*International Journal of Research and Review*
*Vol.7; Issue: 4; April 2020*
*Website: www.ijrrjournal.com*
*Research Paper* *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

# Synthesis and Investigation of Peek Based Hybrid Composite Reinforced with Zinc Oxide and Aluminium Oxide Nanoparticles

**B.Vincent[1], N.Sathishkumar[2], G.Anand[3]**

[1,2]Assistant Professor, Department of Mechanical Engineering, St.Joseph's College of Engineering, Chennai - 600119, Tamilnadu, India.
[3]Associate Professor, Department of Mechanical Engineering, MVJ College of Engineering, Bangalore - 560067, Karnataka, India.

Corresponding Author: N.Sathishkumar

## ABSTRACT

Poly Ethyl Ether Ketone is a high performance thermo plastic polymer widely used in biomedical applications in recent days. The main aim of this research work is to synthesize PEEK powder when it is reinforced with ZnO nanoparticles and $Al_2O_3$ nanoparticles at different proportions. The powder metallurgy process which involves three stages like blending, compacting and sintering were carried out to prepare the samples for testing. The fabricated samples were subjected to various mechanical testing like compression test and barcol hardness test. From the investigation, it is clear that PEEK powder reinforced with ZnO nanoparticles and $Al_2O_3$ nanoparticles possess higher compressive strength and high hardness when compared to other samples.

***Keywords:*** PEEK, Zinc Oxide, Aluminium Oxide, Powder Metallurgy, Barcol Hardness, Rockwell Hardness.

## INTRODUCTION

Poly Ethyl Ether Ketone is a high performance thermo plastic polymer widely used in biomedical applications in recent days. [1,2] It is a semi-crystalline colourless thermoplastic polymer which possesses high thermal stability, good mechanical properties, high wear resistance, etc. Due to such excellent properties, PEEK is widely used in different applications like aerospace industry, automotive industry, mechanical industry, medical and electronic applications etc. [3-6] The friction and wear properties of PEEK and its composites have been studied extensively. [7,8] PEEK has no toxicity, solvent resistance, and can be repeatedly sterilized using conventional methods such as those employing steam, gamma radiation, and ethylene oxide without evident degradation of the mechanical properties. [9,10] Due to these particular properties, PEEK polymers can be used for long-term dental implants. [11] PEEK is an excellent biocompatible material with promising applications in reconstructive medicine. ZnO nanoparticles are multifunctional inorganic nanoparticles, and they exhibit excellent performances. They have high temperature resistance, good thermal conductivity, and low expansion coefficient which can significantly improve the chemical and mechanical stability of the material when they are used as reinforcing fillers. [12-14] ZnO nano particles are believed to be nontoxic, bio safe, low-cost and biocompatible. Aluminium oxide nanoparticles, a class of porous nanomaterials belongs to the family of metal oxide nanomaterials which are cost-effective. [15, 16] They possess high surface area as well as mechanical strength and they have exceptional chemical stability towards high temperatures and harsh conditions such as abrasive environment. This research study aims to synthesize the PEEK powder

when it is blended with nanoparticles and $Al_2O_3$ nanoparticles at different proportions for dental applications. The samples were prepared by powder metallurgy process which consists of different processes like blending, compacting and sintering. The samples were subjected to various mechanical testing like compression test and barcol hardness test.

## EXPERIMENTATION

The materials used for this research study are Poly Ethyl Ether Ketone powder, Zinc Oxide nanoparticles and Aluminium Oxide nanoparticles. PEEK is a colourless organic thermoplastic polymer used in different applications. It is a semi crystalline with excellent mechanical properties and chemical resistance. Zinc oxide (ZnO) nanoparticles are available as powders and dispersions. These nanoparticles exhibit antibacterial, anticorrosive and UV filtering properties. Aluminium oxide ($Al_2O_3$) nanoparticles are class of metal oxide nanoparticles that have diverse biomedical applications owing to their exceptional physicochemical and structural features such as resistance towards wear, chemicals and mechanical stresses. The process that is used to prepare the samples for testing is Powder Metallurgy process. Powder Metallurgy (PM) is a process for fabricating components by compacting finely powdered metallic or non-metallic materials. It is solid state fabrication technique. Two or more metallic or non-metallic powders are thoroughly blended together in a machine and then compacted at very high pressure using a die. The compacted powder will be still in the green state. The green compact is taken out of the die and sintered at very high temperature to get a hardened mass having the desired configuration with enhanced strength and other mechanical properties. The properties of the PEEK powder is presented in table 1. The properties of the ZnO are presented in table 2. The properties of the $Al_2O_3$ are presented in table 3. Similarly the composition of the samples used in this study is given in table 4.

**Table 1 Properties of PEEK Powder**

| | |
|---|---|
| Density | 1.32 g/cc |
| Melting Point | 339°C |
| Glass Transition Temperature | 143°C |
| Tensile Strength | 95Mpa |
| Tensile elongation | 58.4 % |
| Flexural strength | 141MPa |

**Table 2 Properties of ZnO**

| | |
|---|---|
| Chemical Formula | ZnO |
| Density | 5.91g/cc |
| Form | Powder |
| Particle Size | <100nm |
| Molecular Weight | 81.38 g/mol |

**Table 3 Properties of $Al_2O_3$**

| | |
|---|---|
| Chemical Formula | $Al_2O_3$ |
| Density | 3.95g/cc |
| Form | Powder |
| Particle Size | <100nm |
| Molecular Weight | 101.96g/mol |

**Table 4 Composition of Samples**

| Sample | Composition |
|---|---|
| Sample 1 | 100% of PEEK Powder |
| Sample 2 | 99% of PEEK + 1% Of Zinc Oxide Nanoparticles |
| Sample 3 | 99% of PEEK + 0.8% of ZnO Nanoparticles + 0.2% Of $Al_2O_3$ Nanoparticles |

The sample preparation of this study involves six steps as follows.

1) The powder is filled into the region between the two parts of the die.

2).The powder is compacted into a structure for handling with the help of a hydraulic press.

3).The compacted specimen is then placed in a ceramic tray without any physical contact between them.

4).The ceramic tray is placed in the furnace at a temperature of 313°C for 5hours for sintering process.

5).Specimen after sintering is then made to undergo forced curing at a temperature above melting point (370°C).

6).The specimen after curing is taken out.

The hydraulic press used in this study for compacting the powder is shown in figure 1. The compacted specimens collected from the hydraulic press are shown in figure 2.

The box furnace used in this study is shown in figure 3.


**Fig 1: Hydraulic Press**

**Fig 2: Compacted Specimen**

**Fig 3: Box Furnace**

## RESULTS AND DISCUSSION

The samples that have been prepared by powder metallurgy process were subjected to various mechanical testing like Compression test, Rockwell hardness test, and Barcol hardness test. The table 5 shows the specification of the samples used in this study.

**Table 5 Specification of Samples**

| | |
|---|---|
| Sample Type | Round |
| Diameter | 40.60mm |
| Area | 1294.62mm$^2$ |

Compression test is used to determine the behaviour or response of a material while it experiences a compressive load by measuring fundamental variables such as, strain, stress, and deformation. The equipment used is Universal testing machine. The ASTM standard used for testing is D695. The experiments are conducted at room temperature. The results obtained from the compression test are shown in table 6 as follows. The comparison graph is shown in figure 4 as follows.

**Table 6: Result of Compression Test**

| Sample no | Compression load in KN |
|---|---|
| Sample 1 | 9.22 |
| Sample 2 | 12.68 |
| Sample 3 | 14.40 |

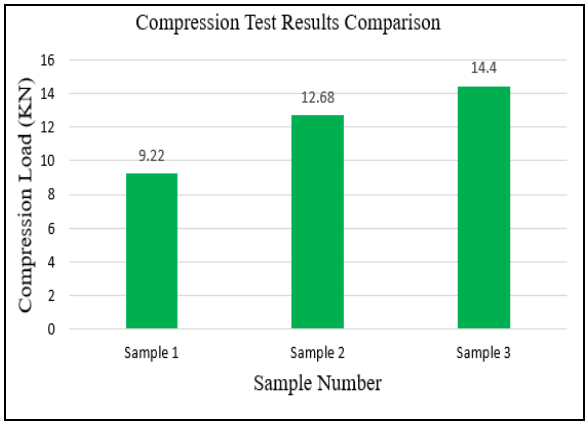


**Fig 4: Compression Test Results**

**Fig 5: Rockwell Hardness testing Machine**

The Rockwell hardness test is the most commonly used indentation testing method. It measures the permanent depth of indentation produced by the force or load. The hardness test is carried out for 3 samples at three different loads with addition to the pre load. In this test, ball indenter is used to find the hardness of the sample. The Rockwell hardness test machine used in this study is shown in figure 5 as follows. The results of Rockwell hardness test is shown in table 7 as follows. The figure 6 shows the comparison of Rockwell hardness test results for different loading conditions.

**Table 7: Results of Rockwell Hardness Test**

| Sample no | Hardness for 60Kgf Load | Hardness for 100Kgf Load | Hardness for 150 Kgf Load |
|---|---|---|---|
| Sample 1 | 40 | 35 | 30 |
| Sample 2 | 44 | 38 | 32 |
| Sample 3 | 48 | 42 | 34 |

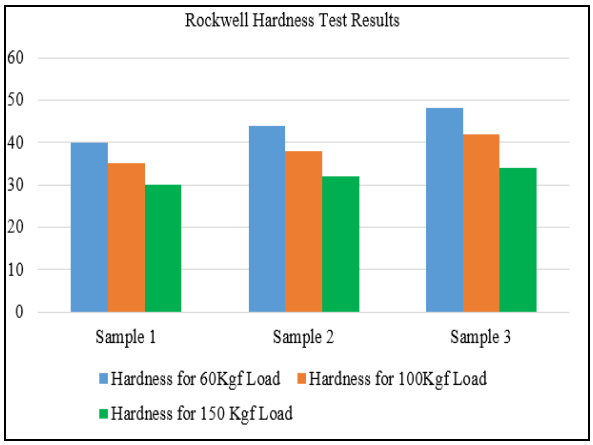


**Fig 6: Rockwell Hardness test results**

The Barcol hardness test characterizes the indentation hardness of materials through the depth of penetration of an Indentor. The depth of the penetration is converted into absolute Barcol numbers. ASTM standard used for testing is D2583. The barcol hardness tester used in this study is shown in figure 7. Similarly the results of the barcol hardness test are shown in table 8. The comparison of barcol test results is shown in figure 8.

**Fig 7: Barcol Hardness Tester**

**Table 8: Result of Barcol Hardness Test**

| Sample no | Barcol Hardness Number |
|---|---|
| Sample 1 | 22 |
| Sample 2 | 24 |
| Sample 3 | 30 |

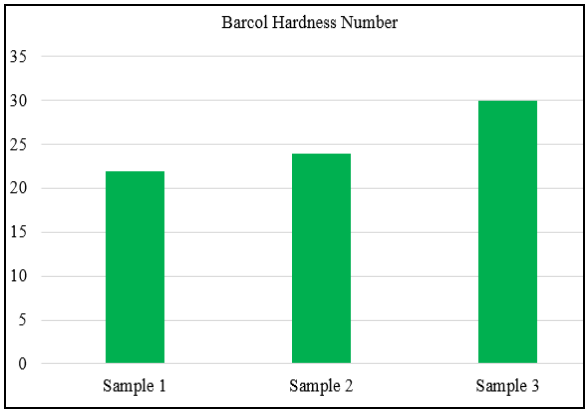


**Fig 8: Barcol Hardness Test Comparison**

## CONCLUSION

From the experiments carried out, the following conclusions are drawn:

i. ZnO and $Al_2O_3$ nanoparticles in the PEEK matrix composite sample can withstand higher compressive strength when compared to other samples due to the interfacial interaction between the nanoparticles and the PEEK matrix when it compacted and sintered at 313°C for 5hours.

ii. Barcol hardness number is high for PEEK/ZnO/$Al_2O_3$ sample.

iii. Therefore, PEEK/ZnO/ $Al_2O_3$ composites can have great potential as biomaterials for Dental implants.

iv. Increase in the proportions of ZnO and $Al_2O_3$ nanoparticles in the PEEK

matrix can improve the compressive strength.

## REFERENCES


1. X. Hou, Y. Hu, X. Hu and D. Jiang, Poly(ether ether ketone) composites reinforced by graphene oxide and silicon dioxide nanoparticles: mechanical properties and sliding wear behavior, High Perform. Polym., 2017, 30(4), 406–417.
2. Sathishkumar, N., M. Sugavaneswaran, and G. Arumaikkannu. "Investigation of sparse mode build style on material consumption, build time and compressive behaviour of additive manufactured cellular structures." 6th International & 27th All India Manufacturing Technology, Design and Research Conference (AIMTDR-2016). 2016.
3. T. J. Hoskins, K. D. Dearn, Y. K. Chen and S. N. Kukureka, The wear of PEEK in rolling – sliding contact – simulation of polymer gear applications, Wear, 2014, 309, 35–42.
4. Balamurugan, L., et al. "Investigation of mechanical behaviour and surface roughness properties on electroplated FDM ABS parts." Int. J. Eng. Res. Mech. Civ. Eng 2 (2017): 60-67.
5. Sathishkumar, N., et al. "Investigation of Mechanical Behaviour and Surface Roughness Properties on Copper Electroplated FDM High Impact Polystyrene Parts." Advances in Additive Manufacturing and Joining. Springer, Singapore, 2020. 287-300.
6. Sugavaneswaran, M., N. Rajesh, and N. Sathishkumar. "Design of Robot Gripper with Topology Optimization and Its Fabrication Using Additive Manufacturing." Advances in Additive Manufacturing and Joining. Springer, Singapore, 2020. 75-85.
7. F. Li, Y.Hu, X. Hou, X. Hu and D. Jiang, Thermal, mechanical, and tribological properties of short carbon fibers/PEEK composites, High Perform. Polym., 2017, 30(6), 657–666.
8. N. Amanat, C. Chaminade, J. Grace, et al., Transmission laser welding of amorphous and semi-crystalline poly-ether-etherketone for applications in the medical device industry, Mater.Des., 2010, 31(10), 4823–4830.
9. Y. Hu, X. Hou, X. Hu and D. Jiang, Improvement in the Mechanical and Friction Performance of Poly(ether ether ketone) Composites by Addition of Modifacatory Short Carbon Fibers and Zinc Oxide, High Perform. Polym., 2017, 30(6), 643–656.
10. Velisaris, Chris N., and James C. Seferis. "Heat transfer effects on the processing–structure relationships of polyetheretherketone (PEEK) based composites." Science and Engineering of Composite Materials 1.1 (1988): 13-22.
11. Schroeder, R., et al. "Failure mode in sliding wear of PEEK based composites." Wear 301.1-2 (2013): 717-726.
12. Prithvirajan, R., et al. "Metal bellow hydroforming using additive manufactured die: a case study." Rapid Prototyping Journal (2019).
13. Sathishkumar N, Kumar VA, Gokulnath M et.al. Performance analysis of palmitic acid coated pcm storage container. International Journal of Research and Review. 2020; 7(3): 495-500.
14. Sathishkumar N, Premkumar P, Bruce AR et.al. Design and analysis of an impeller of a turbocharger. International Journal of Research and Review. 2020; 7(4): 45-51.
15. D'Amore, Alberto, et al. "The effect of physical aging on long-term properties of poly-ether-ketone (PEEK) and PEEK-based composites." Journal of applied polymer science 39.5 (1990): 1163-1174.
16. Song, Jian, et al. "Fretting wear study of PEEK-based composites for bio-implant application." Tribology Letters 65.4 (2017): 150.


How to cite this article: Vincent B, Sathishkumar N, Anand G. Synthesis and investigation of peek based hybrid composite reinforced with zinc oxide and aluminium oxide nanoparticles. International Journal of Research and Review. 2020; 7(4): 189-193.

******