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ABSTRACT

In this work, to enhance the mechanical and wear resistance of the Nylon-6/SiO2 nanoparticles, added to SiO2 at various volume fractions to Nylon-6 matrix material. The composite stirred continuously to maintain the homogeneity of the mixture in injection molding. Tensile test and hardness tests are conducted for specimens to study the influence of the filler content, load, sliding speed, and sliding distance the variation of mechanical properties. Scanning electron microscopic analysis is carried out for micro examination of the surfaces and to study the wear derbies. The result shows there is an influence of the filler material, and Nylon shows high bonding ability.

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In this work, to enhance the mechanical and wear resistance of the Nylon-6/SiO2 nanoparticles, added to SiO2 at various volume fractions to Nylon-6 matrix material. The composite stirred continuously to maintain the homogeneity of the mixture in injection molding. Tensile test and hardness tests are conducted for specimens to study the influence of the filler content, load, sliding speed, and sliding distance the variation of mechanical properties. Scanning electron microscopic analysis is carried out for micro examination of the surfaces and to study the wear derbies. The result shows there is an influence of the filler material, and Nylon shows high bonding ability.

Keywords: nylon-6, nano SiO2, tensile, hardness, wear, SEM.

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I. INTRODUCTION

PMMA composite with hydrophobic SiO2 nanoparticles enhances resistance to wear. The specimen shows hydrophilic behavior due to the PMMA matrix incorporation of the SiO2 nanoparticles[1]. Nylon 66 with CaCO3 filler materials increase the tensile strength of about 112 MPa.with the addition of CaCo3 to Nylon, and there is an enhancement in the tensile strength. RanjanMajhi et al. (2017[2]).Mechanical properties of the material varying with the pure metal. Material with filler enhances the performance of the content when GFRP (glass Fiber Reinforcement Plastic), Nylon with composites are investigated and found that the tensile strength is increasing with the concentration of the filler material Husain Mehdi et al. (2014)[3]. Nanocomposites of polypropylene (PP) and nano α-Al2O3 prepared, and the mechanical test carried out, Mechanical properties of the composites increased by α-Al2O3 particles and dispersant agents. During the Transmission and scanning electron microscopic observations, it observed that the surface is rougher with an increase in the filler content Mirjalili.F(2014)[4]. The hardness of the composite with the filler content is the first increase; then, it decreases with the filler content. Silica fume-filled Nylon composite shows superior properties compared to other filler materials Raja and Kumaravel(2015)[5]. To increase the wear resistance of the content and the pure material composites added with filler material. The filler material of carbon black added to PTFE composites to tribological behavior is studied and found that wear resistance of the material increased with the Carbon black filler material V.A. Shapovalov (2010)[6]. Glass fiber reinforced composite is filled with SiO2 nanoparticles in various proportions and examined the properties of the tensile strength and the impact strength. The results concluded that there is an impact of nanoparticles in the composites. The fractured surface morphology shows that the interfacial bonding increased with the filler content of the material Ramesh Chandra [7]. The addition of secondary filler to composites can influence the behavior of the material. The morphology of the material studied and found that there is a significant change in the properties. Stiffness and elongation of the material during a failure is high then material without filler content Francesco Silva et al. (2014)[8].Input process parameters

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such as the sliding distance load and sliding speed influence the output response of the composite. This input parameter can be optimized to increase the wear resistance and the tensile strength of the material. The amount of wear can be decreased with an increase in graphite content. An increase in the sliding content will increase the tensile strength of the composite[9]. Inorganic filler materials widely used, as the documents show better properties. The tribological behavior of the material with ABS composites increases the tensile strength and is much more useful than inorganic. SBF content in the ABS matrix shows matrix enhanced both the surface hardness and wear resistance. Elongation of the material decreased; as a result, it impacts the improvement of the tensile strength [10]. The flexural strength of composite with the addition of nanoparticles increased with an increase in the filler content. Maximum tensile strength observed at higher content of filler material. By the addition of okra, fiber-reinforced composites show an increase in the tensile strength[11]. A.C Reddy [12] concluded that mechanical properties and wear performance can be enhanced by adding filler materials to Nylon 6 composite.Nylon6 composites, with the addition of the Teflon, increases the tensile strength and hardness of the composite also composite exhibits reduction in the ductility [13].Nylon/Teflon composites with Nano Iron Oxide (γ-Fe_2O_3) particles mechanical properties found to be double to that actual tensile strength of the composite. Flow lines observed in Nylon 6/Teflon/Iron oxide [14]. The bulk density of the silica fume increased with an increase in the filler content. The hardness also found to be supplemented with an increase in filler content. Mechanical properties are improved and found to be high [15]. Vinyl Ester reinforced composite with a combination of SiO_2 Particles are investigated, and fond found that youngs modules increases and tensile strength of the composite decreases.toughess of the material increases, which leads to an increase in the fracture energy.SEM analysis shows the mist zone, hackles, and step-like cracks observed.[16].The addition of 0.2%Wt Nano Silica Particles to the Thermoplastic PA6 improves the coefficient of the friction and wear resistance of the composite[17].

II. APPARATUS AND METHODOLOGY

Nylon-6 matrix material taken, and SiO_2 Nanoparticles taken as the filler material. SiO_2 partial size was approximately 80 nm. Process parameters also influence the mechanical properties, so the input process parameters such as filler content, load, sliding speed, and sliding distance are taken for carrying out the experiments Taguchi L9 orthogonal array is adopted, and test trails fixed. Filler content is ranging from 4% to 20% by weight. During the preparation of the composite SiO_2 nanoparticles, the material is mixed in ME100LA mixer with Nylon at Temperature of 190°C for 20 min at 200 rpm of mixing blades. The mixture is heated to make composite soft and smooth. The mixer passed through the injection molding machine. Material forced into the mold cavity under the pressure of 70 Mpa to remove material shrinkage. The melt flow index of Nylon-6 was 12 g per 10 min. Input parameters vary, but other parameters such as injection pressure, the heating temperature of the charging barrel, and the cooling time of moldings were kept constant. Initially, Mould is at room temperature, Nylon-6 material would solidify below the glass transition temperature (105 °C).after some time specimens were ejected from the mold. The tensile test carried out for the fabricated composites materials.

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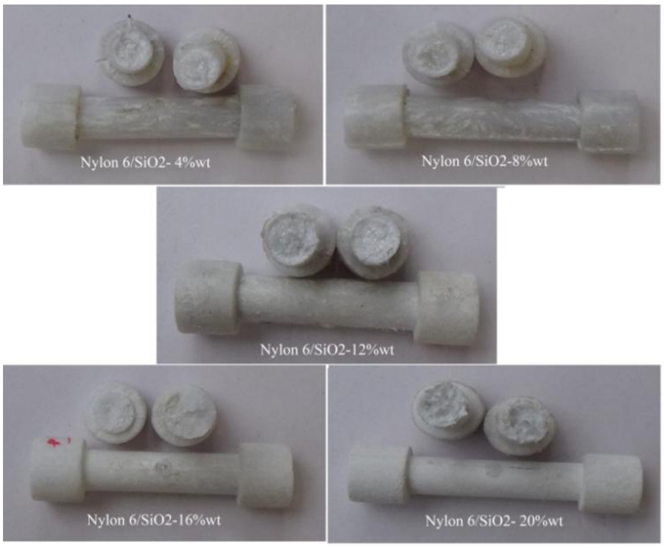

Figure 1: Tensile specimens of nylon-6/ SiO2

Tensometer Model PC-2000 (Fig. 2) used for the tensile test. After then test specimens were investigated using a scanning electron microscope, to study the wear behavior, wear test carried out using wear monitor (ASTM G99) with pin-on-disc type friction on a hardened ground steel (En32) disc emery paper (grade size of 400) fixed.

Figure 2: Tensometer

2.1 Design of experiments

Taguchi L9 design of trials for the factors of Normal Load (N), SiO2 (%wt.), Sliding speed (rpm), Sliding distance (m) given in Table 1. The Rockwell hardness test conducted for Nylon-6/ SiO2 and Scanning electron microscopy analysis carried out to study the composite material's fractography.

Table 1: Different levels of design factors

Factor	BN,wt%.	Normal Load, N	Sliding speed, rpm	Sliding distance, m
Symbol	A	B	C	D
Level–1	4	10	100	500
Level–2	12	15	200	750
Level–3	20	20	300	1000

Table 2: Orthogonal array (L9) and control parameters

Treat No.	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

III. TEST RESULTS AND DISCUSSIONS

Nylon-6/ SiO2 composites prepared with various compositions (0, 4, 8, 12, 16, and 20 wt %) of filler material and the tensile test done. During the tensile test, various load and displacement of the specimen recorded, as shown in Figure 3(a-f). It observed that there is an increase in the tensile strength later. There is a decrease in the tensile strength after composition reaches 8%. It is due to the interface bonding between the filler material, and the matrix is not suitable. This results in the optimum use of filler content are required to maximize tensile strength. The strain rate shows a sudden increase from 4%wt to 8%wt of SiO2 and a sudden decrease from 8% to 12%wt. From 12% to 16%, the strain rate is almost the same, and then it increases from 16% to 20%wt of SiO2.

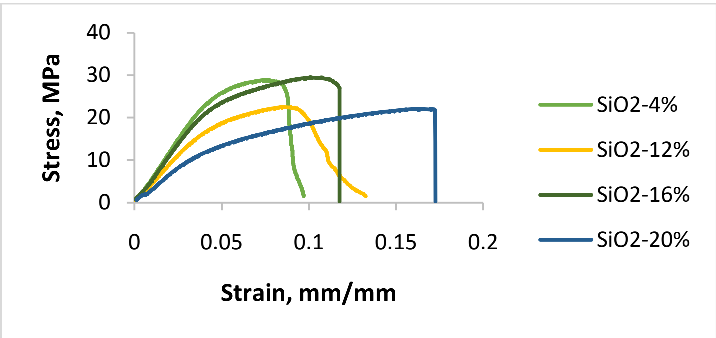

Fig 3: Stress-strain curves of NYLON-6/ SiO_2 polymer composites

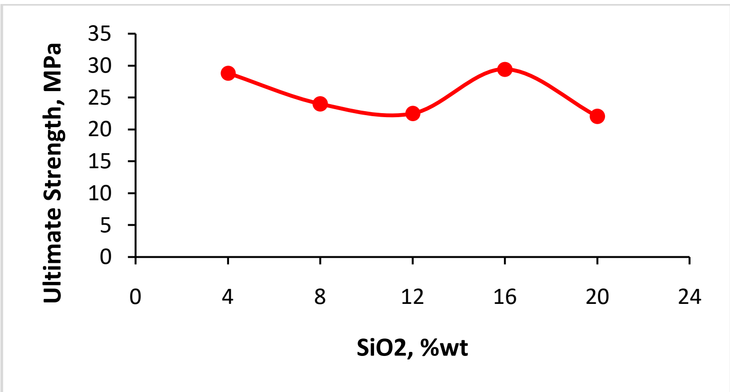

Fig 4: Ultimate strength (a) and corresponding strain (b) as a function of SiO_2.

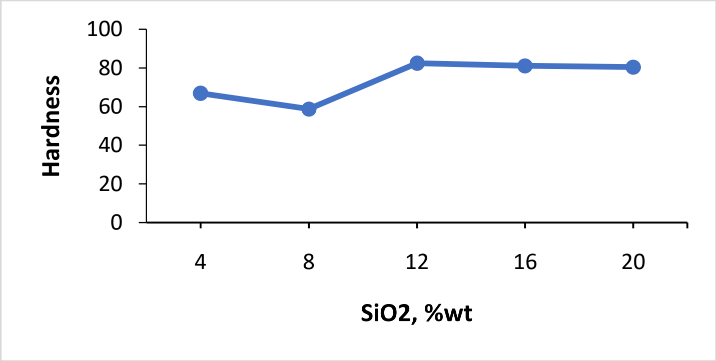

Fig 5: Hardness is a function of % SiO_2

3.1 Micro-Hardness Test Results

The hardness of the sample examined to graph plotted to vary the weight percentage of SiO2, as shown in Fig. 5. Hardness was measured using the Rockwell hardness test. By adding the filler content to the Nylon-6 composite, the hardness of the matrix material increases consistently. It observed that a change in %wt of SiO2 from 4% to 8% causes a slight decrease in hardness of the Nylon/ SiO2 polymer composite. Rockwell hardness increases from 8% to 12% and reaches the maximum value of 82.33 HRM at 12%wt of SiO2. The significant improvement in hardness may be attributed to the better distribution of SiO2 nanoparticles. There is no substantial change in the hardness of the composites from 12%wt to 20%wt of SiO2.

3.2 ANOVA

Parameter	Symbol	DOF	SS	MSS	P%
% SiO_2	A	2	680046	340023	24.30
Load	B	2	1107134	553567	39.56
Speed	C	2	350802	175401	12.53
Sliding Distance	D	2	660642	330321	23.61
Error	e	0	0	..	0
Total	T	8	2798624		100

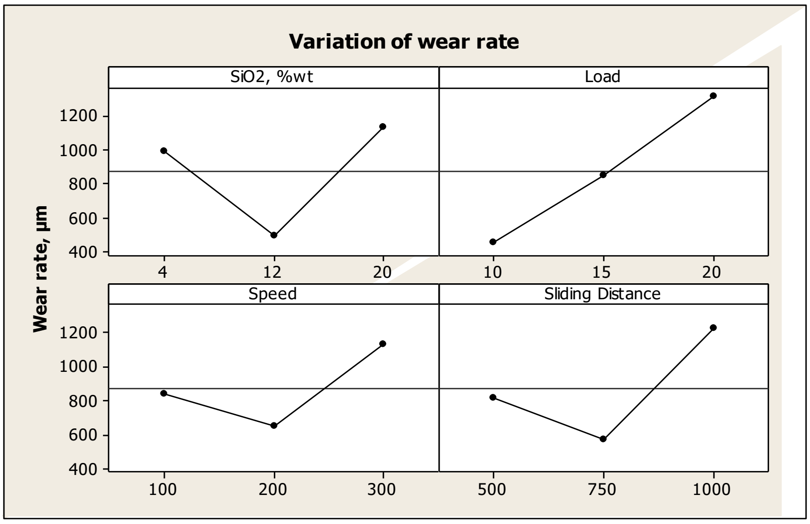

Figure 7: Variation of Wear Rate

Figure 7 shows that the Nylon/ SiO2 polymer composite with 20% wt of SiO2 has a higher wear rate. It observed that with an increase in loads in the range of 10N to 20N, the wear rate increases as the load increases, and the wear rate is maximum at 20N. For sliding speeds in the field of 100rpm to 300rpm, wear rate decreases from 100 rpm to 200 rpm and later increases from 200 rpm to 300 rpm reaching the maximum value at 300 rpm. For sliding distances in the range of 500 to 1000, the wear rate decreases from 500 to 750 and later increases from 750 to 1000.

3.3 Morphology of Fracture surfaces

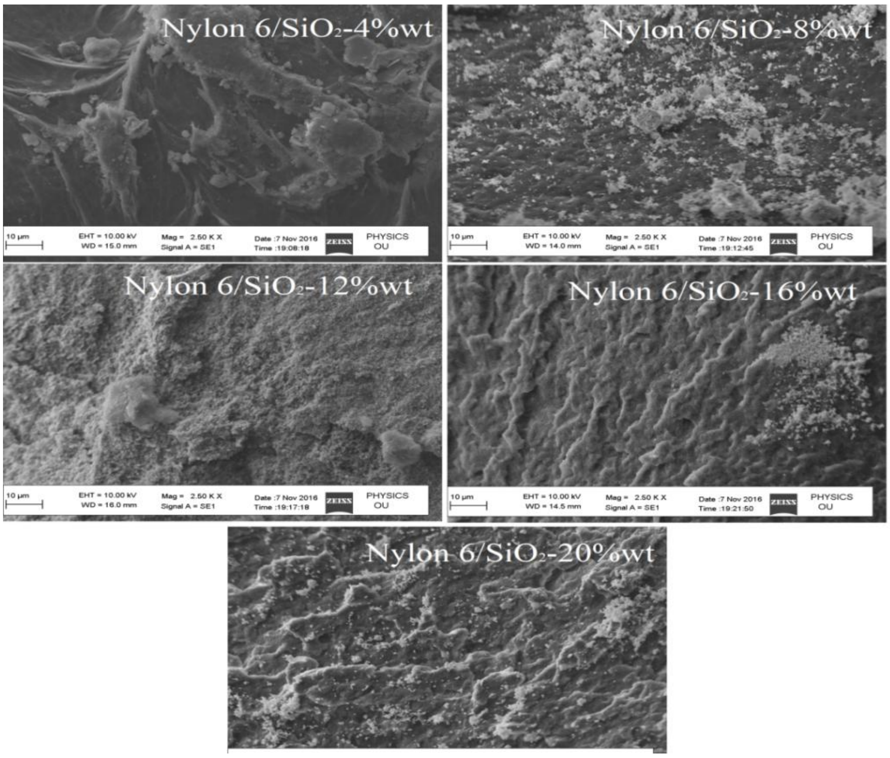

Figure 7: Fractography of Nylon-6/ SiO2polymer composites

Figure 7, Morphology of fracture surface of the material is studied using SEM analysis; it found that micro-cracks increase with an increase in the filler content of SiO2. The micro-cracks produced due to the interaction of the filler material with composite, which results in the strong inter bounding of the filler material with composite. As the bonding strength of materials is increasing, the tensile and wear resistance increases. The layers observed during crack with increasing filler content as the matrix material, and filler material creates a strong bond with each other.

3.4 SEM Analysis of Worn Surface

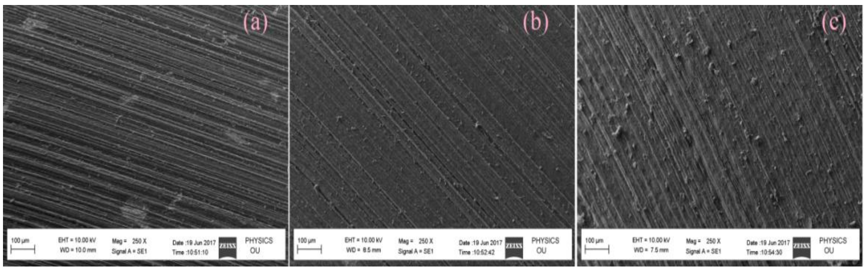

Figure 8: SEM image of worn surface for trial conditions of 1, 2, and 3.

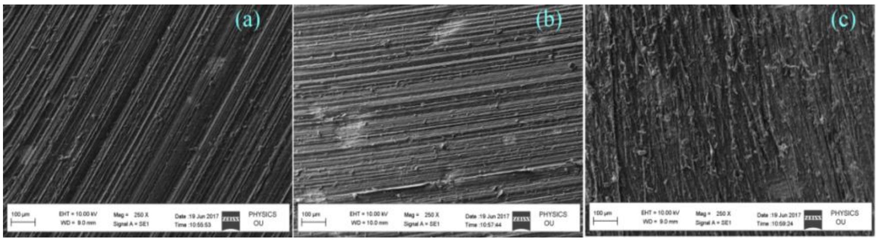

Figure 9: Worn surfaces of specimens for trial conditions of 4, 5, and 6.

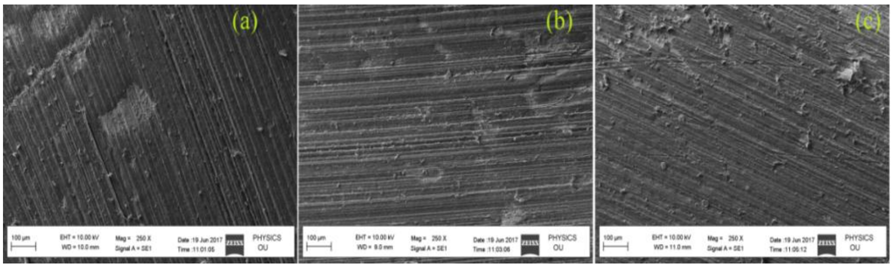

Figure 10: Worn surfaces of specimens for trial conditions of 7, 8, and 9.

Figure 8 to 10 SEM images shows that composite during the wear test. Micro-cracks increased with an increase in the filler content of the material. These micro-cracks are uniformly continuous throughout the surface. These groves are perpendicular to the sliding surface. The intensity of micro cracks and the wear test input parameters compared. It found that with an increase in the SiO2 percentage and load, there is an increase in the wear rate.

3.5. Wear Debris

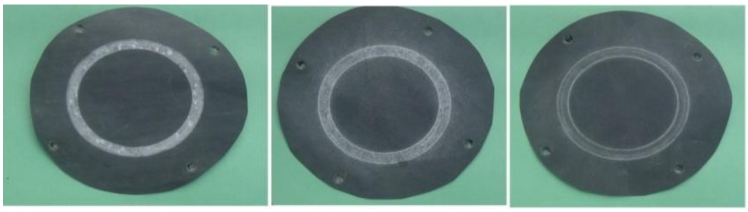

Fig. 9: Debris of specimens for trial conditions of 1, 2, and 3.

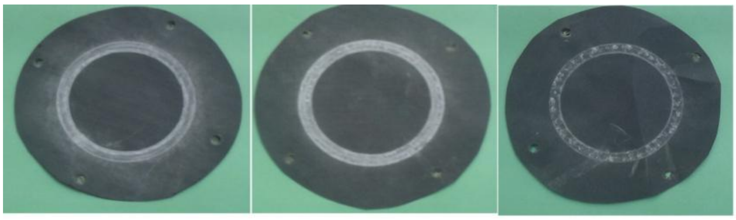

Fig. 10: Debris of specimens for trial conditions of 4, 5, and 6.

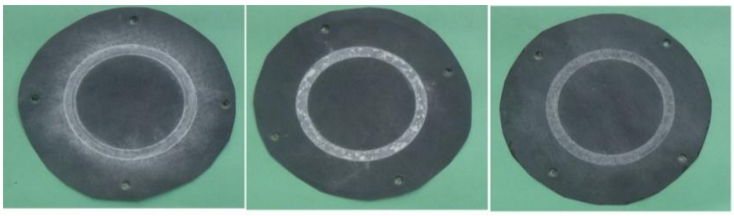

Fig. 11: Debris of specimens for trial conditions of 7, 8, and 9.

Figure 9-11, the wear debris is produced during the wear test were studied. It found that increase in SiO2 and load, size of flakes, and the number of chips also increased.

IV. CONCLUSIONS

In this study, the investigation carried out to observe the influence of SiO2 with Nylon composite material. The mechanical properties include the tensile test, wear test, the hardness of the content carried out, and the following conclusions.

- With the increase in SiO2 nanoparticle increase, the material's tensile strength up to a specific limit later, the material's tensile strength decreases with an increase in the SiO2 percentage.
- The hardness of the composite material increased with an increase in the filler content of the material.
- SiO2, load, and sliding distance are the primary process parameters. The percentage contribution of SiO2 is 24%, the load is 40%, and the sliding distance is 20 %.
- The composites SiO2 filled with nanoparticles showed lower wear rates at the combination of 12% wt SiO2, 10N load, 200 rpm speed, and 500 m sliding distance.
- Morphology of fracture materials is studied and found that roughness of the material increase as an increase in the load and filler content of the material.
- Wear debris of the material are investigated and found that the flakes with the increase in the SiO2.

REFERENCES

1. AI Martınez-Perez et al. (2019): Characterization and sliding wear performance of PMMA reinforced with SiO2 nanoparticles. Journal of Thermoplastic Composite, Materialspp1-15: DOI: 10.1177/0892705718815532.[1]
2. RanjanMajhi et al. (2017): Preparation and Study of Mechanical Properties of Nylon 66 / CaCO3 Engineering Thermoplastic Composite. International Journal of Latest Technology in Engineering, Management & Applied Science, 6(10),pp.31-34.[2]
3. Husain Mehdi et al. (2014): Experimental Analysis of Mechanical Properties of Composite Material Reinforced by Aluminium-Synthetic Fibers. International Journal of Mechanical Engineering, 4(2),pp.59-69.[3]
4. Mirjalili. F(2014) : Mechanical and Morphological Properties of Polypropylene/Nano α-Al2O3 Composites. The Scientific World Journal Volume 2014, Article ID 718765, 12 pages, as.[4].
5. V.L. Raja and A. Kumaravel(2015): Studies on Physical and Mechanical Properties of Silica Fume-Filled Nylon 66 Polymer Composites for Mechanical Components, Polymers & Polymer Composites, Vol. 23, No. 6, 2015,pp.427-434.[5]
6. V.N. Aderikha and V.A. Shapovalov(2010): Effect of filler surface properties on structure, mechanical, and tribological behavior of PTFE-carbon black composites. Wear, 268, pp. 1455–1464.[6]
7. Ramesh Chandra Yadav, Sachin Chaturvedi, Ashutosh Kumar, kamal Kumar Kannauji and Arpan Kumar Mondal, An Investigation of Mechanical and Sliding Wear Behavior of Glass Fiber Reinforced Polymer Composite With or Without Addition of Silica (SiO2).[7]
8. Francesco Silva et al. (2014): The Effect of Matrix and Reinforcement Material Selection on the Tensile Properties of Hybrid Composites.JSM Volume 1 Issue 1,pp.37-52.[8]
9. B. Stojanovic, M. Babi, S. Mitrovic, A. Vencl, N. Miloradovi, M. Panti "tribological characteristics of aluminum hybrid composites reinforced with silicon carbide and graphite. a review", Journal of the Balkan Tribological Association Vol. 19, No 1, 83–96 (2013). [25]
10. Mohammed Y. Abdellah, Hesham I. Fathi, Ayman M. M. Abdelhaleem, and Montasser Dewidar "Mechanical Properties and Wear Behavior of a Novel Composite of Acrylonitrile–Butadiene–Styrene Strengthened by Short Basalt Fiber," Journal

of composites science, 2, 34, pp2-12, 2018.[26]
11. Seelam Pichi Reddy, A. Chennakesava Reddy, "Tensile and Flexural Strength of Okra Fiber Reinforced Polymer Composites," International Journal of Engineering and Management Research, 6(1), pp. 491-495, 2016.[28]
12. A.C.Reddy “Characterization of Mechanical and Tribological Behavior of (Nylon6 Graphite+ Teflon) Nano Particulate Composite: Application Perspective”, Int. Journal of Scientific & Engineering Research, 6(4), pp.378-386, 2015.[22]
13. A.C.Reddy “Characterization of Mechanical Behavior of Nylon/Teflon Nano Particulate Composites,” International Journal of Advanced Research, 3(5), pp.1241-1246, 2015.[20]
14. Karan Agarwal, Nirmala Akhil, Regalla Srinivas, A.C Reddy “Enhancement in Mechanical Behavior of Nylon/Teflon Composites by Addition of Nano Iron Oxide (γ-Fe2O3)”, International Journal of Science and Research (IJSR), 4(5), pp.927-932, 2015. [21].
15. V.L. Raja and A. Kumaravel “Studies on Physical and Mechanical Properties of Silica Fume-Filled Nylon 66 Polymer Composites for Mechanical Components”, Polymers & Polymer Composites, Vol. 23, No. 6, 2015,pp.427-434.
16. D Dehghan Banani, S A J Jahromi and S MOJTABA ZEBARJAD∗ "A study on the role of nanosized SiO2 on deformation mechanism of vinyl ester" Bull. Mater. Sci., Vol. 37, No. 7, December 2014, pp. 1677–1683.
17. Monserrat Garcı, Matthijs de Rooij, Louis Winnubst, Werner E. van Zyl, Henk Verweij "Friction and Wear Studies on Nylon-6/SiO2 Nanocomposites" Journal of Applied Polymer Science, Vol. 92,2004, pp,1855–1862.
18. Yanhuai Ding, Ping Zhang, Yong Jiang, Fu Xu, Jiuren Yin, Yongde Zuo "Mechanical properties of nylon-6/SiO2 nanofibers prepared by electrospinning", Materials Letters, 63, pp. 34–36, 2009

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