

“Tribomechanical Analysis of Polymer Composite Reinforced with Titanium Dioxide and Mos2”

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Abstract - This study investigates the tribological performance of polytetrafluoroethylene (PTFE) composites reinforced with a synergistic combination of titanium dioxide (TiO₂), molybdenum disulfide (MoS₂), and glass fibers. The fabrication process involves blending the materials in an electric blender, followed by the addition of chopped glass fibers. The resulting mixture is molded, cold pressed, and sintered to create PTFE composites with varying compositions. The tribological tests are conducted under fixed conditions, including constant velocities of 1 m/s, 2 m/s, and 3 m/s, with load increments until specimen failure. The experiments are carried out using a hydraulic motor to apply loads rapidly, and various parameters such as normal load, speed, temperature, and friction torque are recorded. The study aims to understand the influence of each ingredient on the tribological behavior of the composite, with a focus on wear rates, specific wear energy, and specific wear rate calculations. The results contribute valuable insights into optimizing PTFE composites for enhanced friction and wear resistance, particularly in applications requiring superior tribological properties.

Keywords: Tribological performance, PTFE composite, Titanium dioxide (TiO₂), Molybdenum disulfide (MoS₂), friction and wear properties, coefficient of friction, mechanical properties.

1.INTRODUCTION

Tribology is the science of rubbing surfaces in relative motion. It is the study of the friction, wear and lubrication of engineering surfaces with a view of understanding surface interactions in detail and then prescribing improvements in given applications. One of the important objectives in tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum. This objective can be understood only after a fundamental understanding of the frictional process for all conditions like load, sliding velocity, lubrication, surface finish, temperature and material properties(3). Now a day there has been a significant growth in the large-scale production of polymers and polymer matrix composites. Polymer composites mostly used as structural components that are very often subjected to friction and wear loadings under use. In some situations, the coefficient of friction is of the highest importance, but mostly the mechanical load-

carrying capacity and the wear life of components that determine their acceptability in industrial applications under different operating conditions. Variables in friction and wear testing are load, velocity, contact area, surface finish, sliding distance, environment, material of counter face, type of lubricant used, hardness of counter face and temperature. Usually wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of accuracy of machine parts. It can produce vibrations, fatigue and consequently failure of the parts. For the particular practical application the kind of wear loading can be different, and therefore the structure of the composite material used for these applications can also be different in order to achieve the particular requirements(2). For over sixty years, our world and the quality of its inhabitant's lives have been improved by a resin known as Polytetrafluoroethylene or PTFE. It is discovered in 1938 by a DuPont chemist, Mr. Roy J. Plunkett. Upon examination, DuPont learned that PTFE provided a combination of friction, temperature, chemical, mechanical and electrical resisting properties. PTFE is a kind of self-lubricating material having super low coefficient of friction, outstanding corrosion resistance, chemical inertness and wide service temperature range. PTFE is a frequently used as a solid lubricant both as a filler and matrix. PTFE is currently finding increasing utility in high performance mechanical seals due to its unique properties like high chemical resistivity, low coefficient of friction and high temperature stability. However, its application has been greatly limited due to its poor mechanical properties, high linear expansion coefficient, bad thermal conductivity and poor wear and abrasion resistance. Adding TiO₂, MoS₂ fillers to PTFE were found effective in reducing the wear rate of PTFE composite. In addition for the range of loads and speeds used in this investigation, wear rate showed very little sensitivity to test speed and more sensitivity to the applied load, particularly at high load value(4). PTFE is extensively used for a wide variety of structural applications as in aerospace, automotive, earth moving, medical, electrical, electronics, computer and chemical industries. On account of its good combination of properties, these are used for producing a number of mechanical components such as gears, cams, wheels, brakes, clutches, bearings, gaskets, seals as well as wires, cables, textile fibers, electronic components, medical implants, surgical instruments etc. India is the largest

market for the food & packaging industry in the world. Presently Indian food industries are operating at different capacity. The food industry use number of running components fabricated with ferrous and nonferrous alloys which requires frequent or continuous lubrication. The bearings used for rotating elements often suffer from corrosion related problems which in turn results in the need for large maintenance, thereby increasing the production cost. Now there is a scope to reduce the cost of production and increase the efficiency of the food handling equipment's by replacing bearings or some of the conventional material components by those of newly developed light weight composites. From the discussion with some engineers from food industry, we came to know the problems faced in the past & the problems raised during the daily working, it came to know that; 1) Use of special lubricating oil satisfying food grade. 2) Sometimes the lubricating oil may get mixed with food or juice of some fruits due to leakage and may change the properties slightly. 3) Juice which containing solid particles may enters in the bearing degrading the lubricant properties. 4) The life of bearings is less due to moisture & corrosive atmosphere. 5) High and non-uniform wear of bearing surface (1 to 5 mm) over its length along with the corrosion, pitting scoring and v grooving. So area of application selected for this project: Single row deep groove ball bearing for medium load and low speed applications in food industry. Similar applications could be found in many units of process industries, chemical industries, pharmaceutical industries, paint industries, food and beverage industries etc. In this work attention is given to suggest the replacement of the existing hydrostatically lubricated gun metal or brass bearing used for motor by self-lubricating PTFE composite bearings. Because of this, In this paper tribological behaviors of:

Sr.no	Composite pin
1.	PTFE+7.5% TiO ₂ +5% MoS ₂ +3%Gf
2.	PTFE+12.5% TiO ₂ +5% MoS ₂ +3%Gf
3.	PTFE+17.5% TiO ₂ +5% MoS ₂ +3%Gf
4.	PTFE+22.5% TiO ₂ +5% MoS ₂ +3%Gf

2. LITERATURE SURVEY

3.1 Review of Book, Journal & international Paper:

The present research work is aimed at developing a new material for industrial application investigators using various mechanism or techniques. Present literature review gives the overview off the some researchers work on composite work.

Following are the research papers which are refer for a future purpose in order to study effect of new composition of composite material.

Barbara Bertoneclj et al.(2021) [1] have done analysis of polymer composites and their thermal properties in a polymer connected phase and CaCO₃particle strengthening phase together reinforced by E-glass fibre (EGF) reinforcement, composition varying from 0 to 15 by wt.%. The addition of EGF percentage up to 10 % showed more improvement in specific heat values such as 0.899 KJ/Kg-K and 0.903 KJ/Kg-K at atmospheric temperature conditions.

Dilek Kumlutas and Ismail Tavman (2020)[2] determined experimentally the different values of thermal conductivity for the high-density polyethylene (HDPE) connecting phase materials with Tin (Sn) as reinforcing particles. The connecting phase and strengthening phase at various compositions on their microstructure size were simulated using three-dimensional models in the determination of thermal conductivities. The contribution of the connecting phase to the maximum of 16% by volume revealed good thermal conductivity value by hot wire method. Actually the property value increased from 10% by volume of strengthening phase, but increased exponentially above 16% of heavily filled strengthening phase.

Volkan Babat and Munir Tasdemir (2022) [3] analyzed the mechanical and wear properties of ABS, connecting phase with aluminum, boron carbide and glass sphere particles of strengthening phase. The strengthening phase particle content varies as 5, 10, 15 and 20% by weight composition. It is subjected to the nature of particle, size of the particle, distribution of particle, interfacial action between connection and strengthening phase, the wear resistance increase or decrease. It is also subjected to wear approach, travelling distance, load selected, testing temperature and moisture.

3. PROBLEM DEFINITION AND OBJECTIVE OF THE PROJECT

3.1Research Gap

The research on tribological and wear analysis of PTFE (polytetrafluoroethylene) composite materials has made significant progress in recent years, yet certain gaps persist in the existing literature. Identifying and addressing these gaps can contribute to a more comprehensive understanding of the tribological behavior of PTFE composites and guide future research endeavors. Here are some potential research gaps in this domain:

- **Limited Focus on Specific PTFE Composites:**

Existing studies may predominantly focus on a specific type of PTFE composite material, neglecting the wide range of possible combinations. Investigating the

tribological properties of different PTFE composites, such as those reinforced with various fillers or additives, could offer insights into the diverse applications of these materials.

• Inadequate Exploration of Operating Conditions:

Many studies may not sufficiently explore a broad spectrum of operating conditions, such as varying temperatures, pressures, or sliding speeds. A comprehensive analysis under different environmental and operational parameters is essential to understand the versatility of PTFE composites in real-world applications.

While general tribological characteristics are often investigated, there may be a lack of studies focusing on the specific needs of certain applications. Tailoring research to address the requirements of industries like automotive, aerospace, or medical devices could lead to more practical and targeted insights.

3.2 Problem Definition

It is reported from one of the best fabrication industry, “Gagraj rolling mill Ltd., Pune, Maharashtra”, having crushing capacity of 1000 tones per day, that in milling section number of mills are there to extract Extracting metal bar from raw metal by passing and compressing fiberized molten metal through slowly rotating (4.5 rpm to 6 rpm) heavy metal mills. These mills are supported on gunmetal or brass journal bearings.

• From the discussion with deputy chief engineer to know the problems faced in the past & the problems arises during the season for the mill bearings of milling section of this sugar factory, it comes to know that: Sometimes the lubricating oil may get mixed with sugar cane juice due to leakage and may change the juice properties slightly.

• Juice which contains bagasse particles may enters in the bearing when the top roll moves up & down during milling, degrading the lubricant properties.

• The life of a bottom roller bearing is one to five seasons longer than that of top roller bearings.

• High and non-uniform wear of journal bearing surface (1 to 5 mm) over its length along with the corrosion, pitting scoring and ‘v’ grooving.

3.3 Objectives of the Project

The purpose of this work is to study the friction and wear behavior of PTFE composites reinforced with varying percentage of particles with respect to varying high loads and varying low sliding velocities, under dry condition at normal temperature and pressure when tested against AISI SS 304 stainless steel. It is expected that, this research will be useful in promoting the applications of PTFE composites for high load and low speed applications under dry condition.

Following are the objectives of the project work,

- To fabricate samples of PTFE composite reinforced with TiO₂ and Glass fiber, MoS₂.
- To do comparative study about friction & wear behavior of different sample materials.
- To Evaluate Tribo-mechanical properties of existing material and novel composites.
- Wear and friction analysis (Pin On Disc)
- Tensile Strength (UTM)
- Compressive strength (UTM)
- Hardness (Brinell Hardness Tester)

4.METHODOLOGY

4.1 Fabrication Process

The composites were fabricated using powder metallurgy technique, which includes:

- Powder mixing (ball milling)
- Compaction using hydraulic press
- Sintering at controlled temperature
- Hot extrusion

4.2 Specimen Preparation

- Pin: 8 mm diameter × 30 mm length
- Disc: Stainless Steel (AISI SS304)

PIN no	Composite pin
1.	PTFE+7.5% TiO ₂ +5% MoS ₂ +3%GF
2.	PTFE+12.5% TiO ₂ +5% MoS ₂ +3%GF
3.	PTFE+17.5% TiO ₂ +5% MoS ₂ +3%GFF
4.	PTFE+22.5% TiO ₂ +5% MoS ₂ +3%GF

Material composition of experimental samples of PTFE composites.

4.3 Experimental Setup

A Pin-on-Disc Tribometer (TR-20LE) was used to measure:

- Wear rate
- Frictional force

Sr. No.	Property	Unit	40 % filled PTFE
1.	Density	gm / cc	3.1-3.2
2.	Tensile Strength	kgf / cm ²	125-150
3.	Elongation	%	100-175
4.	Compressive Strength	kgf / cm ²	85-100
5.	Flexural Strength	kgf / cm ²	85

6.	Flexural Modulus	kgf / cm ²	14000
7.	Hardness	Shore	70-75
8.	Dielectric Strength	kv / mm	Dielectric

a. Typical properties of filled PTFE composite.

Content	C	Si	Mn	P	S	Cr	Ni
Percentage	0.08	0.75	2.00	0.045	0.03	18	10

b. Material composition of AISI SS 304 (04Cr18Ni10) stainless steel disc.

- Lubricant**

Mos₂ added in distilled water lubricant is used during the test conditions.

4.4 Test Parameters

- Load: 100–117 N
- Sliding velocity: 0.09–0.12 m/s
- Test duration: 60–90 minutes.

5.OBSERVATION & CALCULATIONS

1) Sliding velocity: 012 m/sec, Time -60 min, load-100.91N, Speed -152.78 rpm.

Sr.No	Setting Time(Min)	Wear(Micron)	Frictional Force (N)	Coefficient of Friction
	0	0	0	0
	5	3.1	6.2	0.0549
	10	3.2	6.2	0.0530
	15	4.1	6.1	0.0521
	20	4.2	6.1	0.0530
	25	4.2	6.0	0.0530
	30	5.1	5.7	0.0512
	35	5.2	5.6	0.0521
	40	6.1	5.6	0.0494
	45	6.2	5.7	0.0485
	50	7.2	5.7	0.0475
	55	8.2	5.6	0.0485
	60	8.2	5.5	0.0475

Table 1. Experimental Data of Lubrication- PTFE + 7.5% TiO₂ + 5% MoS₂ + 3%GF

2) Sliding velocity: 012 m/sec, Time -60 min, load-100.91N, Speed -152.78 rpm.

Sr.No	Setting Time(Min)	Wear(Micron)	Frictional Force (N)	Coefficient of Friction
	0	0	0	0
	5	4.2	6.2	0.0559
	10	5.7	6.2	0.0542
	15	7	6.1	0.0524
	20	7.2	6.1	0.0506
	25	8	6.0	0.0589
	30	8.9	5.7	0.0471
	35	9	5.6	0.0471
	40	9	5.6	0.0436
	45	9.5	5.7	0.0427
	50	11	5.7	0.0436
	55	12	5.6	0.0453
	60	12	5.5	0.0453

Table 2 Experimental Data of Lubrication- PTFE + 12.5% TiO₂ + 5% MoS₂ + 3%GF

3) Sliding velocity: 012 m/sec, Time -60 min, load-100.91N, Speed -152.78 rpm.

Sr.No	Setting Time(Min)	Wear(Micron)	Frictional Force (N)	Coefficient of Friction
	0	0	0	0
	5	4.9	6.2	0.0544
	10	5.4	6.2	0.0535
	15	6.1	6.1	0.0544
	20	6.5	6.1	0.0561
	25	7	6.0	0.0561
	30	8	5.7	0.0544
	35	9	5.6	0.0561
	40	10.1	5.6	0.0544
	45	11	5.7	0.0535

	50	13.2	5.7	0.0527
	55	15	5.6	0.0518
	60	15.3	5.5	0.0518

Table 3 Experimental Data of Lubrication- PTFE + 17.5% TiO₂ + 5% MoS₂ + 3%GF

4) Sliding velocity: 012 m/sec, Time -60 min, load-100.91N, Speed -152.78 rpm.

Sr.No	Setting Time(Min)	Wear(Micron)	Frictional Force (N)	Coefficient of Friction
	0	0	0	0
	5	6.1	6.2	0.0615
	10	7.2	6.2	0.0615
	15	8.1	6.1	0.0605
	20	9.1	6.1	0.0605
	25	10.2	6.0	0.0695
	30	11.3	5.7	0.0665
	35	12.2	5.6	0.0655
	40	13.1	5.6	0.0655
	45	14.2	5.7	0.0665
	50	15.3	5.7	0.0665
	55	17.2	5.6	0.0655
	60	17.2	5.5	0.0645

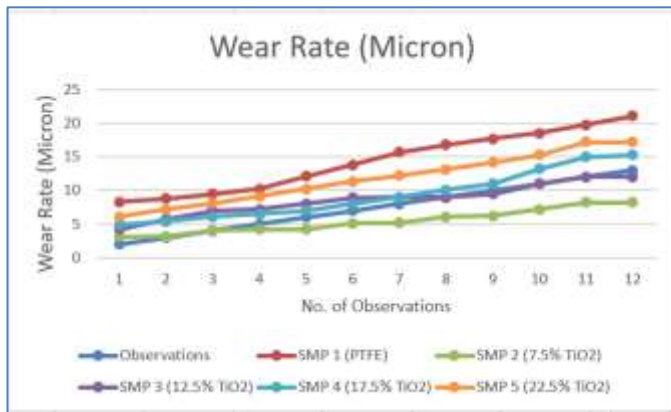
Table 4 Experimental Data of Lubrication- PTFE + 22.5% TiO₂ + 5% MoS₂ + 3%GF

Table 5 Sliding Wear Rate and Coefficient of friction

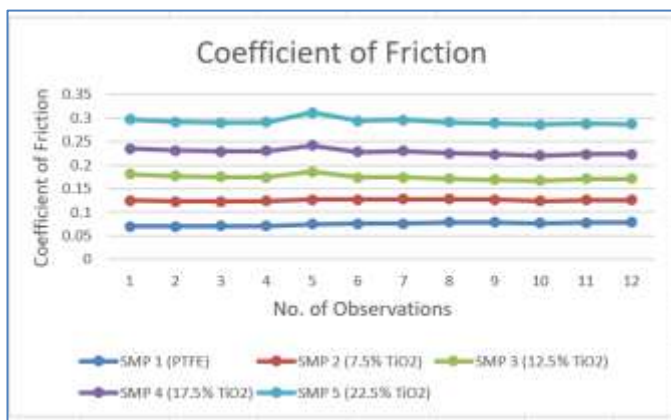
5	10.2	4.2	7.2	6.5	9.1
6	12.1	4.2	8	7	10.2
7	13.8	5.1	8.9	8	11.3
8	15.7	5.2	9	9	12.2
9	16.8	6.1	9	10.1	13.1
10	17.7	6.2	9.5	11	14.2
11	18.5	7.2	11	13.2	15.3
12	19.8	8.2	12	15	17.2
13	21.1	8.2	12	15.3	17.2
Coefficient of Friction (COF)					
SMP 1 (PTFE)	SMP 2	SMP 3	SMP 4	SMP 5	
0	0	0	0	0	
0.0702	0.0549	0.0559	0.0544	0.0615	
0.0702	0.0530	0.0542	0.0535	0.0615	
0.0709	0.0521	0.0524	0.0544	0.0605	
0.0709	0.0530	0.0506	0.0561	0.0605	
0.0745	0.0530	0.0589	0.0561	0.0695	
0.0755	0.0512	0.0471	0.0544	0.0665	
0.0755	0.0521	0.0471	0.0561	0.0655	
0.0785	0.0494	0.0436	0.0544	0.0655	
0.0785	0.0485	0.0427	0.0535	0.0665	
0.0765	0.0475	0.0436	0.0527	0.0665	
0.0775	0.0485	0.0453	0.0518	0.0655	

Sr. No	Wear (Micron)				
	SMP 1 (PTFE)	SMP 2	SMP 3	SMP 4	SMP 5
1	0	0	0	0	0
2	8.3	3.1	4.2	4.9	6.1
3	8.8	3.2	5.7	5.4	7.2
4	9.5	4.1	7	6.1	8.1

0.0785	0.0475	0.0453	0.0518	0.0645
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5.1 Wear rate of different sample



5.2 COF of different samples

6.RESULTS AND DISCUSSIONS

1 Mechanical Properties by Powder Metallurgy

6.1.1 Tensile Strength

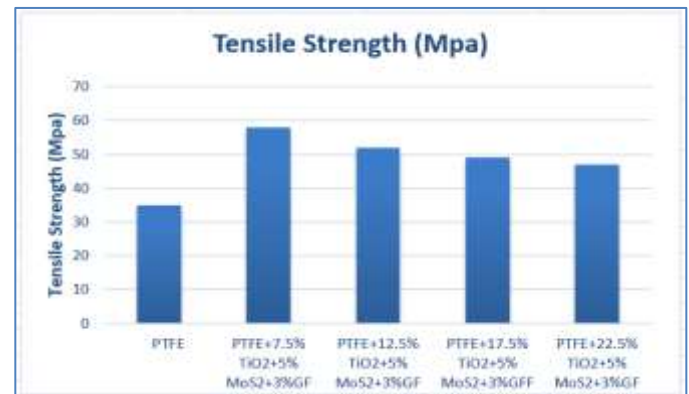
For tensile strength we have used the ISO-6892-1:2009 standard.

The tensile strength of the composites are shown in table 5.4, respectively. In contrast to pure PTFE, which claims a strength of 35 MPa, PTFE+7.5% TiO₂+5% MoS₂+3%GF, PTFE+12.5% TiO₂+5% MoS₂+3%GF, PTFE+17.5% TiO₂+5% MoS₂+3%GF and PTFE+22.5% TiO₂+5% MoS₂+3%GF report strengths of 58, 52, 49 and 47 Mpa respectively.

Material	Tensile Strength (Mpa)
PTFE	35
PTFE+7.5% TiO ₂ +5% MoS ₂ +3%GF	58

PTFE+12.5% TiO ₂ +5% MoS ₂ +3%GF	52
PTFE+17.5% TiO ₂ +5% MoS ₂ +3%GF	49
PTFE+22.5% TiO ₂ +5% MoS ₂ +3%GF	47

6.1 Tensile Strength of different samples



6.1.2 Hardness:

The Brinell Hardness Tester is used to test hardness (B scale). Both before and after the extrusion operation, hardness is measured. On the billets, it is measured three different times, with the average value being used for the final readings.

The hardness values obtained from the Brinell Hardness Tester. It was interestingly found from the testing findings that the composites' hardness steadily increased as the amount of TiO₂ increased. PTFE displays a hardness of 60 BHN. PTFE+7.5% TiO₂+5% MoS₂+3%GF, PTFE+12.5% TiO₂+5% MoS₂+3%GF, PTFE+17.5% TiO₂+5% MoS₂+3%GF and PTFE+22.5% TiO₂+5% MoS₂+3%GF configurations, respectively, report BHN values of 77, 74, 72 and 69 BHN.

Material	Hardness (BHN)
PTFE	60
PTFE+7.5% TiO ₂ +5% MoS ₂ +3%GF	77
PTFE+12.5% TiO ₂ +5% MoS ₂ +3%GF	74
PTFE+17.5% TiO ₂ +5% MoS ₂ +3%GF	72
PTFE+22.5% TiO ₂ +5% MoS ₂ +3%GF	69

6.2 Hardness of different samples



6.2 Hardness of different samples

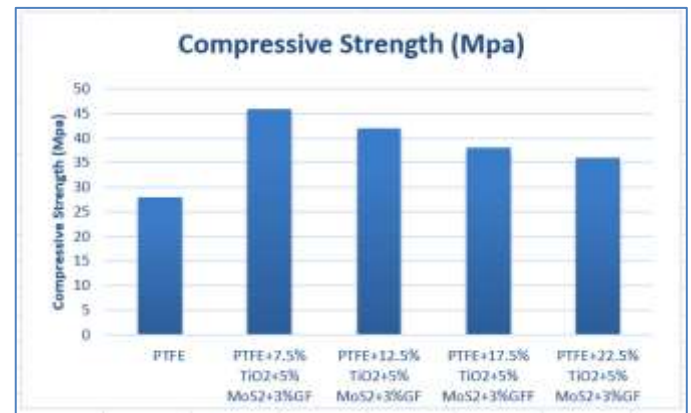
6.1.3 Compressive Strength:

A hydraulic press machine with a 100-ton capacity is used to perform the compression test. The dimensions for billets were 12 mm O.D. and 15 mm in length. The compression test reading is the only factor that determines the highest load that billets can withstand.

In this study, TiO₂ reinforcement reasonably improved compressive strength. The compressive strength of PTFE is 28 MPa, while that of PTFE+7.5% TiO₂+5% MoS₂+3%GF, PTFE+12.5% TiO₂+5% MoS₂+3%GF, PTFE+17.5% TiO₂+5% MoS₂+3%GF and PTFE+22.5% TiO₂+5% MoS₂+3%GF configurations report compressive strengths of 46, 42, 38 and 36 MPa, respectively.

Material	Compressive Strength (Mpa)
PTFE	28
PTFE+7.5% TiO ₂ +5% MoS ₂ +3%GF	46
PTFE+12.5% TiO ₂ +5% MoS ₂ +3%GF	42
PTFE+17.5% TiO ₂ +5% MoS ₂ +3%GF	38
PTFE+22.5% TiO ₂ +5% MoS ₂ +3%GF	36

6.3 Compressive strength of different samples



6.3 Compressive strength of different samples

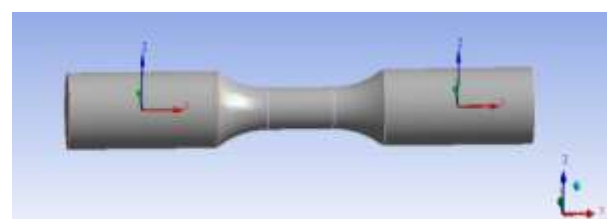
7.FINITE ELEMENT ANALYSIS

Finite Element Method is a numerical procedure for solving continuum mechanics of problem with accuracy acceptable to engineers. Finite Element Method is a mathematical modelling tool involving Composite Specimen bar of a continuous domain? Using building-block entities called finite elements connected to each other by nodes for force and moment transfer. This process includes Finite Element Modeling and Finite Element Analysis. In displacement based FEM, stiffness of the entire structure (Part or assembly) is assembled from stiffness of individual elements. Loads and boundary conditions are applied at the nodes and the resulting sets of the simultaneous equations are solved using matrix methods and numerical techniques. In short, FEM is a numerical method to solve ordinary differential equations of equilibrium.

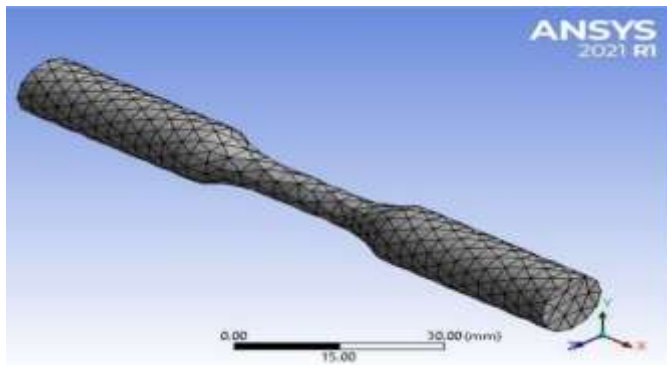
Starting with simple linear static stress and heat transfer analysis, Complex simulations involving highly non-linear, fluid flow and dynamic events can be successfully analyzed on a personal computer using a host of popular software including Cosmos, NASTRAN, ANSYS and NISA among others.

7.1 Building and Importing CAD model in ANSYS

The Composite Specimen bar model is prepared in CATIA using Sketcher and Part Design workbench. The model prepared in CATIA is as shown in the below figure.



7.2 Meshing



7.3 Loading and Boundary Conditions

After completion of the finite element model it has to constrain and load has to be applied to the model. User can define constraints and loads in various ways. All constraints and loads are assigned set ID. This helps the user to keep track of load cases. The temperature is the loading case in the thermal analysis. The air convection is applied over the surface of Composite Specimen bar. The temperature will get generated due to friction while heat is carried away and distributed to surrounding air medium. This convection plays important role in cooling the Composite Specimen bar after braking action.

The maximum temperature generated between Composite Specimen bar and friction pads during action of braking is 60 °C. The steady state thermal analysis is carried out for to check the thermal expansion of the brake Composite Specimen bar.

Thermal conductivity plays an important role in steady state thermal analysis. Therefore, Input provided in the Engineering data for grey cast iron material.

Properties of Outline Row 5: Structural Steel				
	A	B	C	D E
1	Property	Value	Unit	
2	Density	7850	kg m ⁻³	
3	Isotropic Secant Coefficient of Thermal Expansion			
4	Coefficient of Thermal Expansion	1.2E-05	C ⁻¹	
5	Reference Temperature	22	C	
6	Isotropic Elasticity			
7	Derive from	Young's Mo...		
8	Young's Modulus	2E+11	Pa	
9	Poisson's Ratio	0.3		
10	Bulk Modulus	1.6667E+11	Pa	
11	Shear Modulus	7.6923E+10	Pa	
12	Alternating Stress Mean Stress	Tabular		
16	Strain-Life Parameters			
24	Tensile Yield Strength	2.5E+08	Pa	
25	Compressive Yield Strength	2.5E+08	Pa	
26	Tensile Ultimate Strength	4.6E+08	Pa	
27	Compressive Ultimate Strength	0	Pa	
28	Isotropic Thermal Conductivity	60.5	W m ⁻¹ C ⁻¹	

7.4 Solution

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally displacements are stress values are given as output. Some of the capabilities of the ANSYS are linear static analysis, nonlinear static analysis, transient dynamic analysis, etc.

7.5 Summary (From Finite Element Analysis)

Description	Finite Element Analysis	
	Von-Mises stress (MPa)	Tensile Stress (MPa)
Composite Specimen bar	98.71	57

8.CONCLUSION

This study confirms that reinforcing PTFE with TiO₂ and MoS₂ significantly improves its tribological properties. The developed composites demonstrate:

- Reduced wear rate
- Improved load capacity
- Stable friction characteristics

These materials are promising alternatives to conventional bearing materials in low-speed, high-load applications.

9. REFERENCES

1. K. Barbara Bertoneclj, Vojislavljevic, Marko Vrabelj and Barbara Malic, Thermal properties of polymer-matrix composites reinforced with E-glass fibres, *Journal of Micro-electronics, Electronic components and Materials*, **45** (3) (2021), 216-221.
2. Dilek Kumlutas and H. Ismail Tavman, A numerical and experimental study on thermal conductivity of particle filled polymer composites, *Journal of thermoplastic composite materials*, **19** (4) (2020), 441-455.
3. Volkan Babat and Munir Tasdemir, Mechanical and wear properties of Acrylonitrile Butadiene Styrene polymer composites,

Advanced Materials Research, **747** (2022), 299-302.

4. Ankuloriya and Rohit Rajvaidya, Characterization of ABS composites reinforced short glass fibre, *International Journal of Research in Engineering and Technology*, **3** (10) (2020), 35-42.

5. Gurlap Ozkoc, Goknur Bayram and Erdal Bayramli, Short glass fibre reinforced ABS and ABS/PA6 composites, Processing and characterization, *Polymer Composites*, **26** (6) (2021), 745-755.

6. K. Kamal Kar, S. Srivastava, Ariful Rahaman and S. K. Nayak, Acrylonitrile Butadiene Styrene nanocomposites filled with nanosized alumina, *Polymer Composites*, **29** (5) (2022), 489-499.

7. Aamer Khan and Patrizia Savi, Simone Quaranta, Massimo Rovere, Mauro Giorcelli, Alberto Tagliaferro, Carlo Rosso, and Q. Charles Jia, Low-Cost Carbon Fillers to Improve Mechanical Properties and Conductivity of Epoxy Composites, *Polymers*, **9** (642) (2020), 1-14.

8. J. Ervina, M. Mariatti and S. Hamdan, Effect of filler loading on the tensile properties of multi-walled carbon nanotube and graphene nanopowder filled epoxy composites, *Procedia Chemistry*, **19** (2021), 897-905.

9. R. Hemanth, M. Sekar and B. Suresha, Effects of Fibres and Fillers on Mechanical Properties of Thermoplastic Composites, *Indian Journal of Advances in Chemical Science*, **2** (2021), 28-35.