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Effect of Temperature and Strain Rate on the Mechanical Properties of Polycarbonate and Polycarbonate/Thermoplastic Polyurethane Blend

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Abstract : *Polycarbonate and Thermoplastic Polyurethane Blend in the composition 90/10 (by wt/wt, % of PC/TPU) have been prepared by melt mixing using twin screw extruder. The effect of TPU addition on mechanical and fractographical properties of Polycarbonate was studied. It is shown that the toughness of PC was improved effectively with incorporation of TPU at low temperature and room temperature. Tensile tests at different temperatures viz.,*-20^{o}C, 0^{o}C, R.T., *were carried out by using environmental chamber on electro-mechanical machine, Instron 5582 model universal tester at constant cross-head velocity in order to investigate the influence of temperature on mechanical properties of PC/TPU blend. It is observed that there is quite different behavior of PC/TPU blend and pure Polycarbonate at these different temperature conditions.*
Keywords – *Polycarbonate, strain rate, Tension, Thermoplastic, TPU, Toughness, yield strength.*

I. INTRODUCTION

The plastic industry is one of the fastest growing industry in the globe and every year demand of plastic parts increases rapidly [1].Nowadays if we look around our environment most of the things are made up from the plastic materials because plastic materials having some unique properties as compare to the metallic material. Some of them are low weight, low cost, good finishing, availability in more than one colour and easy replacement. These properties make plastic material more popular than the other material. Before 5 to 7 years ago most of the part of automobile is made from the metallic material. Now slowly plastics are replacing the traditional materials giving good combination in the properties as well as in the performance [2]. Nowadays there is need to improve the properties of plastic by making the blends of polymers for suitable application. As a opaque or translucent thermoplastic polymer, polycarbonate is now used in the most of the applications such as the internal decoration of the aero plane and train, building roofing, backside cover case of the mobile and laptops. If carefully observed at these applications then one can realized that there are chances of low impacts on these applications. If taking the example of laptops and mobile phones while using these appliances there may be chances of sudden fall at the time of usage. So whatever plastic material used for these applications that should be sustained at these impact conditions. While numerous studies has taken on the behaviour of the transparent polycarbonate at different strain rate and temperatures[3].Actual applications of opaque PC is deformed most of the conditions having lower to some extend of greater strain rate and therefore it is very important to study this effects for further research. Zhao et al [4] studied the effect of Acrylonitrile- Butadiene-Styrene high rubber powder on the morphological and mechanical properties of Acrylonitrile-Butadiene-Styrene /Poly (Methyl Methacrylate) blends.Poomalai et al [5] studied the thermal and morphological properties of Poly (Methyl Methacrylate)/ Thermoplastic Polyurethane blends. Chang et al. [6] studied the rheological behavior of ABS/PMMA blends by using a cone and plate rheometer. Qifang et al. [7] studied the effect of blend ratio and viscosity of PMMA on the mechanical, thermal and rheological properties of ABS/PMMA blends. One of the common fact about the polymer is that when it is exposed to the lower temperature brittleness property get increased and leads to sudden failure.Hadriche et al. [8] studied the fractography of PA66, PMMA, PC at different strain rates.Kameshwari devi et al. [9] studied the effect of Thermoplastic polyurethane content on properties of PC/TPU blend filled with Montmorillonite. Thus, study on toughness modification on PC/TPU blend is meaningful. Furthermore, Polymer-Polymer blend, the experiment conditions such as test temperature extensively influences the mechanical properties. In this study the behavior of PC in the low and ambient temperature application is improved in addition of TPU.Also analyses of fracture behaviour of PC and PC/TPU blend using Optical microscopy at different temperatures were carried out.

II. EXPERIMENTAL DETAILS

2.1 Materials

A 3 mm sheet of opaque Polycarbonate of Lexan™ manufactured by Sabic Innovative Plastics purchased from Pune Polymer. Specimens were prepared using VMC machine and kept at room temperature without getting contact with direct sunlight to avoid ageing effect on polymer .PC/ TPU blend in the composition 90/10 (by wt./wt., % of PC/TPU) prepared by melt mixing the components in counter rotating twin screw extruder and then injection moulding at GLS polymer Pvt. Ltd., Bangalore.

2.2Tension testing

Tensile testing conducted at three temperature (-20^{o}C, 0^{o}C, R.T) on electromechanical machine, Instron 5582 model universal tester at constant cross-head velocity of 342.5mm/min,34.2mm/min,3.42mm/min (strain rate: 0.1 s^{-1} ,0.01s^{-1},0.001 s^{-1} resp.) to achieve required quasi static and moderate strain rate effect on polymer blend by which actual applications is to be made by this material.

2.3 Characterization

As per ASTM D638 standard dog-bone shaped specimens were used to conduct the tensile testing. Thickness of the specimen was 3 mm, total length was 165 mm, gauge length having 57 mm and width is equal to 19 mm. An environmental chamber and a resistance-wire heated temperature chamber were used to create the testing temperatures below and above the room temperature, respectively. For creating condition below room temperature liquid Carbon-dioxide was used. Static clip on extensometer was used to determine strain having 50 mm gauge length to hold 0-12.5 mm thick specimen. Mechanical wedge action grips were used to hold the specimen having rated capacity 100 kN.The Digital Caliper is a precision instrument that used to measure width and thickness of specimen to sure that dimensions are as per ASTM standard.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Uniaxial tensile testing were conducted at the strain rate of 0.001s^{-1},0.01s^{-1},0.1s^{-1}on Polycarbonate and PC/TPU blend specimens. The test temperature was -20, 0 and R.T (27°C).Specimens were soaked up to 10 minutes to give actual environmental conditions.

3.1 Tensile stress-strain responses

From the graphs in Figure 1 of stress vs. strain for the Polycarbonate and PC/TPU blend it is generally observed that tensile response of this polymeric material is dependent upon the rate of change of strain, simply strain rate and temperature. From the graph an obvious constant elastic region is observed following the yield point then plastic deformation area and then at the end point of failure of material. If particularly observed the stress-strain graph for PC and PC/TPU blend at room temperature then for both the material initial Young's modulus is similar in the elastic area. Now talking about the yield strength. The point where there is no stress change but change in strain or top most point on the stress-strain graph is called as the yield point. The yield effect in the material can be observed with the help of naked eyes at the time of experimentation. At room temperature tensile strength for PC/TPU blend observed more than Polycarbonate. But the % elongation for the blend is lower than the PC. Polycarbonate shows very high % elongation as observed in the graph that we have to stop the tensile testing. The conclusion from this behavior that PC is having only % elongation with lower tensile strength, where the PC/TPU blend is having good combination of tensile strength in addition with the % elongation. This is the indication of toughness property which is very important for the application where continues impact is carried out. The tensile strength increases as increase in the strain rate from low to ambient temperature for both the PC and PC/TPU blend. By observing the stress-strain graph of the PC/TPU blend at every temperature range i.e. from -20^{0}C to room temperature there is sudden failure occurs. There may be different reasons for this behavior. One of the important reasons for this response is the reliability and accuracy of the manufacturing method. At the time of injection moulding and hot melt mixing care has to take that both material should be mixed uniformly to avoid the knit line in the resulting polymer blend. Knit line means region in the polymer where gap is present at the intersection of the two phases. If gap is present in the material there loose bond between the two phases resulting in the sudden failure as happened in the case of PC/TPU blend. So proper care has to take at the time of injection moulding and hot melt mixing process. Another reason for this behaviour is that improper interconnection of twin screw. If there is no proper mixing of polymers then that resulting in the some solid circular impurity which is having fewer tendencies in mixing of polymer-polymer

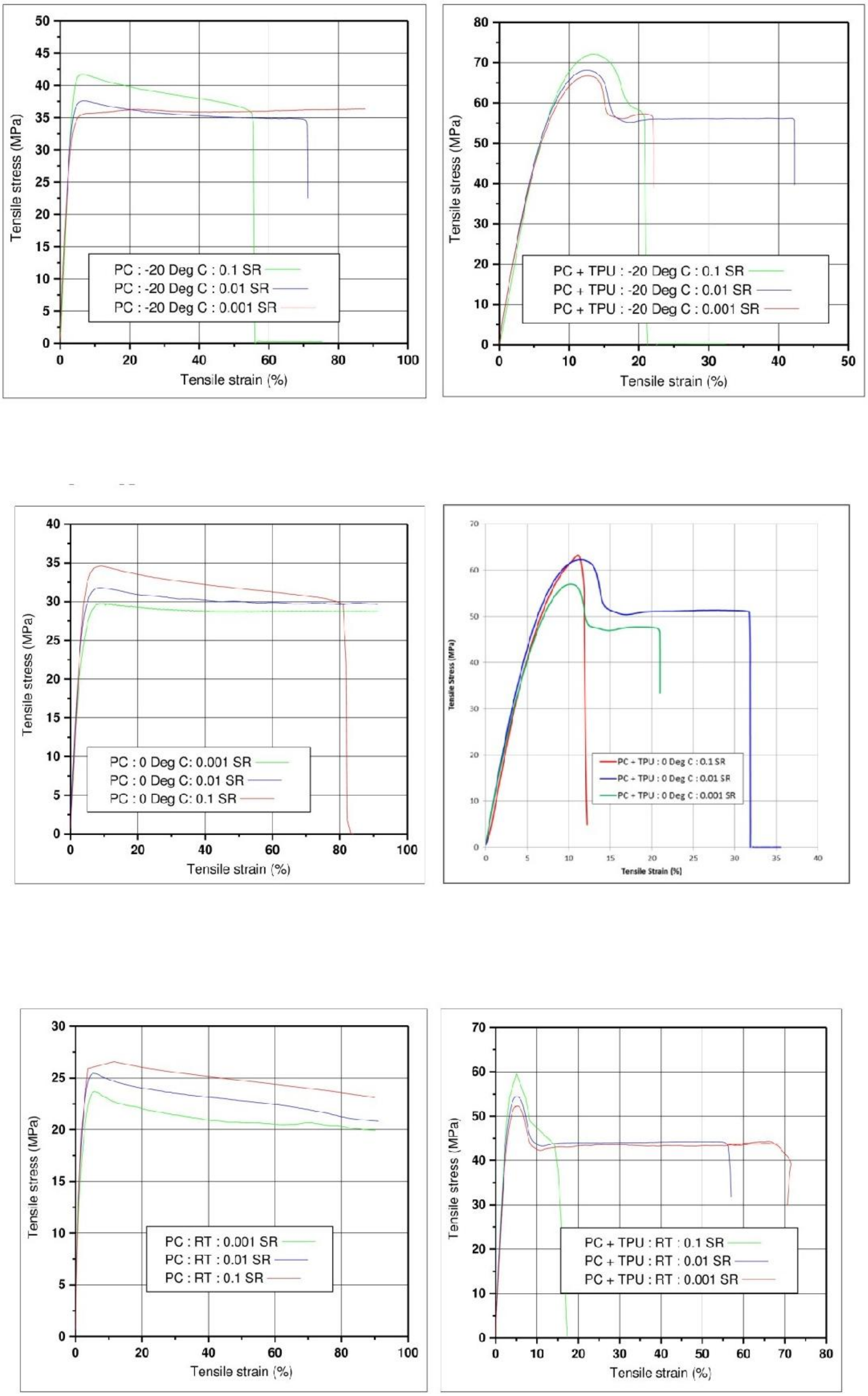

FIG 1: Tensile stress-strain curves at different strain rate and temperature

blend at the time of cooling. This internal generated impurity may lead in the sudden failure of the material. Adaptation of cooling also important parameter to decide properties in the resulting material. In the case of opaque polycarbonate at every temperature smooth failure is observed during the tensile testing.

For PC/TPU blend after yielding it shows little plastic deformation zone and suddenly brittle fracture. At a temperature below the ambient conditions particularly 0^0C and -20^0C upper and lower yield point is observed. This is quite different from the behavior of the PC/TPU blend in comparison with the opaque polycarbonate. Also tensile strength is increased or maximum in the lower temperature for blend polymer showing its suitability in low temperature applications.

IV. Fracture Analysis By Optical Microscopy

It is observed that the fracture surface of opaque polycarbonate under quasi-static and moderate tensile loading is characterized by brittle fracture manner at low temperature i.e. -20°C and 0°C. Comparatively at high temperature above room temperature the fracture is characterized by ductile manner. Figure 2 shows fracture appearance of polycarbonate at -20^0Cwith the help of optical microscopy. Fracture shows brittle fracture showing no fibrous structure. This fracture is exhibiting very low elongation.

Figure 3 shows the fracture appearance of PC/TPU blend at -20°C temperature, shows very ductile fracture showing fibrous structure. The fracture is comparable to cup and cone fracture exhibiting higher elongation. Generally all plastics exhibits brittle fracture at low temperature but PC/TPU shows opposite nature to this general behavior. This behavior indicates hard and tough property of PC/TPU blend. The main reason for the blending of two or more polymer is that to increase the certain properties that either suitable for some particular application. As in this work 10% thermoplastic polyurethane is added in the plain translucent polycarbonate to raise the toughness property at the lower temperature application, because the main tendency of polycarbonate is that it loses its ductility in lower temperature as the opaque polycarbonate is now recently used in the interior parts of the aero plane, train automobile and structural applications. Most of the applications manufactured from plastics always having contact with lower temperature. So polycarbonate cannot sustain at that temperature then the main option in addition with the cost effectiveness may be PC/TPU blend.

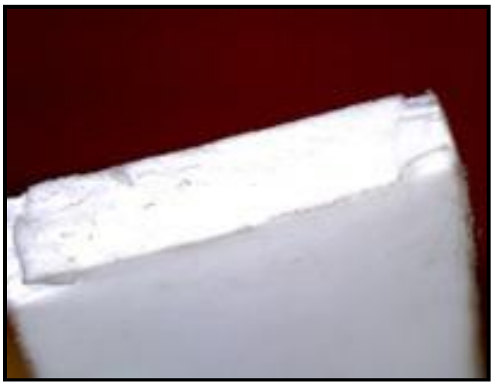

FIG.2: Fracture appearance of polycarbonate using optical microscope at -20°C

FIG.3: Fracture appearance of PC/TPU blend using optical microscope at -20°C

From table 1 it can be observed that for polycarbonate as temperature increases tensile strength decreases but % Elongation increases. But it is observed that for PC/TPU blend as temperature increases tensile strength decreases in addition with % Elongation. It shows the trend that as quantity of TPU increases in the polycarbonate at low temperature tensile strength and % elongation properties get raised. It means that addition of TPU raised properties of polycarbonate in low temperature application. Most plastics at room temperature show their familiar properties of flexibility (a low Young's modulus) and high resistance to cracking but when the temperature decreases this can change rapidly and many common plastics become brittle with low failure stresses. Low temperatures can be more harmful to plastics than high temperatures. Catastrophic failures can occur if materials selection does not take account of the low temperature properties of plastics. Also it is observed the room temperature behavior of PC/TPU blend and the values of tensile strength and % elongation from table.1 at room temperature it shows some unique behavior as compare to other temperature. The values of tensile strength and % elongation are moderate as compare to other conditions and it shows that enhancement of toughness property in the Polycarbonate with addition of TPU. So the unique advantage is that one can manufacture applications from PC/TPU blend which is having service conditions in room as well as below room temperature conditions.

Table 1.Experimental tensile strength and % elongation results for (a) Polycarbonate (b) PC+TPU blend

(a)

Temp. [^{0}C]	**0.001s^{-1}**		**0.01s^{-1}**		**0.1s^{-1}**	
	σ_s [MPa]	% E	σ_s [MPa]	% E	σ_s [MPa]	% E
-20^{0}C	36.4	87.8	37.6	71.1	41.7	56.0
0^{0}C	29.8	91.3	31.8	91.2	34.6	82.2
27^{0}C	23.7	90.0	25.4	90.0	26.6	90.0

(b)

Temp.[^{0}C]	**0.001s^{-1}**		**0.01s^{-1}**		**0.1s^{-1}**	
	σ_s [MPa]	% El	σ_s [MPa]	% E	σ_s [MPa]	% E
-20^{0}C	66.7	22.1	68.1	42.3	72.1	21.3
0^{0}C	57.0	21.0	62.3	31.9	63.0	26.0
27^{0}C	52.3	70.6	54.5	56.8	59.5	17.3

V. CONCLUSION

Uni-axial tension stress-strain behavior of opaque polycarbonate and PC/ TPU blend in the composition 90/10 (by wt. /wt., % of PC/TPU) was investigated at three temperatures in the range of -20^{o}C to 27^{o}C (R.T.) and three strain rates ranging from 0.001 s^{-1} to 0.1 s^{-1}.The experimental results indicate that the tensile response of opaque polycarbonate and PC/TPU blend is dependent on strain rate and temperature. The values of yield strength and strain at yield decreases with increasing temperature. Yield strength increases significantly with increasing strain rate. Also the fracture behaviour of polycarbonate in tensile loading shows the brittle to ductile transition from low to room temperature respectively. Addition of 10% TPU in the Polycarbonate raises the toughness property in room and low temperature which indicates the suitability of PC/TPU blend for the applications where temperature changes are observed from room to low temperature.

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REFERENCES

[1] Tang, S.H.;Kong, Y.M.;Sapun,S.M. Design and thermal analysis of plastic injection mould. *J.Mater.Process. Technol., 171 (2)*, 2006, 259- 267

[2] Chen W;Lu F; Cheng M.Tension and compressive tests of two polymers under quasi-static and dynamic loading. *Polymer Test ,21*,2002,113–121.

[3] Kan C.;Yang W.;Yu W..Experimental investigation and modeling of the tension behavior of polycarbonate with temperature effects from low to high strain rates.*Solids and structure, 51, 2014*, 2539–2548.

[4] Zhang A.;Zhao G.;Gao J.;Guan Y.Effect of Acrylonitrile-Butadiene-Styrene High- Rubber Powder and Strain Rate on the Morphology and Mechanical Properties of Acrylonitrile-Butadiene-Styrene/Poly (Methyl Methacrylate) Blends.*Polym-Plastics Tech and Engg.,49:3*,2010, 296-304.

[5] Poomalai P.;Siddaramaiah.Thermal and Morphological Studies on Poly(Methyl Methacrylate)/Thermoplastic Polyurethane Blends.*J.*

of Macromolecular Sci., Part A: Pure and App. Chem.,43:4-5,2007, 695-702.

[6] Han, C.D.; Yang, H.H. Rheological behavior of blends of poly(methylmethacrylate) (PMMA) and poly(acrylonitrile-stat-styrene) graftpolybutadiene(ABS*). J. Appl. Polym. Sci. , 33 (4)*,1987, 1221–1229.

[7] Qifang, L.; Ming, T.; Kim, D.; Liqun, Z.; Riguang, J. Compatibility and thermal properties of poly(acrylonitrile–butadiene–styrene) copolymer blends with poly(methylmethacrylate) and poly(styrene-coacrylonitrile).*J. Appl. Polym. Sci., 85 (13)*,2002, 2652–2660.

[8] Hadriche I.;Ghorbel E.;Masmoudi N.;Halouani F.E.Influence of strain rate on the yielding behaviour and on the self heating of thermoplastic polymers loaded under tension. *Key Engg.Mat. , 446,* 2010, 63-72.

[9] Shashidhara G.M.; Kameshwari Devi S.H.; Shreyas D. K. Effect of Thermoplastic Polyurethane content on properties of PC/TPU blend filled with Montmorillonite. *Carbon – Sci. & Tech., 5/1*,2013, 218 – 224