International Journal of Mechanical Engineering and Technology (IJMET)
Volume 9, Issue 8, August 2018, pp. 233–240, Article ID: IJMET_09_08_025
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=8
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

MECHANICAL BEHAVIOUR OF PROCESSED PP/PVC LAMINATES

Aniber Benin M
Research Scholar, Mechanical Engineering, Noorul Islam Centre for Higher Education, Kumaracoil, Tamil Nadu, India

Stanly Jones Retnam B
Associate Professor, Department of Automobile Engineering, Noorul Islam Centre for Higher Education, Kumaracoil, Tamil Nadu, India

Edwin Sahayaraj M
Associate Professor, Department of Automobile Engineering, Noorul Islam Centre for Higher Education, Kumaracoil, Tamil Nadu, India

ABSTRACT

The ceramic reinforcement in the thermoplastic polymer has more interest in research work. It replaces the conventional reinforcement with synthetic fibers. The aim of this research work is to prepare the titanium ceramic powder reinforced into the matrix of polypropylene and polyvinylchloride foam and analyse the mechanical behavior of these composites and their laminates combinations. The laminates combination has three layers. The mechanical behavior of the composites and their laminates were analyzed by tensile, flexural and impact test. The physical morphology of the composites was studied using scanning electron microscope. The test result showed that the addition of titanium ceramic powder enhanced the above said properties in polypropylene matrix. The analyzed mechanical properties were enhanced by their laminate combinations.

Keywords: Laminates, Mechanical behavior, Polypropylene composite, Polyvinylchloride composite, Titanium ceramic powder
Cite this Article: Aniber Benin. M, Stanly Jones Retnam. B and Edwin Sahayaraj. M, Mechanical Behaviour of Processed PP/PVC Laminates, International Journal of Mechanical Engineering and Technology, 9(8), 2018, pp. 233–240.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=8

1. INTRODUCTION

The light weight, stiff and toughen multifunctional materials attract variety of engineering applications such as marine, aircrafts, industrial and automotive. One material of this kind is polyvinyl chloride (PVC) closed cell foam. It has received attention since 1970s due to its

extraction. PVC resin is extracted from waste plastics. PVC is widely used as core material in sandwich structures for certain composites which requires damage tolerance and saving in weight [1, 2]. The foam plastics are classified into closed cell and open cell. The closed cell foam is almost spherical in shape and its wall is enclosed by the core of foam metal. In contrast, the open cell types of individual cells are interconnected to make a sponge like structure [3].

The energy absorption of closed cell foam is higher than the open cell foam due to entrapped gas within the cell. The entrapped gases act as a medium for energy absorption. Moreover during mechanical loading, these gases are compressed or sheared to withstand the given load up to break its wall / boundary. When heated gases present inside the foam cell can be whipped into solution of the plastic mixture and volatilized. This improves the strength of the plastic composites by releasing and interacting gases like carbon di oxide and nitrogen di oxide [4]. The dimension and distribution of cells depends on the particular material and adopted foaming process [3]. In general, foam of PVC has low thermal and dimensional stability than their solid counterpart. In contrast, the microcellular foams of PVC by a cell size less than 10 micro meter and cell density higher than 10^9cells/cm^3 offers higher mechanical properties such as strength, toughness, fatigue life and electrochemical property [5].

Now-a-days the rigid polymeric foams based on PVC is modified by the interpenetration of polymer network using aromatic amides. Therefore the molecular structure of PVC could be changed. The changed molecular structure is linear and its transition temperature is enhanced [6]. Several researchers investigated to improve the properties of PVC resin through copolymerization [7], halogenation [8], blending [9] and crosslinking [10]. Also, the addition of nano clay enhances the mechanical properties of the foamed PVC [11, 12]. This work aims to analyse the properties of foamed PVC with the addition of titanium oxide ceramic.

The consumption of plastic materials has decreased due to its disposal problem. The disposal of these materials here and there in the form of thin bags, packaging elements, boxes etc. causes land and water pollution. Recycling and reusing of this material reduces the environmental pollution. The waste plastic materials contains certain quantity of polyethylene, polypropylene, poly vinyl chloride and polystyrene etc.[13]. Polypropylene (PP) is one of the plastic materials which comprises of semi-crystalline polymer. It shows easy manufacturing, resistance to chemicals, weight less and reasonable cost [14, 15]. However, polypropylene has certain demerits as high shrinkage ratio, high brittleness at low temperature and less impact strength. PP resin is extracted from the used plastics and blend with calcium carbonate nano composite [16] and clay composites [17] which enhance the mechanical properties of the PP.

The development of tough material with high fatigue-resistance and damage tolerance design could be increased. Fiber reinforced polymer and aluminum alloys of lightweight materials are used in various fields of engineering application. However, these materials have impact damage and fatigue crack growth [18]. These failures due to damages are overcome by combining both to make laminates [19]. The recent trend is to make a thermoplastic FML (fiber metal laminates) which reduces production time; thereby its demand has increased in transport sector [20]. The thermoplastic PP has been widely used as the matrix for the FML development and it is reinforced with glass fiber. These laminates have great tensile strength compared to unprocessed polypropylene matrix. This work is aimed to prepare laminates of polypropylene and polyvinylchloride foamed sheet and to analyst their physical and mechanical properties.

2. MATERIALS AND METHODS

2.1. Materials and preparation

Polypropylene (PP) of C86/50 AM 120 N grade, Kottayam traders Pvt. Ltd., Kerala, India was used for this purpose and polyvinylchloride of grade SPVC FS: 6701, Plast alloys india ltd., new delhi, India, Finolex Industries, Pune, India. Epoxy glycidyl methacrylate compatiblizer was purchased from Merck, India. CTAB purchased from Central Drug House, Delhi, India. Titanium Oxide Ceramic powder, Merck, India. Foam forming agent was Azodicarbonamide, Ajantha chemicals purchased from New Delhi. Lubricant added was Loxiol 12 which was purchased from agarwal merchanties, New Delhi. The PP mixed with TiO_2 to form a sheet of 3 mm thickness was used in the Injection moulding process. The PVC foam with TiO_2 sheet was prepared by hot extrusion process then the sheets were cut into pieces for the required dimensions for test. The pieces were joined together to make laminates using anabond grade 112 (anabond pvt. Ltd. India). Anabond is a anaerobic type adhesive. The combination of laminates used for this purpose was PVC/PP/PVC (A), PP/PVC/PP (B).

2.2. Tensile Test

The laminate samples and single sheets were prepared for the standard as ASTM D638 as shown in fig. 1. The test was conducted on the computerized servo controlled UTM machine. The laminates were placed in between the gripers of the UTM machine. The gauge length of the specimen is 50 mm and the cross head speed was fixed to 2 mm/minute. The tensile strength and elongation of the specimens were directly got from the machine data system. The obtained values were taken for the analysis.

2.3. Flexural test

The laminate samples and single sheets were prepared for the standard as ASTM D790 as shown in fig. 2. The test was conducted on the computerized servo controlled UTM machine using special attachment. The gauge length of the specimen is 50 mm and the cross head speed was fixed to 2 mm/minute at room temperature. The flexural strength of the specimens was directly got from the machine data system. The obtained values were taken for the analysis.

2.4. Impact test

The laminate impact strength was measured using a charpy impact tester with the laminate specimen and single sheet standard was ASTM D 6110 as shown in fig. 3. After test, the energy absorption of the specimen was obtained from the machine data.

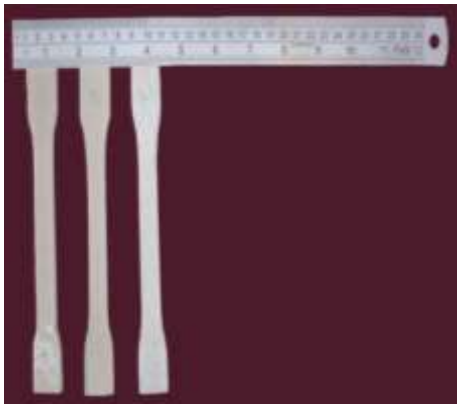


Figure 1 Specimens for tensile test

Figure 2 Specimens for flexural test

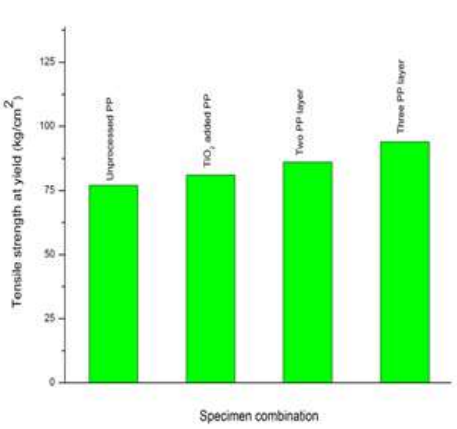
Figure 3 Specimens for impact test

2.5. SEM

A JEOL made JSM 6390 model electron microscopy system was used to analyze the morphology of laminates. The function of this electron microscope is similar to that of its optical counterpart except that a focused beam of electron is employed instead of light to image the specimen and to gain information on its structure.

3. RESULT AND DISCUSSION

The physical properties of the polypropylene are reported as follows: density is 910 kg/m^3, elastic modulus is 870 MPa, Yield strength is 17.2 MPa and the ultimate strain is 1050% which depends upon the density of the material [21]. The polypropylene sheet of 3 mm thickness having 0.7 gram per cubic centimeter of density was used for the test. The obtained tensile strength is 82 kg/cm^2. Similarly the PVC foamed sheet of 0.55 g/cm^3 density has 24 kg/cm^2 tensile strength at yield. In general, the density of the material increases to increase the tensile strength. In this work instead of increasing density, titanium ceramic powder of 50 μm in average is added during forming sheet to analysis the tensile strength of the both PP and PVC sheets. The addition of titanium increases the tensile strength of the PP samples as shown in fig. 4.



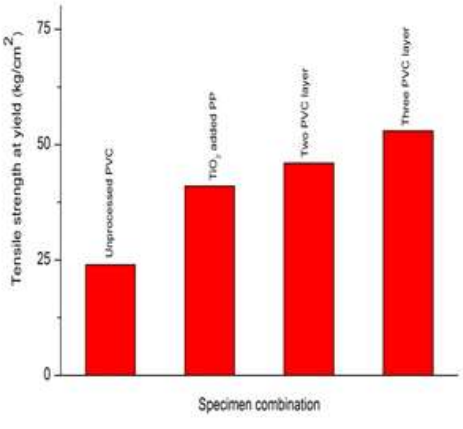


Figure 4 Tensile strength of various combination of PP sheets **Figure 5** Tensile strength of various combination of PVC sheets

Moreover, the tensile strength of the laminates (combining sheets) was increased. This could be due to the increasing thickness of the sheets and the addition of titanium ceramic particles reduces the porosity of the sheets. Also, a local stiffening of composite could occur to increase the same. The stiffened matrix might absorb the applied force due to localized

strain effect. The same pattern of increasing tensile strength was obtained for the PVC foamed sheets also. The tensile strength of the PVC foamed sheet is described in the fig. 5. When comparing the addition of titanium powder, titanium caused more effect on PVC sheets than the PP sheets formation because the tensile strength of the PVC sheets jumped from lower level to higher level. This jumping had not occurred in the tested PP samples. This could be due to the addition of titanium powder which strengthens the walls of the foam bubbles.

During tensile test these walls elongated thereby restricting breakage. Further, the increasing trend of increasing tensile strength was obtained by increasing the combining of PVC sheets. This effect was similar to the tensile properties of PP sheets. At the same time, the combination of PP/PVC laminates also increased its tensile strength than its own combination. This combination showed larger changes in its tensile property. Moreover the higher tensile was obtained in the outer layer of PP. This could be due to the higher tensile nature of the PP resin.

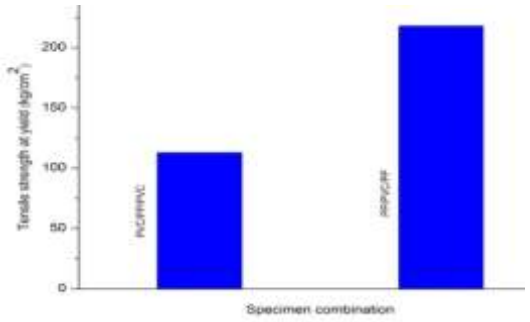


Figure 6 Tensile strength of laminates combination

The flexural test results showed that the reinforcement of titanium ceramic powder in the PP and PVC matrix enhanced the flexural modulus of both. This enhancement was high in PP matrix than the PVC matrix. This improvement in flexural modulus could be due to the restriction in mobility of the polymer matrix chain caused by high localized stiffness produced by the ceramic particle present in the polymer matrix. When comparing this effect, PVC foam had higher flexural strength than the PP matrix. This could be due to the improper mixing of ceramic powder in the PP matrix and these were agglomerated in the matrix as shown in fig. 7. On comparing the laminate, combination A had lesser flexural modulus than the combination B as shown in fig. 8. During flexural test the top layer PVC was in compression and the bottom layer was in tension. The compressive force broke the foam bubbles therefore air got released and reduced the modulus value but the deflection increased.

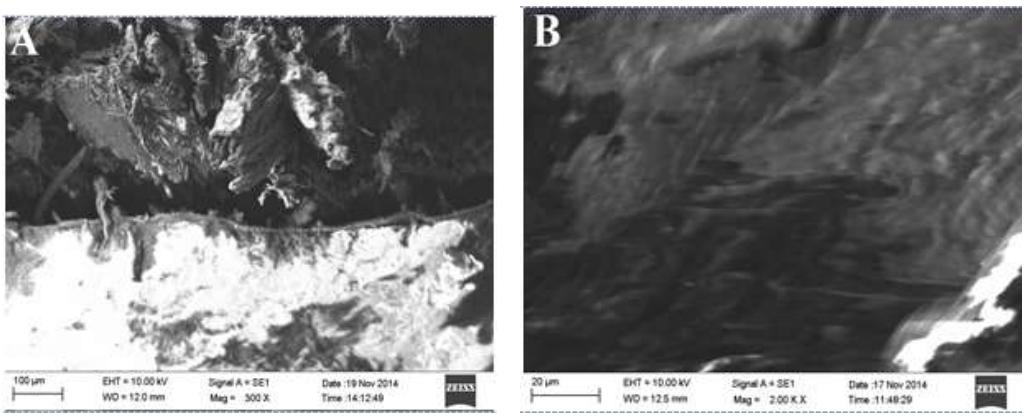


Figure 7 Scanning electron micrographs of samples (a) PP and (b) PVC

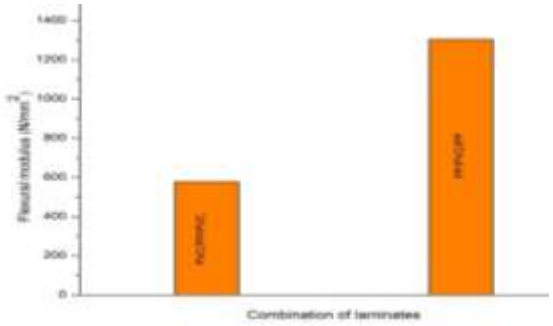


Figure 8 Flexural modulus of laminates combination

The obtained impact energy absorption capability of the PVC foamed sheet was 15.3 J/mm^2 and this value was deteriorated by the addition ceramic powder. Because, the added TiO_2 powder increased the rigidity of the polymer matrix by being present on the walls of the foam bubbles. As stated earlier, the reinforcement of the titanium ceramic powder might be agglomerated on the polymer matrix. The agglomerated powder could be further amplified by the rigidity of the matrix at higher concentrated areas causing brittle fracture under impact loading. The same type of result was obtained by Jamel et.al. [22]. The deterioration effect of reducing impact strength in polymer matrix is lesser in polypropylene matrix than the polyvinylchloride matrix. On comparing, the laminate combinations, the combination B had higher impact strength than the combination A as shown in fig. 9. The density of PP used for this test is higher than the density of PVC that is one of the reasons for this higher energy absorption. During the formation of laminates, the inner layer of PVC might be compressed to bust the air bubbles which is the another reason for the reduction of impact energy.

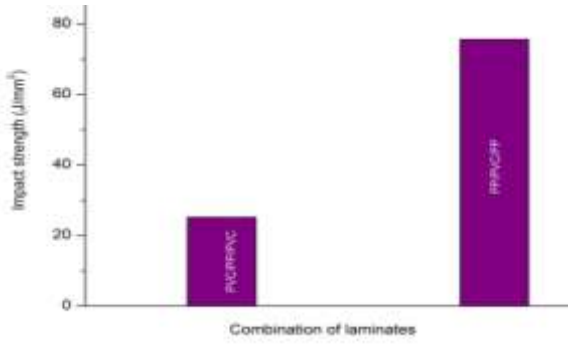


Figure 9 Impact energy of laminates combination

4. CONCLUSIONS

- The polypropylene and polyvinylchloride composites sheets were successfully prepared
- The prepared composites sheets were successfully cut into samples as per the ASTM standard for the prescribed test.
- The obtained result of tensile test showed that the tensile strength of both the titanium ceramic powder reinforced polypropylene and polyvinylchloride composites were enhanced.
- The flexural strength of both the matrix was enhanced by the reinforcement of titanium ceramic powder
- The impact strength of the polypropylene matrix was enhanced by the reinforcement of titanium ceramic powder but the polyvinyl chloride matrix was deteriorated.

- The outer layer of PP could be improved by the impact strength of the laminates
- The mechanical properties such as tensile, flexural and impact properties of the laminates containing outer layer as PP were improved by the addition of titanium ceramic powder.

REFERENCES

[1] Stewart R, At the core of lightweight composites., Reinforced Plastics, 2009, 53(3), 30-35.

[2] Atas C and Sevin V, On the impact response of sandwich composites with cores of balsa wood and PVC foam., Composite Structures, 2010, 93(1), 40-48.

[3] Gibson L.J and Ashby M.F, Cellular solids:structure and properties. 1999; Cambridge university press.

[4] Gimenez I, Farooq M.K, El mahi A, Kondratas A, Assarar M, Experimental analysis of mechanical behavior and damage development mechanism of PVC foams in static tests., Materials Science, 2004, 10(1), 34-39.

[5] Nidal H Abu-Zahra, Ali M Alian, Hong Chang, Extrusion of rigid PVC foam with nano clay: synthesis and characterization, Journal of Reinforced Plastics and Composites, 2010, 29(8), 1153- 1165.

[6] Lin H.R, The structure and property relationships of commercial foamed plastic., Polymer Testing, 1997, 16, 429-443.

[7] Zhang Z, Chen S.J, Zhang J, Improvement in the heat resistance of poly (vinyl chloride) profile with styrenic polymers., Journal of Vinyl and Additive Technology, 2011, 17, 85-91.

[8] Xu C, Wang S.S, Shao L, Zhao J.R, Feng Y., Structure and properties of chlorinated polyvinyl chloride graft copolymer with higher property., Polymers for Advanced Technologies, 2012, 23, 470-477.

[9] Kelkar D.S, Soman V.V., Study of structural, morphological and mechanical properties of PMMA, PVC and their blends., Radiation Effects and Defects in Solids., 2012, 167, 120-130.

[10] Zadhoush A, Esmaeili M, Ghaeli I., Crosslinking of plasticize PVC used in coated fabrics., Journal of Vinyl and Additive Technology, 2009, 15, 108 – 112.

[11] Peprnicek J, Duchet J, Kovarova L, Simonik J, Malak J, Gerard J.F, Poly (Vinyl Chloride) / Clay nanocomposites: X-ray Diffraction, Thermal and Rheological Behaviour. Journal of Polymer Degradation and Stability, 2006, 91 (8), 1855 – 1860.

[12] Wang D, Parlow D, Yao Q, Wilkie C., PVC-Clay nanocomposites: Preparation, thermal and mechanical properties, Journal of Vinyl and Additive Technology, 2001, 74, 203 – 213.

[13] Deka B.K, Maji T.K, Study on the properties of nanocomposites based on high density polyethylene, polypropylene, polyvinyl chloride and wood, Composites : Part A, 2011, 42, 686 – 693.

[14] Cho D, Zhou H.J, Cho Y, Andus D, Joo Y.L, Structural properties and superhydrophobicity of electrospun polypropylene fibers from solution and melt., Polymer, 2010, 51, 6005 - 6012.

[15] Xiao J.M, Chen Y.A, new micro-structure designs of a polypropylene (PP) composite with improved impact property., Materials letters, 2015, 152, 210 – 212.

[16] Ari G.A, Aydin I, Nanocomposites prepared by solution blending: microstructure and mechanical properties., Journal of Macromolecular Science; Part B, 2008, 47(2), 260-267.

[17] Sarkar M, Dana K, Ghatak S, Banerjee A., Polypropylene-clay composites prepared from indian bentonite. Bulletin of Material Science, 2008, 31(1), 23 – 31.

[18] Straznicky P.V, Laliberte J.F, Poon C, Fahr A., Applications of fiber-metal laminates, Polymer Composites., 2000, 21, 558 – 567.

[19] Carrillo J.G, Cantwell W.J, Mechanical properties of a novel fiber-metal laminates based on a polypropylene composite, Mechanical Materials. 2009, 41, 828 – 838.

[20] Zhou J, Gual Z.W, Cantwell W.J., The influence of strain-rate on the perforation resistance of fiber metal laminates, Composite structures, 2015, 125, 247 – 255.

[21] Jud K, Adhesive films for the production of aluminium honeycomb panels, Collano adhesives AG, Switzerland, 2012.

[22] Murtatha M Jamel, Parisa Khoshnoud, Subhashini Gunashekar, Nidal Abu-Zahra, Mechanical properties and dimensional stability of rigid PVC foam composites filled with high aspect ratio phlogopite mica, Journal of Minerals and Materials Charcterization and Engineering, 2015, 3, 237-247.