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Polytetrafluoroethylene (PTFE) based composites

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ABSTRACT

Poly tetrafluoroethylene (PTFE) is a versatile engineering plastic. It has excellent chemical and water resistance, moderate mechanical and thermal properties, superior electrical insulation properties with low coefficient of friction. As the virgin PTFE is having low wear creep resistance and low load bearing capacity, the different fillers are incorporated into PTFE to improve these properties.

Keywords: PTFE, Composite bearings, Fillers.

INTRODUCTION

The story of Poly Tetra Fluoro Ethylene (PTFE) began on April 06, 1938, at Du Pont's Jackson Laboratory in New Jersey, USA. Dr Roy J Plunkett, who was working with gases related to Freon fluorinated refrigerants, discovered that one sample left overnight in a cylinder had polymerized spontaneously to a white waxy solid. It was resistant to practically every known chemical or solvent; its surface was extremely slippery; almost no substance would stick to it; moisture did not cause it to swell and it did not degrade after long term exposure to sun light. It has a melting point of 327^{o}C.

P T F E is a highly crystalline polymer (90-95%) with a melting point ~327^{o}C. It has excellent properties like chemical inertness, low coefficient of friction, non-toxic, non-flammable, negligible water absorption, non-adhesive, anti-stick, high thermal stability, low dielectric constant, moderate mechanical properties and compatibility for compounding with metals and inorganic pigments.

Though PTFE (virgin) has excellent properties as mentioned above, it suffers from some draw-backs like; low wear resistance, low thermal conductivity, low load bearing capacity, high elongation, and low resistance to compressive deformation. Hence, different fillers are incorporated into PTFE to improve these properties.

Structure of PTFE:The PTFE molecule has highly regular structure with a configuration leading to a 166 helix. It is a fully fluorinated Polymer with a linear chain of great molecular length (20,000 to 1, 00,000 Monomer units) and it has a high melt viscosity (10^{11} poise at 380^{0}C). The working temperature of PTFE is –260^{o}C to +260^{o}C and it is insoluble in anyof the commonly known solvents except certain fluorinated oils and molten alkali metals. Its chemical formula is

(- CF2 –CF2-) n. PTFE is made of a carbon backbone chain, and each carbon has two fluorine atoms attached to it and its structure is

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                  F   F   F   F  F   F  F   F
                  |   |   |   |  |   |  |   |
-----------------C - C - C - C -  C - C -  C- C------------------
                  |   |   |   |  |   |  |   |
                  F   F   F   F  F   F  F   F
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PTFE is a completely fluorinated polymer manufactured when the monomer Tetrafluoroethylene(TFE) undergoes free radical vinyl polymerization. As a monomer, TFE is made up of a pair of double bonded carbon atoms, both of which have fluorine atoms covalently bonded to them. Thus the name "Tetra" means there are four atoms bonded to the carbons, "Fluoro" means those bonded atoms are fluorine, and Ethylene means the carbons joined by a double bond as in the classic ethylene structure. When TFE polymerises into PTFE, the carbon – to – carbon double bond becomes a single bond and a long chain of carbon atoms is formed.This chain is the polymer's backbone.

PTFE based composites:

The virgin PTFE was found to be inadequate for a number of more demanding engineering uses. In particular, its cold flow or creeping properties kept PTFE out of mechanical applications. In the sixties, it was discovered that the physical properties of PTFE could be improved by the addition of fillers and a range of filled compounds which were found to be highly suitable for gaskets, valve sheets, piston rings, high voltage switches, bearings, pipe lining etc. It turned out that through a proper combination of basic resin and one or more fillers, compounds could be tailor-made for many useful applications, compounding technology development continuously depending upon end applications.

Practically any material that can withstand the sintering temperature of PTFE (up to 400^{o}C) can be used as filler depending upon the end applications. The characteristics of fillers, such as particle shape, size and the chemical composition greatly affects the properties of the compounds.

Rudner[1] in his book filled fluorocarbons-new component materials, 1955 wrote about filling of PTFE with other materials to get hardness keeping chemical properties affected negligibly. For this purpose he selected glass filled PTFE.

Later in 1966 Bowden[2]etal established the friction and wear properties of few level PTFE resins and PTFE based composites.

The experiment has been done to find out volume shrinkage by Ganz[3]etal in 1966. In their book, it is mentioned that shrinkage depends upon (1) % by volume of filler(2) Performing pressure(3) Dimensions of mouldings (4) Sintering cycle.They have done experiments on only glass filler percentage and also they took only 15% and 25% of filler only. And they used disc of dia 73 mm and 12.7 mm for their experiments.

Lewis[4] paper, "predicting bearing performance of filled Teflon TFE resins confined to discuss about friction, wear and lubrication properties of filled PTFE.

Kobayashi[5] established parameters of tools for skiving of filled PTFE in 1967 and the same was published by McGraw Hill for machining of plastics. He recommended to heat filled PTFE billet upto 200^{O}C when it is required to skive tapes of various thickness of having smooth surface.

Thomas[6] described about the apparatus which is specially developed for studying the compressive creep of PTFE. He observed that the stress to strain behaviour of PTFE is time dependent. It is noticed that on releasing this stress, the creep properties of virgin PTFE is very poor because of cold flow.

Horozumi[7]etal have discussed upon holding a blend of fluoropolymer and poly (phyenylene sulphide) containing 5 to 50% carbon fibres which gave products with improved surface hardness. Thus a blend containing a composite on (A) Teflon G80 [poly (tetrafluoro ethylene)] 70, I (Ryton) 30, and carbon fibres 25 parts was prepared and 0.55 LAY/kg. Isopar E was moulded and backed that 370o to give a disc with Rockwell hardness (R-Scale) 110; compared with 45 for a disc contained from a similar composition not containing carbon fibres.

Hideo kawamura[8] studied filler for transfer of ceramic surfaces. Transfer films for roughening the surface of laminates containing glass fibres and polyesters or epoxy resins were prepared by pressing a fluoro polymer film between a Cu foil having a rough surface and reinforcing sheet to imprint the rough surface on the fluoropolymer removing the Cu, bonding to a polyethylene (I), cellulose triacetate, or polypropylene film to transfer the rough surface and separating. Thus a Teflon FEP 200A film was pressed between the rough surface of 2Cu foils separated from 1Cu foil, laminated to a 1 film and separated to give a transfer film 3 polyster preparations were sandwitched between the rough surface of 2 transfer films, mold of'd' at 100 – 170^{o}C and separated to give a laminated for planting with Cu.

In Fluon Technical service note F12 /F13 of ICI plastics division, Welwyn Garden, Herts[9]gave results of their experiments on tensile strength, hardness, elongation and porosity of glass filled PTFE having filler percentage 15% and 25% respectively which are their commercial grades: They also gave results on above mentioned properties on 60% bronze filled PTFE. In Fluon technical literature of F13, it is given that the quantity of filler percentage should be limited to 40% only.

Bahadur[10]etal presented their paper at the international journal of wear of materials. In this paper, experiments have been carried out between PTFE sliders filled with polar graphite, Pb_3O_4, MoS_2 and CuS in different proportions and combinations rubbing against flat counter faces of mild steel and glass. The counter face surfaces were finished by grinding, abrasion against 600 grade emery paper and lapping. Graphite as a filler reduced the wear rate of PTFE by about a factor of 100 while it increased the coefficient of friction by about 30%. In contrast, CuS provided an equally large reduction in wear rate but did not increase the coefficient of friction. The fillers produced a uniform and coherent film of the filled polymeric material on the steel surfaces. Whereas the worn material in the case of unfilled PTFE was in the form of fragmented sheets, with filled PTFE it was broken into fine particles. The reduced wear rate of filled PTFE is attributed to the changes in the shape and size of the worn aggregates, their bonding to the counter face and the relative ease with which they are dislodged during sliding. The coefficient of friction of PTFE sliding at low speeds against metal surfaces is exceptionally low and even at high speeds it does not exceed that of most other polymers. In contrast, the wear rate of PTFE is extremely high. However, addition of inorganic and some organic fillers was found to reduce the wear rate by a factor of 100, the optimum occurring for a filler content of about 40% volume. For these reasons composites based on PTFE constitute a potential valuable material combining both the favorable frictional properties of PTFE and the low wear properties of the filled polymer. However, the choice and filler content are purely empirical because the mechanism of filler action in reducing wear is not well understood.

Xin-Chunlu[11]etal studied wet ability soil adhesion, abrasion and friction wear of PTFE (TPPS) + alumina composites. For the development of materials which could reduce adhesion and friction of soil to soil engaging components of machines for land locomotion Al_2O_3 + PTFE (TPPS) composites were obtained by using the process of cold processing followed by adhesion and hot pressing. Behaviours of wetability of water and soil adhesion, abrasion and friction wear of the composites are reported in this paper. The composites, dispersed with an appropriate content of Al_2O_3 particles, exhibit superior wear resistance. PPS in the matrix can further improve the wear resistance of the composites.

Masaki[12] studied tetrafluoroethylene compositions having excellent sliding characteristics and compression creep resistance, containing fillers and injection mouldable fluoroplastic powders. Thus Teflon 75 (Tetrafluoroethylene resin) MF 739 111/32" glass fibre powder dia m 13 milli micron (average length 70 milli micron), 25 and Teflon MP – 10 (I) perfluoroalkyl vinyl ether – TFE copolymer average particle dia 36 milli micron. 10 parts were thoroughly premoulded at 450 kg/cm^2 and heated at 360^{o}C for 3 ohm to preparation of moulding. The test of piece from the composition should deformation 4.1 and 2.6% in the compression creep test (140 kg/cm^2, 24 ohm), Tensile strength 170 and 123 kg/cm^2. Elongation 278 and 233% interface & longitudinal direction respectively. Coefficient of friction 0.36 and abrasive loss 11.8 x 10-6 kg/ cm^2 compared with 9.1, 5.9, 161, 131, 118, 201, 0.32 and 156 x 10-10 respectively for a test piece without (I).

Tsukasa[13] observed fluoropolymer materials giving tack-free coatings with excellent high temperature, hardness, are composed of mixtures containing 100 parts spherical perfluoro alkoxy polymer powders and 5 to 400 parts C2F4 polymer powders of smaller grain size. Thus 100 parts MP –10 (perfluoro alkyl vinyl ether tetrafluoro ethylene copolymer powder average size 35 microns) were dry blended, electro statically coated on an aluminum plate, backed 30 min at 380^oC, and left at room temperature to give a coating with contact angle 127^oC, excellent tack resistance at 200^oC.

Asle[14]etal of LNP Corporation Malvern, studied wear behaviour of thermo plastic polymer filled PTFE compositing. Their study was reported in journal of American society of lubrication journals. A variety of new PTFE composites has been produced, which demonstrate unit wear and mechanical properties when compared to inorganic PTFE composites. Results of their study are interpreted both in terms of mechanical properties and morphology of the composites. It is demonstrated that thermoplastic polymer filled PTFE composites extend the range of utility of PTFE bearing and roller applications.

Shunji[15] studies fluorinated alkoxy resins and fluorinated ethylene propylene ether resin containing super fine inert fillers (dia 1 micron) for adhesion of PTFE to metals or ceramic at a temperature higher than the melting point of PTFE. Thus, Teflon PFA perfluoro alkoxy polymers containing 10% Al_2O_3. A1-125 (dia –0.1 microns) was heated at 320^oC and cooled to give strips, SO_33O_4 (3mm thick) stainless plate and 0.3mm PTFE were laminated with strips at 0.1 kg/cm^2 and 350^oC for 10 min to give a sample having adhesive strength 5.5 2.5 kg/cm^2.

Michio[16]etal took powder copolymers containing 98% tetrafluoro ethylene (TFE) and perfluoro ethylene pulverized the same by shear force, and then compacted and heat treated to give mouldings with excellent compression strength and creep resistance. powder Teflon 62J at 40 – 70^oC was stirred 1100 – 2500 rpm to give fibrous powder of dia 25 to 100 micron and length 500 – 1000 micron which was compacted in a mould under 100 kg/cm^2 pressure to and heated at 380^oC to give a moulding with'd' 2.15 gm/cc ; 1% compression strength 45 kg/cm^2 compressed creep (breakage temp.) at 200^oC was reported with this sample.

Barber[17]etal analysed the transfer film lubrication schemes for 25 years, a technique for ensuring lubrication under extreme environment conditions, layer lattice materials such as MoS_2 and WSc_2 have typically been targeted for high temperature service while films of PTFE has been used for service at cryogenic temperatures. Rheological characteristics of these transfer films have been shown to affect the performance and stability of bearings. The investigations have shown that the lubricant rheology at the bearing components and that low friction coefficient at this interface may be required to ensure stability under some operating conditions. Efforts to model stability require some knowledge of both the presence and characteristics of transfer film.

Gong xue[18]etal have explained about the friction and wear behaviour of PTFE based composites filled by incorporating a metallic (stainless steel, copper) net with inorganic fillers, was studied by rubbing composite pins against a mild steel block on a reciprocating tests. The mechanism of load supporting action of the fillers in reducing wear was verified and the process of formulation of smaller wear debris was also discussed. It was found that the wear rate of the composites filled with stainless steel net incorporating graphite is more than 300 times lower than that of pure PTFE. The wear behaviour of filled PTFE has been studied for a long time by many workers and numerous papers and review articles specifically demonstrate the action of reducing wear by fillers from various view points. Certain inorganic fillers also may help to reduce the wear of the polymer by increasing the addition of the first transfer layer to the counter face. There is, therefore, a scientific and technological need to understand the essential action of fillers in reducing wear if are to find the best filler and develop better self-lubricating composites.

Michael[19]etal has discussed on static and kinetic friction experiments and hardness and tensile tests were to evaluate epoxy mixtures (i.e. EPON 815 – EPICURE V 40). They are typically used as impregnants in the preparation of super conducting magnets at room temperature; mixtures which executed a strong tendency towards visco elastic behaviour also demonstrated considerable time dependence in the static friction coefficients. At 77^{o}k all the epoxy mixtures were in the glassy state and their static friction coefficients were noticeably reduced from their room temperatures (25^{o}C).Mechanical properties of Teflon TE 3608 filled mixtures were similar to those of the unfilled epoxies with the exception that the particle filled mixtures were generally much more brittle. Incorporation of the Teflon filler had the additional effect of reducing the friction coefficients. The epoxy mixtures to values comparable to that bulk Teflon.

Semenor[20]etal have studied the effects of sliding rates load, temperature, crystallinity and radiation on tribotech properties of fluoroplastic and other fluoro polymers, and the effects of the type and amount of fillers, their particle size shape and orientation and other factors on the anti-friction properties and wear resistance of composites based on these fluoropolymers are discussed for use in sliding bearings.

Talat Tevruz[21] as studied tribological behaviour of carbon filled PTFE in dry journal bearings. Most laboratory studies on the tribiological behaviours of polymers were performed on the rigs which were in line with pin-on disc or pin-on ring models. Calculation of polymer bearings have been generally based on the data obtained from these studies. But bearings have special geometrical and kinematical characteristics. In this study, effects of sliding distance, bearing pressure, the medium and low speed on friction and wear injournal bearings made of 35% carbon filled PTFE composite are examined. Taking into consideration the large number of factors, and their widely fluctuating characters and effects on the friction and wear, an optimum bearing construction may be achieved.

Reinicke[22]etal studied tribological behaviour of injection moulded thermoplastic composites. In their study, tribiological investigations were carried out on different short fiber reinforced thermoplastic bearing materials, in particular on injection moulded samples of PPA, PPS and PEI compounds with different amounts of glass fibers and PTFE their results prove that using PTFE as an internal lubricant results in an improvement in the tribological behaviour of all polymers tested. Abrasive effect of the reinforcing short glass fibers was more intense under fretting wear than under sliding wear conditions. Regarding all the tests performed, PPA compounds were found to record the best tribological behaviour.

Hiroshi[23]etal studied electrically conductive composite sheets. Electrically conductive sheets with excellent gas barrier corrosion, preventing properties, with chemical resistance are prepared by extruding a mixture of 3 to 40% PTFE and 60 to 97% electrical conductive powder of average particle size 10 microns and filling a hot melt resin in to the voids in the sheet obtained. Thus 200 parts petroleum naptha and 100 parts 15: 85 Denka Block – PTFE mixture were mixed extruded and heated to give a 0.5 mm sheet, and two of this sheet were laminated on both sides of 50 microns FEP sheet and pressed at 350 ^{o}C and 100 kg/ cm^2 to give a gas barrier sheet with volume resistively 0.99 ohm. cm.

Duncan[24]etal studied thermal conductivity of PTFE and PTFE composites using measuring apparatus lees disk and by DSC (Differential scanning calorimetry). The former method was used to study the effect of fillers in PTFE / glass fibre fabric used for conveyor belts in food processing. The effect of crystallinity on thermal conductivity was investigated. The incorporation of aluminum flakes has been found to improve heat transfer through the composites. The thermal conductivity of PTFE with different levels of crystallinity was measured at 232^{o}C and shown to increase linearly with these parameters.

Oshima[25]etal studied fabrication of PTFE / carbon fibre composites using radiation cross linking. A fabrication method for FRP composites based on carbon fibres and PTFE, which was cross linked by electron beam (EB) irradiation under specific conditions, was studied. It was found that the toughness of the PTFE matrix is poor in the composite. On the other hand, single sheet of carbon fibres and cross linked PTFE composite showed good mechanical properties for sheet shape materials.

Jaydeep Khedkar[26]etal have studied the tribological behaviour of PTFE and PTFE composites with filler materials such as carbon, graphite, glass fibers, MoS_2 and Poly-P-Phenyleneterephthalamide (PPDT) fibers etc; The filler additions were found to increase hardness and wear resistance in all composites studied. The highest wear resistance was found for composites containing (i) 18% carbon + 7% graphite, (ii) 20% glass fiber + 5% MoS_2 and (iii) PPDT fibers. Scanning electron microscopy (SEM) was utilized to examine composites. 10% PPDT fibers causes wear reduction due to ability of the fibers to remain embedded in the matrix and preferentially support the load. Differential scanning calorimetry (DSC) analysis was also performed to study the relative heat absorbing capacity and thermal stability of the various composites in an effort to correlate these properties to the tribiological performance. The results indicated that composites with higher heat absorption capacity exhibited improved wear resistance.

Xianhua Cheng[27]etal studied tribological investigation of PTFE composite filled with lead and rare earth modified glass fiber. PTFE composites were prepared using 60% by weight lead and 5% by weight glass fiber (GF). The surface of GF was modified with a coupling agent, a mixture of coupling agent and a rare earth and rare-earth respectively. The friction and wear properties of the composites under oil lubrications were investigated on a pin-on-disc sliding wear machine. It was found that the modified GF, which was filled into PTFE, decreased the wear of the PTFE composite filled with unmodified GF. The friction and wear properties of PTFE composites filled with lead and rare earth modified GF were found greatly enhanced.

Huang[28]etal studied corrosion resistance properties of electroless nickel composite coatings. Electroless nickel (EN) composite coatings incorporated with PTFE and /or SiO_2 properties demonstrated significantly improved mechanical and tribological properties as well as low surface energy which are desired for anti-sticking and wear resistant applications. This work is aimed to investigate the corrosion characteristics of electroless nickel composite coatings using electrochemical measurements. The effects of the co-deposited particles on corrosion behaviour of the coatings in 1.0 NH_2SO_4 and 3% NaCl media were investigated. The results showed that both EN and EN composite coatings demonstrated significant improvement of corrosion resistance in both acidic and salty atmosphere.

Mateus[29]etal has studied ceramic / fluoropolymer composite coatings by thermal spraying. The polymer coatings are widely used for industrial applications and their performance are often limited by a poor scratch resistance or a high water and gas permability. Thermal spraying may help to over come these limitations. The aim of this paper is to develop composite coatings by plasma spraying. Due to different thermal characteristics of PTFE or PFA polymers and Al_2O_3 / TiO_2Ceramic materials, three types of powders injections are elaborated. To compare these three conditions, microstructure, surface wettability and wear resistance deposited behaviour were characterized Al_2O_3 / TiO_2 / Fluoropolymer composite coatings are characterized by a well melted ceramic matrix in which rounded polymer particles are randomly distributed. Highest polymer / ceramic ratio is observed in the coatings made with the separated injection of the Al_2O_3 / TiO_2 and PFA powders. The lowest friction coefficient is also measured for this coating.

Jinhua Chen[30]etal have prepared new polymer electrolyte membrane fuel cell (PEMFC) by simultaneous radiation-induced grafting method. The polytetrafluoroethylene (PTFE) films, cross-linked by electron-beam radiation at molten temperature were used as substrates for grafting of two alkyl vinyl ether monomers, propyl vinyl ether (n PVE) and isopropyl vinyl ether (ipve), under controlled grafting conditions followed by sulfonation reactions. Thermogravimetric analysis (TGA), differential scanning calorimeter (DSC), water contact angle and Fourier transform infrared (FT-IR) were used to characterize the cross linked PTFE (e PTFE) and grafted PTFE films. The degree of grafting was found to be dependent on the grafting parameters such as irradiation temperature and lewis acid catalyst, in which in the presence of lewis acid catalyst or at a temperature close to the boiling point of each monomer, the grafting reaction significantly accelerated even when the relatively low dose was irradiated. Finally, the grafted PTFE films were suffocated in a chlorosulfonic acid solution.

Surface profiles of composites with PTFE matrix was studied by Tomescue[31]etal the paper presents the influence of load and glass fibre concentration on profile parameters obtained after running composites with PTFE matrix against steel in water. PTFE seems to have the poorest tribological and profile characteristics. Adding glass fibres, the surface characteristics become better at least till 30% but concentration of 30 – 40% produces wear as high as the polymer under the same testing conditions.

Effect of nuclear radiation exposure to RT/durlon type PTFE based composites was studied by M/s Rogers corporation[32] USA RT/ durold materials based on PTFE combined with glass microfibre or ceramic filler was developed and studied in detail. The component most susceptible to nuclear radiation damage is the PTFE because of the low coercive forces between PTFE molecular chains. It was reported that mechanical changes in PTFE appear to depend on the total radiation dose and to be independent of dose rate. During irradiation the dielectric constant and loss factor will be temporarily increased. The effect of radiation on these properties is less at elevated frequencies. The degree to which PTFE is affected is essentially a function of the amount of energy absorbed regardless of the identity of the radiation. The radiation dose unit usually employed in radiation studies is the “rad” one rad equals to 100 ergs/gm.

Venkateswarlu[33] in his ph.D. thesis studied about the effect of different fillers namely; glass, granite, graphite, garnet, antimony trisulphide, allumina, carbon, marble, mica, sand, porcelain, bronze, tixolex-25, china clay and wollastonite on various physical, mechanical, electrical and chemical properties like bulk density, particle size, specific gravity, hardness, tensile, % elongation, diametrical shrinkage, expansion or contraction in height, dielectric strength and compressive strength, etc, of virgin PTFE and different filled PTFE composites (filler content 5-50%) were made with an idea to arrive at optimum filler content, for achieving maximum properties. In addition, thermal analysis (TGA and DSC), XRD analysis, SEM studies, Insulation resistance, peeling strength (on etched/un etched tape) and compressive stress, strain and factor of safety are done and reported on virgin PTFE and 15% filled PTFE composites on weight basis in all the cases. Also the effect of temperature and pressure at constant pressure and temperature respectively for 15% filled PTFE composites were discussed. His findings are Addition of ceramic, metallic and non-metallic fillers greatly affect the tensile properties, hardness, dielectric strength, insulation resistance and compressive strength of PTFE. Dielectric strength, tensile strength and elongation of filled PTFE decreases on increasing filler content (in most of the cases). Among the 14 filled PTFE composites studied, higher specific gravity was found in case of bronze filled PTFE containing 40% filler content and the lowest is carbon filled PTFE containing 50% filler content before sintering; and highest is 50% antimony trisulphide filled PTFE and lowest is 50% mica filler content after sintering. The highest hardness value-based composites found to be obtained for 15 & 25% garnet filled PTFE; 50% marble filled PTFE and 40% porcelian filled PTFE. 5% bronze filled PTFE shows highest tensile strength and 50% bronze filled PTFE shows highest percentage elongation values. The lowest tensile strength of sand filled PTFE and lowest percentage elongation of garnet filled PTFE, among all filled grades studied, may be due to the fact that fillers are just lying embedded in the resin matrix without any chemical bonding.5% bronze filled PTFE shows highest dielectric strength value than other filled grades and lowest dielectric strength value obtained on is 20% graphite filled PTFE as graphite itself is a conductive material. Filled PTFE composites with 15% filler content (glass, granite, garnet, graphite, marble, antimony trisulphide, mica, carbon, alumina, bronze, porcelian and wollastonite, etc,) were selected for XRD, SEM, DSC, TGA, IR and peeling strength because almost all properties are in acceptable range. In the Study made, in addition to virgin PTFE, porcelian and alumina filled PTFE composites were found to have highest insulating resistance values compared to other filled PTFE composites.

Yunxia Wang[34] et al prepared PTFE based composites containing 15 vol. % moS_2, graphite, aluminium and bronze powder by compression molding at room temperature and heat treatment in atmosphere. These fillers could prolong wear life of PTFE based composites. They also prepared transfer films of virgin PTFE and composites on surface of AISI – 1045 steel bar using a friction and wear tester in a pin on disc containing configuration, including study on tribiological properties of these transfer films using tribometer by sliding against GCr15 steel ball in a point contacting configuration and found that tribiological properties of transfer films are sensitive to load change.

Herbold[35] et al demonstrated dynamic mechanical properties of high density mixtures of PTFE, Al and W powders tailored by changing the size of the particles and porosity of the mixture. Composites of fine metallic particles and high porosity exhibited higher ultimate compressive strength than less porous composites having equal mass ratios with W particles.

Preparation of Carbon black filled PTFE composites was discussed by Dongxiang

Zhou[36]et al by compact molding of a dry mixture of carbon black and polymer powders followed by sintering technology. The composites showed a very low percolation threshold about5 vol.% which attributed to the segregated distribution of carbon black in the interfacial regions of PTFE particles.

Vail[37]et al used high tenacity expanded PTFE filaments as both fiber reinforcement and reservoir for solid lubricants to reduce the wear of the composites by regulating the PTFE transfer. Reports show that yield strength of these filaments can exceed 500MPa and the wear rates obtained from the inclusion of expanded PTFE filaments were better than conventional powder filled PTFE – PEEK composited reaching values as low as $k=7\times10^{-8}mm^3/Nm$.

Chenxi Xu[38] et al prepared thin CsPOMo-PTFE-QDPSU composite membrane and characterized for use in a high temperature PEMFC. The ionic conductivity of the composite membrane, loaded with a low content of H_3PO_4, was 0.04 Scm^{-1} at 150^0C which was twice that of the pristine loaded PBI (0.02Scm^{-1}) with the same PA doping level. In fuel cell tests power densities of 240 mW $cm^{-2}$and 140$mWcm^{-2}$

were achieved using oxygen and air respectively. The CsPOMo-PTFE-QDPSU composite is considered as a candidate membrane for high temperature PEMFC because of its acceptable conductivity and fuel cell performance with a low PA acid loading.

In the paper of Pushkar Venkatesh[39] et al composite materials was comparatively investigated under actual load and sliding velocities by using in a pump. In addition influence of inorganic fillers MoS_2on the wear of glass and bronze fabric reinforced epoxy composites under dry and wet running conditions has been discussed in detail and found that fillers bronze and MoS_2 combined with PTFE provide excellent bearing properties.55%bronze+5%MoS_2+40%PTFE was found to be suitable for pump application.

Ramteke[40] et al studied optimization of ultrasonication process to improve the mixing of PTFE in lubricating oiland the effect of PTFE on wear preventing and extreme pressure properties of lubricating oil with AISI 52100 steel balls using four ball testers. The composition of oil lubricants changed by addition of 0.5wt% to 4.0wt% of PTFE powder. Reports show that the optimum condition of ultrasonic treatment is 75W/cm^2 ultrasonication intensity, 60 min time duration, and 0.5 -2% total solids concentration. Coefficient of friction decreases with increase in PTFE percentage in lubricating oil.

Baronin[41] et al presented the new methods of fluoro polymer based nanocomposites obtaining from the gas phase environment and evaluation of their operational properties and main technological method of homogeneous fluoropolymer based nanocomposites production is mixture pyrolysis which contains PTFE block and easily decomplsed inorganic ammonium fluoride with the subsequent condensation of pyrolysis products. The molecular PTFE composites obtained by this method with TiO_2, SiO_2 and CoO_2 indicated as TFP,SFP,and CoFP are used as the modifying additives for PTFE.

Dongya Yang[42] et al prepared the blend composites of polyphenyl ester polytetrafluoroethylene by cool pressing and hot sintering inorder to develop high performance sealing material for stirling engine. The effect of potassium titanate whisker (PTW) and calcium sulfate whisker (CSW) on the tribiological properties of the POB-PTFE composites was studied. It shows that the POB-PTFE composites were used as matrix for seal material in stirling engine and the creep and shear resistance of POB-PTFE are improved by the addition of PTW, the friction coefficient of the composites need not be changed with the variation of load.

CONCLUSION

Polytetrafluroethylene(PTFE) is the material which is a choice for a variety of applications. Currently, it is finding increasing utility owing to its unique properties like chemically inert to almost all known substances including corrosive liquids(especially Cl and Caustic), vapours and gases. Nowadays, virgin PTFE is widely used as bearing material which is a self lubricating and subjects to low coefficient of friction. As virgin PTFE has excellent chemical and water resistant property, moderate mechanical and thermal property, superior electrical insulation property with low coefficient of friction, low wear creep resistance and low load bearing capacity, the different fillers like Glass fibre, Granite, Tixolex-25, Antimony trisulpide, Porcelain, Bronze, China clay etc. have been incorporated to improve these properties. The problem with PTFE of high wear-rate also can be reduced by adding suitable fillers.

It was found that, most of the works done on PTFE based composites were focused mainly on commercial requirements. Some of the research which has been done on scientific and technological studies on pure and filled PTFE composites by varying types and concentration of fillers were used with an idea to establish best fillers and filler combinations for specific commercial uses and end applications. Work has also been done on the effects of different fillers on various mechanical properties, Thermal analysis, XRD analysis, SEM studies, on virgin and filled PTFE composites to identify optimum filler content which corresponds to maximum different mechanical properties.

Further, focus can be made on thermal properties (except dielectric strength and insulating resistance)and chemical resistance properties, on virgin PTFE and filled grade PTFE for different uses and end applications.

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