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A STUDY ON ABS/MONTMORRILONITE NANOCOMPOSITE

Mohamed Ansari[1], Hanafi Ismail[2], [3]Ahmad Baharuddin
[1]*Faculty of Engineering and Computer Technology,*
Asian Institute of Medicine, Science and Technology,
Sungai Petani 08000 Kedah Darul Aman
[2]*School of Materials and Mineral Resources Engineering, Engineering Campus,*
[3]*School of Mechanical Engineering, Engineering Campus,*
Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang.

ABSTRACT

Nanocomposites are an emerging class of mineral-filled plastics that contain relatively small amounts (<10%) of nanometer-sized clay particles. These minerals significantly enhance the mechanical and thermal properties of the base resin, as well as improve barrier performance and flame retardancy. All of these performance benefits are available without increasing the density or affecting any properties of the base polymer. This paper is a preliminary study on the methodology of preparation and characterization of an ABS/Montmorillonite nanocomposite which would be used to produce prototypes viz.Fused Deposition Modeling (FDM) process.

Keywords *Fused Deposition Modeling (FDM), Standard Triangularization Language (STL), Acrylonitrile Butadiene Styrene (ABS), Montmorillonite (MMT), Melt compounding,*

1.0 INTRODUCTION

The field of nanocomposites is at a budding stage and has a wide scope. Nanocomposites incorporate low loading (less than 10% by weight) of high aspect ratio mineral or carbon nanotube fillers that have a unique structure. The resultant high surface area and high aspect ratio fillers provide similar reinforcing performance of traditional minerals and fibers used in plastics, and yet do not increase density since loading levels are low. Due to the nanometer size of the particles, which is smaller than the wavelength of visible light, the reinforced polymer remains transparent. Other characteristics of the composites include high barrier performance and improved thermal stability, which make these compounds suitable for many applications[1].
Fused deposition modeling (FDM) is an extrusion-based rapid prototyping (RP) process begins with CAD (Computer Aided Design) representation of the part that is cross-sectionally sliced. The part is built up by depositing on thin layer of hot thermoplastic resin, which is applied by using an application head. The thermoplastic is fed into the head as a wire that is heated inside the head and then laid onto the surface of the platform to form each slice pattern. The platform is then lowered and after the previous slice has cooled and solidified, the next slice pattern is laid down. The FDM process is capable of making a prototype out of the same material as the final part, although some post forming consolidation (by heating) may be necessary to obtain properties that are comparable to the moulded part[2].

In addition, FDM can be used for pattern generation and rapid manufacturing. Environmental exposure does not alter the size of the part or its features. ABS prototypes demonstrate 80% of the strength of injection moulded ABS which make them very suitable for functional testing and can be directly used as finished production parts for certain applications. Ideal for strong parts exposed to temperature, water and many chemicals. High level of finish can be achieved by sanding and other post processing techniques. ABS parts can be further machined, polished or electroplated.

2.0 METHOD AND MATERIALS:

2.1 Melt Compounding:

This approach involves melt compounding the nanoclay and polymer. This method offers significant promise, since the modifying of plastic compounds is a custom business and well suited for many applications. In combination with the pretreatment of the clay itself, the compounding parameters and mixing-screw profile are important variables. Since the clay is an aggregate of thousands of individual platelets, it is critical that those platelets be separated prior to compounding. If the platelets are not separated, it is unlikely that the shear forces generated during the compounding process will be sufficient to overcome the forces holding the aggregates together. Hence, less-than-optimum exfoliation or dispersion will result. The process of opening up the spaces between the plates, which are known as galleries, is called intercalation. The right clay treatment is required to allow for intercalation; after that, it is necessary to make the intercalate compatible with the host polymer so some properties are enhanced without sacrificing others. This allows for improvement in the strength without embrittling the plastic. Secondly, melt compounding must occur such that the prepared clays get maximum dispersion without degrading the polymer. Today, several nanoclay compounds are commercially available and have been used successfully[7.].

Treatment process: The right clay treatment is required to allow for intercalation; after that, it is necessary to make the intercalate compatible with the host polymer so some properties are enhanced without sacrificing others. This allows for improvement in the strength without embrittling the plastic. Secondly, melt compounding must occur such that the prepared clays get maximum dispersion without degrading the polymer. Today, several nanoclay compounds are commercially available and have been used successfully[7].

2.2 MATERIALS:

2.2.1 ABS:

Acrylonitrile Butadiene Styrene is a blend of Polystyrene (PS) and acrylonitrile (Styrene – acrylonitrile, SAN) and acrylonitrile – butadiene – acrylonitrile (AB) (about 65% SAN, 35% AB). It is widely used because of the possibility of varying the amounts of components, yielding a wide variety of grades with different combinations of strength and rubberyness. The addition of different additives also increases the total range of properties attainable.

2.2.2 General properties of ABS:

Combined toughness due to rubbery phase; Chemical resistance due to acrylonitrile; Excellent moldability due to PS; Good strength (SAN); Maximum service temperature about 200^0F – this is low compared with other commercial polymers[3].

2.2.3 Nanoclays:

Due to cost and availability, there is currently great deal focuses on nanoclay fillers are more expensive than glass, yet much less expensive than carbon nanotubes. A small amount of nanoclay fillers required to enhance properties of the material to compete more effectively with traditional glass-fiber reinforced.

The most important factor in the success of polymer reinforcement is the aspect ratio of the clay particle. Clays with a platy structure and a thickness of <1 nm are optimal. The length and width of these choice clays are in the micron range, with aspect ratios between 300:1 and 1500:1.

The surface area of the exfoliated platelets is usually in the range of 700 m^2/g. The nanoclays of commercial interest to date are hydrotalcite, montmorillonite, mica fluoride, and octasilicate. Hydrotalcite and octasilicate have limits of use both from a physical and a cost standpoint. Mica fluoride is synthetic clay, while montmorillonite is natural. Montmorillonite has the widest acceptability for use in polymers. It is a type of smectite clay that can absorb water, and it is a layered structure, with aluminum octahedron sandwiched between two layers of silicon tetrahedron. Each layered sheet is slightly less than 1 nm thin (10 Å), with surface dimensions extending to about 1 µm or 1000 nm. The aspect ratio is about 1000 to 1 and the surface area is in the range of 750 m^2/g. Montmorillonite clays are relatively common throughout the world. Deposits of commercial clays are referred to as bentonite, which generally contains in excess of 50% montmorillonite.

Because montmorillonite clay is hydrophilic, it is not inherently compatible with most polymers and must be chemically modified to make its surface more hydrophobic. The most widely used surface treatments are ammonium cations, which can be exchanged for existing cations already on the surface of the clay. The treatments work on the clay to minimize the attractive forces between the agglomerated platelets. Clay platelets must be purified and chemically modified before they can be used as nanofillers.The process of separating the nanoclay platelets is referred to as the intercalation process. Without this separation, the nanoclay would not be capable of allowing the polymer to penetrate the platelet layers. In the exfoliated form, nanofillers have a very small flexible-platelet-type structure. The thickness of the platelet is in the nanometer range, while the length and width are between 0.1 and 2 µm. Because of this, a single gram of exfoliated nanoclay will contain over a million individual particles[7].

3.0 EXPERIMENTAL FOCUS

The discovery of novel materials, processes, and phenomena at the nanoscale, as well as the development of new experimental techniques for research provide fresh opportunities for the development of innovative nanostructured materials. Nanostructured materials can be made with unique nanostructures and properties. This field is expected to open new venues in science and technology[4].

Acrylonitrile–butadiene–styrene (ABS)/montmorillonite nanocomposites are normally prepared by using a direct melt intercalation technique by blending ABS and organophilic clay of different particle sizes in a twin screw extruder to prepare a thin filament of diameter 1.77mm. The thin filament thus obtained is fed in a FDM machine to prepare the test specimens. Their tensile and flexural properties would be determined by a universal testing machine. Their structure and flammability properties would be characterized by X-ray diffraction, high resolution electronic microscopy (HREM), thermogravimetric analysis (TGA) and cone calorimeter experiments[6]. The structure of the nanocomposite would be studied to determine the properties. The properties of the nanocomposites prepared with different proportions of organophilic nanoclay would be studied in this project. This study is aimed at comparison of the mechanical properties of the samples prepared with the existing material and the nanocomposite ABS with FDM process. This project work is under progress. Therefore, we could not give any results at this stage.

4.0 DISCUSSION

The prototype fabrication process was studied on a FDM 3000 machine at the School of Mechanical Engineering laboratory with the existing material (ABS - P 400) forming a 1 inch cube solid object. The characterization of the existing material is under progress. The objective of this work is to improve the properties of the existing material used for Rapid Prototyping of functional parts.

FDM parts have a ribbed appearance because of plastic is extruded in horizontal layers, which can be easily sanded and polished to smooth finish. Extensive snap and living hinge features could fail due to process and material limitations. FDM could be a slower process for very large build volume parts subject to part complexity and shape. Thin wall and shell parts are faster to make than solid builds. The use of nanocomposite ABS would certainly enhance the properties of the prototypes produced viz. FDM process.

Compatibilization between the nanoclay and the base polymer (ABS) is another underlying critical success factor that must be highlighted. Successful nanocomposite with a consistent repeatability is largely depends upon the level of compatibility between the nanoclay and polymer (ABS).

Previously, most nanoclay research involved the incorporation of nanoclay into a polymer during the polymerization process. With this method, exfoliation or dispersion of the clay particles is more approachable. But the batch sizes required for polymerization is very low—and therefore the cost—has resulted in challenging economics for many commercial applications. To date, only a few commercially available compounds have been made using this method.

5.0 CONCLUSION

Overall, the benefits of layered manufacturing and nanostructured ABS are combined to fabricate complex shapes, without a mould. The effect of nanoclay particles such as montmorillonite on improving mechanical and thermal properties of ABS copolymer is a correlation between polymer morphology, strength, modulus, toughness, and thermal stability of ABS nanocomposites to be studied as a function of layered silicate content. The potential drawbacks are the cost of the binders needed in the initial layering, the dimensional accuracy, the binder burnout, and the transfer ability of a binder delivery system to a variety of ceramic materials. When performance is more important than cost, then layered manufacturing used for a low-volume product or small number of units may be competitive with conventional process such as forging, casting, moulding or machining. FDM parts are strong and rigid which makes them suitable for functional testing Cost effective solution for small to medium size parts in shortest lead time.

REFERENCES

1. A multiclient report by Principia Partners "Nanocomposites 1999" Polymer Technology for the Next Century.
2. A.Brent Strong, 2000 "Plastics Materials and Processing" 2nd edition, Prentice-Hall Inc, USA
3. L.L. Faulkner, 1996 "Introduction to Plastics and Composites" Marcel Dekker Inc. pp 128-129
4. Bushan, 2004 "Handbook of Nano Technology" Springer – Verlag Berlin Heidelberg
5. Myer Kutz, 2002 "Handbook of Materials Selection" John Wiley & Sons, Inc. pp 1120-1123
6. Wang S.; Hu Y.[1]; Lin Z.; Gui Z.[1]; Wang Z.[1]; Chen Z.[2]; Fan W.[1] "Flammability of ABS/Montmorillonite nanocomposite" Polymer International, 1 June 2003, vol. 52, no. 6, pp. 1045-1049(5) John Wiley & Sons, Ltd.
7. Lawrence A Acquarulo and Charles J.O'Neil, "Enhancing Medical Device Performance with Nanocomposite Polymers" @2002Medical Devce Link, Medical Device & Diagnostic Industry.