THE EFFECT OF THERMAL CYCLES ON FRACTURE BEHAVIOUR OF FILLED CALCIUM CARBONATE POLYPROPYLENE RANDOM COPOLYMER

Tülin Şahin[1,a], Zümer Köksal Altıntaş[2], Şenol Şahin[1]

1. Kocaeli University, Machine Engineering Department, İzmit, Turkey
2. Kocaeli University, Machine Engineering Department, İzmit, Turkey
a. Corresponding author (tulsah@kocaeli.com.tr)

ABSTRACT: Thermal fatigue might be damaging in structures internally constrained, which cannot expand or contract freely as in composite materials. During thermal cycling, both matrix and fiber expand or contract according to their coefficients of thermal expansion. This, in turn, influences the structural integrity of the composite and can limit the life of a composite material. In this article, in deference to environment conditions and working temperatures, thermal cycling applications on Polypropylene containing $CaCO_3$ at the different temperatures were realized. In this artical, in deference to environment conditions and working temperatures thermal cycling applications of PPrC (Polypropylene random copolymer) containing $CaCO_3$ at the different temperatures were realized. For different (25, 50, 100, 200) thermal cycling, according to ISO180 standard, charpy impact test was done. Properties of physical and mechanical features are explained as for that filling material and thermal cycle outputs. In this study, the crack propagation characteristic of the material exposed to thermal cycling and the absorbed energy amount during the crack initiation and propagation were analyzed.

Keywords: Thermal Cycling, Polypropylene Random Copolymer, Mechanical Properties

1. INTRODUCTION

Thermal exposure combined with mechanical loading can produce significant damage accumulation in polymer composites which can alter their mechanical and permeability properties [Bechel 2003, Ahborn and Knaak 1988, Nettles and . Biss 1996]. All materials expand or contract during temperature changes. Thermal fatigue might be damaging for structures internally constrained, which cannot expand or contract freely as in composite materials. The composite consists of two distinct components, each with different mechanical properties and coefficients of thermal expansion. During thermal cycling, both matrix and fibre expand or contract according to their coefficients of thermal expansion. As they are internally constrained, temperature fluctuations cause stress build-up at the interface [Biernacki 1999]. Constraint of thermal expansion causes thermal stresses, which may also initiate and propagate fatigue cracks [Spera 1975]. This, in turn, influences the structural integrity of the composite and can limit the life of a composite material [Morris 1989].

Plastic materials indicate different mechanic features at every temperatures. mechanic properties of the materials will be change, which working long time at the high temperatures. For this reason, the physical life of the materials being exposed to thermal aging must be established [Şahin 2002].

In this article, in deference to environment conditions and working temperatures thermal cycling applications

of PPrC (Polypropylene random copolymer) containing $CaCO_3$ at the different temperatures were realized. For different (25, 50, 100, 200) thermal cycling, according to ISO180 standard, charpy impact test was done. Properties of physical and mechanical features are explained as for that filling material and thermal cycle outputs. In this study, the crack propagation characteristic of the material exposed to thermal cycling and the absorbed energy amount during the crack initiation and propagation were analyzed.

2. EMPIRICAL STUDY

2.1. Materials

PP-R as a basic polymer used in this study in natural color and granule form was supplied from Borealis Company under the trade name of RA130E (polypropylene random copolymer).

Table 1: Manufacturer's data for physical and mechanical properties of PP-R pipe material

	Test Method	Test conditions	RA130E Natural
Tensile yield strength	ISO 527-2	50 mm/min	25 MPa
Tensile yield elongation	ISO 527-2	50 mm/ min	%13.5
Tensile elasticity module	ISO 527	1 mm/ min	900 MPa
Charpy impact (wi notch)	ISO 179	+23°C	20 kJ/m^2
Charpy impact (with notch)	ISO 179	-20°C	2 kJ/m^2
Hardness	ISO 868	Shore D	60
Vicat softening temperature	ISO 306	B (50 N)	65 °C
Density	ISO1183	gr/cm^3	0.900

2.2. Preparing Test Samples

Test samples were prepared in two groups in this study. For the first group, calcium carbonate ($CaCO_3$) mineral filler was added into the natural material during injection at the ratios of 5%, 15%, and 30% by volume. The test sample of natural material (unfilled) were prepared by injection for the second group. The first and second group test samples were manufactured by employing Erat FE130/95 Model Injection Machinery.

Table 1 shows some significant physical and mechanical properties provided by the manufacturer taken through the standard test samples manufactured by injection molding method [Leong et al. 2004, Sahin ve Yayla 2005]. Table 2 shows some basic properties of $CaCO_3$ manufactured in granule form and used for the entire polyolefin group.

Table 2: Some data about calcium carbonate ($CaCO_3$) used in the study

	Test Method	Mineral Material
$CaCO_3$ ratio	-	%98
Average particle diameter (D%50)	-	µm 2
The highest particle diameter (D%98) [TopCut]	-	µm 10
Density	ISO787/10	g/ml 2.17
Brightness	DIN 53163	%85(Ry, C/2)

2.3. Material Testing

2.3.1. Thermal cycle

After shaping %5, %15 and %30 PPRc filled materials into Charpy test's standard sample dimensions, the sample parts are hold 1 min in a water filled receptacle which is set at 5 C°. After that they are again hold 1 min in another receptacle at stable 100 C°. This is determined as one cycle. That procedure is repeated 25 times, 50 times, 100 times and 200 times. The samples are dried in a room temperature without using any tools or methods. After that, all materials, which are filled and non-filled, are gathered and Charpy tests are done to these parts in a room conditioned to 20 C° and the results of the experiments are analyzed and graphics are drawn with their mechanical outputs.

2.3.2. Charpy impact test

Instrumented impact testing provides valuable information on energies involved in the fracture process, giving individual evaluation of the energy for crack initiation and also the energy required to propagate the crack through the material, which is not possible with the conventional Charpy impact test. In many materials, the formation of the crack at the notch root occurs just prior to or at the peak load. Therefore, it is a reasonable approximation to define the energy up to the peak load as the 'crack initiation resistance' [Sahin And Yayla 2005, Manahan et al. 2000].

Charpy tests were applied on the Charpy samples for determining the effect of calcium carbonate ($CaCO_3$) on the behaviors of PP-R materials against impacts at the temperature of 22°C ± 1°C and 50% ± 10 humidity ratios according to ISO 179 standard. These tests were carried out through instrumented Charpy impact test device with strike rate of 2.53 m/s under the trademark of CEAST. The values for the materials such as maximum force (F_{Max}) [N], maximum energy W [J] and the energy at maximum force (W_{Fmax}) [J] were determined by using force (F)-time (t)- and force (F)-distance (x) diagrams derived from Charpy tests. Two types of energy were obtained from the tests. One is the energy until maximum force and this can be considered as Charpy crack initiation energy [E_{Fmax}]. The other one is the total energy spent across the impact known as conventionally Charpy maximum impact energy. Consequently, the difference between these two energies may be considered as Charpy crack propagation energy [E_{pro}]. This energy comes after the maximum force.

The values derived from Charpy test samples used for each value were statistically evaluated according to Chouvenant criterion and variations were shown on graphics as % based on natural (unfilled) Charpy sample [Holman 1994].

3. RESULTS

Besides applied thermal cycle, amount of $CaCO_3$ in PPRc material causes great changes on materials' mechanical features and that may give us significant outputs in order to compare endurance against brittle fracture.

Mechanical effects occurred by $CaCO_3$ in PPRc material, according to thermal cycle, are shown as it is seen at graphics below in Figure 1 to 4. Ratio of filling material, number of cycle cause changes on, maximum energy, crack initiation energy and propagate crack energy of the material.

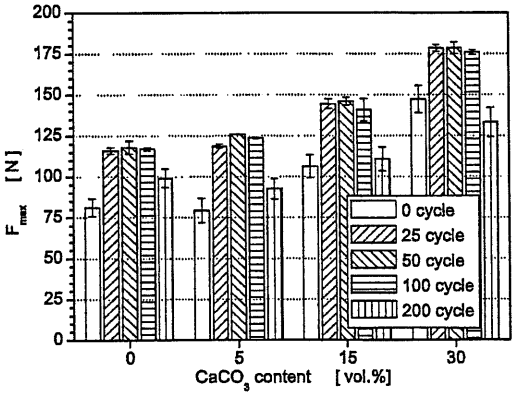


Figure 1: Maximum Force

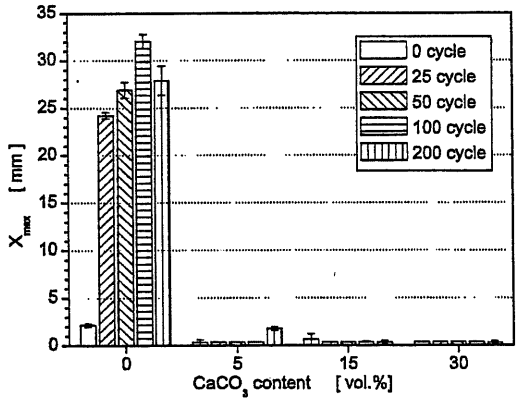


Figure 2: The crack propagation energy

Maximum breaking force rises with ratio of filling material and thermal cycle round.

Thermal cycle applied on pure material boosts the value of crack propagate energy; hence that causes increase on maximum energy. In addition to this, to reinforce the material decreases the energy of crack propagates.

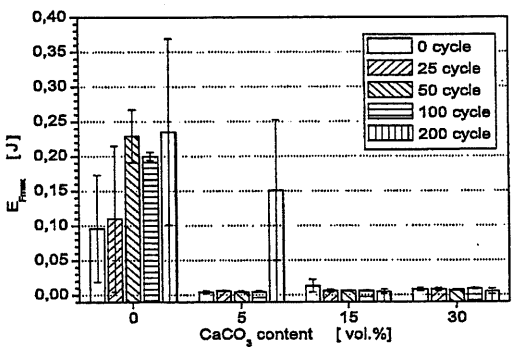


Figure 3: Crack initiation energy

Adding filling material caused high decline on crack initiation energy of material. And that rises tendency of damage formation. The effect of thermal cycle actually cannot be observed because of this decline on crack initiation energy.

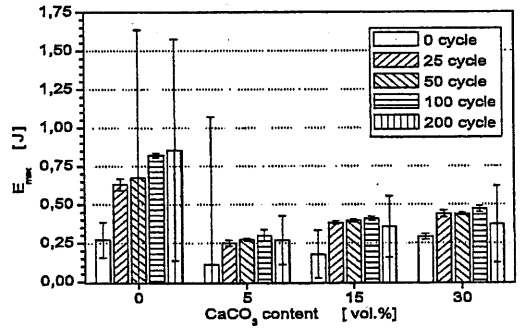


Figure 4: Maximum energy

Proper to the literature reinforcing with $CaCO_3$ lessens total crack energy. But, it is observed that %30 filled material has higher crack energy than the %5 filled material. Thermal cycle round is directly proportionate to total crack energy of non-filled material. But in 200 cycles, filled material's crack energy decreases in figure 4.

In the experiments four different values are criticized and it is observed that filling procedure is not important after a defined limit. Thermal cycle's relatively positive results are signals that inner structure of plastic changes into a regular state (it is formed to crystalline structure). When PPRc material's usage areas are considered, differentiation on material's cracking behaviors, which may change the material's state model, caused by continuous temperature changes is important for working productivity.

REFERENCES

Bechel, V.T., Fredin M. B., Donaldson S.L., Kim R. Y. and Camping J.D., 2003.Composites: Part A 3, 663..

Ahborn K. and Knaak S ., 1988. *Cryogenics* 28, 273.

T. Nettles and E.S . Biss, 1996. Low Temperature Mechanical Testing of Carbon-Fiber/Epoxy Resin Composite Materials. NASA Technical Memorandum, NASA Center for Aerospace Information, pp3663.

Biernacki K., Szyszkowski W. and Yannacopoulos S .1999., *Composites: Part A* 30, 1027.

Spera, D. A., 1975. What is Thermal Fatigue in Thermal Fatigue of Materials and Components, Philadelphia, PA:, American Society for Testing and Materials, vol. 3.

Morris W.L., James M.R. and Inman R.V.,1989. *J. Engng.Mat. Tech.* 331.

Şahin, Ş. 2002. Polipropilen Random Kopolimer (PPRC) Boruların Mekanik Özelliklerine Etki Eden Parametrelerin İncelenmesi. Doktora Tezi, Kocaeli Üniversitesi Fen Bilimleri Enstitüsü.

Tamer SINMAZÇELİK and A.Armağan ARICI, 2006. J MATER SCI 41, 1233–1241.

Leong, Y.W., Mohd.Ishak, Z.A., Ariffin, A.,2004. Journal Of Applied Polymer Science, 91, 3327-3336.

Sahin S. And Yayla P.,2005. Polymer Testing 24, 613–619.

Manahan Sr., M.P, Cruz Jr., C.A., Yohn, H.E., In: Peraro, J.S (Ed.) ,2000. Astm Stp 1390, American Society For Testing And Materials, West Conshohocken, Pa.

Holman, J. P., 1994. Experimental Methods For Engineers, Sixth Edition, Mcgraw-Hill, Inc., ISBN 0-07-029666-9, Singapore

Preparation and Characterization of Uniform Tio2 Membrane on Porous 316l Stainless Steel Substrate 216

Obtaining and Characterisation of Hydroxyapatite–Zirconia Powders by Chemical Precipitation 222

Relationship Between Cell Wall Morphology and Energy Absorption Behavior of Aluminum Foams Produced via Melt Route 227

X-Ray Microtomography of Geological Soft Sediment Samples: Reduction of Motion Artifact by Resin Consolidation 232

Processing and Characterization of Porous Tini Alloys 237

Development of Anticorrosion Composite Polymer Materials and Coatings Based on Them with Using Powdery Wastes of Various Productions 242

Production and Characterization of Chitosan/Peo Polymer Nanofibers Using Electrospinning Technique 248

Composite Membrane Synthesis for Pervaporation Membrane Bioreactor 253

Characterization and Formation of Porous Surface on Magnesium Coated by Plasma Electrolytic Oxidation 258

The Effect of Structural Characteristics on the Reflectivity of Porous Silicon 263

The Estimation of Pore Anisotropy and its Relationship with Morphometric Properties of Porous Solids 268

Grain Size Assessment in Supercoarse Hardmetals With Cobalt And Nickel Based Matrices 274

Application of Nano-Sized Up-Conversion Phosphors Doped With Rare-Earth Elements in Polymer Photonics 278

Tensile Properties of Ground Colemanite Filled Polypropylene Homopolymer 283

The Effect of Thermal Cycles on Fracture Behaviour of Filled Calcium Carbonate Polypropylene Random Copolymer 288

Synthesis and Characterization of ZSM-5 Zeolite From Wheat Hull Ash 292

Zeolite Filled Polyvinylalcohol Membrane Preperation and Alcohol Dehyration by Pervaporation 297

Surface Roughening of Stainless Steel Plates by Electrochemical Etching Techniques Used for Porous P/M Applications 301

Synthesis and Characterization of Hydroxyapatite 306

Synthesis and Characterization of Pr3+ Doped Yttrium Aluminum Garnet (Yag) Nanophosphors 310

Electrodeposition of Layered Manganese Oxides under Hydrothermal Conditions 315

Mesoporous Materials from a Novel Silica Source 320

Superacidic Mesoporous Sulfated Titania-Silicates for Dehydration of Fructose 325

Mechanical Proporties of a Composite Produced by using Electroless Ni Plated Fe-Co-Cr Powders 331

SCIENTIFIC COMMITTEE

Seniz Akin	TUBITAK
Gokhan Aksoy	Ege University
S. Alsoy Altinkaya	Izmir Institute of Technology
Sabri Altintas	Bogazici University
Gursoy Arslan	Anadolu University
Vedat Arslan	Dokuz Eylul University
Alper Arslanoglu	Izmir Institute of Technology
Levent Artok	Izmir Institute of Technology
Ali Ata	Gebze Inst. of Technology
Devrim Balkose	Izmir Institute of Technology
Yusuf Baran	Izmir Institute of Technology
Ergin Basar	Akzo Nobel
Hasan Boke	Izmir Institute of Technology
Volga Bulmus	Izmir Institute of Technology
M. Sabri Celik	Istanbul Technical University
A. Erdem Senatalar	Istanbul Technical University
Osman Ersoy	Arcelik Inc.
Ayhan Ezdesir	PETKIM PetroChemicals Inc.
Hasan Gocmez	Dumlupinar University
Sasidhar Gumma	Indian Institue of Technology
Sebnem Harsa	Izmir Institute of Technology
Cengiz Kaya	Yildiz Technical University
Erol Kaya	Dokuz Eylul University
Seda Keskin	Koc University
J. L. Lopez-Lacomba	University Complutense
Christos N. Likos	University of Vienna
Arzu Marmarali	Ege University
M. P. Ginebra Molins	Univ. Politecnica de Catalunya
Keshavan Niranjan	University of Reading
M. Lutfi Ovecoglu	Istanbul Technical University
Orhan Ozturk	Izmir Institute of Technology
Gulnur Ozyuzer	Izmir Institute of Technology
Aysegul Pala Iyilikci	Dokuz Eylul University
Ferda Soyer	Izmir Institute of Technology
Nurettin Sahiner	Onsekiz Mart University
Gamze Tanoglu	Izmir Institute of Technology
H. Ibrahim Unal	Gazi University
Serife Yalcin	Izmir Institute of Technology
Talat Yalcin	Izmir Institute of Technology
Ismail Ozgur Yaman	Middle East Technical Univ.
Yuda Yurum	Sabanci University
Hadi Zareie	Gediz University
Haifei Zhang	University of Liverpool

LOCAL ORGANIZING COMMITTEE

Mehmet Polat	Symposium Chair, Izmir Institute of Technology
Metin Tanoglu	Symposium Chair, Izmir Institute of Technology
Sevgi Kilic Ozdemir	Symposium Secretary, Izmir Institute of Technology
Ozgenc Ebil	Izmir Institute of Technology
Nuran Elmaci	Izmir Institute of Technology
Tahir Kemal Erdem	Izmir Institute of Technology
Ayten Nalbant	Izmir Institute of Technology
Devrim Pesen Okvur	Izmir Institute of Technology
Engin Ozcivici	Izmir Institute of Technology
Ekrem Ozdemir	Izmir Institute of Technology
Banu Ozen	Izmir Institute of Technology
Fehime Ozkan	Izmir Institute of Technology
Hurriyet Polat	Izmir Institute of Technology
Yusuf Selamet	Izmir Institute of Technology
Selahattin Yilmaz	Izmir Institute of Technology

ACADEMIC ORGANIZING COMMITTEE

Halil Bakan	TUBITAK Marmara Research Center
Erdal Celik	Director, Nanotechnology Center, Dokuz Eylul University
Mustafa Demir	Director, Materials Research Center, Izmir Institute of Technology
Mustafa Demircioglu	Chemical Engineering, Ege University
Can Erkey	Chemical Engineering, Koc University
Gultekin Goller	Metallurgical and Materials Engineering, Istanbul Technical University
Mustafa Guden	Rector, Izmir Institute of Technology
Uner Ipekoglu	Mining Engineering, Dokuz Eylul University
Hasan Mandal	Vice Rector, Sabanci University
Salih Okur	Dean, Faculty of Engineering and Architecture, Katip Celebi University
Lutfi Ozyuzer	Applied Quantum Research Laboratory, Izmir Institute of Technology
Kambiz Ramyar	Vice Dean, Faculty of Engineering, Ege University
Ender Suvaci	Vice Rector, Anadolu University
Funda Tihminlioglu	Dean, Faculty of Engineering, Izmir Institute of Technology
Suleyman A. Tuncel	Chemical Engineering, Hacettepe University
Mehmet Turker	Vice Rector, Gazi University
Ahmet Yemenicioglu	Director, Biomaterials Research Lab., Izmir Institute of Technology

INSTITUTIONAL ORGANIZING COMMITTEE

Sedat Guldogan	Deputy Undersecretary, Undersecretariat for Defence Industries
Erguder Can	General Secretary, Izmir Development Agency
Bahadir Tunaboylu	Manager, Materials Institute, TUBITAK Marmara Research Center
Yalcin Yilmazkaya	Aerospace Clustering Association
Necmi Sadikoğlu	Istanbul Chemicals and Chemical Products Expoters' Association
Arslan O. Erdinc	President, Aegean Mine Exporter Union
Saadet Caglin	President, Izmir Chamber of Chemical Engineers
Muhammet Yildiz	President, Izmir Chamber of Mining Engineers
Erol Paksu	President, Ege PLASDER
Suleyman Temizci	Association of Natural Isolation Materials
Yusuf Usta	President, Turkish Powder Metallurgy Association

INDUSTRIAL ORGANIZING COMMITTEE

Adnan Altas	R&D Manager, Eczacibasi ESAN
Levent Gokce	General Director, Weber Saint-Gobain Turkey
Cagri Gurbuz	Deputy General Manager, SentesBir Inc.
Cagan Heris	Deputy General Manager, Akdeniz Kimya Inc.
Nafiz Karabudak	Sr. Manager, Technology Initiatives, Lockheed Martin Corp., USA
Saim Kirgiz	R&D Manager, Bosch Thermotechnology
Sanal Limoncuoglu	General Manager, Akzo Nobel Paint Inc.
Murat Muduroglu	Development Manager, Adacal Industrial Minerals Inc.
Osman Okyay	Technical General Manager, Kale Holding Inc.
Goksel Paker	CEO, Inci Aku Inc.
Arslan Salman	General Manager, EastChem Inc.
Mustafa Sezer	R&D Technology Group Leader, Materials Technologies, Arcelik Inc.
Emre Tutuncu	General Manager, Cimstone Inc.
Ugur Uzgan	Product Manager, AKG Gazbeton Inc.
A. Murat Yildirim	R&D Manager, Tupras Turkish Petroleum Refineries Co.

Published By:
The Organizing Committee of
The International Porous and Powder Materials Symposium and Exhibition

Sevgi KILIC OZDEMIR
Symposium Secretary
Izmir Institute of Technology, Department of Chemical Engineering
Urla Izmir Turkey
sevgikilic@iyte.edu.tr
+90 232 750 6647

Mehmet POLAT
Symposium Chair
Izmir Institute of Technology, Department of Chemical Engineering
Urla Izmir Turkey
mehmetpolat@iyte.edu.tr
+90 232 750 6693

Metin TANOGLU
Symposium Chair
Izmir Institute of Technology, Department of Mechanical Engineering
Urla Izmir Turkey
metintanoglu@iyte.edu.tr
+90 232 750 6693

Editorial Board:
Aybike Nil OLCAY, Izmir Institute of Technology Environmental Engineering Program, Urla Izmir Turkey
Elif Suna SOP, Izmir Institute of Technology Chemical Engineering Program, Urla Izmir Turkey
Serkan KANGAL, Izmir Institute of Technology Mechanical Engineering Program, Urla Izmir Turkey

Printed by:

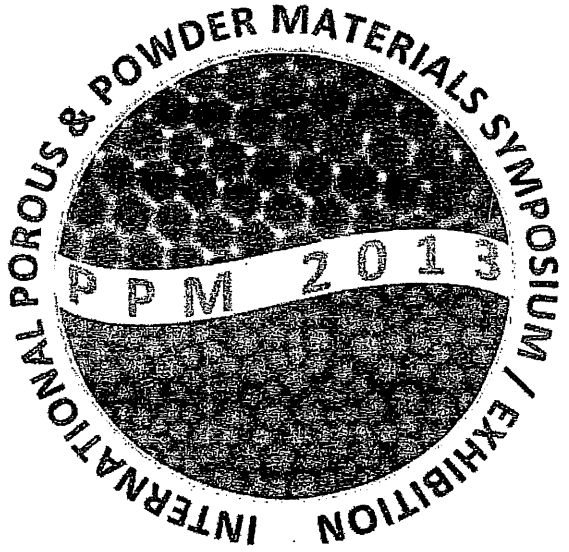
Üç Adım Printing House
Shop: 2824 Sok. No 41 Sanayi Sitesi Izmir Turkey / Tel +90 232 458 35 13
Office: 8001 Sok. No 8/1 Cigli Izmir Turkey / Tel +90 232 376 16 39
ucadimmatbaa@hotmail.com

Cover Design:
Mutfak: theBRANDkitchen
Mecidiye Kuyu Sk. , Ozdemir Apt. No:18/5, Mecidiyekoy, Sisli, Istanbul Turkey
Tel: +90 532 614 3854 / +90 212 264 0858
www.markamutfakta.com

ISBN: 978-975-6590-05-8

The Proceedings of
the 1st International

Porous and Powder Materials Symposium and Exhibition PPM 2013



3-6 September 2013
Çeşme Izmir-TURKEY

Edited by
Sevgi KILIC OZDEMIR
Mehmet POLAT
Metin TANOGLU