point can reach -100℃ , so it is an engineering plastic that retains its physical properties at low temperatures. The excellent thermal properties of PC, especially the long- term working temperature, are considered excellent among the engineering plastics, ranking behind PBT but are better than Nylon 6, POM and modified PPE. The 30% glass fiber reinforced PC can be used in a wide range of temperatures (-100℃ ~130℃) over long periods of time, as can be shown in Table 4.

Table 3: Electrical Resistance Properties of PC Engineering Plastic

Property		Test Method	Unit	Unit	
				NAN YA 5110 0% Glass Fiber	NAN YA 5210G6 30% Glass Fiber
Electrical Resistance	Volume Resistivity	ASTM D-257	Ω• cm	10^{16}	10^{16}
	Dielectric Strength	ASTM D-149	kv/mm	16	18
	Dielectric Constant (10^6 HZ)	ASTM D-150	---	2.31	3
	Dissipation Factor (10^6HZ)	ASTM D-150	---	0.01	0.009
	Arc Resistance	ASTM D-495	sec	120	120

GF30%: plus 30% glass fiber reinforcement

Table 4: Thermal Properties of PC Engineering Plastics

Property		Test Method	Unit	Unit	
				GF 0% NAN YA 5110	GF 30% NAN YA 5210G6
Thermal Properties	Melting Point	DSC Method	℃	230	---
	Specific Gravity	ASTM D-792	cal/g℃	0.3	0.27
	Heat Deflection Temperature (18.6kg/cm^2)	ASTM D-648	℃	135	145
	Heat Deflection Temperature (4.6kg/cm^2)	ASTM D-648	℃	141	---
	Linear Expansion	AS;TM D-696	10^{-5} x1/℃	3.8	2.18
	Flammability	UL 94	---	V-2	V-0
	Long Term Heat Resistant Temperature	UL 746B	℃	120	130

GF30%: plus 30% glass fiber reinforcement

PHYSICAL PROPERTIES

♦ Excellent Dimensional Stability, little influence from temperature and moisture

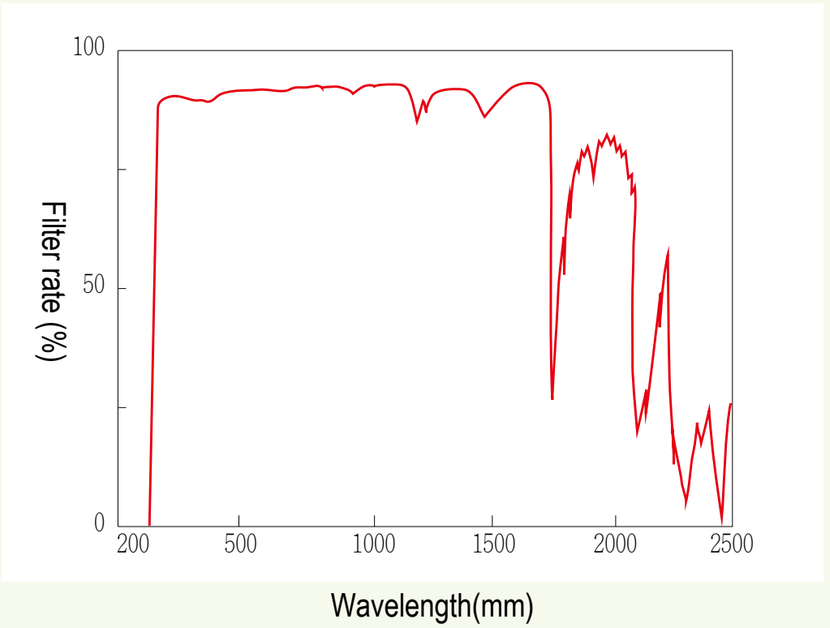
The dimensional stability of PC is ranked among the top in the engineering plastics. Factors influencing dimensional stability include water absorption, creep deflection and heat shrinkage. Their effects on PC dimensional changes are shown in Table 5.

Table 5: Influence of Moisture Absorption, Creep Deflection and Heat Shrinkage on PC Dimension Change

Property	Conditions	Influence of Dimension Change
Moisture Absorption	Every 1%	0.002%
Creep Deflection	100kg x1000hrs	0.9%
	200kg x1000hrs	2.4%
Heat Shrinkage	Treated at 120℃	0.1%

♦ Excellent Transparency

PC is a non-crystalline resin. Normally, non-crystalline plastics have higher transparency than crystalline plastics. The light transmittance spectrum of PC is shown in Graph 1. Transmission of visible light wavelengths (400mμ~800mμ) is up to 90%. As PC has transparency qualities that other engineering plastics do not possess, the applications of PC are greatly increased. As PC is acknowledged as a high-end transparent material and possesses heat resistant and lightweight qualities, it is now widely used in illumination lights, lamp shades, laser discs, optical lenses, and safety glass.



Graph 1: Light transmittance spectrograph of PC

♦ Excellent Flame Retardancy

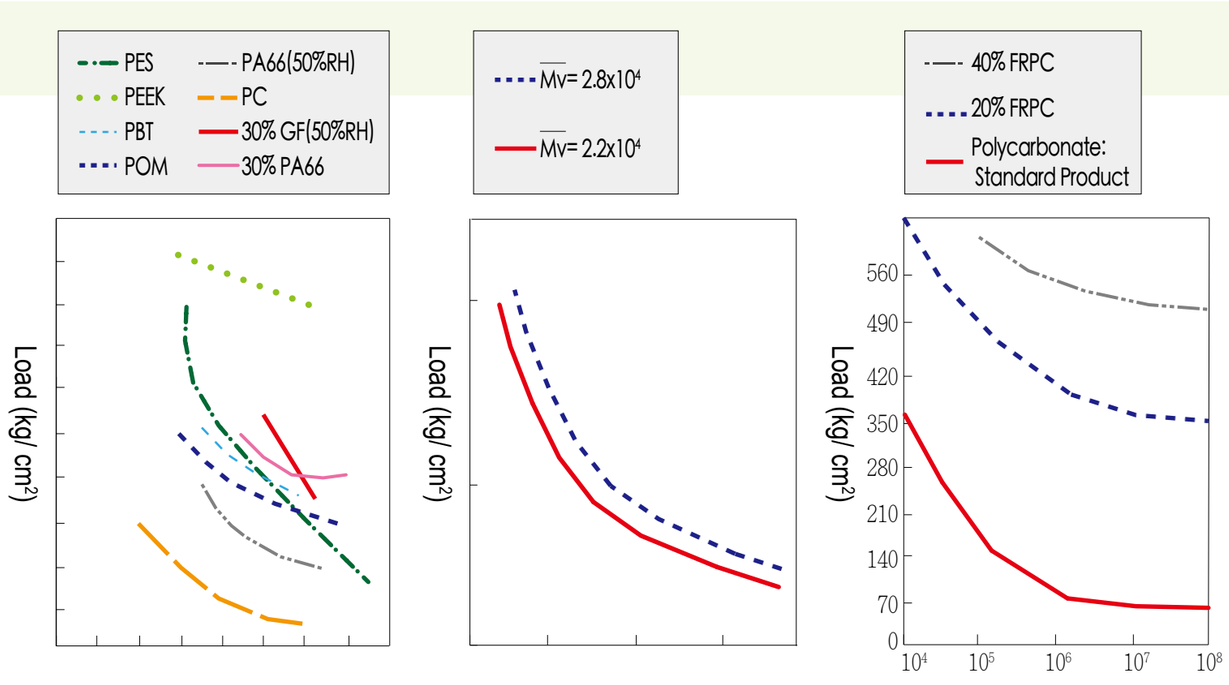
Without adding flame retardants, PC resins already possess self-extinguishing characteristics. As shown in Table 6, through the addition of flame retardants, PC can become an excellent flame resistant plastic. By selecting suitable flame retardants, the flame resistance of PC can reach UL94V-0 standards (Similar to NAN YA PC-531P PC-5420 specifications)

♦ Fatigue Resistance

Fatigue resistance of PC is not exceptional. From Graph 2, the impact strength and fatigue resistance of PC is weaker than Nylon, PBT, and POM, but through the addition of glass fibers or increasing molecular weight of PC molecules, PC fatigue resistance may be increased, as shown in Graphs 3 and 4.

Table 6: Flame Retardancy of PC resin (Without adding flame retardant agents)

Test Conditions	Test Results
ASTM-D635	Self- Extinguishing
UL 94 Testing Thickness 1.6 mm 3.2 mm 6.4 mm	 V-2 V-2 V-1
Oxygen Index	25~27



Graph 2: Fatigue Resistance of Different Plastics

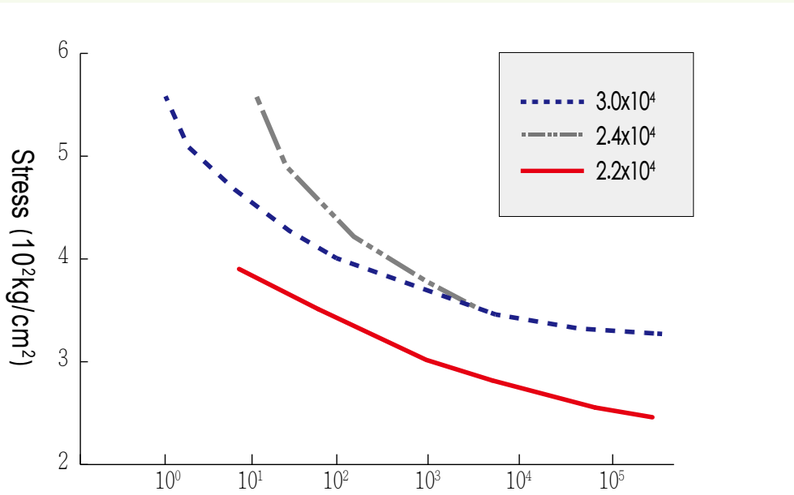
Graph 3: Relation between PC Molecular Weight and Fatigue Resistance

Graph 4: Influence of Glass Fiber on PC Fatigue Resistance

NOTES ON PC CHARAC-TERISTICS

♦ Stress Cracking Resistance

The stress cracking resistance of PC is not exceptional and environmental factors such as oil, solvents, chemicals, plastic additives, and temperature, will exacerbate the cracking of PC. Under normal conditions, PC can be soaked in Carbon Tetrachloride (CTC) to observe the cracking symptoms of PC. Blending PC and other polyesters together may improve the cracking resistance of PC. As Graph 5 shows, increasing the molecule weight may improve the cracking resistance of PC.



Graph 5: Relation between PC molecular weight and stress cracks

♦ Chemical Resistance

Table 7 shows that although PC exhibits good resistance against weak acids, alkali and active gases at room temperatures, it has a poor resistance against strong alkali, benzene, acetone, carbon tetrachloride, esters, and gasoline and will undergo dissolving or decomposition, so care should be taken with the use of chemicals. The blending of PC with other polyesters such as PBT and PET resins may improve PC chemical resistance.

Table 7. Chemical Resistance of Five Major Engineering Plastics

	Weak Acid	Strong Acid	Weak Base	Strong Base	Active gas	Oil	Acetone	Benzene	CTC	Alcohol	Esters	Gasoline
PBT	●	△	○	X	○	●	○	○	●	●	○	●
NYLON 6	○	X	○	○	△	○	○	●	○	△	●	●
POM	△	X	△	X	△	○	○	○	●	●	○	●
PC	●	△	○	X	○	△	X	X	X	△	X	X
Modified PPE	○	○	○	○	–	○	○	X	X	○	X	△

● : Excellent ○ : good △ : Normal X: inferior

♦ Abrasion and Wear Resistance

Table 8 shows that the abrasion and wear resistance of PC is unexceptional. In the table, the PV values represent the abrasion and wear resistance of PC. Higher PV values represent a better abrasion and wear resistance and can withstand more pressure P and at higher velocities V without undergoing melting or become deformed from the heat generated. As PC is not self-lubricating, it has poor abrasion resistance, and is generally not used in gears or other transmission purposes. But the dimensional stability of PC is suitable for making products of high precision and in recent practices; fluorocarbon resins and lubricants are added to improve PC abrasion resistance for applications in precision gears.

Table 8: Abrasion and Wear Resistance of Plastics

Plastics	Specific Abrasion Volume mm3/kg•mm	Coefficient of Friction M	PV limits Kg/cm^2• cm/sec
POM	1.3×10^{-8}	0.21	124
NYLON 66	4.0×10^{-8}	0.26	89
NYLON 6	4.0×10^{-8}	0.26	89
PC	50.0×10^{-8}	0.38	18

♦ Flowability

As PC has high melting viscosity, it has a slow flow speed during molding, and is therefore harder to mold into thin products. In recent years, there are many developments in high flowability PC models and molding machines. This type of molding machine uses increased injection pressure, increased screw rotation speeds, improved mold design techniques to improve PC injection molding.

In mold design, the sprue and runner lengths are shortened, diameters of nozzle and gates are increased to improve the flowability issues of PC in molding. At the same time, the markets offer alternative solutions such as reducing PC molecular weight or adding PS and ABS to improve PC flowability. Currently, PC faces less flowability issues in injection molding.

♦ Hot Water Resistance

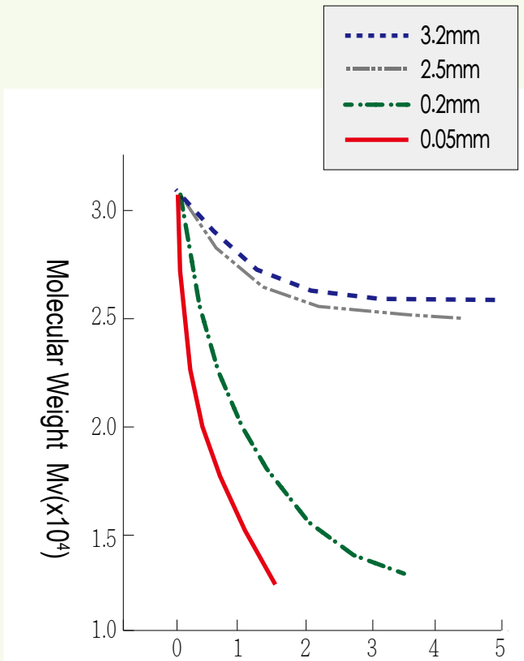
As PC is a polyester plastic, like other polyesters, PC will face issues of reduced physical properties when undergoing hydrolysis. Through tests, when PC is immersed in water below 60℃, there is almost no change in physical properties. But when the water temperature exceeds 80℃, there will be significant influence on the physical properties; hence it is not advised to immerse PC in water above 80℃ for long periods of time. For example, the pipes of water heaters should not use PC materials but PC may still be used for intermittent supplies of hot water. Table 9 shows the influence of hot water on PC impact strength.

♦ Weather Resistance

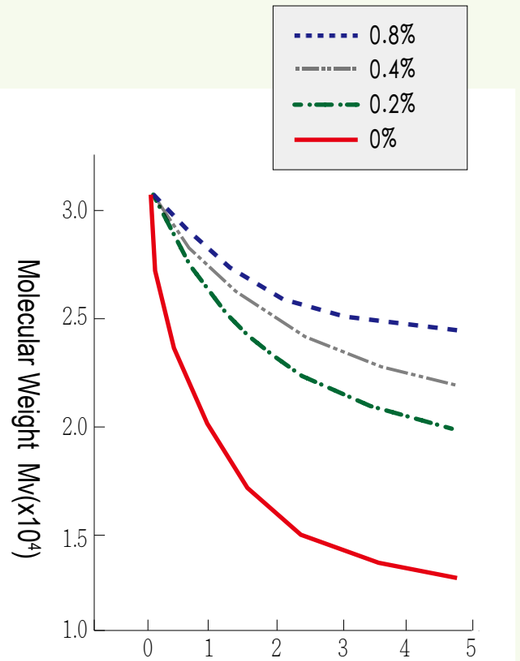
When PC thickness exceeds a certain thickness, it has good weather resistance properties and has UV resistance. Graph 6 shows that when thickness exceeds 2.5mm, PC exhibits excellent weather resistance under long term exposure. But when PC thickness is below 0.2mm, the weather resistance is poor. Hence for roof applications, the PC thickness must exceed certain values to ensure UV resistance. Graph 7 also shows the addition of UV protection agents will enhance the weather resistance of PC. injection molding.

Table 9: Influence of Hot Water Immersion on PC Impact Strength

Retention of Impact Strength	Hot Water 0 hrs	Hot Water 24 hrs	Hot Water 74 hrs	Hot Water 120 hrs	Hot Water 240 hrs	Hot Water 360 hrs	Hot Water 720 hrs
	100%	111%	94%	88%	65%	73%	64%



Graph 6:
Relation of PC Thickness and Exposure Degradation



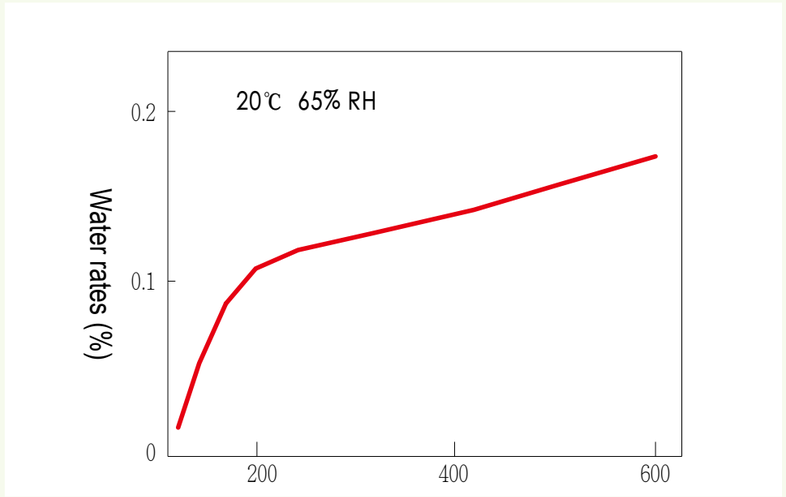
Graph 7:
Improvement of PC Weather Resistance through addition of UV Protection Agents

NOTES ON PC CHARAC-TERISTICS

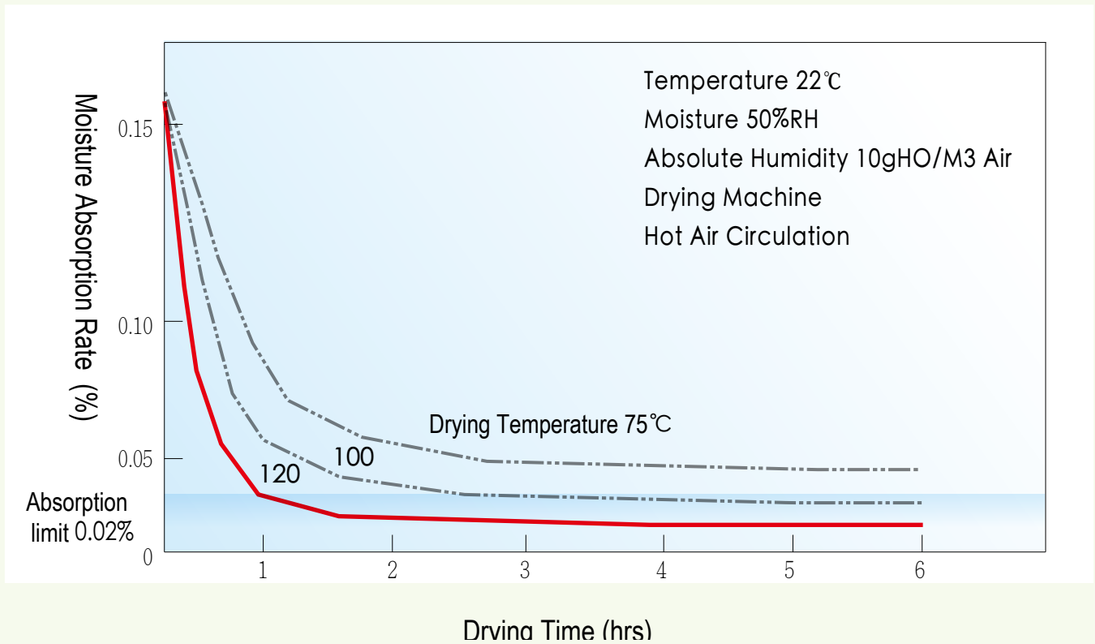
During PC molding, moisture control and molding conditions are the 2 major factors influencing product quality, as described in the following:

♦ Moisture Control

Although PC has poor water absorption, Graph 8 shows that when left standing, PC will exhibit signs of moisture absorption. As PC is a polyester plastic, and polyester plastics will react with water to undergo hydrolysis and the breaking of molecular chains, reduction in molecular weight and decrease in physical properties, the moisture content of PC particles should be strictly controlled within 0.02% to avoid the product from suffering a decrease in impact strength, or surface defects such as air bubbles and silver streaks. To avoid such issues, the PC particle should undergo pre-molding drying at 120℃ x4-5hrs and heaters should be installed in the funnel portion to ensure that water will not be absorbed through the funnel. As Graph 9 shows, if drying temperature is calibrated below 100℃ , the effects will not be significant despite heating over long periods. To avoid coloring changes of PC particles, the drying process should not be heated at temperatures above 150℃ .



Graph 8: Curve of PC moisture absorption in air



Graph 9: Relation between PC drying temperature and moisture absorption rae

NOTES ON PC CHARACTERISTICS

♦ Molding Conditions

Normally, quality products may be obtained under the following molding conditions. But optimal PC molding conditions may change with different molding machines, different molding shapes and different grades of PC, so adjustments should be made accordingly.

- **Cylinder Temperature:**
  Varies with different grades of PC; for normal screw injection models, calibrate cylinder temperature between 230~310℃ to increase molding temperature and decrease melting flow viscosity. This will improve flowability but when temperature is calibrated too high, decomposition and pyrolysis may occur, so caution must be taken.

- **Injection Pressure: Calibrate to1000~1400kg/cm^2.**
  As PC has a higher melting flow viscosity, flowability is poor, and if injection pressure and speed is insufficient, the mold may not be completely filled. But if injection pressure is too high, it may cause residue stress which will lead to distortion.

- **Screw Rotation Speed: 40~160rpm.**
  (Depends on size of molding machine)

- **Screw Compression Ratio: 2.4**

- **L/D: 15~24**

- **Mold Temperature: Calibrate to 80~120℃ .**
  Temperature of 110℃ should allow production of quality products. If mold temperature is increased, the surface quality of product may be improved and the inner resilience of molding will be reduced, reducing the cracking symptoms, but the production cycle will be longer.

- **Injection Speed: As a general rule, thin products require faster speeds while thick products require slower speeds.**
  Improper operation of injection speed will cause surface cracking.

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