International Journal of Advanced Research in Engineering and Related Sciences

OPEN ACCESS

Available online at: www.ijarers.com

VOL 1 ISSUE 6 (33-45)

Mechanical Performance of Short Glass Fiber Reinforced POM/PTFE Polymer Blends for High-Strength Applications

Arjun Mehta *[1], Priya Iyer [1], Arjun Patel [1]

[1] Indian Institute of Science (IISc), Bangalore, India

Abstract

Polymer blending offers an effective route for tailoring material properties for demanding mechanical applications. This study investigates the influence of short glass fiber (SGF) reinforcement on the mechanical behavior of Polyoxymethylene (POM) and Polytetrafluoroethylene (PTFE) polymer blends. Composites were fabricated with 10, 20, and 30 wt.% SGF using extrusion and injection molding techniques, and their properties were evaluated following ASTM standards. Mechanical tests, including tensile, flexural, impact, and hardness measurements, revealed that SGF addition significantly enhanced tensile strength, flexural strength, and modulus, with optimum performance observed at 20 wt.% reinforcement. However, higher fiber content (30 wt.%) increased brittleness and reduced impact resistance. These findings demonstrate that SGF-reinforced POM/PTFE composites exhibit a favorable balance of strength and stiffness, making them promising candidates for high-strength tribo-mechanical components.

Keywords: Polymer blends, Polyoxymethylene, Polytetrafluoroethylene, Short glass fiber, Mechanical properties, Composite materials, Reinforcement

INTRODUCTION

The rapid development of polymer-based materials has expanded their use across various engineering applications due to their lightweight, corrosion resistance, and ease of processing. However, individual polymers often possess limitations in mechanical strength, stiffness, or thermal resistance, which restrict their performance under demanding service conditions. To overcome these drawbacks, polymer blending has emerged as an effective strategy for tailoring material properties, combining the favorable attributes of two or more polymers into a single system.

Among engineering polymers, Polyoxymethylene (POM) is widely valued for its high strength, rigidity, and dimensional stability, making it suitable for precision components. Polytetrafluoroethylene (PTFE), on the other hand, is known for its excellent chemical resistance, low coefficient of friction, and outstanding thermal stability. Despite these merits, POM suffers from low wear resistance, while PTFE exhibits poor mechanical strength, limiting their individual applications in high-stress environments. Blending POM with PTFE provides a potential route to achieve complementary performance, where the toughness and wear resistance of PTFE can balance the stiffness and load-bearing capability of POM.

To further improve the mechanical behavior of such blends, short glass fiber (SGF) reinforcement is frequently employed. SGFs act as an effective load-bearing phase within the polymer matrix, significantly enhancing tensile and flexural properties while maintaining acceptable toughness. Several studies have reported that SGF-reinforced composites display improved modulus, hardness, and dimensional stability, though excessive fiber loading may increase brittleness.

In this context, the present work investigates the mechanical performance of SGF-reinforced POM/PTFE blends. Composites with varying fiber contents (10, 20, and 30 wt.%) were prepared through extrusion followed by injection molding. Standard mechanical tests were carried out to evaluate tensile strength, flexural strength, impact resistance, and hardness. The findings provide valuable insights into optimizing fiber loading for achieving a desirable balance between strength and toughness in advanced polymer composites.

MATERIALS AND METHOD

The matrix material system selected is Polyoxymethylene (POM) [1-2], Polytetraflouroethylene (PTFE) [3-4] and short glass fibers (SGF) [5-6]. The details of the material sources and their properties have been shown in Table -1, 2 and 3.

Table – 1 Material Data

Materials	Designation	Form	Density (gm/cm^3)	Melting Point (^{0}C)
Polyoxymethylene	POM	Pallets	1.42	175
Polytetrafloroethylene	PTFE	Pallets	2.15-2.3	327
Short glass fiber	SGF	Fibers	2.58	>500

Table – 2 Strength Properties of POM, PTFE and Short Glass Fibers

PROPERTY	POM	PTFE	SGF
Tensile Strength (MPa)	67-110	10-43	3445
Tensile Modulus (MPa)	3500	400-1800	40000-45000
Yield Strength (MPa)	67-85	9-30	-

Table - 3 Details of Composition of Matrix, Reinforcement Material and Their Weight Percentage

Composite Material System						
Material ID	Composition		POM	PTFE	SGF	TOTAL
1X	(80% POM + 20 % PTFE) BLEND	Wt.%	80	20	0	100
		Wt. in Kg	1.6	0.4	0	2
2X	(80% POM + 20 % PTFE) BLEND + 10 %SHORT GLASS FIBERS	Wt.%	0		10	100
		Wt.	1.44	0.36	0. 2	2
3X	(80% POM + 20 % PTFE) BLEND + 20%SHORT GLASS FIBERS	in Kg Wt.%	0		20	100
		Wt. in Kg	1.28	0.32	0.4	2
4X	(80% POM + 20 % PTFE) BLEND + 30 %SHORT GLASS FIBERS	Wt.%	0		30	100
		Wt. in Kg	1.12	0.28	0.6	2

Sample Preparation

The polymers and fibers are dried for 2days to stay away from the plasticization and the hydrolysing impacts from the environment and to obtain the sufficient homogeneity. The materials mixture was extruded by the Bar bender corotating screw extruder. The temperatures are kept up in the seven zones of the barrel, were Zone 1(235ºc), Zone 2 (240ºc), Zone 3 (245ºc), Zone 4 (250ºc), Zone 5 (255 ºc), Zone6 (260 ºc) and Zone7 (265 ºc) and the temperature at the die was set at 75^{0}C. The screw pace was set to be at 100 rpm with a feeding rate of 5 kg/hr. The extruded products obtained are quenched in the water and palletized. The extruded materials are discarded to remove impurities out of the chamber before obtain the polymer samples. Before injection moulding, all the pallets are dried at 100 ^{0}C in vacuum for 1 day. The critical length can be determined by the fiber, rheological properties, and instrument factors. Screw-type injection moulding occurs more fiber damages when compare to plunger type injection moulding machine. A high degree of mixing will not achieve from the plunger type injection moulding machine.

All test specimens are obtained from injection moulding which is pelletized polyblend material from the co-rotating extruder. The temperatures in the two zones of barrel were zone 1 (265 ºC) and zone 2 (290 ºC) and mould temperature was maintained at 27 ^{0}C. Finally, the specimens are produced as per ASTM standards.

Flow Chart of Different Stages of Fabrication

The fabrications of all specimens used in this work were manufactured by ‘injection molding technique. The process of manufacturing a composite product has been split into different stages. Below flowchart shows the stages of composite product manufacture. Polymers, fillers and fibers of different composition are used in creating the product.

1. Selection of the materials in proper proportions as per weight percentage of all the materials ((POM+PTFE) / SGF)
2. Preheating of the polymers, fillers and fibres is done in an oven at 80◦C to remove the hydrolysing effects.
3. Compounding of all the associates of polymer composites for the extrusion
4. Heating is done across the seven zones at an extruder.
5. Extrusion of the mixture using twin screw extruder.
6. Extrusion of the mixture using twin screw extruder.
7. Quenching of the extrudates after Extrusion using cold water
8. Palletizing the extrudates to get pallets for injection molding after heating for 48 hours
9. Injection molding using molding machine maintaining the barrel temperature of 250^{0}C and production of specimens as per ASTM.

Fig.1 Different Stages of Fabrication

TESTING OF COMPOSITE MATERIALS

The composite materials fabricated were subjected to various mechanical tests listed below. In all the below listed figures ‘a’ part shows the test specimen before testing and ‘b’ part shows the specimen after testing.

Tensile Behaviour

Two samples are tested for each composite type and the average value has been recorded. Tensile tested [7] specimens of POM/ PTFE polymer blend (1X) and short glass fiber reinforced polymer blend (2X), (3X) and (4X) are shown in below Fig. 2.

Flexural Behaviour

The 3-point bend test is conducted using the UTM according to the ASTM standard D790 [8]. The recorded data during the test can utilized to calculate the flexural strength. Flexural Test Specimens of Different Percentage of Glass Reinforced POM/PTFE are shown in below Fig. 3.

Impact Strength

Izod impact tests are carried out on these composite specimens and these tests are conducted as per the ASTM standard D256 using Izod impact tester [9]. Test specimens are shown in below Fig. 4.

Fracture Toughness Test

A sample is loaded to obtain the load v/s displacement (CMOD). Using the UTM, the load acts on the specimen to record the Load v/s CMOD relations [10], [11]. Test specimens are shown in below Fig. 5.

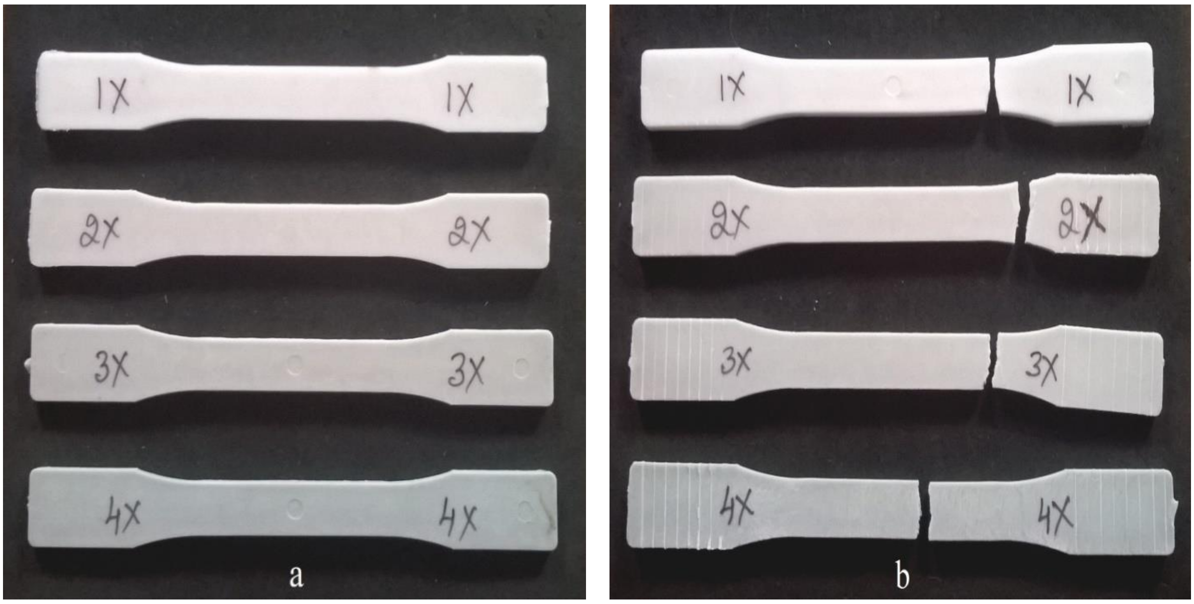


Fig. 2 ASTM D638 Tensile Test Specimens of Different Percentage of Glass Reinforced POM/PTFE

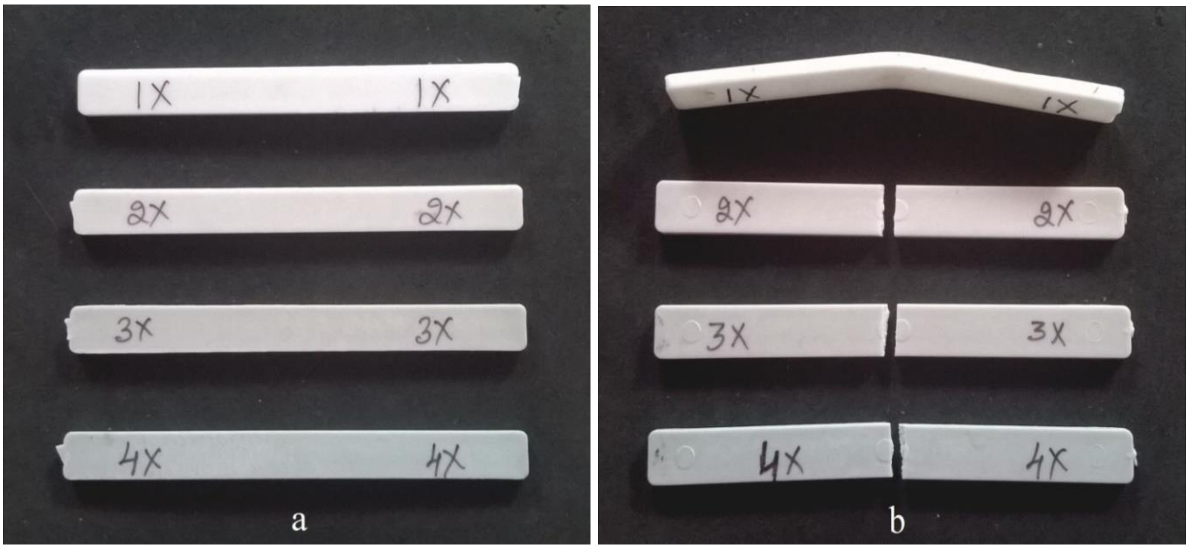


Fig. 3 ASTM D790 Flexural Test Specimens of Different Percentage of Glass Reinforced POM/PTFE

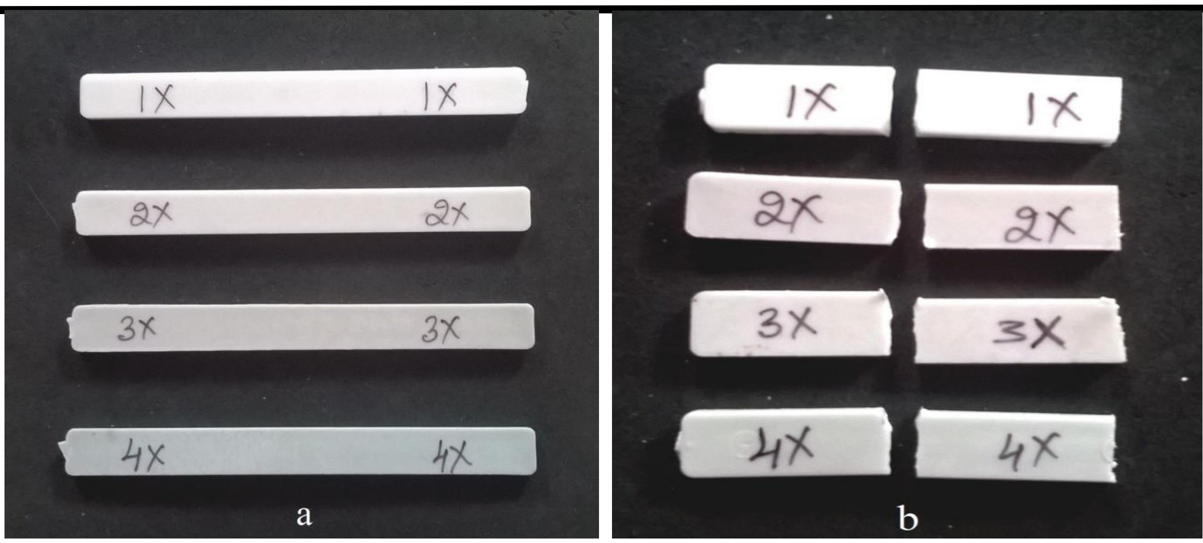


Fig. 4 ASTM D256 Impact Test Specimens of Different Percentage of Glass Reinforced POM/PTFE

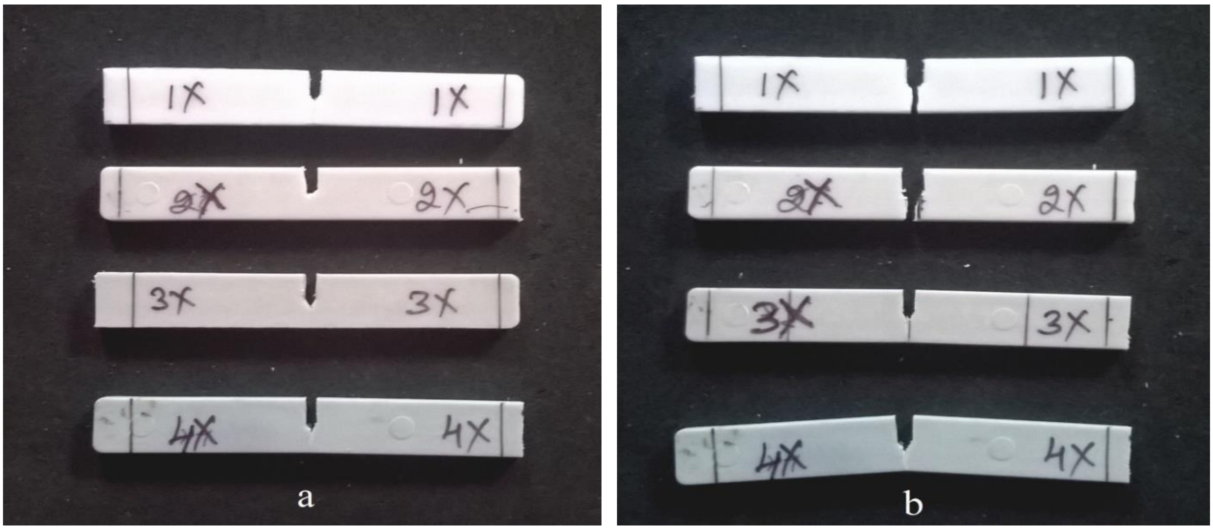


Fig. 5 Fracture Toughness test specimens of different percentage of the glass reinforced POM/PTFE

RESULTS

This section presents mechanical properties of 80wt% POM+20% of weight PTFE reinforced with 10, 20, 30% short glass fibers. As a comparison, the mechanical and tribological properties of pure blend are calculated under the identical test conditions. The following are the results obtained during the experimentation.

Mechanical Properties

The mechanical properties of the short glass fiber reinforced (POM/PTFE) blend are fairly good and must be analysed in detail. The properties of the POM/PTFE polyblend and POM/PTFE blend like tensile strength, percentage elongation at yield, flexural strength and Izod impact strength are listed in the Table -4.

Density

Using Archimedes principle, density of composites was determined by the high precision electronic balance. The density of the short glass fiber reinforced POM/PTFE blend composites are shown in Fig. 6. The tests are performed according to ASTM D 792 [12]. When the polyblend was reinforced with 10% wt. of short glass fiber, the density increased from1.49 to 1.56. Further addition of the short glass fiber to the polymer blend, 30% of weight the density increased to 1.62 and 1.64 respectively. This shows that addition of short glass fibers reinforcement to the polyblend will increases the density.

Hardness

Hardness of the composites was determined by using the Rockwell hardness tester. The tests are done as per ASTM D785 (M scale) 1/4' steel ball indenter was used for M scale. This scale is only suitable for plastics, soft metal bearing and other soft materials [13]. The hardness of the short glass fiber reinforced POM/PTFE blend composites are shown in Fig.7. The pure polyblend Rockwell hardness is 34, when the polyblend was reinforced with 10 wt. % of short glass fiber, the hardness slightly increased from 34 to 39. Further addition of the short glass fiber 20% of weight to the polymer blend, the hardness increased to 55. It results in almost 61.66% increases in the hardness against the pure polymer blend. With 30% of weight of short glass fiber reinforcement to the polyblend, results in almost 11.7% increase than that of pure polyblend polymer composites POM/PTFE but it decreases when compare to the 10% of weight and 20% of weight. It shows that further addition of short glass fiber after 20% of weight the material becomes brittle.

Table – 4 Mechanical Properties of POM/PTFE, POM/PTFE /10%SGF, POM/PTFE /20%SGF and POM/PTFE /30%SGF Polymer Blends

Sl No	Properties	Test Method	Unit	Test Values			
				1X	2X	3X	4X
1	Density	ASTM D792	-	1.49	1.56	1.62	1.64
2	Rockwell Hardness Test (M Scale)	ASTM D785	-	34	39	55	38
3	Tensile Strength at	ASTM D638	MPa	47	60	70	76.5
4	Tensile Elongationyield 5mm/min	ASTM D638	%	16	14	11.5	12.5
5	Tensile elongation at break at yield	ASTM D638	%	26	13	12	13
6	Flexural Strength 1.33 mm/ min	ASTM D790	MPa	85	109	130	139
7	Flexural Modulus 1.33 mm/ min	ASTM D790	MPa	2385	3917	5100	6200
8	Impact Strength	ASTM D256	J/m	42	45	40	33

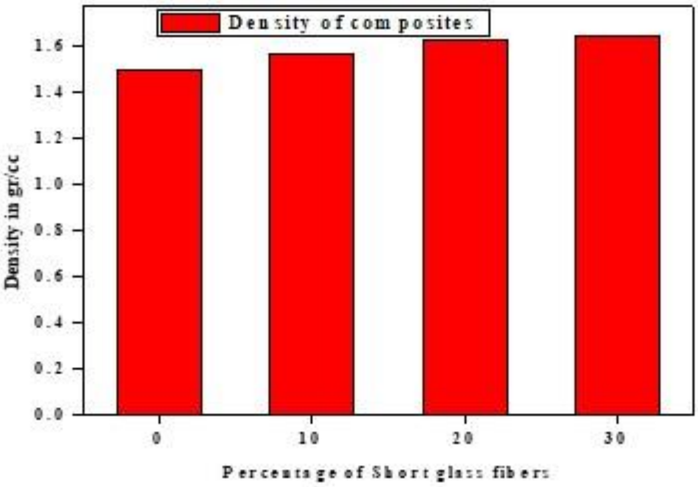


Fig. 6 Densities Of Different Polymer Blend Composites

Fig. 7 Hardness of Different Polymer Blend Composites

Table - 5 Tensile Test Details of Different Polymer Blend Micro Composite

MATERIAL	1X	2X	3X	4X
Load Limit	900kg	900kg	900kg	900kg
Travel Limit	700mm	700mm	700mm	700mm
Peak Load	192.5kg	257.6 kg	277.7kg	306.1kg
Break Load	186.6kg	257.6kg	277.7kg	306.1kg
Elongation at peak load	19.02mm	16.51mm	13.6mm	14.57mm
Elongation at break load	30.44mm	16.51mm	13.6mm	14.57mm

Yield load	192.5kg	36.8kg	277.7kg	306.1kg
Elongation at Yield load	18.13mm	4.93mm	13.6mm	14.57mm
Specimen length	115mm	115 mm	115mm	115mm
Specimen Width	12.7mm	12.7mm	12.7 mm	12.7mm
Specimen thickness	3.2mm	3.2mm	3.2mm	3.2mm
Speed	5mm/min	5 mm/min	5mm/min	5mm/min
Area	40.64 sq.mm	40.64 sq.mm	40.64 sq. mm	40.64 sq.mm
Tensile strength at peak load	509.843 kg/sq.cm	633.858 kg/sq.cm	683.317 kg/sq.cm	753.199 kg/sq .cm
Tensile strength at break load	473.671 kg/sq.cm	633.858 kg/sq.cm	683.317 kg/sq.cm	753.199 kg/sq.cm
%Elongation at Peak	16.54%	14.36%	11.83%	12.67%
% Elongation at break	26.47%	14.36%	11.83%	12.67%
Yield strength	473.671 kg/sq.cm	90.551 kg/sq.cm	683.317 kg/sq.cm	753.199 kg/sq.cm
%Elongation at yield	15.76%	4.29%	11.83%	12.67%
Tensile Modulus	104.066Mpa	104.065Mpa	381.574Mpa	346.879Mpa

Tensile Strength

These tests are performed at the speed of 5mm/min. Fig. 8, Fig. 9, Fig. 10 and Fig. 11 shows the graph of load Vs. displacement of 80 wt.% POM, 20% of weight PTFE (1X), 10% of weight of short glass fiber reinforcement into the 80 wt.% POM /20% of weight. PTFE (2X), 20% of weight SGF reinforced into the 80t% of weight of POM/20% of weight of PTFE (3X) and 30% of weight of SGF reinforced into the 80% of weight POM/20% of weight PTFE (4X) respectively.

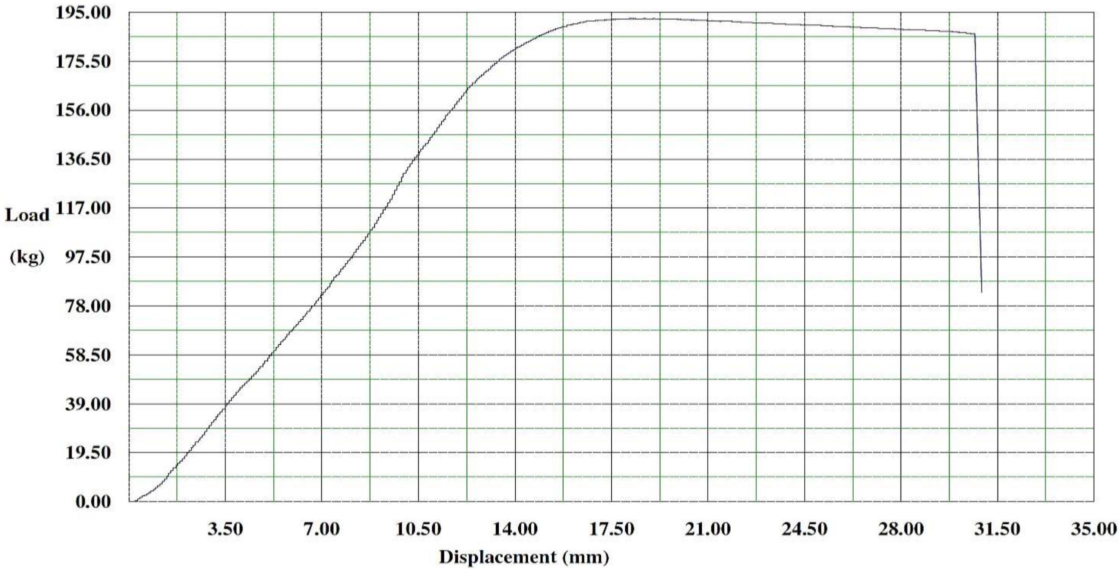


Fig. 8 Load v/s Displacement Curve of Tensile Test of POM/PTFE Polymer Blend Composites

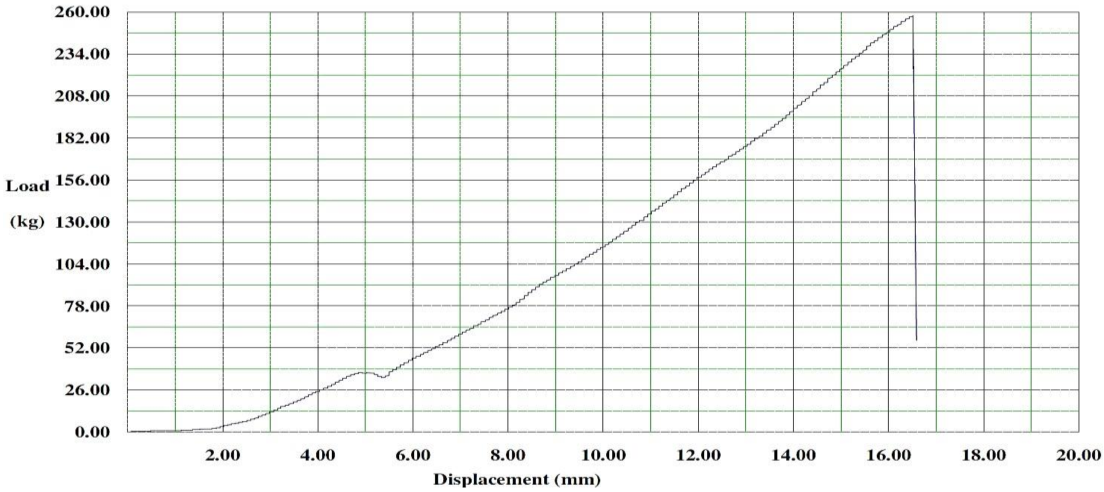


Fig. 9 Load v/s Displacement Curve of Tensile Test for 10% SGF Reinforced POM/PTFE Polymer Blend Composites

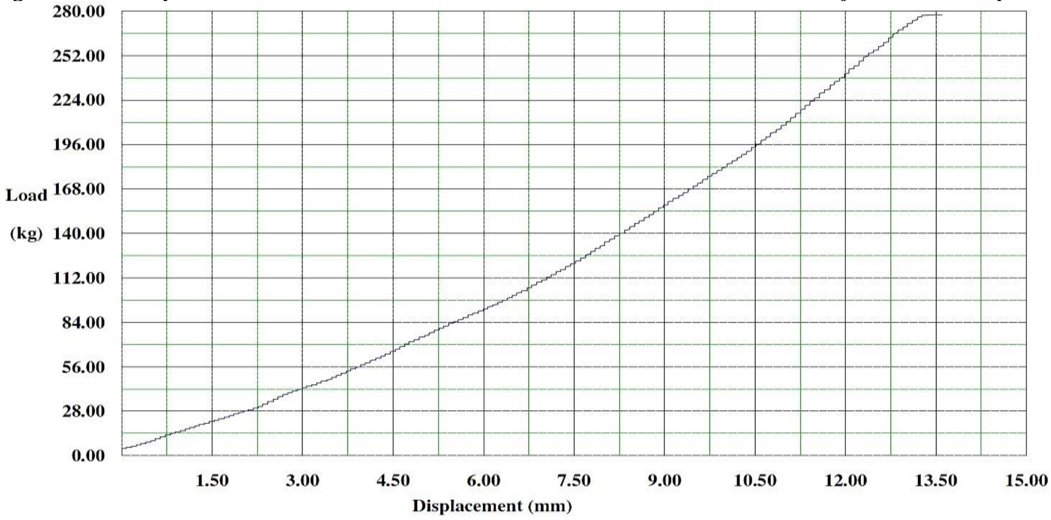


Fig. 10 Load v/s Displacement Curve of Tensile Test for 20% SGF Reinforced POM/PTFE Polymer Blend Composites

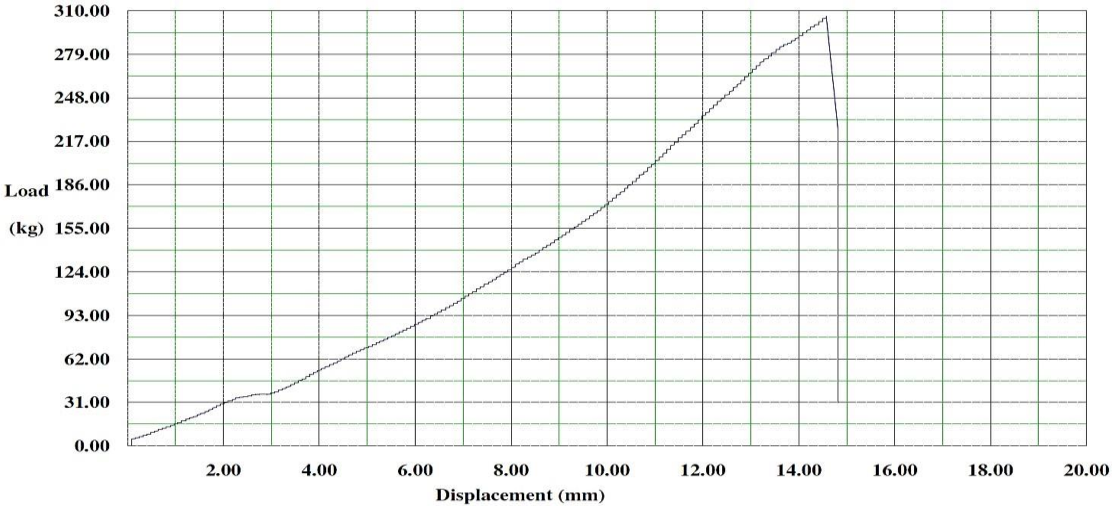


Fig.11 Load v/s Displacement Curve of Tensile Test for 30% SGF Reinforced POM/PTFE Polymer Blend Composites

The load Vs dispalcement curve of POM/PTFE polyblend , short glass fiber reinforced POM/PTFE polyblend and paticulate filled short glass fibers reinforced POM/PTFE polyblend composites are shown in Fig.8, Fig.9. Fig.10 and Fig.11. From the above graphs , we can conclude that short glass fiber reionforced polyblend composites have more load carrying capcity when compared with the pure polyblend PA66/PP. The maximum peak load of short glass reinforced POM/PTFE polyblend is 306 Kg , which is 50 % increase to that of POM/PTFE pure polyblend. This is because of the properties of the short galss fibers . SGF results will increase in load carrying capacity and stiffness of pure polyblend .

On the other hand, the ductility of the SGF reinforced POM/PTFE polyblend composites decreased. This shows the compatibility of the short glass fibers with the pure polyblend decreases and also the slenderness ratio of these fibers enable the polyblend composites to improve the ductility and at the same time to decrease the same. Further addition of SGF, reduces capacity of load carrying and the ductility of the polyblend. This shows that more number of fillers will have poor degree of compatibility with the studied polymer blend. This is because of poor bonding and addition of more glass fibers leads to the brittleness of the composites. Further, fibers act as stress raisers and causes inefficiency of stress distribution**.**

Flexural Strength

The load carrying capacity of short glass fiber reinforced POM/PTFE polymer blend is more when compared with that of pure polymer POM/PTFE blend during flexure situation. This is due to length to diameter ratio of the glass fibers which enables the polyblend to withstand high bending load undergoing rich ductility.

The flexure strength of short glass fiber reinforced POM/PTFE polymer blend composites are shown in the Fig.16. The flexure test is performing at the cross head rate of 1.33mm/min. When the polyblend was reinforced with 10% weight of short glass fiber, the flexure strength increased from 85 N/mm^2 to 109 N/mm^2 which is to be 28.23% increases. This shows that addition of the short glass fiber to the polymer blend have superior degree of compatibility between the polymer matrix and the fibers. Further addition of the short glass fiber to the polymer blend 30% of weight, the flexure strength gradually increased. This results in almost 52.94% increase in the flexure strength against the pure polymer blend. This is due to the addition of the short glass fiber to the polymer blend is in good binding between the associative of the polymer blend composites. With 30% of weight short glass fiber reinforcement to the polyblend, results in almost 63.52% more than that of pure polyblend polymer composites POM/PTFE. More percentage of short glass fiber reinforcement leads to brittleness of the material. The combined action of both ductile and brittle nature of the SGF reinforced POM/PTFE blend has got appreciable mechanical properties. Therefore, the flexural strength of the polymer blend composites is in the increasing order of POM/PTFE/30% of weight SGF > POM/PTFE/20% of weight SGF > POM/PTFE/10% of weight SGF > POM/PTFE.

The flexural modulus of the short glass fiber reinforced POM/PTFE polymer blend composite are shown in Fig.17. The flexural modulus tests are performing at the cross head rate of 1.33mm/min. When the polyblend was reinforced with 10% weight of short glass fiber, the flexural modulus increased from 2385N/mm^2 to 3917 N/mm^2 which is to be 64.23% increases. This shows that addition of the short glass fiber to the polymer blend have superior degree of compatibility between the polymer matrix and the fibers. Further addition of the short glass fiber to the polymer blend, 30% of weight, the flexural strength gradually increased. This results in almost 113.8% increase in the flexural strength against the pure polymer blend. This is due to the addition of the short glass fiber to the polymer blend in good binding between the associative of the polymer blend composites. With 30% of weight of short glass fiber reinforcement to the polyblend, results in almost 159.95% more than that of pure polyblend polymer composites POM/PTFE.

More percentage of short glass fiber reinforcement leads to brittleness of the material. The combined action of both ductile and brittle nature of the SGF reinforced POM/PTFE blend has got appreciable mechanical properties. Therefore, the flexural modulus of the polymer blend composites is in the increasing order of POM/PTFE/30% of weight SGF > POM/PTFE/20% of weight SGF > POM/PTFE/10% of weight SGF > POM/PTFE.

Table – 6 Flexural Test Details of Different Polymer Blend Micro Composite

MATERIAL	1X	2X	3X	4X
Load Limit	45kg	45kg	45 Kg	45kg
Travel Limit	20mm	20mm	20 mm	20mm
Peak Load	15.167 Kg	18.921 Kg	21.747 Kg	25.381 Kg
Deflection at Peak Load	9.23 mm	5.74 mm	3.96mm	3.96mm
Support Span	50mm	50 mm	50mm	50mm
Specimen Width	12.7mm	12.7mm	12.7 mm	12.7mm
Specimen Depth	3.2mm	3.2 mm	3.2 mm	3.2mm
Speed	2 mm/min	2 mm/min	2 mm/min	2 mm/min
Area	40.64Sq.mm	40.64 Sq. mm	40.64 Sq. mm	40.64Sq.mm
Deflection Achieved	1.29mm	0.72mm	0.32mm	0.32mm
Load Achieved	12.822 Kg	18.38 Kg	-	-
Flexural Stress at Peak Load	874.696 Kg/Sq.cm	1091.193 Kg/Sq.cm	1254.171 Kg/Sq.cm	1463.748 Kg/Sq.cm
% Deflection at Peak Load	18.46%	11.48%	7.92%	7.92%
Flexural Modulus	2400.6 MPa	3981.08 MPa	5039.25 MPa	6241.37 MPa

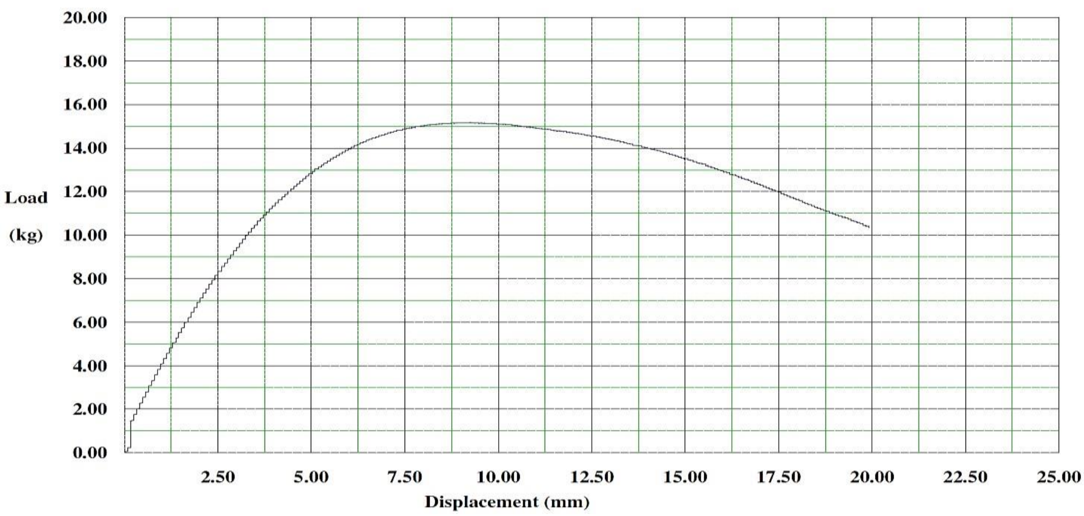


Fig. 12 Load V/S Displacement Curve of Flexural Test for POM/PTFE Polymer Blend Composites

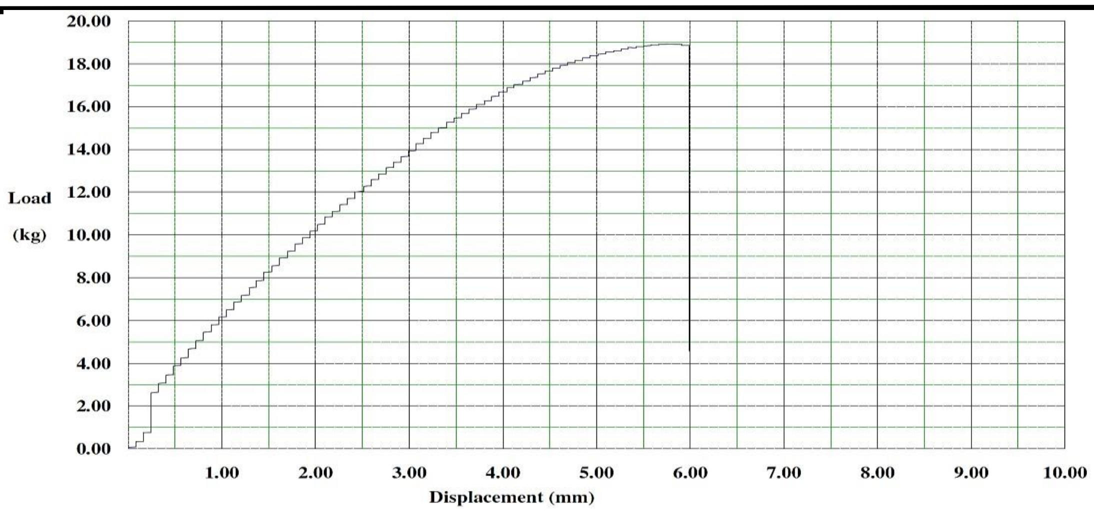


Fig. 13 Load V/S Displacement Curve of Flexural Test for 10% SGF Reinforced POM/PTFE Polymer Blend Composites

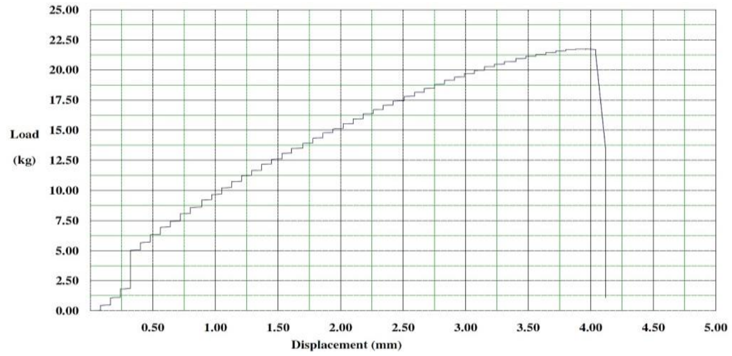


Fig. 4Load V/S Displacement Flexural Test 2 % SGF Reinforced POM/PTFE Polymer Blend

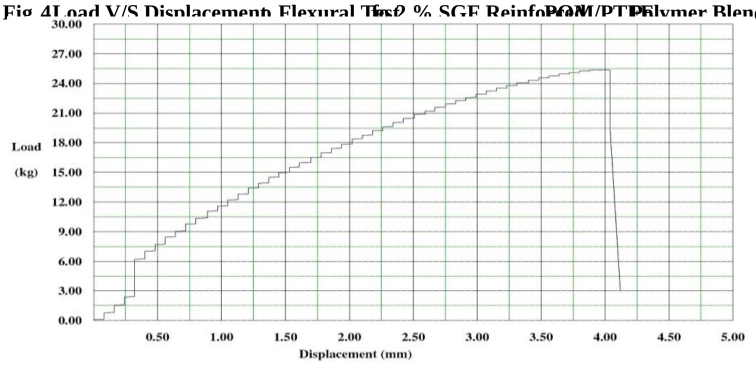
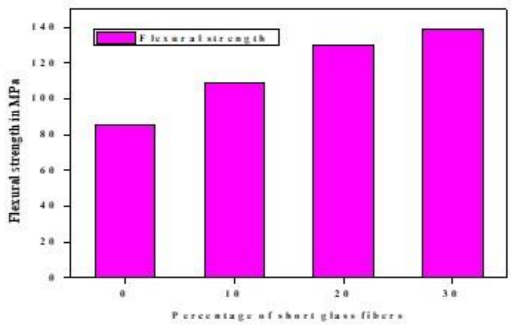
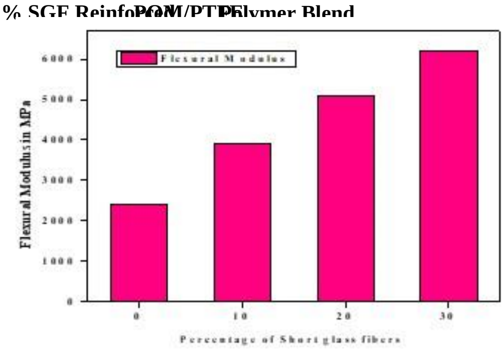


Fig. 5Load V/S Displacement of Flexural Test 3 % SGF Reinforced POM/PTFE Polymer Blend





CONCLUSION

This study examined the mechanical performance of short glass fiber (SGF) reinforced Polyoxymethylene (POM)/Polytetrafluoroethylene (PTFE) polymer blends with fiber contents of 10, 20, and 30 wt.%. The experimental findings demonstrated that incorporating SGF significantly enhanced the tensile and flexural properties of the composites, owing to efficient stress transfer between the polymer matrix and the reinforcing fibers. Among the formulations, the 20 wt.% SGF blend achieved the most favorable balance, offering notable improvements in tensile strength, flexural modulus, and hardness without a substantial reduction in impact resistance. In contrast, the 30 wt.% SGF blend, while exhibiting higher stiffness, showed increased brittleness and reduced impact strength, underscoring the trade-off between reinforcement and toughness at higher fiber loadings.

The results confirm that POM/PTFE polymer blends reinforced with SGF can be engineered to deliver superior mechanical performance compared to neat polymers, with clear potential for use in high-strength, tribo-mechanical applications. Such composites are particularly promising for automotive, aerospace, and industrial components where a combination of dimensional stability, wear resistance, and load-bearing capacity is required.

Future research should extend beyond mechanical testing to include tribological behavior, thermal stability, and long-term durability under cyclic loading and environmental exposure. Additionally, studies on fiber surface treatments and coupling agents may further optimize fiber-matrix interfacial bonding, thereby enhancing overall performance. By addressing these aspects, SGF-reinforced POM/PTFE composites can be more effectively tailored for advanced engineering applications.

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