International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 74-78 22nd March 2014

Wear Characteristics of Polypropylene Nano $Caco_3$ Composite

[1]Thuraimurugan.P, [2]Ashok Gandhi.R
[1]PG Student CAD/CAM, Sri Sairam Engineering College, west -Tambaram, Chennai, India-44.
[2,] Asst. Professor, Department of Mechanical Engineering, Sri Sairam Engineering College, west-Tambaram Chennai, Tamil Nadu, India-600044.
Corresponding Email:thuraimurugan00@gmail.com

Abstract— ***Toady Nano composites have recently become attractive to researchers, engineers and scientists. Polypropylene is one of the widely used material in automotive and baking industry, because of its high mechanical properties like increased tensile strength, young's modulus. Polypropylene when combined with calcium carbonate ($caco_3$), its properties may get increased. Though it has many advantages over many other materials, it has its main disadvantages over its application on automobiles. Wear is one of the important parameter which affects the effectiveness of polypropylene. In this study we try to combine the Polypropylene either Nano material say calcium carbonate ($caco_3$), to reduce the wear during its wages. The specimen is prepared by using injection molding method. And the specimen is subjected to wear test in pin-on-disc wear test machine at various velocity load. The scanning electron microscope (SEM) and stand of distance result were compared to study their morphological properties.***

.Keywords— Nano composites; Polypropylene; calcium carbonate; scanning electronic microscope; wear.

I. Introduction

Over the recent years, reinforcing polymers with natural fibres has become very attractive mainly because of the good mechanical properties that can be obtained at relatively low cost. Natural fibre reinforced thermoplastics have light weight, adequate strength and stiffness, and low cost and can be easily produced by conventional plastics processing techniques. The use of natural fibres as an alternative of glass fibres is also driven by ecological reasons and because natural fibres have several advantages. They are low cost fibres, highly available with low density and high specific properties as well as biodegradable. However, their potential use as reinforcement is greatly reduced due to their incompatibility with the hydrophobic polymer matrix, their poor resistance to moisture and their tendency to form aggregates during processing. Poor mechanical and physical properties of natural fibre reinforced composites are frequently attributed to a weak fibre matrix interface. Therefore, different additives able to react with the fibre and the matrix are frequently added in the formulations.

Poly(propylene) (PP) is a useful commodity polymer with outstanding properties such as low density, good surface hardness, very good abrasion resistance, excellent electrical properties, as well as good mechanical and barrier
properties to water. It also has low cost, worldwide production, simplicity of processing, capability to burn without producing toxic emissions, working security, and recyclability.

Generally the young's modulus has been increased with the addition of wood flour to polypropylene, whereas tensile strength, strain at break and fracture toughness were observed to decrease as fibre content increased[1]. When maleated polypropylene (MAPP; Epolene G-3003e) was used as the coupling agent leads to an increase in the tensile strength of the composites, compared with the specimens made of pure polypropylene. And also for those composites containing the coupling agent, the creep deflection was significantly lower than those made without any coupling agent[2]. CNFs formulated into wood flour (WF)/maleated polypropylene (MAPP)/polypropylene (PP) composites by high shear blending alone improved flexural properties. The adhesion between WF and PP/MAPP matrix was good (SEM), but CNF adhesion to the PP/MAPP matrix was poor [3]. The incorporation of hemp fibre increases the tensile (strength and modulus) and flexural properties of the MAPE matrix(maleated polyethylene. The increase in hemp content also leads to higher water uptake and longer saturation time. After ageing in water, the mechanical properties and thermal stability were unchanged for samples up to hemp content of 30%[4]. The water absorption and thickness swelling of the nano composites decreased with increasing with amount of the SWCNTs and maleic anhydride grafted polyethylene (MAPE) in the panels[5]. Composites of vinyltrimethoxy silane grafted high density polyethylene and wood flour were produced by compounding in a twin-screw extruder showed the reduced creep deformation [6]. Stiffness is completely independent of the presence or absence and also of the amount of the functionalized polymer [7]. This result agrees well with some literature sources claiming that the presence of maleinated PP does not influence stiffness[11,16].
Ichazo et al. founds that the tensile strength of the composites increase by 40% and the elongation at break approximately decreased by 82% for various compositions of wood flour with PP [8]. The tensile test results of the specimen made by adding the sawdust and wheat flour with pure PP samples revealed that

the average tensile strength of pure PP was decreased by the addition of both sawdust and wheat flour [9]. On the otherhand flexural strength, stiffness, and yield stress of the samples were decreased regardless of type of weathering when the composite of polypropylene (PP), and pinus radiata sawdust wich is prepared by hot mold press[10]. Scanning electron microscopy images of samples showed a considerable numbers of voids and cavities resulting a poor interfacial bonding[10,21]. The incorporation of maleated polypropylene (MAPP) coupling agent in composition with saw dust of pine wood flour improves the stability of the composite[11]. When the wood content was enough higher in the composite, the particles were uniformly distributed in the PP matrix[12]. And also the WPC compounds needed more heat to melt. The use of MAPP improves interaction and adhesion between the fibers and matrix leading to better matrix to stress transfer[12]. The chemical bonding of wood fillers and PP matrix is more important for the improvement of the adhesion properties than the surface compatibility[7,13,17,20]. Wood fillers can be completely isolated and covered by PP owing to their high wetability to wood cell wall and high permeability into narrow macro-cavities[13,24]. The coupling agents silane (A-1100) increases tensile strength at break of the composites by about 66-80% in the composition of the wood filler (beech) in comparison with pure polypropylene matrix , indicating that they improved the adhesion at the filler/matrix surface[14]. In the polypropylene as the matrix and rice-husk flour as the reinforcing filler the tensile strengths of the composites slightly decreased as the filler loading increased. Tensile modulus improved with increasing filler loading[14,15].

II. Materials and Methods

Materials

The thermoplastic polymer polypropylene was supplied by Reliance Polymers, in the form of homopolymer pellets with a density of 0.91 g/cm3 and a melt flow index of 12 g/10 min (230°C/2.16 kg). The reinforcing filler in the composites was neem and jack wood flour; the particle sizes were 80–100 mesh. WF was supplied by local vendor from Cuddalore, Tamil Nadu, India. The coupling agent used was maleic anhydride grafted polypropylene.

Composite preparation

The formulations were prepared by melt blending using a co-rotating conical twin-screw extruder. The operating conditions of extruder such as temperature and screw rotation rate were set at 1900C and 40 rpm respectively. The components were hand-blended prior to feeding the extruder until a uniform mixture was obtained. The extrudate was pelletized without immersion in water (it was cooled down to near room temperature in air). The resulting pellets were injection molded using Ray–Ran injection molding machine to produce specimens according to ASTM standard samples for tensile, impact, water absorption and flexural testing. The injection molding was performed keeping the barrel temperature at 1900C and mold tool temperature at 500C with injection periods of 15 s at 100 psi.

The water absorption measurements were made according to ASTM D570-98 specifications. The sample specimens were dried in an air circulation oven at 1080C ± 0.5 for 1 h. Later, the samples were cooled to room temperature in a desiccator, weighed and then immersed in deionized water at 23 ± 10C.

Three specimens from each formulation were used for water absorption measurements. Tensile, Impact and Flexural strengths of the samples were investigated on sample specimens prepared by injection molding. Conditioning the sample and analysis procedure followed are as per ASTM D790-03 for flexural, ASTM D-638 for tensile and ASTM D3763 for impact.

Prior to conditioning, injection molded samples were annealed at 1500C for 10 min and then were cooled down at a rate of 100C/min to have a homogenized crystallinity for all the samples and to erase any thermal history taken place during the injection molding.

Measurements

Water absorption and thickness swelling

Water absorption and thickness swelling tests of the nanocomposites were performed according to ASTM D-570 standard. Five specimens from each combination were taken and dried in an oven for 24 h at 100 ± 30C. The weight and thickness of dried specimens were measured at an accuracy of 0.001 g and 0.001 mm, respectively. The specimens were then immersed in distilled water for one week and kept at a temperature of 22 ± 20C. Weight and thicknesses of the specimens were measured after excessive water was removed from their surface. The value of the water absorption in percentage was calculated using the following equation:

$$WA(t)=[(W(t)-W0)/W0] \text{ X } 100$$

where WA(t) is the water absorption (%) at time t, W0 is the oven dried weight and W (t) is the weight of specimen at a given immersion time t.

Also the value of the thickness swelling in percentage was calculated using the following equation:

$$TS(t)= [(T(t)-T0)/T0] \text{ X } 100$$

where TS(t) is the thickness swelling (%) at time t, T0 is the initial thickness of specimens, and T(t) is the thickness at time t.

Mechanical tests

The flexural tests were measured according to the ASTM D790–03 and tensile tests were measured according to the ASTM D-638, using an Universal Testing Machine. The tests were performed at crosshead speeds of 5 mm/min. A Zwick impact tester (Model 5102, Germany) was used for the Izod impact test according to ASTM D376 standard. Five replications were tested for each treatment in both flexural and impact strength measurements.

Scanning Electron Microscopy (SEM)

Scanning electron micrographs (SEMs) were used to study the morphology of the compounds and to observe the interfacial quality between the phases. A JEOL model JSM-840A was used to take SEM micrographs at different magnifications. Fractured surfaces of the samples from the notched impact tests were coated with a gold/palladium alloy and observed at a voltage of 10 kV.

III. Results and discussion

The combination of all the compositional variables resulted in a very large number of composites. As a consequence we refrain from the presentation of all results and focus our attention on materials containing 20 wt% filler material. However, all the results are presented in figures showing general correlations. In the first two sections we present tensile properties and structure, while impact resistance is analysed in detail in the next part of the paper. General correlations and practical consequences are discussed in the last section.

Mechanical tests

Tensile and flexural properties of the composites are presented in Table 2 and compared to the properties of neat PP. As presented in Table 2, after incorporation of wood flour to the PP matrix, tensile modulus (E) and even tensile strength (σy) increased noticeably. Incorporation of 15% neem and jack wood flour to the matrix increased tensile modulus from 1.5 to 2.74 GPa, while tensile strength also slightly increased from 1.8 to 1.873 GPa. The tensile strength value decreased as the filler content increases is shown in the table 2.

Table 2: Mechanical properties of PP/wood flour composites

Sample	σ_y(GPa)	E(GPa)
PP	1.8	1.5
Flour(10)	2.258	3.328
Flour(15)	1.873	2.742
Flour(20)	1.726	2.55

But further increase in wood content (20%) led to lower tensile strength (1.726 GPa), while an increase in modulus is still observed. This result is due to increased fibre–fibre contact (aggregation) at high concentrations. Effective reinforcement by fibre is also observed from flexural properties of the composites in Table 2. Incorporation of 10% flour to PP increased its flexural modulus (Fm) compared to neat PP.

Water absorption test

Water uptake data of the composites are presented in Fig. 3. Water absorption in natural fibre composites may occur due to two major mechanisms: (1) presence of natural fibre in the compound which increases the hydrophilic behaviour of the composite, and (2) presence of filler particles in the matrix disturbing the structural homogeneity in the material, which can produce voids at the interface and may increase the ability of water molecules to penetrate the composite through capillary transport.

It is expected that suitable compatibility between the phases should lead to a decrease in both mechanisms. The maleic anhydride part of PP reacts with the hydroxyl groups on the surface of natural fibres decreasing the hydrophilic behaviour of the fibres, while good compatibility between the phases should decrease the number and size of gaps in the composite.

It can be seen in Fig. 3 that water absorption is fast initially and then gradually slows down until saturation. Increase in wood content increases both water uptake (equilibrium value) and the time to achieve it.

Adel Ramezani Kakroodi et al. [26] studied water absorption properties of different hemp fibre filled PP composites. Hemp fibre filled composite, for instance, showed a mass gain of around 18% after saturation through almost 1850 h of immersion in distilled water. Unfortunately, treating hemp fibres with a silane coupling agent did not have a noticeable impact on water uptake.

Microstructure Characterization

Microstructure of the fractured surface of specimens tested in tensile is examined using SEM. SEM images of the wood flour-PP composites at filler loading of 20 wt. % for PP matrices are shown in Fig.4(a) and (b), in 500x and 1000× magnification. From these images, it is clearly observed that there are distinct cluster and gaps between polymer matrix and wood. The patterns from wood flours that are so weakly bonded to the matrix have been released from the matrix during fracture. The failure surface is undulated with clear wood flour surfaces with visible trachaids and lumen, indicating the path of weaker part through the wood-wood interface and weakest polymer matrix.

This suggests that the interface between the wood and PP matrix is weaker due to the poor dispersion and compatibility. The dispersion of the wood flours in the PP matrix Fig. 5(a). This

ISSN:2319-6890)(online),2347-5013(print)
22nd March 2014

may be due to the different grade of plastic and other impurities in the PP.

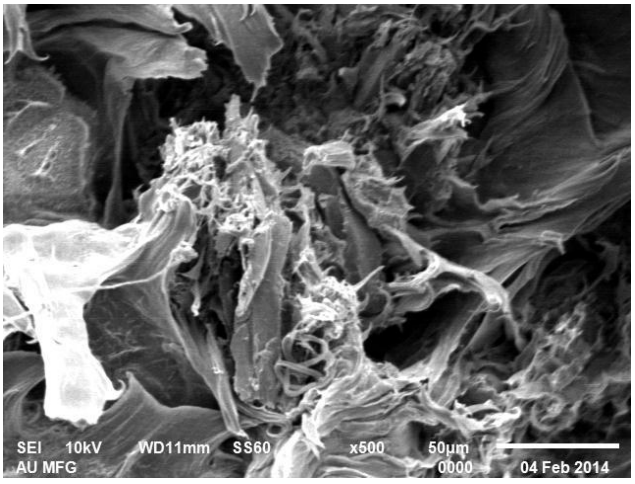

Fig 4 (a)

Fig. 4 SEM images (PP80W20) of fractured surface (tensile) of (a) ×1000, (b) x500

In some cases, the part of the wood lumen is filled with plastic that could increase the strength of the composites because of mechanical interlocking. When wood content is increased, the polymer matrix is no longer continuously distributed and many wood flours are in direct contact with one another, resulting in poor bonding at adhesion at the interface. SEM image showed that there are no clear gap between wood flour and PP matrix, indicating the good interface bonding. The fracture surface of the composite showed a very limited amount of torn matrix, suggesting that the matrix is more brittle than those composites. It is also seen that a crack running through the wood flours, and this could be an indication of stress-transfer from the matrix to the wood flours. The interfacial bonding between the filler and the PP matrix is improved due to the esterification mechanism and the fracture occurred at the filler itself. This means that the stress is well propagated between the filler and the matrix polymer, resulting in enhanced flexural strength and modulus in response to stress. In addition, the fracture surface showed a very limited amount of torn matrix, suggesting that the composite is more brittle. In general, coupling agent is randomly distributed in composites and randomly reacted with wood flours and the matrix to form graft polymerization.

Hence, grafting sites are randomly distributed on wood, and a network of coupling agent is formed at the interface. However, there is a limit for chemical coupling reaction and only part of coupling agent was grafted onto wood surface and even cross-linked at the interface.

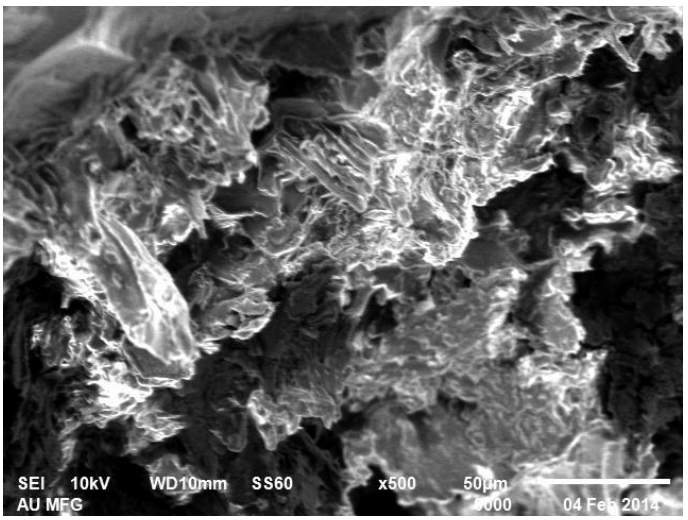

Fig. 5 SEM images (PP80W20) of fractured surface (flexural) of ×500

However, with the MAPP coupled composites, the wood flour is combined with the PP matrix through the covalent bonding or strong interfacial bonding, and interfacial fracture usually accompanied with a cross section damage of the wood flour. Hence, after the failure, the flour surface in the untreated composites is smooth.

IV. Conclusion

Natural fibre composites based on polypropylene and neem and jack wood flour were produced, and the mechanical behaviour of the composite is also discussed. SEM micrographs showed that very good compatibility between each component and PP occurred. Adding wood flour to PP led to a noticeable increase in tensile and flexural properties to some extent. Increasing wood content also led to higher water uptake in the composites. Nevertheless, samples with 10% and 20% flour showed very good stability against degradation via immersion in water after 23 weeks. SEM images of the fractured surfaces of composites confirmed that bonding strength between PP and wood flour stronger. Wood plastic composites (WPCs) are made using polypropylene (PP) with wood flour (neem and jack) as filler. WPCs sample are made through melt compounding and injection moulding based on plastic type (PP).

V. References

i. Ezequiel Pérez, Lucía Famá, S.G. Pardo, M.J. Abad, Celina Bernal. Tensile and fracture behaviour of PP/wood flour composites. Composites: Part B 43 (2012) 2795–2800.

ii. Sun-Young Lee, Han-Seung Yang, Hyun-Joong Kim, Chan-Seo Jeong, Byeong-Soo Lim, Jong-Nam Lee. Creep behavior and manufacturing parameters of wood flour filled polypropylene composites. Composite Structures 65 (2004) 459–469.

iii. Yongcheng Zhang, Jilei Zhang, Junli Shi, Hossein Toghiani, Yibin Xue, Charles U. Pittman Jr. Flexural properties and micromorphologies of wood flour/carbon nanofiber/maleated polypropylene/polypropylene composites. Composites: Part A 40 (2009) 948–953.

ISSN:2319-6890)(online),2347-5013(print)
22nd March 2014

iv. Adel Ramezani Kakroodi, Yasamin Kazemi, Denis Rodrigue. Mechanical, rheological, morphological and water absorption properties of maleated polyethylene/hemp composites: Effect of ground tire rubber addition. Composites: Part B 51 (2013) 337–344.
v. Hamed Younesi Kordkheili, Mohammad Farsi, Zahra Rezazadeh. Physical, mechanical and morphological properties of polymer composites manufactured from carbon nanotubes and wood flour. Composites: Part B 44 (2013) 750–755.
vi. Magnus Bengtsson, Paul Gatenholm, Kristiina Oksman. The effect of crosslinking on the properties of polyethylene/wood flour composites. Composites Science and Technology 65 (2005) 1468–1479.
vii. Lıvia Danyadi, Tunde Janecska, Zoltan Szabo, Ga´bor Nagy, Janos Moczo, Bela Pukanszky. Wood flour filled PP composites: Compatibilization and adhesion. Composites Science and Technology 67 (2007) 2838–2846.
viii. M.N.Ichazo, C.Albano, J.Gonzalez, R.Perera, M.V. Candal. Polypropylene/wood flour composites: treatments and properties. Composite structures 54(2001) 2838-2846.
ix. Takian Fakhrul, Rubayyat Mahbub and akian Fakhrul. Properties of Wood Sawdust and Wheat Flour Reinforced Polypropylene Composite. Journal of Modern Science and Technology Vol. 1. No. 1. May 2013 Issue. Pp.135-148.
x. Kamal Babu Adhikary, Shusheng Pang, And Mark P. Staiger. Durability of wood flour-recycled thermoplastics Composites under accelerated environmental conditions.
xi. J. Bhaskar, S. Haq, A.K.Pandey, N. Srivastava. Evaluation of properties of propylene-pine wood Plastic composite. J. Mater. Environ. Sci. 3 (3) (2012) 605-612.
xii. Diene Ndiaye, Bouya Diop, Coumba Thiandoume, Papa Alioune Fall, Abdou Karim Farota and Adams Tidjani. Morphology and Thermo Mechanical Properties of Wood/Polypropylene Composites.
xiii. FUJII Tomoyuki and QIN Te-fu. Microscopic Study on the Composites of Wood and Polypropylene.（Bulletin of FFPRI）, Vol. 1, No. 1 (No.382), 115-122, March, 2002.
xiv. Milanka Diporovic, Jovan Miljkovic, Eva Dingova. On Engineering Of Properties Of Wood-Polypropylene Composite. BIBLID: 0353-4537, (2006), 93, p 59-70.
xv. Han-Seung Yang, Hyun-Joong Kim, Jungil Son, Hee-Jun Park, Bum-Jae Lee, Taek-Sung Hwang. Rice-husk flour filled polypropylene composites; mechanical and morphological study. Composite Structures 63 (2004) 305–312.