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Processing and Characterization of PEEK with CKP Particles: Use of Industrial Waste in Composite Making

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Abstract: Composites are materials consisting of two or more chemically distinct constituents, having a distinct interface separating them. One or more discontinuous phases are embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed the matrix. Matrix can be metallic, polymeric or ceramic. When the matrix is a polymer, the composite is called polymer matrix composite. Fillers are widely used to improve the properties of matrix materials. The particle can be either randomly oriented or preferred oriented. In the present work CKP particles are reinforced in unsaturated PEEK resin. Nickelnephthalate as accelerator is mixed thoroughly in PEEK resin followed by cobalt acetate as hardener prior to reinforcement. The reinforcement improves the flexural strength, flexural modulus, tensile strength.

Keywords: Composite, matrix, reinforcement, CKP, PEEK.

I. INTRODUCTION

Polymers find wide engineering applications due to their low density, reasonably good strength and wear resistance as compared to monolithic metal alloys. For weight sensitive uses, undoubtedly they are the most suitable materials but prohibitive costs and stability of properties pose challenge for the researches in the process of development of composites. In order to bring down the cost, cheap and easily available fillers are a viable option. However, mechanical properties of the composites should not be degraded in the attempt of reducing the cost. Therefore, purpose of using fillers is twofold: first, to improve the mechanical, thermal or tribological properties, and second, to reduce the cost of the component. Specifically, in polymers, a large number of materials such as minerals and inorganic oxides (alumina and silica) are mixed with thermoplastics like polypropylene and polyethylene. Through judicious control of reinforcing solid particulate phase, selection of matrix and suitable processing technique, composites can be prepared to tailor the properties needed for any specific application.

Research is underway worldwide to develop newer composites with varied combinations of fibers and fillers so as to make them useable under different operational conditions. The improved performance of polymer composites in engineering applications by the addition of filler materials has shown a great promise and so has become a subject of considerable interest. Abu Bakar, Cheng, Tang, Yu, Liao, Tan, Khor, Cheang repored [7] that Polyetheretherketone-hydroxyapatite composites were developed as alternative materials for load-bearing orthopedic applications. The amount of hydroxyapatite (HA) incorporated into the polyetheretherketone (PEEK) polymer matrix ranges from 5 to 40 vol% and these materials were successfully fabricated by injection molding. Jones, Leach and Moore [6] evaluated PEEK and the composites for increasing test severities for strength characteristics; stress concentration, loading form and test temperature are considered. Wang, Xu, Shen, Xue [5] found that nanometer SiC reduces the friction significantly and that 2.5 wt. % to 10.0 wt. % SiC as filler is very effective in reducing the wear of PEEK. Ceramic filled polymer composites have been the subject of extensive research in last two decades.

Recently, it has been observed that by incorporating filler particles into the matrix of fibre reinforced composites, synergistic effects may be achieved in the form of higher modulus and reduced material costs, yet accompanied with decreased strength and impact toughness. The physical and mechanical characteristics of a polymeric matrix can be modified by adding a solid filler phase to the matrix body during the composite preparation. Various kinds of polymer matrix composites reinforced with ceramic powders have been the subject of extensive research in last two decades.

II. EXPERIMENTAL

A. Processing

1) Matrix: Poly-ether-ether ketone (PEEK):

PEEK is a strong and stiff thermoplastic material that is often used in applications where performance at elevated temperatures is required. PEEK has outstanding chemical resistance as well as resistance to steam and hot water. Virgin PEEK or unfilled PEEK is naturally abrasion resistant. Bearing grade PEEK has enhanced bearing and wear properties.

2) Filler: Cement Kiln Powder (CKP)

Cement kilns are used for the pyro-processing stage of manufacture of Portland and other types of hydraulic cement, in which calcium carbonate reacts with silica-bearing minerals to form a mixture of calcium silicates. Over a billion tonnes of cement are made per year, and cement kilns are the heart of this production process: their capacity usually define the capacity of the cement plant. As the main energy-consuming and greenhouse-gas–emitting stage of cement manufacture, improvement of their efficiency has been the central concern of cement manufacturing technology.

During the cement making process, large amounts of fine material are given off and carried out by the flow of hot gas within a cement kiln. This kiln dust isn't incorporated into the cement clinker formed within the kiln, and instead becomes a waste byproduct. The potential exists to reuse CKP within the cement making industry as well as in other fields due to its lime content and its cementitious properties. Today's technology minimizes the generation of CKP and allows most, and sometimes all of the cement kiln dust to be reused, minimizing air pollution and disposal problems. In some facilities though, cement kiln powder is still an issue and some cement kilns don't reuse all of the dust they produce. The material is collected using pollution control systems like cyclones, electrostatic precipitators, or bughouses, and is then land filled either on or off site. Some facilities also have stockpiles of the cement kiln powder that was produced before technology allowed for its reuse in cement production.

B. Composite Fabrication

CKP particles (collected from OCL Ltd.) with average size 100μmare reinforced in unsaturated PEEK resin (modulus 2.25 GPa, density 1.15 gm/cm^3) to prepare the composites. Two percent (2%) nickelnephthalate (as accelerator) is mixed thoroughly in PEEK resin followed by 2% cobalt acetate (CA) as hardener resin prior to reinforcement. The dough (PEEK resin mixed with CKP) is then slowly decanted into the glass tubes, coated beforehand with uniform thin film of silicone-releasing agent. The composites are cast by conventional hand-lay-up technique in glass tubes so as to get cylindrical specimens (dia 9 mm, length 120 mm). Composites of three different compositions filled with 0 and 10wt% of CKP respectively are made. The castings are left to cure at room temperature for about 24 h after which the tubes are broken and samples are released.

C. Evaluation of Tensile Strength

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen and straight-sided specimen with end tabs. A uniaxial load is applied through the ends. The ASTM standard test method for tensile properties of fiber–resin composites has the designation D3039-76. It recommends that the specimens with fibers parallel to the loading direction should be 11.5 mm wide and mode with 4-6 plies. Length of the test section should be 100 mm. The test-piece used here is of dog-bone type and having dimensions according to the standards. The tensile test was performed on the universal testing machine and results were analyzed to calculate the tensile strength of composite samples.

D. Evaluation of Flexural Strength The flexural strength is a measure of resistance of the composite to bending. It is the ability of the material to withstand bending before reaching the breaking point. 3 point bend test was conducted for all the 3composites and the flexural strength for each of them was evaluated.

Flexural Yield Strength is reported instead of flexural strength for materials that do not crack in the flexure test. The strength of a material in bending, expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in MPa is equal to: $\frac{3LP}{2bd^2}$

Where P = the load applied to a sample

L=test length

b=*width*

d=thickness

Flexural modulus is the ratio, within the elastic limit, of the applied stress on a test specimen in flexure, to the corresponding strain in the outermost fibers of the specimen. The Flexural test measures the force required to bend a beam under 3 point loading conditions.

The data is often used to select materials for parts that will support loads without flexing. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end use environment.

Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three point bending at a specified rate. The parameters for this test are the support span; the speed of the loading; and the maximum deflection for the test. These parameters are based on the test specimen thickness, and are defined differently by ASTM.

III. RESULT AND DISCUSSION

Tensile strength measures the force required to pull something such as a structural beam to the point where it breaks. The addition of fillers enhances the tensile strength of the composites.

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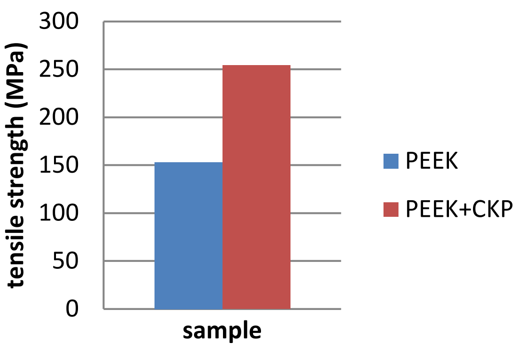

Fig.1 chart showing the Effect of CKP on tensile strength of PEEK composites.

Flexural modulus is the ratio, within the elastic limit, of the applied stress on a test specimen in flexure, to the corresponding strain in the outermost fibers of the specimen. The Flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing.

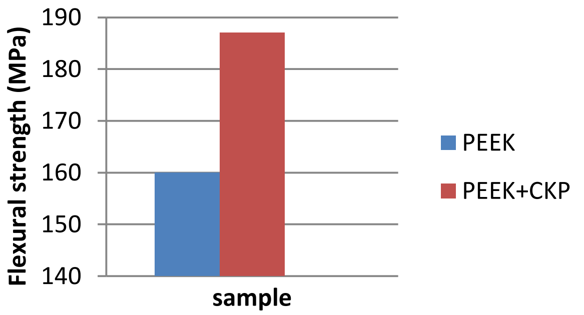

Fig.2 Effect of CKP and SIC filler on flexural strength of PEEK composites.

The flexural strength of the composite drastically increases with the addition of the filler material as shown in Fig. 2

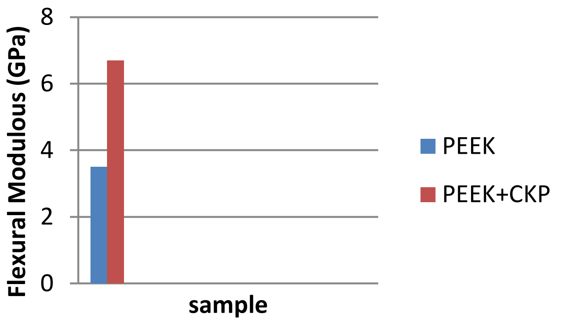

Fig. 3 Effect of CKP and SIC filler on flexural modulus of PEEK composites.

Flexural modulus is used as an indication of a material's stiffness when flexed. Flexural modulus of filled Poly-ether-ether-ketone composites increased as the concentration of fillers increased, as shown in Fig 3.

IV. CONCLUSION

Reinforcement of glass fiber into the PEEK matrix improves the flexural strength quite significantly, thus making them potential materials for structural applications. Addition of CKP and SIC to glass fiber reinforced composites also enhances the flexural strength, flexural modulus and tensile strength of the material. PEEK with glass fiber reinforcement exhibits better resistance to solid particle erosion in comparison to the un-reinforced PEEK resin.

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