"Comprehensive study and analysis mechanical properties on MoS_2 reinforced nylon66 composites"

Swapnil N. Dhole[1,a)], Shantisagar K. Biradar[2,b)], Girish M. Joshi[3,c)] , Ravindra R. Deshmukh[4,d)]
[1,] *Research Scholar, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad,Maharashtra, India*
[2]*Department of Mechanical Engineering, Matsyodari Shikshan Santha's College of Engineering, Jalna,Maharashtra, India*
[3]*Associate Professor,Institute of Chemical Technology, Jalna. Maharashtra, India,*
[4]*Professor, MGM JNEC Aurangabad, Maharashtra, India,*

Abstract- In this article's abstract, we look at the mechanical characteristics of composites with various polymer matrices. To the this aim, studies are being conducted on the mechanical characteristics of Nylon 66 composites containing 30% glass and molybdenum disulphide (MoS2) in varying volume fractions. Mechanical characteristics of nylon 66 composite are studied in relation to the amount of MoS2 reinforcement used. Using an injection moulding machine, we create test specimens of nylon66 30% glass filled with 2%, 4%, 6%, and 8% MoS2. Tensile strength, compressive strength, flexural strength, and hardness tests are performed. The findings show that the amount of glass fibre has a major impact on the mechanical characteristics of the nylon composites. In order to investigate and analyse the morphology of the fracture surfaces, a scanning electron microscope (SEM) examination was conducted.

1. Introduction

Polymers and composites made from polymers are often utilised now when high-quality tribological and mechanical qualities are essential. Tribological applications like cams, brakes, bearings, gears, etc., have specific property requirements that can't be met by homopolymers alone. Fillers are used in polymer goods to both enhance their qualities and reduce their overall production costs. Metallic particle matter, organic fillers, and inorganic fillers in micron and nanometer sizes are all viable options. In recent years, there has been a lot of interest in modifying the tribological behaviour of polymers by adding fillers in order to alter friction coefficients and wear rates.

During the last few decades, Nylon 66 has become an indispensable engineering thermoplastic polymer. Throughout the years, several investigations have been conducted on the mechanical characteristics of Nylon 66. As a result of their expanding usage in industry, polymers with inorganic fillers have been the subject of much research. Micrometer-sized inorganic particle fillers are used to increase tensile strength, hardness, impact strength, and toughness at the cost of elongation. To fill polymer composites, MoS2 is a crucial component. It is a promising reinforcing material since it is simple to mix and process and has the potential to enhance the mechanical, tribological, and rheological characteristics of polymer composites.

There has been a shift towards enhancing composites' mechanical and tribological qualities. There are several studies, analyses, and investigations being conducted in this area in order to discover its various potential uses across a variety of industries while keeping costs to a minimum. This viewpoint is at the forefront of the investigation of nylon 66 filled with MoS2 and glass fibre. As a material, nylon 66 composite has several desirable qualities, such as flexibility, abrasion resistance, and a balanced set of toughness and strength. MoS2 also has a low coefficient of friction, a high creep value for moulding, and oil solubility. Its employment, however, was restricted to a select few industries and not expanded to structural components because of drawbacks like as nylon's unstable dimensions and a higher water absorption rate. Nylon66 with different filler materials has been studied to eliminate these drawbacks and broaden the scope of its potential uses. The adhesive connection between the matrix and the fibre material has a significant impact on the characteristics of composite materials. To improve mechanical properties like mechanical strength, flexural strength, modulus, stiffness, and fatigue strength at high strength, it is common practise to include filler material within the matrix mixture. This helps to extend the bonding strength of the structure by narrowing the gap between the materials.

2. Experimentatal work

We used an injection moulding machine to create the test specimens. Injection moulded dogbone specimens were prepared for tensile testing in accordance with ASTM D638 standards. These specimens were made from pure nylon as well as nylon composites with 2, 4, 6, and 8% MoS2 content (reinforced and unreinforced plastics). Pure nylon and nylon composites are mechanically characterised by how they respond to mechanical stress. Key mechanical qualities were identified by tensile testing. Tensile tests were performed on the samples using an Instron universal testing machine (Jit 80 T0). Modulus of elasticity, yield strength at 0.2% offset, tensile strength, tensile elongation at break, and flexural strength are all examples of mechanical characteristics. Pure nylon and nylon composites with varying molybdenum disulphide reinforcing weights were tested for compressive strength and hardness.

2.1 Materials

The material for the experiment is Nylon 66 available at CIPET Aurangabad and the reinforcement selected is molebdenum disulphide (MoS2) supplied by Institute of Chemical Technologies Mumbai (Marathwada campus, Aurangabad), All the reagents used in this study were acquired from commercial sources

In this context, "nylon" denotes a class of man-made polymers. In this case, aliphatic or semiaromatic polyamides are preferred. It's a thermoplastic material that may be spun into yarn or rolled out into thin films. Nylon is a synthetic fabric available in a wide range of densities, from nylon 6 to nylon 66, and even higher to nylon 11 and nylon 12. Aliphatic polyamides, of which Nylon 66 is a kind, are a class of synthetic polymers with a wide range of applications. The material is a common plastic. Reinforcement materials introduced into the nylon polymer matrix, together with design optimization and enhanced manufacturing techniques, may significantly increase mechanical qualities while reducing weight.

2.2 Composite preparation

Compounding using a twin screw extruder allowed for the production of a Nylon 66 composite containing microparticles of Al2O3 in varying concentrations.

Powder blends that need to be extensively mixed in addition to being melted and shaped are processed often using twin screw extruders because of their outstanding mixing of material and shaping. Maintaining a temperature of around 240 °C, this technique is used to pull nylon 66 wires from granular form. The composite is preheated at 130 C for 1 hour to remove any remaining moisture before being subjected to the technique. After collecting the wires, a cutter was used to trim them down to the correct dimensions before they were sent into an injection moulding machine.

2.3 Apparatus and Methodology

The specimen is prepared by using injection moulding machine model JITMATCH 80T. A heater is used for preheating the sample to remove moisture and it helps in melting.. The tests were conducted according to ASTM D 638 standard. Table 1 states the specification of the Ijnection molding setup used in this study. All the experiments were conducted CIPET, Aurangabad, and Maharashtra, India

Fig. 1: Injection Molding

Make	**JIT**
Model	Jit 80 T
Clamp Force (TON)	80
Max. daylight (mm)	850
Injection pressure (bar)	160
Injection stroke (mm)	160
Mould height Max/min (mm)	100/320
Distance B/M tie bars (mm)	130

Table1: Injection moldng specification

2.4 Specimen Preparation

Standard size Specimen as shown in Figure 2 is prepared by injection moulding machine, model JIT 80T injection moulding machine is used for moulding the specimen.

Fig. 2: The Specimens manufactured as per ASTM D 638 dimensions.

The injection moulding machine specimens were produced under conditions of 40Mpa injection pressure, 40s of cooling time, and 60rpm screw speed. In Fig.2, we see the process by which the collected specimens were prepared for mechanical testing in accordance with ASTM D638.

3. Results and discussion

Table 1 displays the results of a number of tests conducted on the mechanical characteristics of produced ASTM D 638 composite material.

Table:1 Mechanical Properties of composite material.

Sr. no.	Test Name	Nylon66 reinforced with MoS2				
		0%	2%	4%	6%	8%
1	Tensile Strength Mpa	79	84	86	92	90
2	Elongation %	21	16	13	10	9
3	Density gm/cm^3	1.09	1.12	1.21	1.28	1.32
4	Flexural Strength Mpa	115	121	125	124	120
5	Compressive Strength Mpa	76	77	84	87	88
6	Hardness	56	58	59	59.5	60.1

3.1 Tensile Strength

Tensile strength measures how much force a material can bear while being pulled. Nylon 66's tensile strength improved after being reinforced with composites. Figure 3 shows the beneficial effects of increasing the MoS2 content of nylon66 from 2% to 8% wt%.

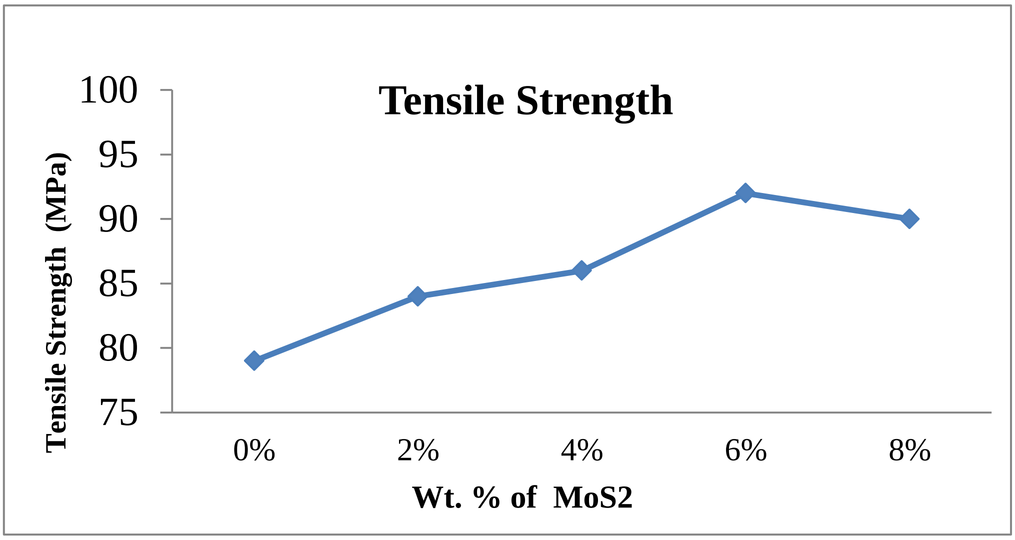


Figure: 3 Comparison of Tensile strength with wt% of MoS2 composition

Tensile strength of nylon composite with various molybdenum disulfide percentages is shown in Fig. 3. The tensile strength of a composite material is its intense attribute; it is the greatest stress the material can bear before breaking when stretched at a certain strain rate. With this data, we can determine that the tensile strength of 100% nylon is 79Mpa. The addition of only 2% MoS2 increases the tensile strength of nylon66 by 6.32 percent, to 84 MPa. Tensile strength is more than 86 MPa for the 14% MoS2 composite. The tensile strength of the composite increases to 92 MPa when the molybdenum disulphide concentration is raised from 4% to 6%. Ultimately, the tensile strength of an 8% MoS2 composite is found to be 92 MPa, or around 16.92% greater than that of pure nylon66. Good interfacial bonding between the fibre and the nylon is thought to boost the strength as the molebdenum disulphide level rises.

3.2 Flexural Strength

If the flexural strength value is high, it means the specimens are more resistant to bending, and the fibre can bear the majority of the applied stresses.

Using MoS2 as reinforcements to strengthen nylon66's bonding results in enhanced flexural characteristics between 2 and 4 wt%, and then diminishes progressively as more composite material is added.

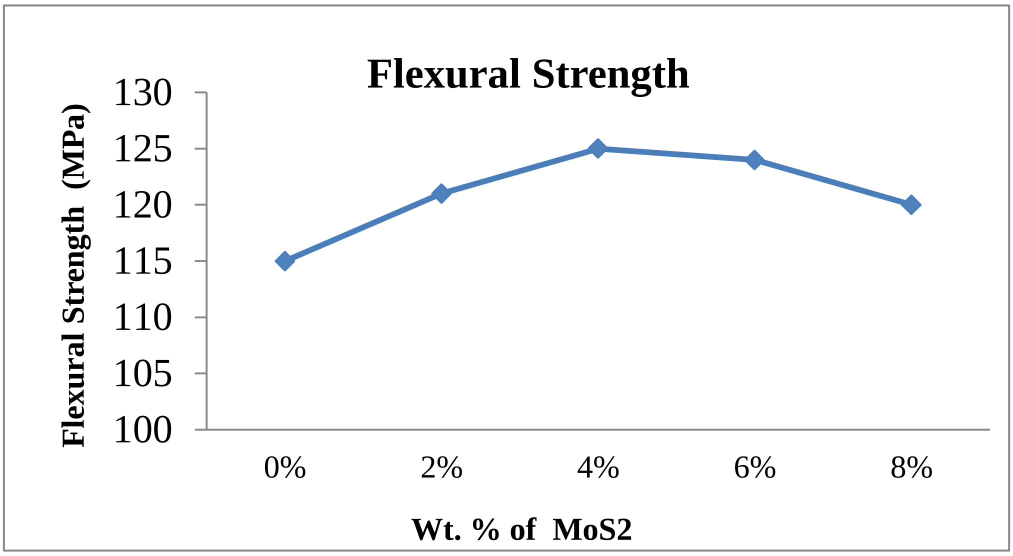


Figure: 4 Comparison of Flexural strength with wt% of MoS2 composition

3.3 Compressive Strength

When the specimen's compressive strength is strong, it means the fibres inside it can take a greater range of stresses without breaking.

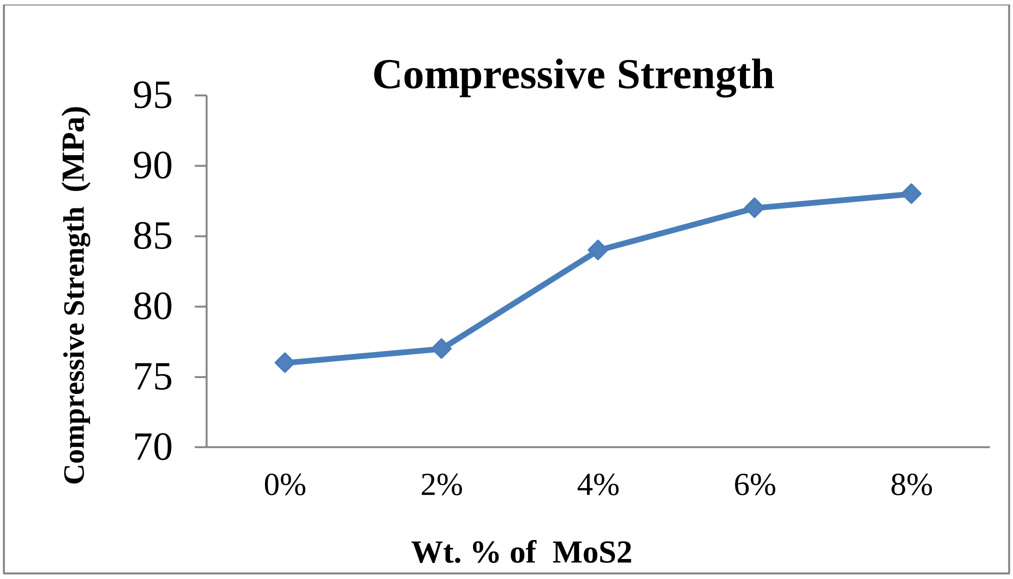


Figure:5 Comparison of compressive strength with wt% of MoS_2 composition

Compressive strength of MoS2 reinforced nylon66 composite is found to grow from 0 to 6 wt% as 76 N/mm2 and 87 N/mm2, and thereafter decrease with increment of wt% composition. Values increase dramatically from 77 N/mm2 to 84 N/mm2 when 4 wt% MoS2 are utilised as a composite in nylon66 material. As can be seen in Figs. 5 and 6, the compressive strength decreases as the mixture's excessive composition causes weaker bonds

3.4 Hardness

Durometer or Shore durometer is a standardized way to measure the hardness of plastics materials.

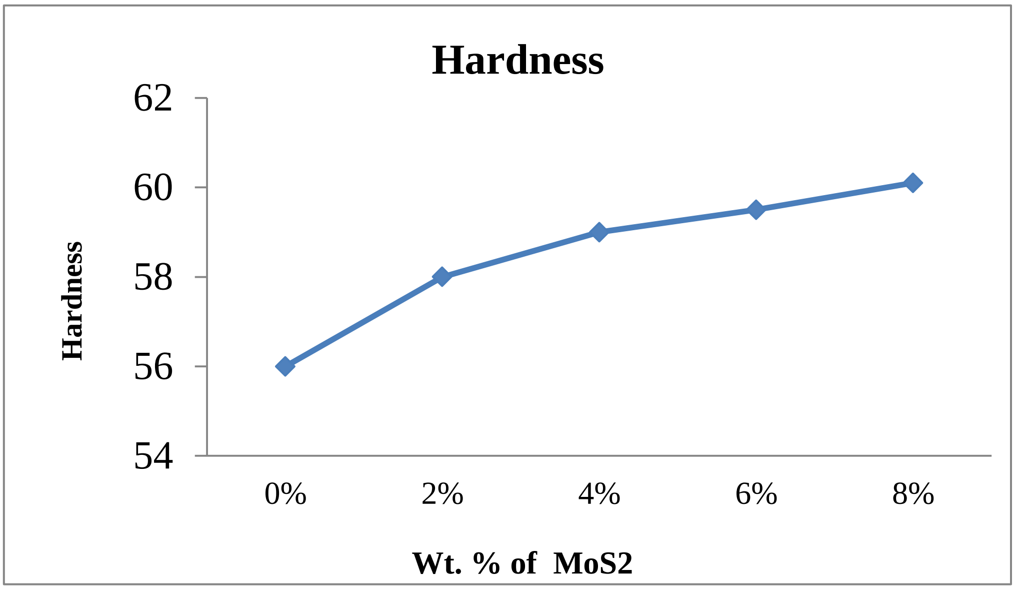


Figure:6 Comparison of compressive strength with wt% of MoS_2 composition

Nylon 66 material hardeness can be increased by adding MoS2 into it. The Figure 6 shows that the increase value of hardness of Nylon 66 by adding the molebdenum disulphide reinforcement. All the sample test value shows that by increasing composite material, the hardness is increasing its value up to 59.5 by adding 6% of MoS2.

4. Scanning Electron Microscopy (SEM)

The distribution of MoS2 particulate reinforcement in polymer metal matrix composite needs to be carried out to check the presence of reinforcement. Scanning Electron microscopy images of worn surfaces of molding speciemn were taken at Central Facilty Center, Dr. Babasaheb Ambedekar Marathwada University, Aurangabad. Electrode surface morphology was analysed using this method (JEOL JSM-6510A).

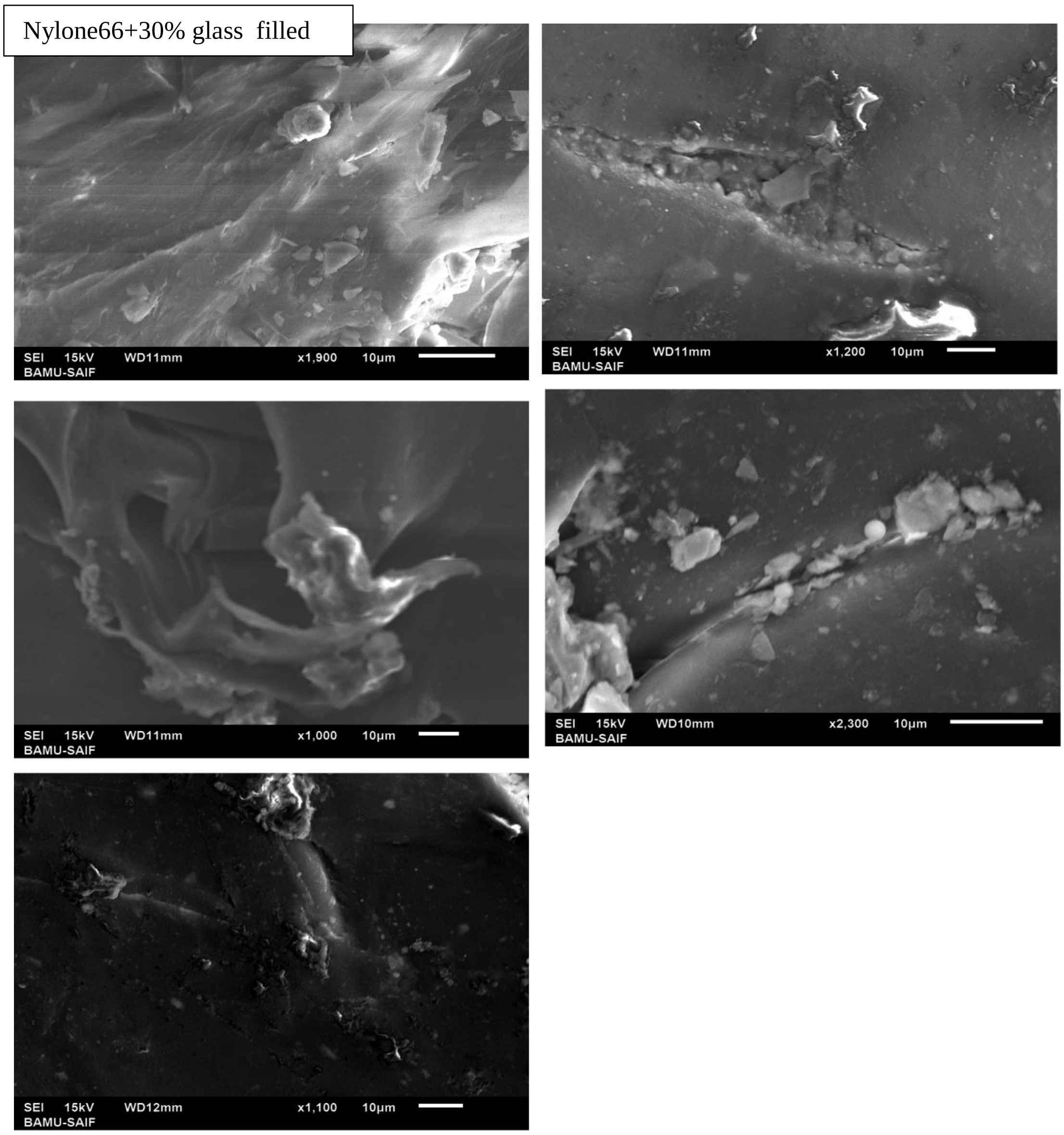


Fig. 7: SEM image analysis

5. EDS (Energy-dispersive X-ray spectroscopy) Analysis

Energy dispersive X-ray (EDX) analysis is a microanalytical technique for the quantitative analysis of elements that uses a characteristic spectrum of X-rays. Its provides both qualitative and quantitative information related to the elemental composition of the materials.

Pure Nylone66:

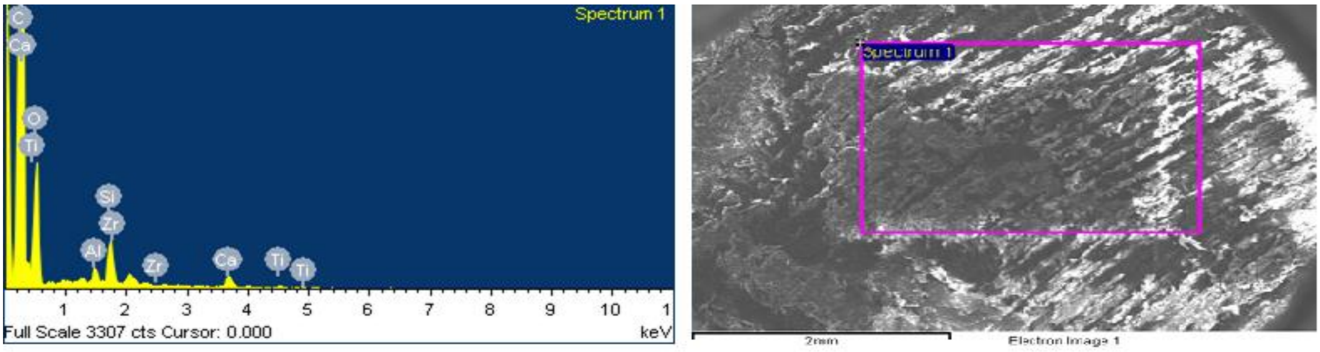


Fig.8 SEM micrograph of worn surface and corresponding EDX result of Pure Nylon66

Sr. No.	Elements	Weight %	Atomic %
1	C	69.05	76.65
2	O	25.95	21.62
3	Al	0.53	0.26
4	Si	1.77	0.84
5	Ca	1.08	0.36
6	Ti	0.27	0.07
7	Zr	1.36	0.20
Totals		100.00	

Table 2 Elemental composition of nylon66

Nylone66 with 2% MoS_2:

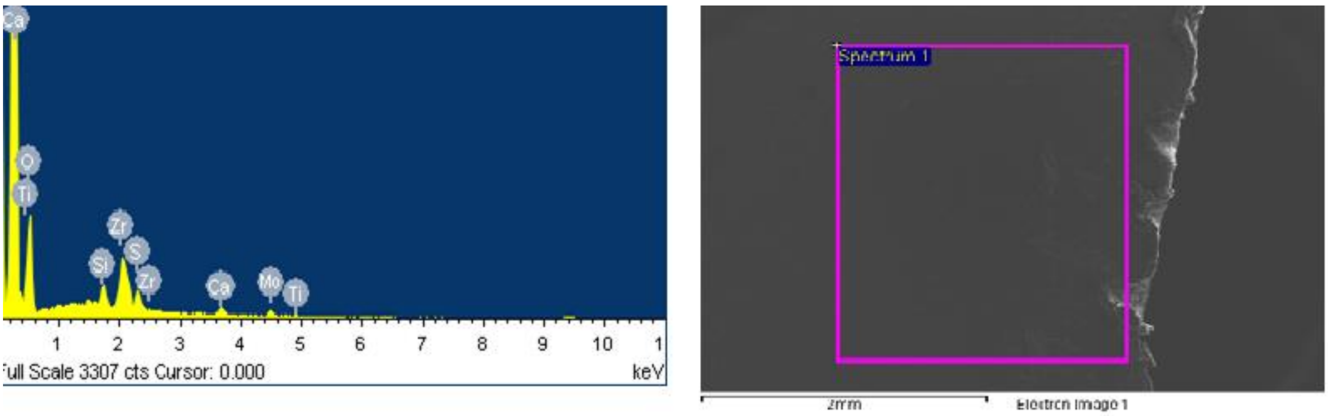
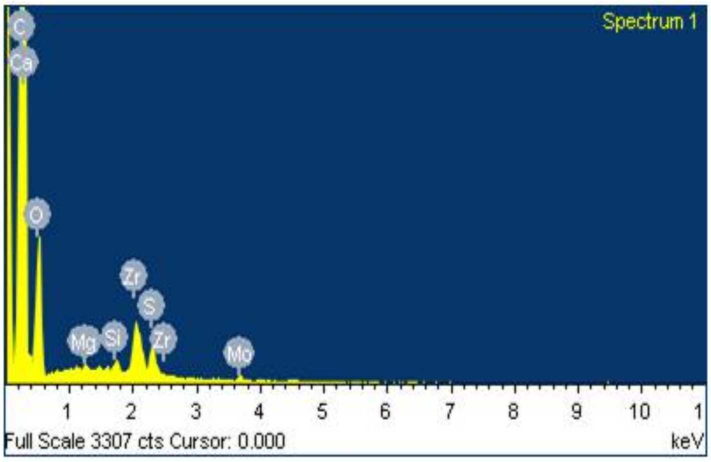


Fig.9 SEM micrograph of worn surface and corresponding EDX result of 2%MoS_2 with Nylon66

Sr. No.	Elements	Weight %	Atomic %
1	C	72.52	81.78
2	O	19.18	16.20
3	Si	0.81	0.39
4	S	0.92	0.39
5	Ca	0.55	0.18
6	Ti	0.67	0.19
7	Zr	5.06	0.75
8	Mo	0.28	0.12
Totals		100.00	

Table 3 Elemental composition of 2%MoS_2 with Nylon66

Nylone66 with 4% MoS_2:



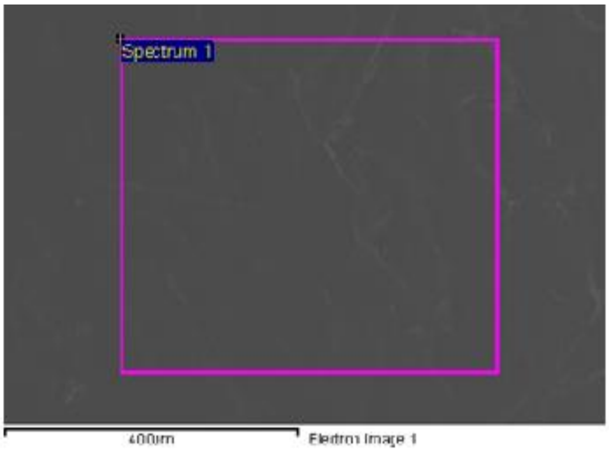


Fig.10 SEM micrograph of worn surface and corresponding EDX result of 4%MoS_2 with Nylon66

Sr. No.	Elements	Weight %	Atomic %
1	C	69.73	79.71
2	O	21.31	18.18
3	Si	0.82	0.40
4	S	0.92	0.39
5	Ca	0.55	0.19
6	Ti	0.46	0.13
7	Zr	5.69	0.85
8	Mo	0.52	0.14
Totals		100.00	

Table 4 Elemental composition of 4%MoS_2 with Nylon66

Nylone66 with 6% MoS_2:

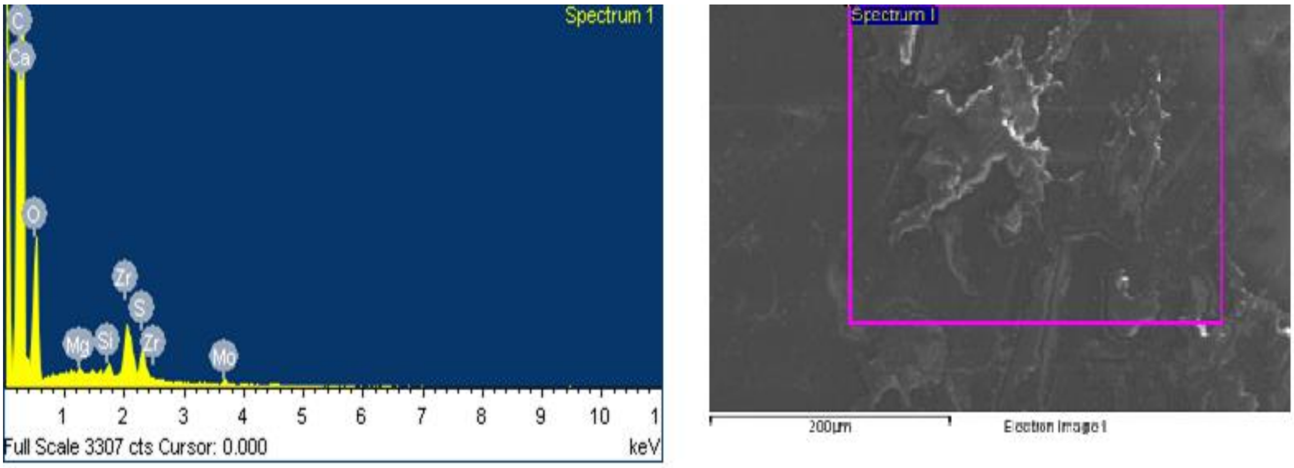


Fig.11 SEM micrograph of worn surface and corresponding EDX result of 6%MoS_2 with Nylon66

Sr. No.	Elements	Weight %	Atomic %
1	C	7.049	79.28
2	O	23.02	19.24
3	Mg	0.20	0.11
4	Si	0.32	0.15
5	S	0.96	0.40
6	Ca	0.25	0.08
7	Zr	3.89	0.57
8	Mo	0.86	0.16
Totals		100.00	

Table 5 Elemental composition of 6%MoS_2 with Nylon66

Nylone66 with 8% MoS_2:

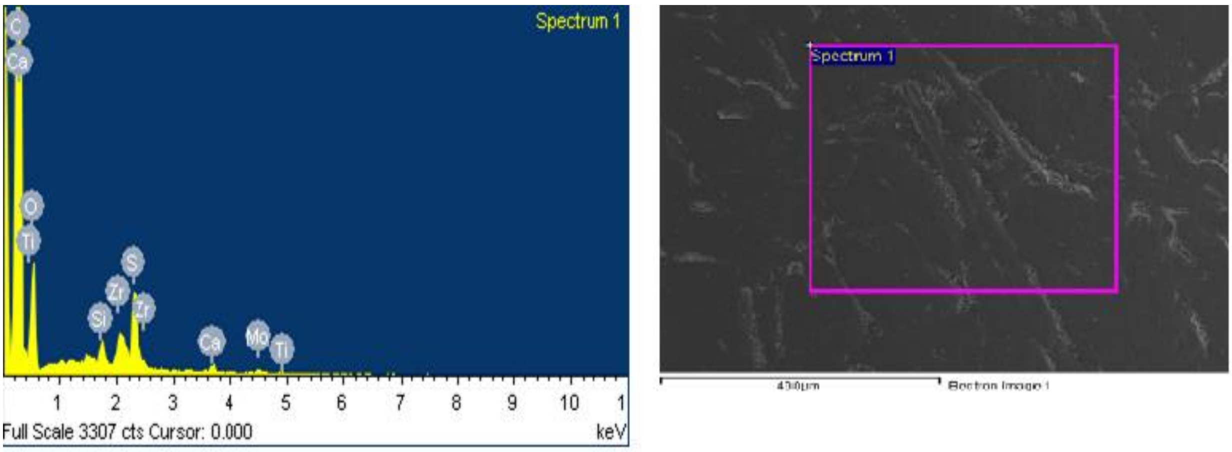


Fig.12 SEM micrograph of worn surface and corresponding EDX result of 8%MoS_2 with Nylon66

Sr. No.	Elements	Weight %	Atomic %
1	C	73.85	82.73
2	O	18.02	14.97
3	Si	0.74	0.35
4	S	2.84	1.18
5	Ca	0.48	0.16
6	Ti	0.34	0.09
7	Zr	2.70	0.39
8	Mo	1.03	0.13
Totals		100.00	

Table 7 Elemental composition of 8%MoS_2 with Nylon66

6. Conclusions

The specimens of nylon66 with 30% glass filled reinforced MoS2 composite at various wt% like 2, 4, 6 and 8 wt% produced using twin screw extruder and molded by using injection molding. The examination for mechanical properties were gone through in detail. It was determined that some of the mechanical properties like Tensile strength, Flexural strength, Compressive strength and hardness increases up to 6 wt% of MoS_2 and then decreases.

1. molybdenum disulfide added to nylon66 nanofiber reinforcement improved the material's mechanical qualities even more than they already were. Mechanical parameters such as tensile strength, flexural strength, compressive strength, and hardness were all found to be improved when compared to nylon66..
2. Nylon66 shows the lowest tensile strength which increases gradually with the increase in MoS2 content of the nylon composites. However, 6% molebdenum disulphide nylon66 composite shows significantly improved tensile strength. Test reports were analysed and it is found thatinNylon66 addition of 6% MoS2 increase its tensile strength upto 92MPa, hardness also increases as elongation decreases.
3. The flexural strength was improved upto 124 Mpa with 6 wt% of molebdenum disulphide content and compressive strength upto 88Mpa with 8 wt% of molebdenum disulphide content
4. The methods in this work may provide new ideas for the preparation of high-performance nylon66 composite materials by other reinforcement and provide a reference for other nylon material.

7. References

[1] Lancaster J. K. Relationships between the wear of polymers and their mechanical properties. In Proceedings of the Institution of Mechanical Engineers, Conference Proceedings; Sage UK: London, England: SAGE Publications, Vol. 183(16), 1968; p. 98–106.

[2] Li X., Gao Y., Xing J., Wang Y., Fang L. Wear reduction mechanism of graphite and MoS2 in epoxy composites. Wear 2004, 257, 279–283.

[3] Wang S., Ge S., Zhang D. Comparison of tribological behavior of nylon composites filled with zinc oxide particles and whiskers. Wear 2009, 266, 248–254.

[4] D M Nuruzzaman, AKM Asif Iqbal, IOP Conf. Series: Materials Science and Engineering 114 (2016)

[5] N. L. Surampadi, N.K.Ramisetti, Material Science & Engineering, (2007) 230-235

[6] B.Mouhmid, A. Imad, Polymer testing, Science direct, 2006, (544-552)

[7] K.Shiva Kumar, A.Chennalesava Reddy, Results in Materials, Science Direct, 2020

[8] Kawaljit Singh Randhawa & Ashwini D. Patel Polymer Engineering, 2021; 41(5): 339-355

[9] J.Charles, E-Journal of Chemistry, FTIR and Thermal Studies on Nylon-66 and 30% Glass Fibre Reinforced Nylon-66, ISSN: 0973-4945

[10] Saheb, D. N., Jog J. P. Natural fiber polymer composites: a review. Adv. Polym. Technol. 1999, 351–363. https://doi.org/10.1002/ (SICI)1098-2329(199924)18:43.0.CO;2-X.

[11] Miracle D. B., Donaldson S. L., Henry S. D., Moosbrugger C., Anton G. J., Sanders B. R., Hrivnak N., Terman C., Kinson J., Muldoon K., Scott Jr W. W. ASM Handbook; Materials Park, OH: ASM International, 2001, 21, 107–119

[12] Sviridyonk A. I. Self-lubrication mechanisms in polymer composites. Tribol. Int. 1991, 24, 37–43.

[13] Sliney H. E. Solid Lubricants. 1991. 12. Briscoe B. J., Sinha S. K. Wear of polymers. Proc. IME J. J. Eng. Tribol. 2002, 216, 401–413. 13. Rees B. L. Static friction of bulk polymers over a temperature range. Research 1957, 10, 331–338.

[14] Wang J. X., Gu M. Y. Investigation of the influence of CuO filler and carbon fiber on wear and transfer film of nylon composites. J. Appl. Polym. Sci. 2004, 91, 2397–2401.

[15] Crivelli Visconti I. Engineering potential of composite materials. Polym. Eng. Sci. 1975, 15, 167–177.

[16] Agarwal B. D., Broutman. L. J. Analysis and Performance of Fiber Composites 2nd ed.; John Wiley & Sons, 1990, 2–16. https://doi. org/10.1017/S0001924000023757.

[17] Schwartz M. M. Composite Materials Handbook; McGraw-Hill: New York, 1984.

[18] Eckold G. C. Design and Manufacture of Composite Structures; Elsevier: Cambridge, 1994.

[19] Hollaway, L. C. The evolution of and the way forward for advanced polymer composites in the civil infrastructure. Construct. Build. Mater. 2003, 365–378. https://doi.org/10.1016/S0950-0618(03) 000382.

[20] PNE Naveen, Bhau Kiran Goriparthi, "Evaluation of mechanical properties on Tio2/GF reinforced nylon66 composites", Materials Today: Proceedings, 2019