Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 4, April -2017

A Review on polymer composites

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Abstract — *In today's world, due to increasing awareness about eco-friendly habitation various methods are adopted for decomposition and/or recycle of polymer compounds. The present study aims to study different polymeric materials and reinforcement agents used to prepare composites which are eco-friendly in nature and sometimes available as waste. The paper represents the production and characterization of polymer composites from waste polymers as base material and various reinforcement materials using different techniques as heating, hand layup, mixing and so on. These composites formed are then tested for various mechanical as well as other chemical properties.*

Keywords- *Composites, polymers, Reinforcement, Eco-friendly*

I. INTRODUCTION

Now a day's impact of everyday material is increasing rapidly, if we can reduce our carbon footprint and protect our natural heritage for coming generation. Polymer material is one of the common examples of everyday material. Polymeric material plays important role in our day to day life. A polymer material is any of wide range of synthetic or semi-synthetic organic material that are mouldable, with high molecular mass, most commonly derived from petrochemicals, but may partially natural. The huge quantity of polymeric material produced is used for household purposes, packaging and handling of the materials. Most polymeric materials used for this purpose are expanded polystyrene (EPS), HDPE, LDPE, PVC, Polypropylene, PET, etc.

One of the common example of polymer is expanded polystyrene (EPS) it is an excellent material used for packaging and for construction as it is light yet rigid foam with good thermal insulation and high impact resistance. Generally, after couple of uses it is considered as scrap. This scrap EPS is non-biodegradable and is mostly land-filled or incineration. The common methods for waste management of EPS are not very effective as it causes land pollution while the latter requires 40 m^3 air/ kg of EPS for incineration. Toxic gases like HCFC-21 and 22 have been released during incineration process. Thus, considering these cons of waste management techniques we have come up with this technique. The paper is inclined towards the recycling of the Expanded Polystyrene in the formation of bricks which could be used by the construction industry.

All polymer scrap after their uses had been thrown into landfill earlier year, but for last 15 years recycling technology had so developed that now a day the scrap polymer material is use for production of fuel in industry to save economy and would decrease the environmental problems. This type of practice is seen in European countries. The other method used for utilization of polymer scrap is making polymer composites from them. This will be done by mixing polymer blend with different reinforced agents. The current study is focused on understanding different polymer and reinforcement material properties which are suitable for making composites.

II. CONVENTIONAL METHODS TO RECYCLE POLYMER

Polymer recycling is the process of recovering different types of polymer material in order to reprocess them into varied other products, unlike their original form. An item made out of polymer is recycled into a different product, which usually cannot be recycled again.

Stages in Polymer Recycling

Before any polymer waste is recycled, it needs to go through five different stages so that it can be further used for making various types of products.

1. **Sorting: I**t is necessary that every polymer item is separated according to its make and type so that it can be processed accordingly in the shredding machine.
2. **Washing:** Once the sorting has been done, the polymer waste needs to be washed properly to remove impurities such as labels and adhesives. This enhances the quality of the finished product.
3. **Shredding:** After washing, the polymer waste is loaded into different conveyer belts that run the waste through the different shredders. These shredders tear up the polymer into small pellets, preparing them for recycling into other products.

4. **Identification and Classification of Polymer:** After shredding, a proper testing of the polymer pellets is conducted in order to ascertain their quality and class.
5. **Extruding:** This involves melting the shredded polymer so that it can be extruded into pellets, which are then used for making different types of polymer products.

Processes of Polymer Recycling

Among the many processes of recycling polymer waste, the following two are the most popular in the industry.

- **Heat Compression:** This type of polymer recycling is gaining special demand in the United States, Australia, and Japan because of its ability to recycle all types of polymer at once. It takes unsorted and cleaned polymer waste and mixes it in huge tumblers that churn the entire mixture. The major advantage of this process is that it does not require matching forms of polymer to be recycled together.

- **Monomer:** Through the elaborate and accurate monomer recycling process, major challenges of polymer recycling can be overcome. This process actually reverses the polymerization reaction in order to recycle the same type of condensed polymer. This process not only purifies but also cleans the polymer waste to create a new polymer.

Benefits of Polymer Recycling

After knowing the processes and stages of polymer recycling, it is also important to know its various benefits. A few of them are:

- **There's A Ton of Polymer:** One of the biggest reasons for recycling polymer is its huge quantity. It has been observed that 90% of the waste accumulated by the municipal corporation is a polymer waste. Apart from this, polymer is used for manufacturing various types of goods and items that are being used on a daily basis. This will not only help increase the production of polymer but will also take care of the environment.

- **Conservation of Energy and Natural Resources:** The recycling of polymer helps save a lot of energy and natural resources as these are the main ingredients required for making virgin polymer. Saving petroleum, water, and other natural resources help conserve the balance in nature.

- **Clears Landfill Space:** Polymer waste is accumulated on land that should be used for other purposes. The only way this polymer waste can be removed from these areas is by recycling it. Also, various experiments have proven that when another waste material is thrown on the same ground as polymer waste, it decomposes faster and emits hazardous toxic fumes after a certain period. These fumes are extremely harmful to the surrounding area as they can cause different types of lung and skin diseases.

The polymer composite is one of the methods of recycling of wastes polymers. The following are the review of various researchers:
Vijaya kumar Nimmagadda, M.M.M. Sarcar, Ramji Koona [1] studied the dielectric strength of the polymer composite with respect the weight of the reinforcement agent. They used materials like polyester and polypropylene as polymer matrix phase. Cobalt was used as accelerator, MEKP as a hardener and glycidoxy propyl tri-methoxy silane as a coupling agent. Sludge, Slug and Flue dust, Granite and Silica fume powder are used as reinforcing agents. Samples were prepared in the ratios of 0, 10, 20, 30, 45 and 60 of matrix material (polymer) and silane. Hand layup technique and injection moulding were used for preparing the samples. Curing time for samples is 24 hours at room temperature. The study reported the decrease in the dielectric strength with the increase in the weight of the reinforcement material. Dielectric strength is plotted with weight of slag.

I Slieptsova, B Savchenko, N Sova, A. Slieptsov [2] studied mechanical and thermal stability of the polymer sand composites. Polyolefins like polyethylene and linear low density polyethylene and PET- polycarbonate were used as polymer matrix. The average particle size 200 – 300 microns was used to facilitate homogenous mixing with the filler. Sand with a particle size from 0.2 mm to 1.2 mm was used. 2.0 weight % of di-cumyl peroxide (DCP) initiator and 3.0% of maleic anhydride was also used. The polymer-sand composite materials were prepared in two ways: a) The polymer powder and filler were mixed at room temperature and then, heated in muffle furnace at 250^0 – 270^0 C for 10 - 15 minutes and mixed in the heated twin rotor mixer. b) Polymers were melted in the single screw extruder and then fed in the twin blade mixer with hot sand by keeping the mixing time mixing time from 3 to 10 minutes. After mixing soft polymer-sand composite (PSC) was compression moulded in hydraulic press. Increase in the filling capacity of the filler agent from 50% -80%, the compressive and bending strength increases. Various physical properties like density, bending strength, tensile elongation, tensile strength and tensile module of the materials like polyolefins and polyesters and their co-polymer bends were studied. Polymer sand composites based on contaminated polyester waste have much higher properties in comparison to the systems based on polyolefins.

A.H. Bhat, H.P.S. Abdul Khalil and A. K. Banthia [3] used materials like polyhydroxy ether of Bisphenol A (Phenoxy), boric/ phosphomolybdic acid modified-red mud. Polymer modified red mud nano-composites were made by mixing different loading percentages of acid modified red mud and organically modified red mud into PVA solution. The composition of PRM materials was varied from 0-5% of RM with respect to the PVA content. The chemical bonds of the raw red mud and modified red mud were studied with a FTRI spectroscopy. The values of FTRI spectral bands of various groups like –OH, -OH bond, B-O, Si-O, P-O and Mo-O_c-Mo are compared with pure PVA and PVA modified nano-composite membrane. X-ray diffraction study was also carried out on the materials to calculate the 2θ, d-spacing (Aº). The graphs for various values of these were plotted. Transmission Electron Microscopy enables to see the polymer and filler adhesion at a nano scale. The information about the matrix is provided by TEM at nano scale.

Niharika Mohanta, Dr S K Acharya [4] studied the polymer composites using materials like epoxy resin, e-glass fiber, red mud and dust. They reported that the micro-hardness increases as the filler concentration increases. It was found that density increased with red mud filling. The tensile strength test was carried according to the ASTM D 3039-76 while length of specimen is 154mm. The tensile property decreases with addition of red mud filling. Erosion test at different angles (i.e. 30, 45, 60 and 90) by test it was seen that maximum erosion test at 60^0.

Tayfun Uygunoglu, Ibrahim Gunes, Witold Brostow, [5] studied various properties of polymer composites. The polymer matrix phase included commercially available Teknobond 300 (liquid di-glycidyl ether of bis-phenol –A) epoxy resin along with hardener NN0(2-amineethylethane-1,2-diamin) was mixed in 2:1 ratio. The reinforcement phase included boron and other wastes of various sizes (max size of 500 μm). The weight percent of epoxy resin was varied and accordingly samples were prepared. The specimens were tested for compressive, flexural strength, ultrasonic pulse velocity, water absorption, apparent porosity, dry unit weight, slum flow and viscosity. They compared the age of curing along with the properties. The increase of waste material content resulted with the increase of internal friction between particles and thus, PCBs has higher viscosity values and lower slump flow values when compared to control mixtures. The composites containing 50% waste material shows the highest compressive strength at all ages. The flexural strength decreased largely first but later increased slightly with increasing waste content in 7 days aged curing products. The voids (water absorptive capacity) were found maximum in polymer composites at waste content of 66%. The ultrasonic pulse velocities of polymer composites were increased with increasing waste content.

Haiying Wang, Yilong Bai, Sheng Liu, Jiali Wu, C.P. Wong [6] prepared samples of the same resin matrix but were filled with spherical silica particulate by 0, 14, 21, 28, 33, and 39% filler volume fractions. The mean diameter of silica particulate was about 4 μm. The curing condition was 250°C for 40 min. To avoid the thickness effect, efforts were made to obtain thin, void-free sample sheets (about 0.40 mm) of uniform thickness during the process. The specimens were about 50 mm in length, 2.4 mm in width, and 0.4 mm in thickness. TMA tests show that the glass transition temperature (*T*g) of these samples is about 150°C. Thin strips of specimen were cut out of the formed composites and pure tensile tests were conducted on the six-axis mini-tester with fixed strain rate of 3.125×10-3/s at ambient temperature, 50, 75, 100 and 115°C, respectively. Two to six specimens were tested under each testing condition. Mechanical properties of the materials with different filler contents are compared in terms of Young's modulus, yield stress and flow stress. The Young's modulus is obtained from the initial slope of the stress–strain curve. The young's modulus increases with the increase in the filler content at ambient temperature and at 115ºC. The stresses at 0.2% inelastic strain, $\sigma_{0.2}$ is plotted with volume fraction of particulate at different temperatures. As the temperature decreases the value of $\sigma_{0.2}$. The addition of silica filler to epoxy resin increases as the filler concentration increases. At elevated temperatures the yield stress, flow stress and other material properties varies with monotonically with particulate volume. The addition of reinforcement particles gives large distribution of stress concentration.

Hanna Haase, Tom Schanz [7] studied the hydro-mechanical properties and micro-fabrics of clay and polymer composites. The polymeric material used is high molecular weight polyacrylamide polymer. Three types of sands were used namely MX 80 Bentonite, Calcigel Bentonite and Spergau Kaolin. The hydro mechanical properties like hydraulic permeability were studied. With respect to their hydraulic permeability, composites differ from their pure clay counterparts by different tendencies depending on polymer charge. In general, due to composite formation with PAA+ an increase in hydraulic permeability can be observed. For bentonites, this increase amounts about 0.5–1 order of magnitude along the whole void ratio range tested, Spergau kaolin-PAA+ composites, on the other hand, do not differ significantly from their pure clay counterparts. In case of PAA composites, the tendency are vice versa, i.e., hydraulic permeability is decreased. This behaviour is most evident for Spergau kaolin clay with reductions by about 2 orders of magnitude. However, PAA composites of bentonites have reduced hydraulic permeability only in case of mono-valent counterions (MX 80), whereas in case of predominantly divalent counterions (Calcigel), hydraulic permeability does not differ from pure clay values. Similarly, the effect of PAA− composite formation on hydraulic permeability is of no significance, which is independent of the dominant clay mineralogy.

APPLICATIONS

Polyolefins and polyesters as well as their blends allow producing thinner and lighter parts with high rigidity and excellent thermal stability [2]. It was found that reinforcement material like boron and other wastes along with epoxy resin could be used in various mechanical applications [4]. Polymers composites are used more in construction work and also in other industries. Epoxy glues are used as highly performing adhesives in concrete prefabricated applications. [5]

CONCLUSION

Polymer materials are the materials which are mainly responsible for the pollution and causes damage to the environment. The various methods of decomposition like land-fills, incinerations, etc. are not efficient. To overcome with these techniques, researchers came with the techniques of recycling these polymers. By utilizing the advantageous properties of the polymer as a matrix phase and reinforcement materials like sludge, slug, sand, red mud, etc. polymer composites can be prepared. These composites have good mechanical properties like tensile strength, flexural strength, density and many other properties to make its use in commercial industrial purpose. The study also suggests an effective method to recycle the polymers and reduce the carbon footprints of environment.

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