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Adhesive wear studies of Fiber reinforced Filler filled polymer Based composites-A Systematic Review

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Abstract:

Composite materials are becoming increasingly popular in today's world, with their use in a variety of commercial applications. With the increased use of these materials in Automobiles, it is critical to investigate their wear and friction performance. Since these materials experience vibration while Automobile movement. Many researchers are currently working to determine the wear and friction behaviour of polymers. The purpose of this paper is to provide critical information about the dry sliding impact on FRP Composites. The article mainly focused on the dry sliding response of polymers, with filler material and fiber reinforcement. Further polymers operating in different Environmental condition also studied. Furthermore, the reviews provide both continuous and statistical instruments for determining specimen wear behaviour.

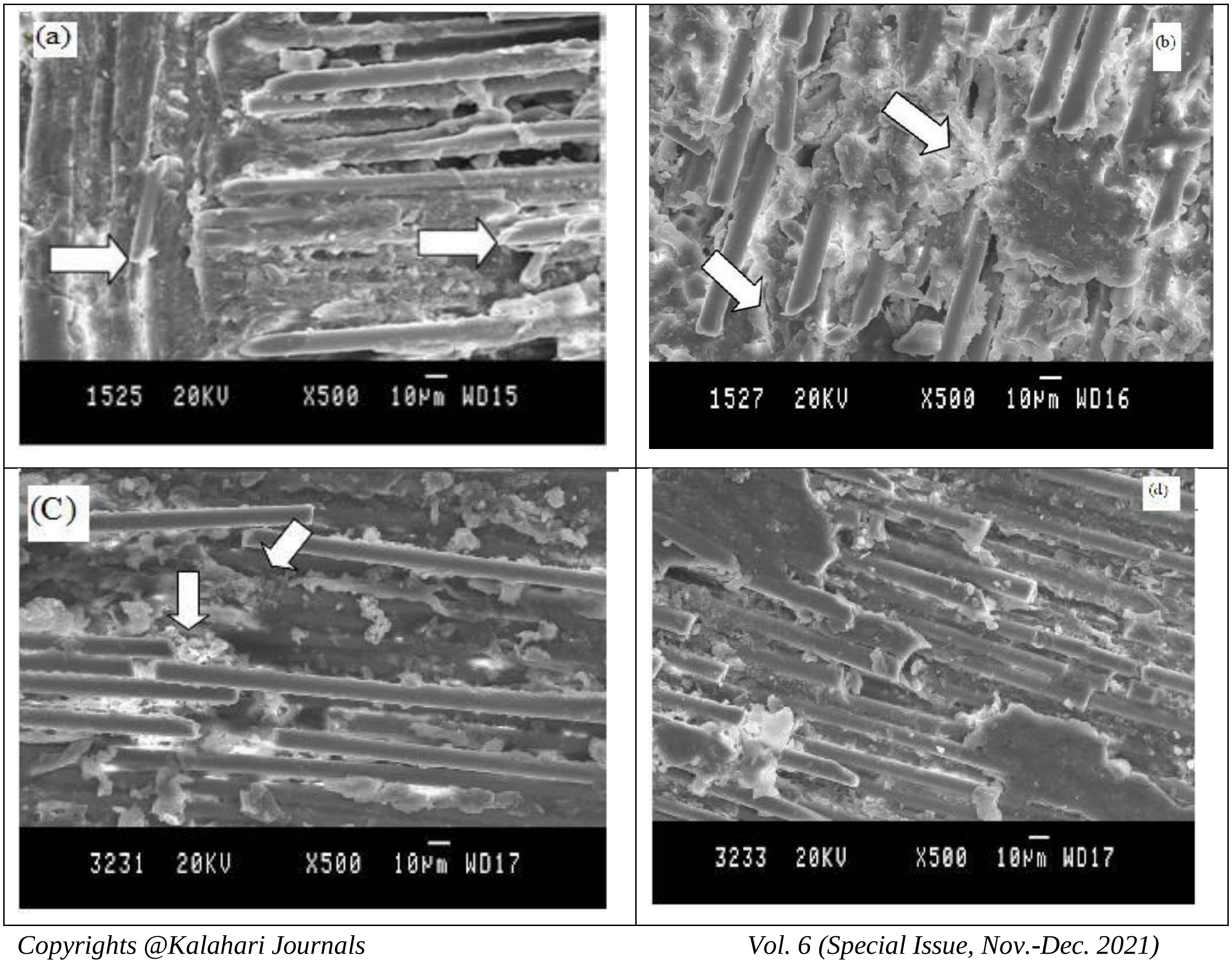
Keywords: *Epoxy, Dry sliding wear, SEM, Taguchi technique, POD Machine.*

Introduction:

Polymer composites are used in a variety of applications and under a variety of operational situations. Polymer composites are used in several industries, including the automotive, aerospace, naval, and, more recently, oil and gas industries. Due to their outstanding strength, cheap cost, and high strength-to-weight ratio, polymers and polymer-based materials are often utilised. [1-3] FRPs are extensively used in the self-propelled vehicle and flying machine industries, as well as in the construction of spacecraft and maritime vehicles, due to their exceptional qualities [4-6]. Many applications need polymer composites with machine driven behaviour and dry sliding wear properties. Specimens of polymer were subjected to a battery of tests to forecast their resistance to dry sliding impact and guarantee their strength and service life. The wear process is characterised by the slow loss of material resulting from the sliding motion of two rubbing surfaces. Sixth, wear effects were made public to ensure that components are used properly. Several studies have shown the resistance to wear of polymer matrix specimens subjected to sliding and abrasive wear. It is governed by the material's general characteristics and the external wear state, which is characterised by pressure and contact velocity [7]. In addition, the addition of fibres to polymers does not inherently improve their wear resistance [8]. Utilized in the dry sliding process, it reduces wear rates under situations such as adhesion and fatigue type wear [9]. The improved load bearing capacity, creep resistance, thermal and electrical conductivity, and thermal and electrical conductivity of the fibres contribute to the decreased wear. Adhesive wear is the consequence of rolling and sliding contact between rubbing surfaces, which results in material transfer. The adhesion between the smooth and counter face polymers might lead to surface deformation of the polymer [10-11]. Adhesive wear is a complex process that is influenced by several factors, such as material qualities and service conditions. Thus, study into the phenomenon of adhesive processes in polymer composites is necessary [12]. Factors that affect the dry sliding properties of polymers include load, sliding distance, sliding velocity, contact pressure, duration, fibre orientation, and aspect ratio. In this article, an attempt has been made to show the effect of the aforementioned characteristics on polymer composite wear. The effect of fibres and fillers on the abrasion resistance of polymer specimens is thoroughly examined. In addition, the statistical and numerical methods employed in Wear study were investigated.

Dry sliding Wear test on Glass fiber and carbon fiber added specimens:

The wear behaviour of graphite filled G-E composites was studied by.S Basavarajappa.et.al [13] Using a POD machine, the research was conducted out with varied loads, distances, and speeds. It was reported that adding Gr to a Glass-Epoxy specimen resulted in lesser weight loss which was further lowered when the filler amount in the composite increased. At a lesser load of 40N, the weight loss of 5 percent and 10 percent Graphite was nearly identical. At a greater load of 100N, the 5 percent GR specimen lost 6.6mg of weight, whereas the 10 percent GR specimen lost 5.7mg.This was because a homogeneous layer forms on the steel disc, as well as lubricant particles, reducing three-body abrasion. Due to matrix wear, the SEM image Figure 1. (a-f) displayed matrix debris generation, micro cracking, and exposure of both long and diagonal fibre.



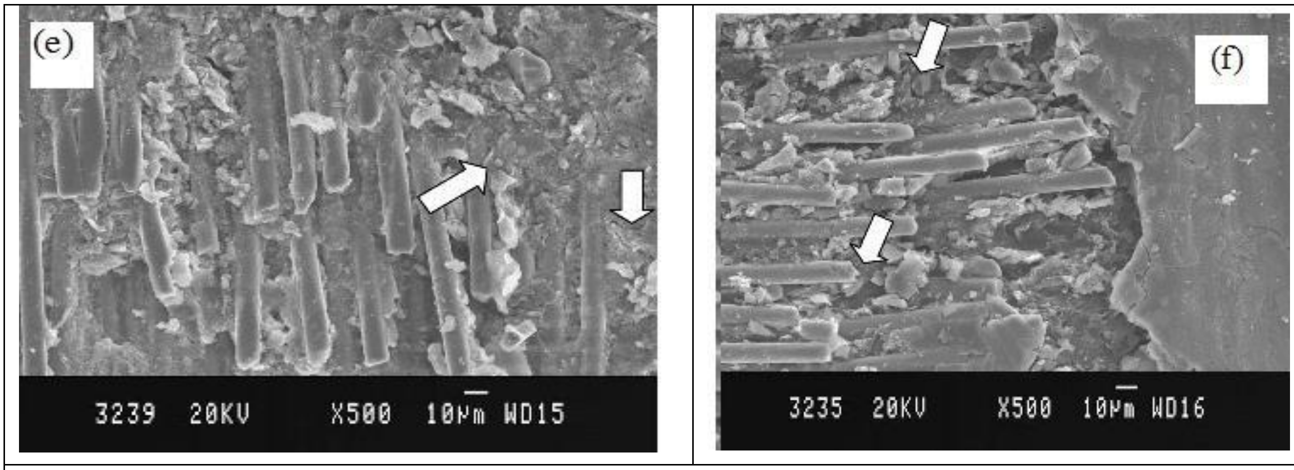


Figure1. (a-f): (a) SEM Micrograph of G-E Composite without filler at 60N load, 5.44m/sec, 3000m

(b) SEM image of G-E specimen without filler at 100N, and 5.44/sec, 3000m

(c) SEM image of Specimen 5wt%GR at 60N, 8.16m/sec And 3000m

(d) SEM image of Specimen 5%Gr at 80N, 5.44m/sec And 3000m

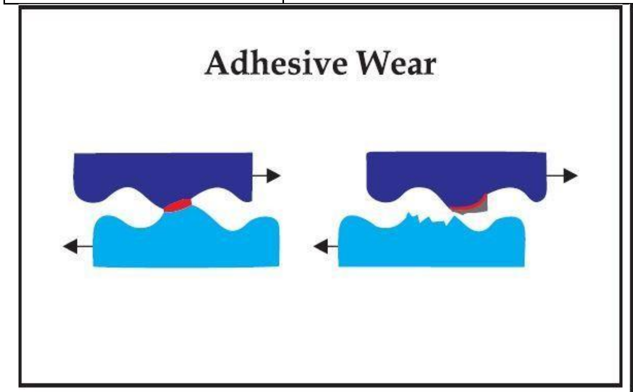
(e) SEM image of Specimen 5%GR at 80N 5.44m/sec, and 3000m

(f) SEM image of specimen 5%GR at 60N, 6.8m/sec and 3000m

Suresh et al. [14] studied the friction and wear of glass and carbon fibre added to vinyl ester composites. The carbon fabric reinforced vinyl ester samples exhibited less wear than the glass fabric reinforced vinyl ester samples. According to reports, the specific wear rate of pure vinyl ester samples is nonlinear, but carbon vinyl ester and glass vinyl ester samples exhibit linear wear rates. The carbon vinyl ester sample deteriorated 184 percent more quickly than the glass fabric vinyl ester sample. At 142N and a greater load and velocity, plain vinyl ester composites (about 3x10-12mm3/N-m), glass vinyl ester composites (approximately 11x10-14mm3/N-m), and carbon vinyl ester composites (approximately 7x10-14mm3/N-m) exhibit a high specific wear rate. During sliding, adhesive and ploughing processes transmit normal and tangential stresses via the contact sites, while hard asperities on the counter face or hard particles between the sliding surfaces plough and micro cut the soft surfaces. During sliding, both adhesive and abrasive wear mechanisms are at work, resulting in powdery wear debris at varying sliding speeds. As sliding velocity/load rises, frictional heat increases, lowering the brittleness of both matrix and reinforcing glass fibres. During the wear process, a combination of adhesive and abrasive wear technologies were developed. These wear structures are visible in SEM pictures. The SEM image revealed matrix tearing, the formation of a thin layer on the film, and fibre fracture. Paulo-Davim et al. [15] developed the Polyetheretherketone Composite, which was strengthened with carbon and glass fibres. This work examines the wear and friction of PEEK, PEEK C30, and PEEKGF30 under long-term dry sliding. During prolonged dry sliding, the reinforced composites demonstrated a considerable reduction in wear rate. PEEK CF30 has superior friction and wear characteristics in comparison to PEEK and PEEK-GF30. The weight loss of PEEK, PEEK-GF30, and PEEKCF30 were 5.21x10-6mm3/N-m, 0.937x10-6mm3/N-m, and 0.610x10-6mm3/N-m, respectively, while their COF values were 0.21,0.25,0.18 at Pv=2Mpa-m/sec, sliding distance 15KM, condition v=0.25m/sec, and P=8Mpa. Chen and Wan et al. [16] Tribological features of 3D carbon-fabric adding epoxy resin specimens were investigated. This research investigated the wear rate and coefficient of friction (COF) as a function of load, velocity, and sliding. The specimen with a larger Fiber volume % displayed a reduced initial wear rate at 250N. and 0.84m/sec, as well as a lower wear rate in steady state. At a load of 250N, the influence of fibre volume % on friction coefficient was likewise reported to be less significant, ranging from 0.20 to 0.23. J. Quanilier et al. [17] reported on the dry sliding wear of Glass Polyester Composite at varying weights between 60N and 300N at a constant velocity of 10mm/sec. The authors observed the formation of a thin coating surrounding the Wear track. The influence of fibres on Wear led to the creation of Wear track. The fibres dictated the wear track's shape. In wear-tested composites, the authors observed a variety of wear processes, which are outlined in Table-1. The many wear processes shown in (Figures 2-5).

Table-1.: Typical wear phenomena caused by the main wear mechanisms

Wear mechanism	Wear Phenomenon
Abrasion	Micro cutting, Micro Ploughing, Micro cracking
Adhesion	Transferred material due to adhesive joint formation and rupture
Erosive	Matrix Deboning, Micro Cracking, Micro cutting,, Kinking, Chipping, Fiber Bending, Fiber Shear, Detachment of Fiber
Surface Fatigue	Stress cycles, Micro structural changes, Crack formation and Delimitation



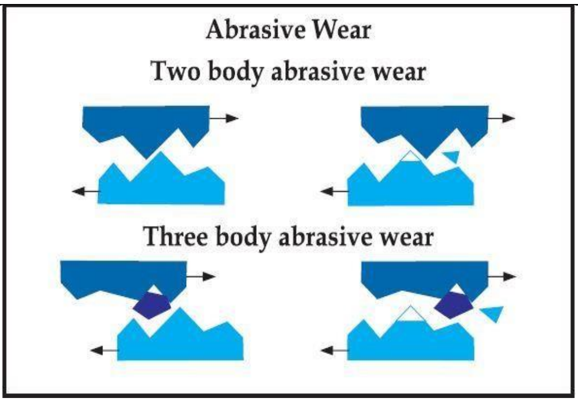


Figure 2. Shows the adhesive wear process Figure 3.shows the abrasive wear process

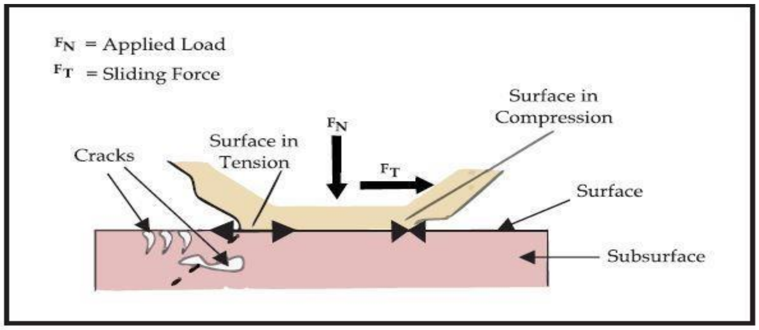
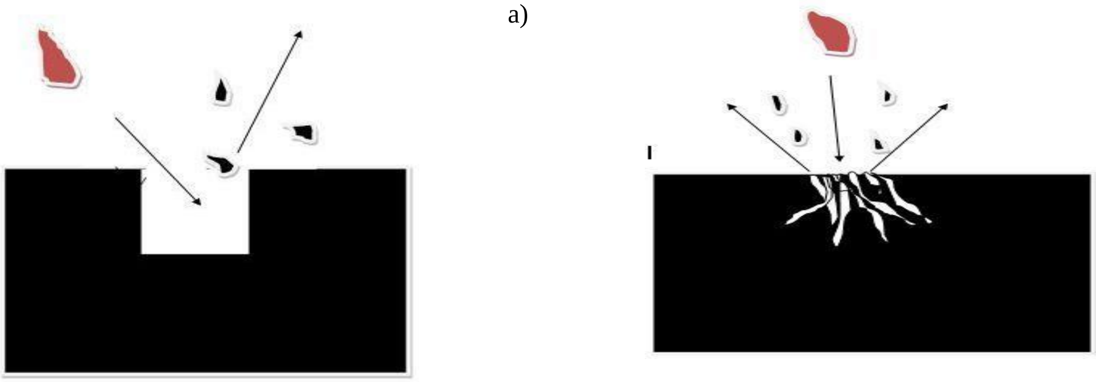


Figure4. Shows the process Fatigue wear



a)

b)

Figure5. Shows the Erosion process a) Ductile Erosion b) Brittle Erosion

Filler Effect on Dry sliding Wear behavior of Polymer Composites:

Fillers are additions used in the production of composites to enhance the qualities of blended specimens. The inclusion of fillers enhances the composites' strength, which is crucial since the composites' wear characteristics may be altered. However, differences in wear are driven by filler characteristics such as size and shape. Hong-Bin Qiao et.al. [18] investigated the dry sliding wear characteristics of nanoscale filled Polyetheretherketone (PEEK)-based composites. Al2O3 particles and nanoscale inclusion reduced the wear coefficient of PEEK, but not the friction coefficient. The specimen with the lowest wear rate, 7.5x10-6mm3/N-mm without PTFE and 10x10-6mm3/N-mm with PTFE, was enhanced with Al2O3 particles with a mass fraction of 5% and a particle size of 15nm. A tribo-layer produced on the counter face using a 15Nm Al2O3-filled peak decreased friction and wear. S.R. Chauvan et al. [19] produced a composite by including cenospere particle-packed vinyl ester composts and reporting on size, weight, and distance. In this study, 20m, 900nm, and 400nm cenosphere particles were filled with vinylster composites. It was revealed that using submicron cenophere particles as fillers significantly improved specimen machine driven properties. The wear rate for all vinyl ester specimens decreased from 0.3x10-5 mm3/N-m to 0.5x10-6 mm3/N-mm for all 2 percent, 6 percent, and 10 percent This was due to the uniform distribution of cenospere particles in the matrix material and the formation of a transfer layer at the counter surface, both of which contribute to the enhancement of tribological properties.

The mechanism of wear is composed of sticky and abrasive wear. Zhenguo Zhu and Shuo Bai [20] investigated dry sliding wear-acting pin-on-disc equipment for resin graphite. The experiment's parameters were determined to be the load, sliding distance, and temperature. It was observed that furan resin may significantly strengthen graphite, resulting in enhanced mechanical properties. Compared to graphite, the friction co-efficient of resin/graphite was decreased by 18.3 percent below 10Mpa, with the lowest friction co-efficient being 0.12 at 20Mpa. The wear rate of resin/graphite was 170 percent at 8Mpa and 104 percent at 10Mpa, while the dusting wear rate of graphite at 15Mpa was about 800 times more than composite. K.Srinivas et al. [21] investigated the wear characteristics of hybrid Epoxy specimens. In this study, three types of particles were added to epoxy: GR, SIC, and GR-SIC. Epoxy with SiC/GR is said to wear less and resist wear more effectively. In conjunction with other composites, the SIC/GR-containing epoxy hybrid specimens exhibited the lowest wear rate of 2.89x10-5mm3/N-mm. Utilizing Sic and Graphite filler reduced the wear rate by 5x10-5mm3/N-m at 30N load. While the resistance to wear has been enhanced.Feng-hua Su [22] demonstrated the machine-driven qualities and wear/friction characteristics of nanoparticle-reinforced carbon fibre. Dip-coating with phenolic resin produced three nanoparticles: nano-SiO2, nano-TiO2, and nano-CaCO3. Using the POD machine, the friction and wear properties of these specimens were evaluated. It was discovered that the addition of nanoparticles to carbon fabric enhanced its machine-driven properties and abrasion resistance. As a filler, nano-CaCO3 is the most effective of the three nanoparticles in enhancing wear resistance. Adding more Nano-SiO2 to the mixture decreased the machine-driven characteristics of composites even more. Y.Xie, G.S. Zhuang, et al. [23] fabricated composites, such as PEEK/PTFE specimens packed with potassium titanate whiskers, and conducted dry sliding wear testing on a pin-disc machine at varying weights. It has been found that PTW provides a robust reinforcement for PEEK/PTFE composites. The addition of PTW increased the micro hardness of the PEEK/PTFE composite. PTW may also boost the wear resistance of PEEK/PTFE specimens while lowering the friction coefficient. Under varying loads, the friction coefficient and wear rates of this specimen decreased as the PTW content increased. The PTW 5% component enhanced wear resistance more efficiently. H.Una et al. [24] investigated the friction and wear of polyamide 6 and graphite and wax polyamide 6 specimens using a pin on disc machine. This experiment investigated the effect of filler type, quantity, load, and speed on wear and friction characteristics. Experiments were conducted with sliding speeds of 0.4, 0.8, and 1.6 m/sec with loads of 50, 75, and 100 N. In this work, wax composites performed well, with a low coefficient of friction and excellent wear resistance. The specific wear rates of pure PA-6, PA-6G, and PA-64 percent wax composites are around 10 14 m2/N, 10 14 m2/N, and 10 15 m2/N, respectively.

Crivelli Visconti et al. [25] investigated the wear properties of composite materials using hard particles. In this work, the produced composite was composed of glass fibre with three distinct matrices: epoxy resin, epoxy resin filled with silica particles, and epoxy resin filled with TIO2. The research was conducted on a pin-on disc machine at various speeds and weights. The wear rate increased with increasing load, but not in a linear fashion; a significant increase was seen in the transition from 20N to 30N, 30x10-10mm3/N-m to 50x10-10mm3/N-mas for a typical load. Kishore et al. [26] studied the dry sliding wear behaviour of a polymer matrix containing glass fibres. During the wear test, the sliding distance was increased from 500 metres to six kilometres. Little distance ran specimens had a distinct pattern for the matrix rather than the continuous bunch-like morphology with debris accumulation, according to the results. Long-term specimens showed interface separation with debris adhering to them. S.Basavarajappa and S.Ellaangovan [27] produced the G-E specimen, which is a composite including Sic and Gr Particles. The samples were assembled by hand. The silicon carbide content of the composite varied between 5 and 10 percent, whilst the graphite content stayed constant at 5 percent. The rate of deterioration was computed using load, velocity, and sliding distance. It was observed that the addition of fillers to G-E Composite increased its resistance to wear. The specific wear rate of unfilled G-E Epoxy composites is 8.16m/sec, or roughly 13x10-6mm3/N-m, while the specific wear rate of filled G-E Epoxy (10 percent Sic, 5 percent Gr) is approximately 9x10-6 mm3/N-m. The particular wear rate at a greater load of 100N is 16x10-6 mm3/n-m for clean G-E composites and 6x10-6 mm3/n-m for loaded G-E composites (10Sic and 5 percent Gr). At a larger sliding distance of roughly 5000m, the wear rate for unfilled G-E composites is approximately 9x10-6mm3/N-m, while the wear rate for filled G-E composites is around 6x10-6mm3/N-m. Because fillers have greater thermal conductivity, filled G-E composites have superior wear resistance compared to unfilled G-E composites. To improve the wear performance of filled G-E specimens, the counter-top tribofilm structure was created. The impact of load on the rate of deterioration was greater than that of other factors. Figure 6 illustrates the pin on disc machinery used by a number of writers.

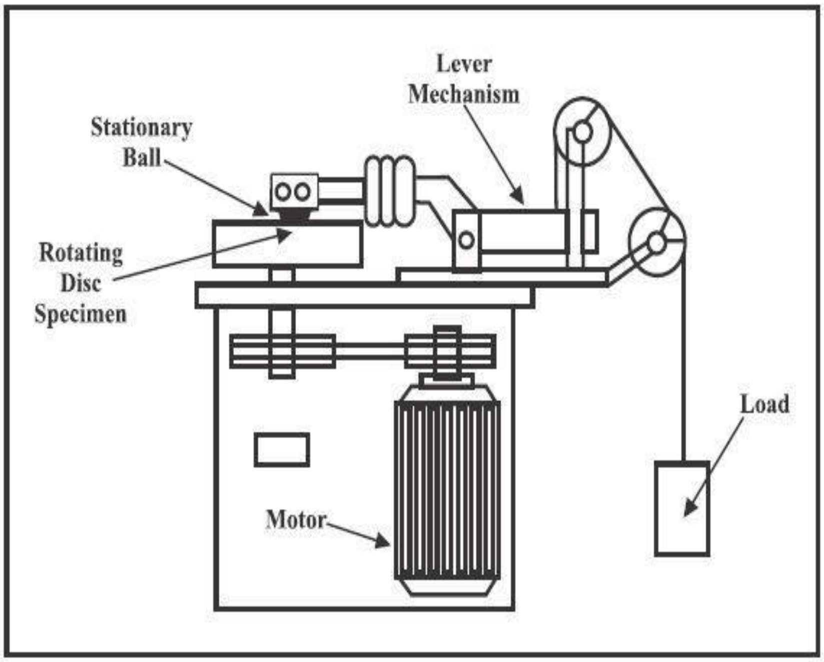


Figure 6. Shows the pin on disc Machine used by different Authors

In another paper, S.Basavarajappa et al. [28] others evaluated the impact of two secondary fillers, SiC and Graphite, on the dry sliding wear performance of polymer matrix using the Taguchi method. In this experiment, the effects of load, speed, and distance on wear rate were explored. In this experiment, the Taguchi approach was implemented using the L27 orthogonal array. The impact of process factors on the wear of these composites was examined using analysis of variance. According to the results, the addition of SiC particles to the polymer matrix as a secondary filler enhanced the material's wear resistance. 10mg for GE composites that are empty and 5mg for those that are full. Utilize DOE techniques, such as the Taguchi method, to analyse the wear characteristics of composites while taking into consideration load, velocity, speed, and filler content as test factors. S.Manoharan et al. [29] developed recycled basalt and aramide fibre hybrid composites utilising the Taguchi model based on the Gray equation. In this study, a POD rig was utilised to conduct wear testing on a Taguchi L27 array employing variables such as load, speed, and percent filler content. The findings demonstrated that the addition of filler significantly boosted the specimen's resistance to wear and friction. The SEM images demonstrate fibre matrix deformation, fibre pull-out, cracks, and matrix wear.

Basappa Halappa et al. [30] examined the effect of fibres on the machine driven properties and fracture toughness of G-Reinforced epoxy specimens. This experiment included a hand-lay method followed by a hot press to produce graphite and silicon carbide fillers (5to10wt percent). The machine driven properties and mode-1 fracture toughness of these specimens were evaluated in accordance with the ASTM standard. G-E with 5% graphite has the highest KIC value, 28.7 MPa m1/2, followed by G-E with 10% graphite, 27.2 MPa m1/2. This may be due to the increased filler loading in G-E, which induces the pining effect and thus reduces the matrix's toughness. Similar conclusions were reached in earlier published works. The KIC values for samples containing 5 and 10% Sic were respectively 25.5 and 23.92 MPa m1/2. Composites with the greatest fracture toughness were those containing graphite. When the whole mechanical result is considered, GE Composites packed graphite particles perform better. Both SIC and graphite particles enhanced the G-E specimen's fracture energy. B.Suresh et al. [31] submitted an additional investigation on the influence of GR filler on the sliding and wear properties of CF-added epoxy specimens. Carbon fibre with epoxy was used as a reference material in this experiment. Using a sliding distance of 6000m and weights of 25, 50, 75, and 100N, the wear testing technique for POD machine weight loss was determined in terms of velocity. Also employed in two body abrasive tests were abrasive materials with 150 and 320 grit. Also measured were abrasion distance, wear loss, and load-related wear rate. According to the data, greater loads and speeds led to excessive wear loss. The addition of carbon-epoxy to graphite material enhanced its resistance to wear. The 10wt percent GR wear rate in CF-Epoxy is very low. 0.0242 x103mm3 wear volume. It has been observed that a Graphite-Tribo-film on the surface of Gr-filled C-E samples may enhance their wear resistance.

B.N.Ramesh et al. [32] studied the addition of alumina and molybdenum disulphide (MOS2) to carbon epoxy hybrid composites in another study. On wear performance composites, variables such as normal load, filler content, and sliding distance were examined. In this study, the L18 array and five parameters that influence the abrasion process were used. Using multiple replies, the GRA Technique was utilised to optimise wear and friction parameters. Utilizing ANOVAs, the importance of wear-related characteristics was determined. According to the results, filler loading and filler type are the most critical elements in influencing the wear rate of C-E Composites. The specific Wear rate for unfilled carbon Epoxy at a 10M abrading distance is 0.6x10-9mm3/N-m and 0.27x10-9mm3/N-m for 10% MOS2-filled C-E composites. At higher loads, unfilled C-E composites have around 0.45x10-9 mm3/N-m, while filled C-E composites with 10% MOS2 have approximately 0.3x10-9 mm3/N-m. At high temperatures, N.Mohan et al. [33] studied the machine-driven and tribological properties of SIC-filled G-E composites. In this investigation, the machine driven properties and wear/friction of G-E composite and Sic-filled G-E specimens were examined. The specimen was tested on a Pin-On-Disc machine at temperatures of 30, 60, 90, and 120 degrees Celsius with loads of 10N and 20N at 1.5 metres per second over a distance of 5000 metres. As the temperature and load rose, the wear loss of both specimens also increased. In a similar setting, the rate of wear accelerated. In contrast, SIC-added G-E specimens exhibited a lower wear rate of about 3.8x10-4 gramme and a greater 0.3 at 120OC than pure G-E specimens. C.R.Mahesha et al. [34] studied the impact of incorporating Nano-filler into Basalt Epoxy nano-samples on machine driven and sliding wear parameters. Nano-titanium (TIO2) and nano-clay were utilised as fillers in this study of the machine driven and tribological activity of Basalt–Epoxy specimens. Using a vacuum-assisted resin transfer moulding procedure, B-E specimens were generated in this study. Machine-driven properties such as tensile strength, tensile modulus, and Elongation at break were evaluated using ASTM standards. On the wear resistance performance, the effects of different loads (10N to 30N) and sliding lengths (2000 to 8000m) were determined. It was discovered that adding fillers to specimens lowered wear loss while increasing wear loss with increasing sliding distance. In terms of mechanical qualities, increasing the filler content of B-E composites enhanced their strength and stability. The coefficient of friction (COF) of nano-clay-B-E composites was marginally larger than that of nano-TiO2 and TIO2/clay filler composites. N.Mohan and S. Natarajan et al. [35] studied the adhesive wear behaviour and machine driven characteristics of Jatropa-Oil-Cake-filled G-E specimens. In this experiment, composites were manufactured using VARM methods. The wear characteristics of mechanical and sliding surfaces were determined. This project selected three elements: sliding distance, load, and constant velocity. The severity of wear increases as the sliding distance and applied force increase. However, the G-E specimen approach used by JOC exhibited improved wear resistance. As the sliding distance grew, the wear loss reduced, reaching 1.2x10-3g at 2000m. The use of JOC into G-E Composites enhances tensile strength as well as frictional and abrasion resistance. The SEM image depicts matrix fragmentation, fibre fracturing, matrix cracking, void formation due to matrix chipping, and fibre exposure. Ashokkumar,R.T and N.Mohan et al. [36] have published a new paper. The composites were created by filling Basalt Epoxy specimens with UHMWPE. The specimens were prepared using the RTM method, and wear tests were conducted. It was anticipated that the introduction of UHMWPE into B-E specimens will lower the specimens' wear rate by 1.25 10-15 mm3 /N-mm. The wear properties of the specimen were reduced by polymer-film layers on the steel disc counter face, which operate as a stress-bearing support to prevent fibre and matrix degradation. K.Kumaresan et al. [37] used a hand-lay-up technique to synthesise carbon-epoxy containing silicon carbide. Using the POD machine, these specimens were investigated. In this experiment, specimens were examined under various circumstances, such as tension and sliding velocity. Experiments were done at a given distance while varying the mass and velocity. It has been shown that faster load and greater sliding velocity correlate to increased wear loss. The wear resistance of the C-E material loaded with SiC was 6x10-6 mm3/N-mm for the unfilled EP composite and 4x10-6 mm3/N-mm for the Sic-filled Epoxy composite. The rate of wear of 10% SiC in C-E was very low. 5wt percent and 10wt percent SiC in C-E result in a 21 and 35 percent improvement in wear resistance, respectively, compared to unfilled C-E Composites. Kishore Debanth et al. [38], explored G-E composites packed with rice husk. This study studied the wear and frictional performance of polymer composites reinforced with glass fibres and utilising rice husk as a filler material. The wear tests were conducted on a POD device. Experiments were conducted at speeds of 1.2m/sec and 3m/sec with standard forces of 10,20N, and 30N. By adjusting the sliding distance from 1000m to 3000m, the wear loss and friction force may be calculated. The highest wear rate was 11.48x10-8 mm3/N-mm. The lowest wear rate recorded is 1.28x10-8 mm3/N-mm. The wear rate of Glass-Epoxy specimens injected with rice husk decreased as the applied stress increased. With the exception of the specimen with a sliding velocity of 2m/sec, the COF decreased as the applied normal force increased. With a standard load of 30N, a velocity of 3m/sec, and a distance of 1000m, the lowest COF measured was 0.17. According to the SEM image, back transfer film and debris creation are the primary reasons of low wear rate. Resinous regions exhibited deboning of fibres, cracking and fibre breakage, and ploughing. Darshan, S.M et al. [39] explored nanocomposites containing zirconium-filled bisamaleide. Using the L27 orthogonal array, the impact of several aspects on wear behaviour, such as sliding velocity, load, and filler content, was examined. The COF of BMI nanocomposites containing ZrO2 was shown to decrease as the ZrO2 concentration rose. As sliding distance increased, the wear rate of the BMI and ZrO2 loaded BMI nano-composites reduced. At a sliding distance of 1000m and a load of 20N, the highest specific wear rate is 3.2125mm3/Nm. At a load of 40N and a distance of 1000m, the lowest specified wear rate is 1.80708mm3/N-mm. The impact and dynamic strength of nanocomposites with high wear resistance were studied. DMA results also indicated that the addition of nano-ZrO2 to BMI increased its storage and loss moduli. According to the ANOVA results, normal load was the most significant factor, followed by velocity, sliding distance, and filler material. The effects of load on the wear properties of a polypropylene/Carbonized bone ash filler specimen have been examined by F.Asuke et al. [40] this research examined the use of bone-ash particles that have been carbonised as reinforcement. During the experiment, the weight changed from 5N to 15N. It was determined that as load rose, the rate of wear increased, but when CBp increased, the rate of wear reduced. Wear was negligible while the load was little, but it increased as the load rose. The wear rate at 15N load is about 5x10-3mm3/g/min. According to the literature, load increases the rate of deterioration. The wear rate rises as the load increases and reduces as the percentage of carbonised filler material increases. B.Shivamurthy et al. [41] investigated the wear characteristics of graphite-added epoxy specimens. Using lay-up, the specimens in this procedure were constructed by hand. Using a POD device, the wear characteristics of these specimens were assessed. Graphite boosts the machine-driven characteristics of a glass/epoxy specimen. At a load of 60N, specimens having 3% graphite exhibited a lower wear rate of about 4x10-8 g/N-mm. additionally, enhanced machine-driven characteristics. At greater loads, graphite particles that have separated from the surface of the specimen get stuck between the specimen and the sliding surface, functioning as a lubricant by producing a thin layer and decreasing the coefficient of friction (COF) and specific wear rate. Naveed Anjum and S.L Ajith Prasad et al. [42] these investigations examine the machine-driven features and wear behaviour of G-E specimens with variable weight (SiO2) filler. Utilizing the Taguchi L9 array, the impact of load, velocity, and distance on the dry sliding wear characteristics was investigated. It was revealed that the addition of SiO2 filler to the material enhanced the specimen's machine-drivability. Adding SiO2 filler to the composite decreased the wear volume loss and wear rate of several specimens. At 1500m, the lowest recorded wear loss was 0.0012g. The SiO2 particles also act as supplemental reinforcement, carrying load and minimising wear. Figure 7 illustrates the fabrication chart used by several writers.

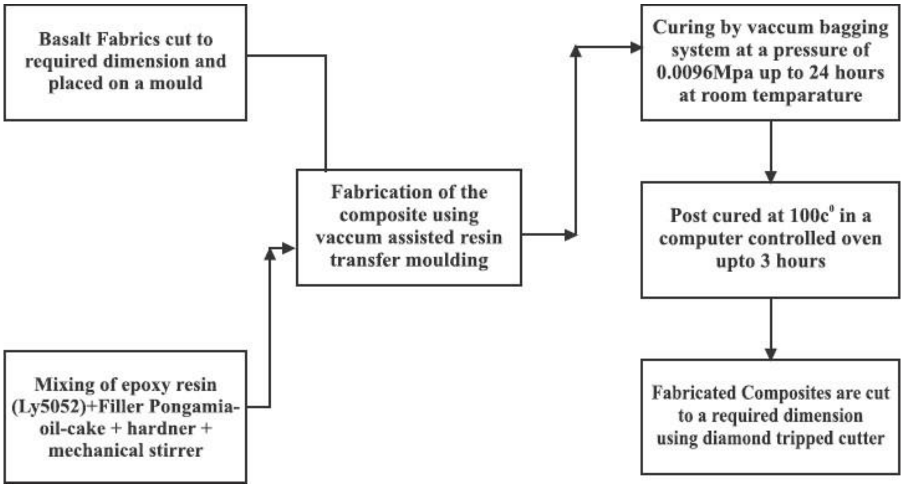


Figure 7. Fabrication of Composites chart used by Authors

J.S. Sindhu and G.S.Lathakar focused on the mechanical and sliding wear parameters of WS2 particles-filled epoxy specimens in their study [43]. This research examined machine-driven properties. In addition, a dry sliding wear test was conducted utilising Taguchi Design of Experiments. With a hardness of 25 for unfilled resin and 35 for filled composite, the hardness increased as the filler quantity grew. The strength increased as the percentage of filler increased. At 3wt percent WS2, the tensile strength was about 47.79Mpa. Using the DOE method, we reanalyzed the wear characteristics of WS2-added specimens. The S/N ratio (Delta) for wear rate is 6.05 for sliding velocity, 6.97 for Normal load, 15.46 for filler content, and 1.90 for sliding distance. Using the POD machine, V.S.Aigbodion et al. [44] studied the wear and friction behaviour of polyethylene polymer specimens containing bagasse particles. This research examined wear parameters such as speed, load, and sliding distance, in addition to the impact of bagasse as a filler. Using linear regression and ANOVAs, the impact of process factors on sample wear rate was analysed. As a boosting material, the inclusion of Bagasse particles to the polymer boosted the medium's S14 wear resistance by about 0.16gram. Speed and load have the most natural and static impact on the deterioration of the two specimens. Bon-peng Chang et al. [45] compared UHMWPE coupled with micro- and nano-Zinc at different filler loadings. The specimens were subjected to dry sliding wear testing under varying abrasive conditions. Using a hot compression mould, micro- and nano-scale UHMWPE specimens were made. Using a pin-on disc machine, the samples were evaluated for wear and friction. It was discovered that increasing the quantity of filler in the UHMWPE matrix may enhance the wear resistance of specimens. Compared to nano-zno/UHMWPE specimens, those with 5% micro-zinc filler saw reduced weight loss. When both fillers were applied to the UHMWPE matrix, the coefficient of friction remained unchanged. When the load is increased from 10N to 30N, the COF for both fillers, including micro/nano UHMWPE specimens, decreases by 60%. Figure 8 illustrates a specimen with a steel disc used by several writers.

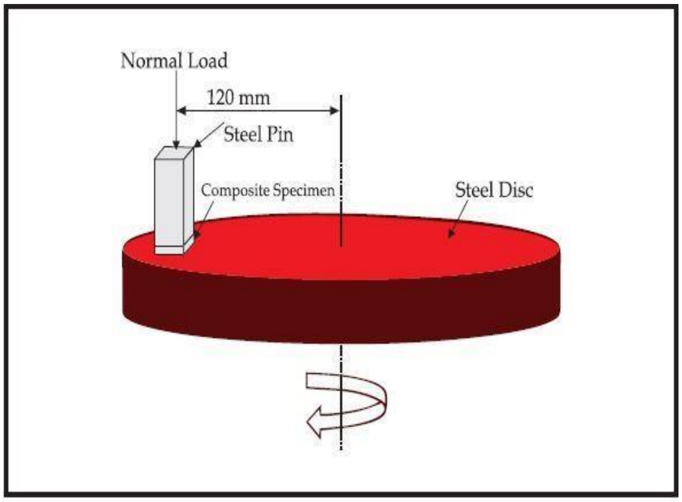


Figure 8. Specimen with Steel disc used by Author

Influence of fibers on synthetic and Natural fibers on Dry sliding wear of Polymer Composites:

The relative motion of two surfaces leads polymer matrix specimens to experience friction and wear. This may lead to matrix delamination, and repeated rubbing can damage both the fibres and the matrix. Several ways have been investigated in an effort to enhance the Tri-bo-achievement of the polymer samples. Matrix fibre reinforcement is one method for resolving the delimitation problem. In use now include glass fibres, carbon fibres, basalt fibres, and natural fibres. Suresh.B.et al.[46] studied the friction and wear characteristics of short glass fibres (SGF) applied on thermoplastic polyurethane (TPU) specimens. This procedure included the incorporation of short fibres into a TPU matrix at weight ratios of 20, 30, and 40%. The specimens were created using injection moulding. Changes were also made to force and velocity during the pin on disc wear test. As load and sliding velocity increase, so does wear. As SGF rose, the composites' COF and wear rate dropped. In terms of wear resistance, the 40 percent SGF-reinforced TPU composite beats the 20 percent and 30 percent SGF-reinforced TPU composites in all examined situations. The increased weight percentage of SGF reinforcement in the TPU matrix, which generates a thin layer during sliding, may account for the decreased wear loss in the 40 percent SGF–TPU composite. On the counter face, the presence of (pulverised glass and polymer wear debris) increases wear resistance. 40% SGF has a wear loss of 0.008g, 30% SGF has a wear loss of 0.009g, and 20% SGF has a wear loss of 0.0011g. SGF weights around 0.012g TemesganBerhanuYallow et al. [47] The composites were manufactured via compression moulding. Evaluation of tribological behaviour, including wear and friction. In this experiment, the sliding speed was set to 1 to 3 metres per second, the applied force was set to 10 to 30 Newtons, and the sliding distance was set to 1000 to 3000 metres. Incorporating woven jute cloth into a polypropylene matrix increases wear resistance by 35 to 45 percent while reducing the coefficient of friction. Incorporating woven jute cloth as reinforcement into a polypropylene matrix decreased wear by 65%. The particular wear rate at 30N tension is 7x10-8mm3/N-mm. Using the Taguchi Method, Vinaykumar.D et.al. [48] studied the Tribomechanical properties of natural fibres such as coconut coir/banana fiber/glass fibre hybrid specimens. Various proportions of natural and glass fibres were manufactured using the hand lay-up technique. The specimen's wear resistance was examined under a variety of conditions, including load, speed, and the fraction of fibres used by weight. A pin-on-disc machine was used with a Taguchi L16 array. The acquired data was statistically analysed using ANOVA techniques in order to determine the influence of different test conditions. It was discovered that the weight of the fibres is crucial, followed by load and speed. Vinaykumar et al. [49] evaluated the tribological and machine-driven features of coir-silk-enhanced polypropylene-based specimens in a separate investigation. In this experiment, three unique specimen weight percentages were prepared: specimen with silk fibre added, specimen with coir fibre added, and specimen with both silk and coir fibre added. Multiple tests were conducted on the specimen that was generated. The composites were evaluated for abrasive wear using the slandered method. Using the DOE L9 orthogonal array, the optical wear behaviour of produced specimens was evaluated. The method of design of experiments indicated that the specimen's weight % had the biggest impact, followed by load and speed. Compared to specimens C1 (Coconut fibre polypropylene) and C2 (Silk fibre polypropylene), the wear life of specimen C3 (Silk and Coconut fibre) increased by 35%. In addition, the composite's wear life was increased by 35%, and its water absorption capacity was increased by 42%. Satish and

Kumaresan.K.et.al [50] investigated the machine-driven and physical properties of flex and bamboo fibre-added hybrid Epoxy specimens. In this instance, compression moulding was used to make the specimens. Using FTIR analysis, the chemical process of flex and bamboo fibres was identified. The tensile, impact, flexural, and ILLSS properties of 40:0 (Flex: bamboo) hybrid specimens were shown to be superior. The 40:0 (flax: bamboo) composite samples have an excellent tensile strength and can withstand up to 34.27, which is somewhat greater than the other hybrid composites. Due to the dense packing of flax fibres and increased compatibility with epoxy resin, the void content of 20:20 (flax: bamboo) hybrid composites is reduced. The composites composed of forty percent flax fibre and zero percent bamboo fibre had the maximum flexural strength at 89.90 MPa. The maximum impact strength and ILSS of Composites at the same volume percent are 2.35 J and 3.52 MPa, respectively. N.Karthin and Kumaresan.K.et.al [51] developed these jute and banana fibres filled with epoxy-based composites. This research used compression moulding to produce three composites: MC1-15wt percent banana and 15wt percent jute, MC2-20wt percent banana and 20wt percent jute, and MC3-25wt percent banana and 25wt percent jute. Different load conditions (20, 40, and 60N) and distances (602.88, 1205.76, and 1864.64mm) were used to conduct the wear test (602.88, 1205.76, and 1808.64mm). In terms of wear resistance, it was proved that hybrid composites outperformed single-fibre reinforced composites. At 40N and 60N, the MC1 (15wt %) wear duration in 6 minutes is 6.21 percent and 10.47 percent, respectively. The MC2 (20wt%) Wear duration in 6 minutes and the percent decrease in specific wear rate are, respectively, 6.31 and 10.47. At 40N and 60N loads, the MC3 (25wt percent) wear time in 6 minutes percent decrease in SWR is, respectively, 6.28 and 10.05

C.W. Chin et al. [52] examined composites such as Kenaf fibres and epoxy composites for wear. Using a closed mould method and a vacuum system, a Kenaf fibres added to epoxy (KFRE) specimen was produced. Using the counter face POD machine, the wear and frictional behaviour of the specimen was evaluated at different weights (30-100N), sliding lengths (0-5KM), and sliding velocities (1.1-3.9m/sec). Consideration was given to the effect of fibre orientation, such as parallel, ant parallel, and normal. The N-O orientation of the fibres improved the wear resistance of epoxy by about 85 percent. The effects of load and sliding velocity on the wear rate of KFRP composites were minimal. In general, the wear resistance of N-O was superior than that of P-O and AP-O. Micro cracks (N-O) and debonding were prominent in the composites' fibre section wear processes (P-O). Kartthikeyan et al. [53] fashioned jute/polymer composites having sliding wear properties. In this experiment, jute fibre and polyester resin were combined. To increase its performance in heavy-loading applications, jute fibre is treated with sodium hydroxide solution and 2% PTFE filler tribolubricant. The samples were created using the hand-lay-up method. A dry sliding wear test was conducted to measure the wear rate and coefficient of friction. During the sliding distance, the temperature increased substantially. N.K.Batra.et al. [54] studied the effect of dry sliding wear on carbon, Aramid, and Glass fabric polythermide (PEI) specimens. In this study, polythermide composites reinforced with a range of fibres, including carbon and glass aramid fibres, were used. The specimens were manufactured using compression moulding. A POD Tribometer was used to conduct a wear examination on the specimen. In comparison to glass and aramid-added specimens, carbon fibre with PEI exhibited superior wear resistance owing to its high modulus and bonding. Aramid fibres and hybrid Composites have a lower wear rate than Composites with additional Glass fibre due to their high wear resistance and low COF. V.Armuganprabhu et al. [55] the specimens were fabricated by hand using the lay-up method. The specimens' tensile, flexural, and impact strengths, as well as the weight percentages of 2, 4, 6, and 8 percent red mud particle addition, were measured. Red mud was added to a hybrid composite to boost its machine-driven l characteristic. The sisal/Glass specimen had 33 percent more tensile strength and 54 percent greater flexural strength, while the banana/sisal specimen demonstrated 25 percent greater impact strength. K.Sabeel Ahmed et al. [56] examined the wear properties of ceramic fillers, including Sic/Al2O3-filled jute/epoxy examples. Depending on resin weight, samples of Jute/epoxy with fillers at 5wt percent, 10wt percent, and 15wt percent were created by hand lay-up. The POD/machine was used for the wear test. For each configuration, varying speeds and weights were used to conduct wear tests. Utilizing both kinds of fillers, we evaluated wear loss and COF. The addition of fillers to the jute/epoxy sample enhanced its resilience to wear. Al_2O_3-enhanced specimens demonstrate superior wear characteristics compared to Sic-enhanced specimens.

Effect of sliding wear of Polymer composites on different Environment Condition:

Li Chang et al. [57] studied the wear and friction characteristics of high temperature-resistant thermoplastics, such as Polyetheretherketone (PEEK) and Polyetherimide (PEI), when combined with carbon fibres, graphite filler, TiO2, and ZnS in a dry sliding environment. For friction and wear measurements, POD apparatus with improved PV ranges and higher temperatures was employed (up-to15O). According to the researchers, both SGF and Graphite flexes may significantly improve the wear resistance and load bearing capacity of base polymers. J.WU X H.Chenget et al. [58] studied the tribological behaviour of Kevlar pulp-added epoxy samples under dry and wet sliding circumstances. The specimens were created by compression moulding. We studied the impact of Kevlar pulp content on specimen wear and friction. Adding Kevlar pulp to epoxy significantly increased friction and wear. The addition of Kevlar pulp to epoxy decreased the coefficient of friction and wear rate of materials in both dry and wet situations. Epoxy and Kevlar/pulp specimens exhibited greater friction and anti-wear behaviour when lubricated with water compared to dry sliding. With the addition of Kevlar pulp, the specific wear rate decreased significantly, with the lowest value (5.8103 mm^3/Nm) recorded at a filler concentration of 40%. It demonstrates that Kevlar pulp enhances the tribological performance of epoxy, namely its wear resistance. Compared to dry sliding, friction efficiency reduced from 0.33–0.57 to 0.14–0.17, and the rate of particular wear decreased by about 100 times. This was a result of water's cooling and boundary lubricating properties, which reduced friction-induced heat and hence prevented plastic deformation and matrix fracture due to the thermal effect. This might be because of its lubricating and cooling properties. H.Meng et al. [59] investigated the friction and wear characteristics of PA6/CNT composites under dry sliding circumstances with water lubrication. The inclusion of carbon nanotubes proved PA6's effectiveness (CNTs) It was revealed that adding CNTs to PA6 provides efficient reinforcing for enhancing wear properties. Under sliding and water-lubricated circumstances, when a typical load of 20N to 50N was applied, the COF and wear rate of PA6 were lowered in the presence of CNTs. The specific wear rate of composites under a 20N stress is about 3x10-6mm3/N-mm for dry sliding and 16x10-6mm3/N-mm for wet sliding. At higher loads of 50N, the specific wear rate is about 20x10-6mm3/N-mm for dry sliding and 45x10-5mm3/N-mm for water lubrication. The use of carbon nanotubes increased the self-lubricating and heat conductivity of PA6 (CNTs).

Taguchi Analysis in Wear Evaluation process

In recent years, statistical methods have been extensively used in several engineering fields to reduce the complexity of analysis. Using these techniques, the process and each variable involved in the process effect may be analysed to meet the requirements. Using the Taguchi approach, the DOE method was able to examine the wear characteristics of specimens with many test factors. [60]. To develop a regulated and well-defined dry sliding wear rate, it is necessary to adequately characterise method variables. Dry sliding parameters include weight, speed, and distance travelled. Therefore, it is necessary to develop a statistical tool for evaluating the impact of each variable on the output response. [61] Taguchi procedures are a well-designed methodology to test assessment. Recent studies have reported it often owing to simplified methods and better results [62]. The approach simplifies the work flow and guides the evaluations toward a conclusion that identifies the operation's strengths and faults. The DOE technique is an excellent way for studying the control parameters of an experiment [63]. DOE facilitates the identification of insignificant components in advance [64] The Taguchi method decreases the disadvantages of evaluating the final product while also reducing the expense of the procedure[65] Utilizing the Taguchi Method, Satapathy and Patnaik[66] investigated the influence of wear variables on the outcome. It is a simple, systematic, and controlled procedure. SabareesPrabhakaranet al. [67] investigated the impact factors involved in the wear test of Graphite-filled ISopthalic specimen using the Taguchi method. This research analysed and reported on three criteria influencing the slide wear test using the L9 orthogonal array. Numerous researchers use the Taguchi method, which has been utilised to develop a vast array of applications and procedures. [68-69.]

Conclusion:

In the current study, a short overview of polymer composites and their dry sliding wear characteristics was conducted. The main characteristics of the wear resistance of fibre reinforced composites have been determined. The following findings are reached based on the review:

1) Both composite fibres and fillers may increase wear resistance.
2) However, the enhancement is contingent on the unique qualities of the fibre and filler as well as the production process. Reinforcement of filler in composites prepared the way for a new era in the fabrication of wear-resistant specimens.
3) In general, reinforcing alterations the wear properties of the matrix. It is observed that up to a specific reinforcement %, wear resistance was strong, but after reaching a certain reinforcement percentage, wear loss increased. Due to the filled and matrix bonding qualities, this was the case. It has been determined that the optimal degree of reinforcement should be maintained in composites to ensure excellent wear resistance.
4) Fiber orientation, fibre treatment, and fibre weight % affect friction and wear. The regular orientation of the fibres increased the sliding wear characteristics. The fibre strength, aspect ratio, and fibre and matrix binding strength all contribute to the enhancement of dry sliding wear characteristics.

5) Many investigations have been conducted on the incorporation of fibres and fillers into polymer specimens that have been exposed to wear. However, developing a polymer reinforced with natural fibres with dry sliding wear behaviour is difficult. Despite the fact that several work studies have been recorded, there are few statistical investigations on the dry sliding wear performance of PMCs.

REFERENCES

1. Kishore, Sampathkumaran P, Seetharamu S et.al SEM observation of the effects of velocity And load On the Sliding wear characteristics of the glass fabric-Epoxy composites with Different fillers. *Wear* 2000; 237: 20-27
2. Collyer AA,Rubber Toughened Engineering materials 1994, Chapman Hall London, Springer
3. Hasim Pihtili, Nihat Tosun Investigation of the Wear Behavior of a Glass fiber reinforced Composite plain polyester resin. *Compos.Sci.Technol* 2002; 62: 367-370
4. EI-Tayeb NS, Gadelrab RM, Friction and Wear Properties of E-Glass fiber reinforced Epoxy Composites under different Sliding Contact Conditions. *Wear* 1996; 192: 112-117
5. Navin Chand, Ajay Naik, Somit Neogi, Three body abrasive wear of Short-Glass fiber Polyester Composites. *Wear* 2000; 242: 38-46
6. Xianqiang Pei, Klaus Friedrich, Erosive wear Properties of Unidirectional Carbon Fiber Reinforced Peek Composites. *Tribol Int* 2012; 55:135-140
7. Friedrich K, Wear of Reinforced Polymers by different abrasive Counterpartes.Composite Material series 1986; 1:233 Elsevier
8. Cirinom, Pipes RB, The abrasive wear Behavior of Continuous fiber Polymer Composites' *J Mater Sci* 1987; 22:2481-2492
9. BiJwe J, Logani CM, and Tewari US, Influence of Fillers and Fiber reinforced on abrasive Wear resistance of Some Polymeric Composites. *Wear* 1990; 138:77-92
10. Jayashree Bijwe, Indumathi J, John Rajesh J,et.al. Friction and wear of Polythermide Composites in Various Wear modes. *Wear* 2001; 249: 715-726
11. Rohatagi PK, Balu PJ, Yust CS, Tribology of Composite Materials Materials park 1990;21
12. Suresha B, Kunigal N.Shivakumar Investigation on Mechanical and Two body abrasive Wear behavior of Glass/carbon fabric reinforced Vinyl ester Composites.*Mater Des* 2009; 30:2056-2060
13. Basavarajappa S, Ellangovan S, Arun KV, Studies on Dry Sliding Wear Behaviour of Graphite Filled Glass-epoxy Composites *Mater Des* 2009; 30:2670-2675
14. Suresha B, Kunigal shivakumar, Seetharamu S, et.al Friction and dry Sliding Wear behavior Of Carbon and Glass fabric reinforced Vinyl Ester Composites. *Tribol Int.*2010; 43: 602-609
15. Paul Davim J, Rosaria Cardso, Effect of the reinforcement on Friction and Wear Behavior of The Peek against steel Surface at long dry sliding. *Wear* 2009; 266: 795-799
16. Wan YZ, Chen GC, Raman S, et.al Friction and Wear Behavior of Three dimensional Braided carbon Fiber/ Epoxy Composites under dry Sliding Conditions. *Wear* 2006; 260:933-941
17. Quintelier J, De Baets P, Samyn P, et.al On the SEM features of Glass-Polyester Composite System Subjected to dry Sliding Wear. *Wear* 2006; 261:703-714
18. Hong-Bin Qiao, Qiang Guo, Ai-GuoTian.et.al A Study on Friction and Wear characteristics Of Nanometer Al_2O_3/PEEK Composites under the dry Sliding Condition *Tribol.Int* 2007; 40:105-110
19. Chauhan SR, Sunil Thakur, Effects of particle Size, Particle loading and Sliding distance on The friction and Wear Properties of Cenosphere Particulate Filled Vinyle ester Composites *Mater Des* 2013; 51: 398-408.
20. Zhenguo Zhu, Shuo Bai, Jungfeng Wu, et.al Friction and Wear Behavior of Resin/Graphite Composite under dry Sliding *J Mater Sci Technol* 2015; 30:1-6
21. Srinivas K, Bhagyashekar MS, Wear behavior of Epoxy Hybrid Composites, Proceed Engg 2014; 97:488-494.

22. Feng-hua SU, Zhao-Zhu Zhang, Wei-Min Liu, Mechanical and Tribological properties of Carbon fabric Composites Filled with Several nano-particles *Wear* 2006; 26:861-868

23. Xie GY, Zhauang GS, Sui GX.et.al Tribological Behavior of Peek/PTFE Composites Reinforced with Potassium Titanate Whiskers *Wear* 2010; 268:861-868

24. Unal H, Mimaroglu A, Friction and wear Performance of Polyamide 6 and Graphite and Wax Polyamide 6 Composites under dry sliding Conditions. *Wear* 2012; 289:132-137

25. Crivelli Visconti I, Langella A, Durante M, The Wear Behaviour of Composite Materials With Epoxy Matrix filled with Hard Powder *Appl Compos Mater* 2009; 30:2670-2675

26. Kishore, Sampathkumaran P, Seetharamu S, On the SEM features of Glass-Epoxy Composite System Subjected to dry sliding Wear. *Wear* 2001; 247: 208-213.

27. Basavarajappa S, Ellangovan S, Dry Sliding Wear Characteristics of Glass-Epoxy Composite Filled with Silicon Carbide and Graphite Particles *Wear* 2012; 296:491-496

28. Basavarajappa S, Arun KV, Paulo Davim J, Effect of filler Materials on Dry Sliding Wear Behavior of polymer Matrix composites- A-Taguchi Approach *JMMCE* 2009; 8:379-391

29. Manoharan S, Vijay R, and Lenin Singaravelu D, Mater. *Res Express2019;* 1:21

30. Basappa H, Mysore V, Achuta.et.al Effect of fillers on Mechanical Properties and Fracture Toughness of Glass Fabric reinforced epoxy Composites *JMMCE* 2016; 4:1-14

31. Suresh B, Siddaramaiah, Kishore.et.al Investigation on the Influence of Graphite Filler on the Dry Sliding Wear and abrasive wear Behavior of Carbon fabric reinforced epoxy Composites *Wear* 2009*;* 267: 1405-1414

32. Ramesh BN, Suresha B, Optimization of Tribological Parameters in abrasive Wear made of Carbon-Epoxy hybrid Composites. *Mater Des* 2014:59: 38-49.

33. Mohan N, Mahesha CR, Raja R, Tribo-Mechanical Behavior of SIC Filled Glass-Epoxy Composites. *IJEST* 2014; 6:44-56

34. Mahesh CR, Shivarudraiah, Mohan N, Role of nano-fillers on Mechanical and dry Sliding Wear Behavior of Basalt-Epoxy Composites.*Mater Today Proc*; 2017; 4: 8192-8199.

35 . Mohan N, Nagarajan S, KumareshBabu SP, Investigation On Sliding Wear Behavior and Mechanical Properties of Jatropa-Oil-Cake Filled Glass-Epoxy Composites *J Am oil Chem.* Soc 2011; 88: 111-117.

36. Mohan N, Ashokkumar R, Rajesh K et.al Investigation on Sliding Wear Behavior of UHMWPE filled B-E Composites *AIP conf Proc 2009* (2057), 020048

37. Kumaresan K, Chandramohan G, Senthilkumar M et.al Dry Sliding Wear Behavior of Carbon Fabric Reinforced Epoxy Composites with and without Silicon carbide *Compos Interface* 2011; 18:509-526

38. Kishore Debanth, Vikas Dhavan, Inderdeep Singh.et.al Adhesive Wear and frictional Behavior of Rice husk filled Glass-Epoxy composites *J Prod Engg* 2014: 17; 21-26

39. Darshan SM, Suresha B, and Ravikumar BN, Optimization of Dry Sliding Wear Behavior of Zirconia filled Bismilide nano-composites.*IJMET* 2014; 5:62-70

40. Asuke F, Abdulwahab M, Aigbodion VS, Effect of Load on the Wear Behavior Of Polypropylene/Carbonized bone ash particulate Composite, *Egypt J basic appl sci* 2014; 30 : 1-4

41. Shivamurthy B, Krishnamurthy, Peter C Josef et.al Mechanical Properties and Sliding Wear Behavior of Jetropha seed Cake Waste /Epoxy Composites *J Mater Cycles Waste Manag* 2014,DOI.10.1007/s10163-014-0235-0

42. Naveed AnJum, Ajith Prasad SL, Suresha B, Role of silicon dioxide Filler on Mechanical And dry Sliding Wear Behavior of Glass-Epoxy Composites Adv. *Tribol* 2013, Article ID:324952:13,DOE.Org/10.1155/2013/324952

43. Sidhu JS, Lathakar GS, and Sharma SB, Mechanical Properties of Micro-Tungsten Disulphide Particles filled epoxy Composite and its resistance against Sliding Wear. *Malay Polym J* 2014; 9:24-32

44. Aigbodion VS, Hassan SB, Agunsoye JO, Effect of bagasse ash reinforcement on dry Sliding Wear behavior of Polymer matrix Composites. *Mater Des* 2012; 33:322-327

45 Boom-Peng Chang, Hazizan Md. Akil and Ramdziah Bt. Md. Nasir Comparative Study of Micro and nano-Zno reinforced UHMWPE Composites under dry Sliding Wear *Wear* 2013; 297:1120-1127

46. Suresh B, Friction and dry Slide Wear of Short Glass fiber reinforced Thermoplastic Polyurethane *Composite J. Reinf Plast Compos* 2010; 29:1055-1061

47. Temesgen Berhanu Yallew, Pradeep Kumar and Inderdeep Singh Sliding Wear Properties of Jute Fabric reinforced Polypropylene Composites Proceed Engg 2014; 97:402-411

48. Vinaykumar D, Mohan N, and Arunkumar Bong ale Tribological investigation of Coconut-Coir/Banana fibers/Glass fibers reinforced hybrid Polymer matrix Composites *Mater Res Express* 2019 http://doi.org/10.1088/2053-1591/ab3d4a

49. Vinaykumar D, Nanjunda Swamy, Mohan N, Sachit TS Tribological and mechanical Investigation of Coir-Sic reinforced Polypropylene based matrix Composites.IOP con Series. *Mater Sci Engg* 2021 article ID: 1091(2021)012052 http:// doi.org/10.1088/1757- 899X/1091/1/012052

50. Satish S, Kumaresan K, Prabhu L.et.al experimental Investigation on Volume fraction of Mechanical and Physical Properties of Flax and bamboo-Fibres reinforced Hybrid Epoxy Composites.*Polym, polym, Compos* 2017:252:229; 235

51. Karthi N, Kumaresan K, Rajeshkumar, Gokulkumar S, Satish S, Tribological and Thermo-Mechanical Performance of Chemically Modified Musa Acuminata/Corchorus Capsularis Reinforced Hybrid Composites *J Nat Fibers* 2021 http://doi.org/10.1080/15440478.2020.1870614

52. Chin CW, Yousif BF, Potential of Kenaf fibers as reinforcement for Tribological Applications *Wear* 2009:267; 1550-1557

53. Karthikeyan Subramanian,Rajani Nagarajan Jacob Sukumaran.et.al Dry Sliding wear Properties of Jute/polymer Composites in high loading applications 2020:7-15

54. Batra n k, Iti Dikshit, Neera Batra, Effect of Dry Sliding adhesive wear on woven carbon, Aramid and Glass fabric polythermide reinforced Composite 2020 J.Crit.Rev:7; 19-20

55. Armuga Prabhu V, Manikandan V, Uthayakumar M, Investigation on The Mechanical Properties of red filled Sisal and Banana fibre reinforced Polyester Composites 2012 *Mater Phy Mech*: 15; 173-179

56. Sabeel Ahmed K, Syed Sha Khalid, Mallinath V et.al Dry Sliding wear behaviour of Sic/Al_2O_3 Filled Jute/Epoxy Composites Mater Des 2012:36; 306-315

57. Li Chang, Zhong Zhang, Lin Ye, et.al *Trobol Inter* 2007; 40:1170-1178

58. Wu.J, Chang X.H The Tribological Properties of Kevlar pulp reinforced epoxy composites Under dry sliding wear and water lubricated condition *wear* 2006:1293-1297

59. Meng H, Sui GX, Xie GY et.al Friction and Wear behaviour of carbon nano-tubes reinforced Polyamide 6 Composites under Sliding and Water lubricated conditions *Compos Sci & Tech* 2009:69:606-611

60. Patnaik A, Sat apathy A, Mahapatra S et.al Erosive Wear Assessment of Glass-Reinforced Polyster-Flyash Composites using Taguchi Method Inter Polymer Processing 2008:23; 192- 198

61. Mishra SC, Satyabati Das, Alok Sat apathy et.al Erosion Wear Analysis of Plasma Sprayed ceramic coating using the Taguchi Technique *Tribol Trans* 2009:52; 401-404

62 Basavarajappa S, Chandramohan G,and Paulo Davim J, Applications of Taguchi Technique to study dry sliding wear behaviour of metal matrix Composites Mater Des 2007; 28:1393- 1398.

63. Sahiny. The Prediction of Wear resistance model for the metal matrix composites *Wear* 2005:258:1717:1722

64. Taguchi G, Chowdhury S, Wu Y, Taguchi Quality hand book, 2005,John wiley &Sons, Inc,Hoboken

65. Glen SP, Taguchi Methods A Hands on Approach 1992,522

66. Alok Sat apathy, Amar Patnaik, J Rein plast Compos 2010:29; 2883-2897

67. Subarees Prabhakaran, Sekar M, optimization of Dry Sliding Wear performance of Graphite Filled Isophathalic Composites using Taguchi Approach. IJCSIT 2019:6:580-584
68. Arun Rout, Alok Sat apathy Analysis of Dry Sliding wear Behaviour of Rice Husk filled Epoxy Composites Using Design of experiment and ANN 2012 Proced Engg: 1218-1232
69. Satish S, Ananda KrishnanV, Sankaranara Yanan S et.al *Journal Tribologi* 2019 :23;76-89