Comparative Studies of Mechanical Properties of UHMWPE Composites

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Abstract- *Many advanced engineering materials today are built from polymer with various types of reinforcement: organic and inorganic materials, minerals, short fiber etc. These polymer composites offer a wide range of advantages as compared to metals and ceramics such as ease of processing, light in weight and low cost with comparable mechanical strength. Ultra-high molecular weight polyethylene (UHMWPE) is one of the most important, commercialized polymer that possesses high performance and unique properties such as biocompatibility, chemical inertness, excellent impact strength and highest abrasion resistance relative to other thermoplastics. A number of research have been conducted using various types of filler reinforcement to improve the mechanical properties and wear resistance of UHMWPE.*

Keywords- composites, UHMWPE , mechanical properties, comparision.

I. INTRODUCTION

Ultra-high-molecular-weight polyethylene (UHMWPE) is a thermoplastic polyethylene. Also known as high-modulus polyethylene (HMPE), it has extremely long chains, with a molecular mass usually between 3.5 and 7.5 million amu. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions. This result in a very tough material, with the highest impact strength of any thermoplastic presently made.UHMWPE is odourless, tasteless, and nontoxic.

It embodies all the characteristics of high-density polyethylene (HDPE) with the added traits of being resistant to concentrated acids and alkalis, as well as numerous organic solvents. It is highly resistant to corrosive chemicals except oxidising acids; has extremely low moisture absorption and a very low coefficient of friction; is self-lubricating (see boundary lubrication); and is highly resistant to abrasion, in some forms being 15 times more resistant to abrasion than carbon steel. Its coefficient of friction is significantly lower than that of nylon and acetyl and is comparable to that of polytetrafluoroethylene (PTFE, Teflon), but UHMWPE has better abrasion resistance than Polytetrafluoroethylene (PTFE) [1].UHMWPE is a type of polyolefin. It is made up of extremely long chains of polyethylene, which all align in the same direction. It derives its strength largely from the length of each individual molecule (chain). Van der Waals bonds between the molecules are relatively weak for each atom of overlap between the molecules, but because the molecules are very long, large overlaps can exist, adding up to the ability to carry larger shear forces from molecule to molecule. Each chain is bonded to the others with so many vander Waals bonds that the whole of the inter-molecule strength is high. In this way, large tensile loads are not limited as much by the comparative weakness of each vander Waals bond.

When formed into fibres, the polymer chains can attain a parallel orientation greater than 95% and a level of crystallinity from 39% to 75%. In contrast, Kevlar derives its strength from strong bonding between relatively short molecules. The weak bonding between olefin molecules allows local thermal excitations to disrupt the crystalline order of a given chain piece-by-piece, giving it much poorer heat resistance than other high-strength fibres. Its melting point is around 130 to 136 °C (266 to 277 °F),[8] and, according to DSM, it is not advisable to use UHMWPE fibres at temperatures exceeding 80 to 100 °C (176 to 212 °F) for long periods of time. It becomes brittle at temperatures below −150 °C (−240 °F)[1].

Under tensile load, UHMWPE will deform continually as long as the stress is present— an effect called creep.

When UHMWPE is annealed, the material is heated to 135 °C to 138 °C in an oven or a liquid bath of silicone oil or glycerine. The material is then cooled down at a rate of 5 °C/h to 65 °C/h or less. Finally, the material is wrapped in an insulating blanket for 24 hours to bring to room temperature.

II. OBJECTIVES OF PRESENT WORK

The objectives of the present investigation are as given below:

- Prepare nano alumina (50 gram quantity) by sol-gel method.
- Develop UHMWPE composites reinforced with ceramic oxides of different weight percentage (2 wt% , 6 wt %, 10 wt %) of grain size 70-80 nanometer for nano alumina and 100-200 micrometer for micro alumina.
- Evaluate dry wear characteristic using pin on disc tribometer.
- Analyse surface roughness characteristics by 3-D surface profilometer.

III. EXPERIMENTATION

Nano Al2O3 was prepared by sol-gel method using aluminium metal (commercially available foil,60g) and sodium hydroxide (30 wt %) solution. The process flow sheet used in the present work is presented in the figure 4.3, and photographs of the sol gel process in figure 4.5. Nano Alumina Hydroxide was thoroughly washed with distilled water several times until it is free from chloride ions (absence of precipitate when supernatant liquid was tested with Silver Nitrare). The Nano Aluminium Hydroxide was dried at room temperature for about 48 hours. It was packed in self sealing plastic bags with label and stored in dessitator. It was characterised for particle morphology and size by Scanning Electron Microscopy (SEM).

Flow chart for the preparation of alumina (Al2O3) powder by sol-gel method has been presented in figure FL 4.2.1.Aluminum (Al) foil (having a thickness of 0.016mm to 0.02 has been cut into small pieces approximately 8-10mm. A stock solution ofNaOH 25weight % has been prepared. 60 grams of aluminum foil pieces have been taken into 2000ml capacity glass round bottom flask. About 200ml NaOH solution is carefully added into Round Bottom (R.B) flask and R.B flask is kept in a heating mantle. A water condenser has been fixed and clamped. Contents of the R.B flask has been carefully heated for speeding up of complete dissolution of aluminum foil. This process is known as refluxing as shown in flow chart.After cooling and removing the condenser, the contents of R.B flask have been filtered through Whatman 41 filter paper through vacuum filtration process to obtain clear solution of sodium aluminate (NaOAl).

Equal volumes of sodium aluminate and isopropyl alcohol (IPA) have been taken in a clear beaker. The content of this beaker namely organic-inorganic mixture have been carefully transferred into round bottle flask(2000ml) the content of the R.B flask have been refluxed as described above.After 48 hours of refluxing the contents of R.B flask have been cooled to room temperature. This process is known as alkoxylation. Excess isopropyl alcohol has been collected by distillation process. The remaining solution which is left over consists of aluminium isopropoxideand has been found to have a pH value in the range of 12-14..Aluminium isopropoxide has been collected in a clean dry beaker of 1000 ml capacity.

IV. RESULT AND DISCUSSION

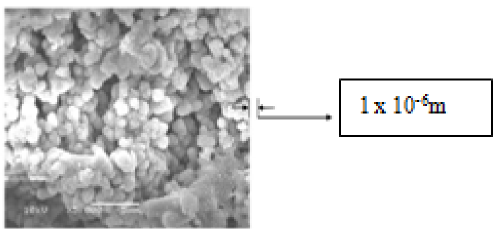
The scanning electron micrographs of nano alumina (Al2O3) powder observed at a magnification of 5,000X and 25,000X have been presented in the figure 5.1.

From figure 5.1(a), it can be observed that the nano alumina particles are spherical in shape and the particles are agglomerated. The average size of an agglomerated secondary particle has been found to be approximately 100nm.

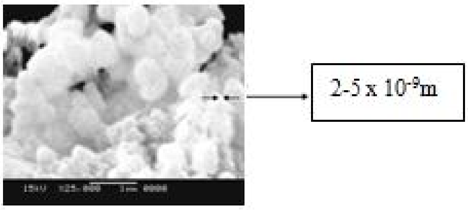
From figure 5.1(b), which is taken at a higher magnification, it can be observed that the agglomerates consist of small primary particles. The average size of small particle (which agglomerated into secondary particle) has been found to be in the range of 2nm to 5nm. The size of the secondary agglomerated particles of nano alumina (Al2O3) powder is in the range of 70nm to 100 nm.

In the encyclopaedia of Nano Science and Nano Technology and earlier research workers have defined nano particles according to their physical dimensions as particles with a size range of 1nm to 100 nm. A typical nano particle most often consists of several small “primary particles”. The size of nanoparticles usually refers to the “secondary” particle size. Primary particles agglomerate into these “secondary” particles. Similar observations have been reported by earlier research workers. The observations made in this investigation are similar to the observations reported by earlier research workers.

(a) taken at a magnification of 5,000X



(b) taken at a magnification of 25,000X



V. CONCLUSION

- Nano alumina was prepared by Sol-Gel method.
- Nano Zinc Oxide was prepared using zinc acetate and sodium oxide.
- UHMWPE composites were prepared in multi cavity split dies by hot compression molding at a temperature of 130°C± 2°C for 90±2minutes.
- characteristics of UHMWPE composites reinforced with ceramic oxides.
- To characterize the worn out surfaces by 3-D surface profilometer.

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