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DESIGN AND DEVELOPMENT OF IRON NANO AND HYDROXYAPATITE PARTICLES FILLED ALUMINUM ALLOY COMPOSITE

Suryajeet Kumar Singh[1], Dr. Devender Singh Punia[2]

Department Of Mechanical Engineering, Ganga Institute of Technology & Management Kablana, Jhajjar, Haryana, India

ABSTRACT

Due to its advantageous qualities, which include a high strength-to-weight ratio, light weight, high thermal property values, and resistance to corrosion, aluminium and its alloys are widely employed in a variety of sectors worldwide. On the other hand, some of the backgrounds are low part properties, including hardness and wear resistance. Advanced composite materials reinforced with one or more elements to create a distinctive combined effect are called Metal Matrix composite materials. This approach permits a greater degree of material design limit extension. In this current study, the main objective of this work was to evaluate physical and mechanical properties experimentally and numerically using finite element modelling (FEM). Iron nano particle and hydroxyapatite reinforced into aluminum 6061 alloy composites are fabricated simultaneously by adopting stir casting approach by changing weight percentages of filler powder from 0.0 wt.%, 1.00 wt.%, 1.5wt.% . On the opposite hand, fabrication of composite numerically was done through ANSYS Workbench 2020 R2. In result, void percentage of AA 6061 composites varied from 0.77 to 1.73 for 0 to 1.5 weight percent when filler was introduced and micro-hardness value raised from 13.9 HB to 24 HB with the increasing nano filler amount. Dry sliding wear tests were conducted for iron nano and hydroxyapatite filled alloy composites and there after implementing Taguchi approach at four distinct loads (30N – 60N), sliding speed (30 rpm – 60 rpm), Test run time duration (10-25 min) and filler powder weight percentages (0 wt.% - 1.5 wt.%) respectively using pin-on-disc machine. Finally, for finding some other characteristic properties mechanism of composite and for numerical approach the Finite Element Analysis was performed by using ANSYS 20.0 and various stresses such as maximum principal stresses, Von- Mises stresses, directional deflection, total deformation, and penetration, contact pressure surfaces, occurred throughout operating condition were evaluated.

Keywords:

Physical properties, Mechanical properties, finite element analysis, RVE, Ansys, Taguchi, wear

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1. INTRODUCTION

Various lightweight materials with outstanding physical, mechanical, and thermal characteristics have become available for scientific study and engineering applications during the past decade due to advancements in science and technology. The composite material is an example of this type. A composite is a multiphase material made up of more than two chemically different phases with an interface that divides them. Reinforcement and matrix are the two stages, with reinforcement being stronger, discontinuous, and stiffer than matrix, which is continuous and weaker. A matrix material can be made of metal, ceramic, or polymer. Composites are becoming more important as a vital material in the fields of aircraft, space, satellites, automobiles, ships, and civil infrastructure due to their high strength, stiffness, light weight, low coefficient of friction, high thermal conductivity, excellent fracture resistance, and low electrical resistivity. High wear resistance, vibration damping ability, strong corrosion resistance, and creep resistance are some of the other benefits of composite. Because of their superior mechanical, physical, and thermal characteristics, composites are increasingly replacing metals in a variety of applications.

Composites are materials made up of two or more chemically different elements with a distinct interface that separates them from one another on a macro-scale. To produce a composite, one or more discontinuous phases are reinforced in a continuous phase. The reinforcement refers to the discontinuous phase, which is generally tougher and stronger than the continuous phase, whereas the matrix refers to the continuous phase. Because these materials have various tailorable features, higher quality, and a long-life period, the field of alloy composites has become exciting. Every day, new alloys with outstanding and extraordinary characteristics are created as a result of technological advancements and research. Aluminum alloys with exceptional features such as low density, high strength-to-weight ratio, and capacity to withstand wear and corrosion have been developed as a result of recent study on the metal. Aluminum and its alloys are used to make structural components for the aircraft industry, as well as other transportation and structural elements. By adding a solid filler, it is also possible to modify the physical and mechanical characteristics of the composite being formed, resulting in a material with equivalent or even greater qualities than those existing metallic materials. It's possible that adding particles to a metal alloy can increase its characteristics and usability in some cases. The quality of composites may simply be changed by adding certain filler. Adding filler to an alloy composite enhances mechanical strength, resulting in a direct cost savings by utilizing less particle filler material. To enhance and reform the overall characteristics and behaviour of particle reinforced metal matrix composite material, certain fillers are applied.

1.1 MATRIX PHASE

1. The primary phase, which is continuous in nature.
2. The hard and ductile phase, which is typically less hard and more ductile;
3. Maintains the reinforcing phase while sharing a load with it.

1.2 REINFORCING PHASE

The second phase, or phases, have a discontinuous form that is embedded in the matrix. Typically, it is more powerful than the matrix., which is why it is frequently referred to as the reinforcing phase.

In the context of engineering materials, composites generally refer to materials with the following characteristics

1. These are produced in a industry (thus, excluding natural material such as wood).
2. These consist of a minimum of two category with a clearly defined interface.

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3. The qualities of substances are influenced by their volume percentage.
4. These possess at least one attribute lacking in the separate parts.

2. OBJECTIVE OF THE PRESENT WORK

1. Study of Aluminum Alloy, Iron Nano and Hydroxyapatite MM composites.
2. Development of series with particulate (HAp and Iron nano) filled metal alloy composite by Stir casting method.
3. To investigate the Physical (Void content, Density, Hardness), thermal (Conductivity and Heat flux) and mechanical characteristics of the proposed alloy composite both experimentally and numerically
4. Evaluation of Tribological behaviour of the alloy for structural applications under different operating conditions
5. Application of optimization methodology with the layout of an experiment (DOE).
6. Numerical examination of composite using FEM models in Ansys.

3. ENGINEERING MATERIALS AND ITS PROPERTIES

Al %	Mg %	Fe %	Si %	Ti %	Mn %	V %	Cu %
97.25	5.04	0.148	0.44	0.56	0.065	0.023	0.024

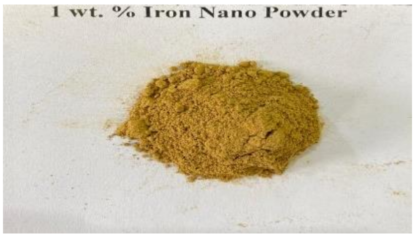
Base Materials	Density	Poisson Ratio	Melting Point	Elastic Modulus	Thermal conductivity	Specific Heat	Tensile Strength	Hardness
AA6061	2.65 g/cc^3	0.33	650 ^{0}C	68 GPa	151-183 W/m-K	885 J/kg-K	317 MPa	14 HB

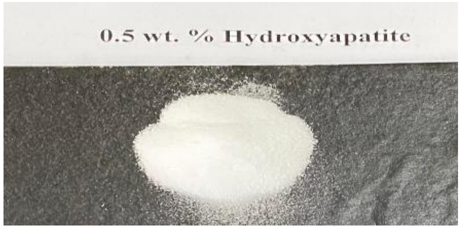
Filler Materials	Density	Poisson Ratio	Melting Point	Elastic Modulus	Thermal conductivity	Specific Heat	Size
Iron Nano	7.874 g/cc^3	0.29	1538 ^{0}C	211 GPa	286 W/m-K	443.8 J/kg-K	50 nm
HAp	3.18 g/cc^3	0.40	1100 ^{0}C	151 GPa	0.05 W/m-K	700 J/kg-K	10-40 nm

Figure: . Al6061 Base(Raw) material bar used for Fabrication

4. PROPOSED FILLER MATERIAL

Iron Nano Powder and Hydroxyapatite particles were utilized as reinforcement fillers in this work to fabricate the required composites. Iron nano powder, a mustard yellowish powder made up of iron particles ranging in size from 20 to 100 nanometers, has seen a lot of use in manufacturing and research in recent years. Iron nano powders have been used or studied extensively in a range of medical and biological applications.





Its unusual optical characteristics, like those of many other nanoparticles, make it interesting for clinical imaging. It's also been used as a medication carrier in several delivery systems. Applications in the environment. Iron nanopowders have looked good as a remedy for some types of soil pollution, aiding in the degradation of heavy metals and other possibly hazardous environmental contaminants. Hydroxyapatite (Ca5(PO4)3OH2H2O) is a naturally occurring calcium phosphate mineral with the formula Ca5(PO4)3OH2H2O. Fluoride, chloride, or carbonate can swap the OH ion, resulting in fluorapatite. or the mineral chlorapatite the stiffness of bones and teeth is due to hydroxyapatite. Hydroxyapatite comes in a number of forms. Orthopedic, dental, and maxillofacial uses are only a few examples.

5. DETAIL INSTRUCTION OF PROCESS

- The graphite crucible is preheated (about 200°C) first to prevent oxidation of base material (i.e., aluminum alloy) and its easy melting.
- Thereafter pieces of base material are put inside the crucible. Future, crucible is heated till 700°C. This melts the base material.
- The reinforcing phase (i.e., HAp and Iron Nano powder) is added to the molten base alloy slowly and mechanical stirrer at 80-100 rpm is used to mix the ingredients at least for 0.8-1.2 minutes. To ensure proper wettability between ingredients 1 wt. % magnesium power is added to the mixture. Thus, homogeneity in the mixture is ensured.
- Metal alloy composites were prepared for 0.5 wt. %, 1 wt. %, 1.5 wt. of particulates separately for both compositions.
- After successful addition of reinforcements, the alloy melt was poured into the mold (made of rectangular stainless steel) for solidification. The mold is kept in the room for around 20 minutes so as to achieve proper curing.
- When the room temperature of casting is obtained the specimen, samples were taken out and prepared as per characterization or testing methods. Standard samples were prepared for, Density, Micro-hardness test, tensile test, thermal and wear analysis.

6. CASTING PLATE FABRICATED

The casted plate with 0.5% , 1% wt ,1.5% wt iron Nano powder used as filler material for reinforcement into Al 6061 matrix which is shown below.

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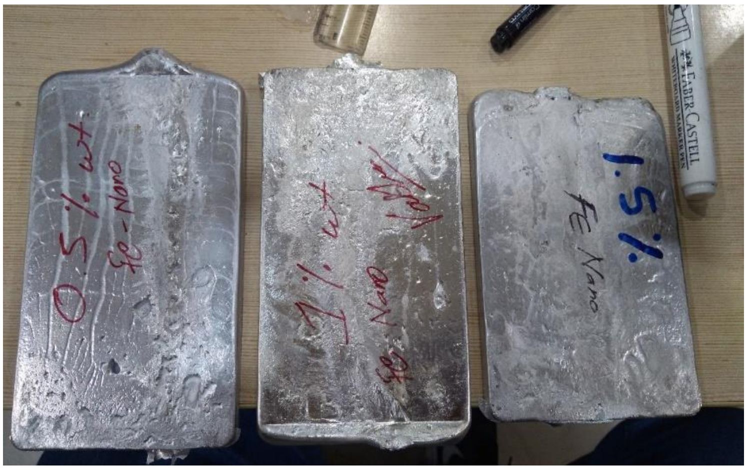

The casted plate with 0.5% , 1% wt ,1.5% wt HAp powder used as filler material for reinforcement into Al 6061 matrix which is shown below.

7. CONCLUSIONS

This thesis provides a thorough investigation into the physical, mechanical, and tribological characteristics of composites made using a stir casting process. The observable results led to the following deductions:

Tested Sample (Fe- Nano)

Tested Sample (Hydroxyapatite)

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- The thermal conductivity of the HAp-reinforced composites was found to be lower than that of the unreinforced AA 6061 alloy, and this tendency to decline was observed as the HAp percentage increased. When the weight fraction of the composite rose from 0.5 wt% to 1.5 wt% of HAp, a slight rise in micro-hardness (from approximately 13.9 to 20 HB) was detected. This resistance to material deformation results in an improved hardness value. Some of the mechanical characteristics and even the performance of the composites is greatly impacted by the pores and voids present in the composite structure. Greater sensitivity to weathering, water intrusion, and fatigue resistance are typically associated with higher void contents.
- For 6061 alloy composites, the tensile strength was found to be 138 MPa for 0.5 weight percent HAp and rose to 144 MPa for 1.5 weight percent HAP. For iron nanoparticles, it was found to be 141.3 MPa for 0.5 weight percent Fe particles and grew to 148.9 MPa for 1.5 weight percent filling particles.
- The thermal conductivity of the Fe-reinforced composites was found to be higher than that of the unreinforced AA 6061 alloy, and it was also found to rise as the Fe concentration increased. A slight increase in micro-hardness (from about 13.9 to 26.46 HB) was noted when the composite's weight fraction of Fe Nano increased from 0.5 wt% to 1.5 wt%.
- Technique of RVE for fabricating composite and getting initial properties of new fabricated composite can be done through FEM (Properties like Density , Elastic Modulus , Thermal Conductivity and flux)
- Taguchi's design method is implemented so as to procure optimal parameter for specific wear rate. As the filler percentage is raised from 0 to 1.5 wt.%, the specific wear rate value got increased for all sliding speeds (30, 40, 50 and 60 rpm) and loads (10, 20, 30 and 40N) and results shows filler percentage was dominant factor effecting in wear rate of fabricated sample
- Particulate fabrication and testing also cover the use of filler as reinforcement in metal matrix composites, which can be utilized to improve the mechanical properties of base materials for the production of biocompatible components. Metal matrix composites can be made using metals or ceramics.

8. FUTURE SCOPE

There is still more room for research and development that would add to the topic of this study, and some potential areas for further investigation include:

- The stir casting procedure has been the exclusive focus of this inquiry. The other methods of casting could be examined and tested. This could result in combining the weight fraction of the particles, from which a conclusion can be made.
- The experimental setup can be enhanced to observe more accurate ring performance findings.
- It would also be possible to test and evaluate various coating methods in order to ascertain the impact of coating thickness for certain alloys utilized in various applications.
- As was previously mentioned, there is a chance that adding specifically designed Hydroxyapatite particulate fillers to aluminum alloy composites could enhance their mechanical, wear resistance, and fracture toughness as the weight percentage ratio rises. However, there is currently a dearth of information regarding wear phenomena and fracture toughness following the addition of fillers to Al 6061 alloy composites.
- Mechanical properties of both filled and unfilled composites, such as impact strength, tensile modulus, flexural strength, and flexural modulus test, may be studied and analyzed. In the future, research on alloy composites' characteristics like corrosion and erosion may also be conducted.

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REFERENCES

1. S. Prabhakaran, K. Chinnarasu and M. S. Kumar, "Design and Fabrication of Composite Bumper for Light Passenger Vehicles," Internation Journal of Modern Enginneering and Research, vol. 2, no. 4, pp. 2552-2556, 2012.
2. A. Jambor and M. Beyer, "New cars — new materials," Materials & Design, vol. 18, no. 4-6, pp. 203-209, 1997.
3. S. S. Cheon , D. G. Lee and K. S. Jeong, "Composite side-door impact beams for passenger cars," Composite Structures, vol. 38, no. 1-4, pp. 229-239, 1997.
4. Y. Li, Z. Lin, A. Jiang and G. Chen, "Use of high strength steel sheet for lightweight and crashworthy car body," Materials and Design, vol. 24, pp. 177-182, 2003.
5. V. K. Stokes, "Energy Absorbing Double-Beam Concept for Thermoplastic Automotive Bumpers," Polymer Engineering and Science, vol. 33, no. 21, pp. 1381-1389, 1993.
6. S. Skolianos, T.Z.Kattamis, Mater.Sci.Engg.A163 (1993) 107.
7. Akbulut, M. Darman, F. Yilmaz, Wear 215 (1998) 170.
8. M.K.Surappa, S.C.Prasad, Wear 77 (1982) 295.
9. S. K. a. S. M. R. Kumar, "Towards sustaiable solutions for flyash through mechanical activation," Resources Conservation and Recycling , vol. 52, pp. 157-179, 2007.
10. C. T. W. Hull D, An Introduction to Composite Materials, Cambridge, UK: Cambridge Univ. Press, 1996.
11. Matthews F.L. and Ralwlings R.D, Composite materials engineering ans science, Glasgow, UK,: Champaman and hall, 1994.
12. C. Calow, "Practical Metallic Composites," Proceedings of the spring meeting I.M., p. B17, 1971.
13. W. Hunt, "Particulate reinforced MMCs," Comprehensive Composite Materials, Metal Matrix Composites, vol. 3, p. 701–715, 2003.

1. 14.P.K. Rohatgi, R.Q. Guo, P. Huang, S. Ray, "Friction and abrasion resistance of cast aluminium alloy-fly ash composites", Metall. Mater. Trans. A (1997), 28, pp.245–250.

14. B.W. Chua, L. Lu , M.O. Lai, "Influence of SiC particles on mechanical properties of Mg based composite. Composite Structures", (1999), 47, pp. 595-601.
15. Ferraz, M. P., F. J. Monteiro, and C. M. Manuel. "Hydroxyapatite nanoparticles: a review of preparation methodologies." Journal of Applied Biomaterials and Biomechanics 2.2 (2004): 74-80.
16. Huber, Dale L. "Synthesis, properties, and applications of iron nanoparticles." Small 1.5 (2005): 482-501.
17. G. Chandramohan , S. Basavarajappa, "Wear studies on metal matrix composites: A Taguchi method", Journal of Materials science Technology, (2005),pp. 104-114.
18. Mamatha TG, Patnaik A, Biswas S, Kumar P, "Finite element modeling and development of SiC filled ZA-27 alloy composites in erosive wear environment: a comparative analysis. Proc I MechE, Part J: J Engineering Tribology, (2011), 225, pp.1106–1120.
19. A.R.I Kheder, G.S. Marahleh, D.M.K. Al- Jamea, "Strengthening of aluminium by SiC, Al2O3 and MgO", Jordan Journal of Mechanical and Industrial Engineering, (2011), 5 (6), pp.533-541.
20. P. Shanmughasundaram, R. Subramanian, G. Prabhu, "Some Studies on Aluminium-Fly Ash Composites Fabricated by Two Step Stir Casting Method", European Journal of Scientific Research, (2011), 63, pp. 204-218.
21. H.C. Anil Kumar, H.S. Hebbarand K.S. Ravishankar, "Mechanical properties of fly ash reinforced aluminium alloy (Al6061) composites", IJMME, (2011), 6(1),pp.41-45.

22. H.S. Grewal, S. Bhandari, H. Singh, "Parametric Study of Slurry-Erosion of Hydro turbine Steels with and without Detonation Gun Spray Coatings using Taguchi Technique", Metallurgical and Materials Transactions A, (2012), 43 pp.3387-3401.
23. R. S. Rana, Rajesh Purohit and S. Das, "Fabrication and testing of ultrasonically assisted stir cast AA 5083-SiC composites", IJERA, 2013, 3 (5), pp.386-393.
24. Y.M. Shivaprakash, K.V. Sreenivasa Prasad, Y. Basavaraj, "Dry sliding wear characteristics of fly ash reinforced AA 2024 based stir cast composite" IJCET, (2013), 3(3), pp.911-921.
25. M. Ramesh, T. Karthikeyan and A. Kumaravel, "Effect of reinforcement of natural residue (Quarry Dust) to enhance the properties of aluminum metal", JIPC, 2013.
26. Amir Hussain Idrisi and Shailendra Deva, "Development and testing of metal matrix composite by reinforcement of SiC particles on Al 5xxx series alloy", IJERT, (2014), 3 (2), pp.1303-1309.
27. Ayatollahi, M. R., et al. "Mechanical and tribological properties of hydroxyapatite nanoparticles extracted from natural bovine bone and the bone cement developed by nano-sized bovine hydroxyapatite filler." Ceramics International 41.9 (2015): 10818-10827.
28. Vikas Kukshal, Swati Gangwar and Amar Patnaik, "Experimental and finite element analysis of mechanical and fracture behavior of SiC particulate filled A356 alloy composites: Part I", Proc IMechE Part I: Materials: Design and Applications, (2015), 229 (2) pp.91-105.
29. . Fomin, Aleksandr, et al. "Composition, structure and mechanical properties of the titanium surface after induction heat treatment followed by modification with hydroxyapatite nanoparticles." Ceramics international 42.9 (2016): 10838-10846.
30. Pu'ad, NAS Mohd, et al. "Syntheses of hydroxyapatite from natural sources." Heliyon 5.5 (2019): e01588.
31. Fahami, A., Nasiri-Tabrizi, B., Beall, G. W., & Basirun, W. J. (2017). Structural insights of mechanically induced aluminum-doped hydroxyapatite nanoparticles by Rietveld refinement. Chinese journal of chemical engineering, 25(2), 238-247.
32. Castkova, K., Hadraba, H., Matousek, A., Roupcova, P., Chlup, Z., Novotna, L., & Cihlar, J. (2016). Synthesis of Ca, Y-zirconia/hydroxyapatite nanoparticles and composites. Journal of the European Ceramic Society, 36(12), 2903-2912.
33. K.L. Tee, L. Lu, M.O. Lai, 1999, Synthesis of in situ Al-TiB2 composites using stir cast route, Composite Structures 47, 589-593.
34. Veeresh Kumar, GB, Rao, CSP, Selvaraj, N, & Bhagyashekar, MS. (2010). Studies on Al 6061-SiC and Al 7075-Al2O3 metal matrix composites. Journal of Minerals & Materials Characterization & Engineering, 9(1), 43–55. USA.
35. Kouzeli M, Weber L, Marchi C.S and Mortensen A, (2001). Influence of damage on the tensile behavior of pure aluminium reinforced with ≥ 40 vol. pct alumina particles, Actamater, 49:3699–3709.
36. Alen John1, Dr. Y.V.K.S Rao, Jerin Sabu, Rajeev V. R, April 2014. Stress Analysis of Polyoxymethylene which Leads to Wear in Pin on Disc Configuration using Finite Element Method, Department of Mechanical Engineering, Mar Baselios College of Engg & Technology, Trivandrum, India
37. P. Prabhu, M. Suresh Kumar, Ajit Pal Singh & K. Siva, 2014, Experimental Study and Verification of Wear for Glass Reinforced Polymer using ANSYS, Defence University, Ethiopia
38. Podra, Priit, and Sören Andersson. "Simulating sliding wear with finite element method." Tribology international 32.2 (1999): 71-81.

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International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

39. Suresh, R., Kumar, M. P., Basavarajappa, S., Kiran, T. S., Yeole, M., & Katare, N. (2017). Numerical Simulation & Experimental study of wear depth and Contact pressure distribution Of Aluminum MMC Pin on Disc Tribometer. Materials Today: Proceedings, 4(10), 11218-11228.
40. Ravindra Singh Rana, Rajesh Purohib, Anil kumar Sharma, Saraswati Rana,2014, Optimization of Wear Performance of Aa 5083/10 Wt. % Sicp Composites Using Taguchi Method Procedia Materials Science 6, 503 – 511
41. B.N. Ramesh, B. Suresha. Optimization of tribological parameters in abrasive wear mode of carbon-epoxy hybrid composites. 2014. vol. 59, pp. 38-49.
42. PatnaikA, SatapathyA, MahapatraSS, DashRR.,2009,Tribo-performanceofpolyester hybrid composites: damage assessment and parameter optimization using Taguchi design. Mater Des;30:57–67.
43. Karunamoorthy L and Kandasami G.S, (2004). A finite element analysis study of micromechanical interfacial characteristics of metal matrix composites, Journal of Materials Processing Technology, 153–154:992–997.
44. Prabu S.B and Karunamoorthy L, (2008). Microstructure-based finite element analysis of failure prediction in particle-reinforced metal–matrix composite, Journal of Materials Processing technology, 207:53–62.
45. V. M. a. S. K., "Experimental Evaluation of Aluminium-Fly Ash Composite Material to increase the mechanical and wear behaviour by stir casting method," CARE Journal of Applied Research (ISSN 2321-4090), pp. 14-17, 2013.
46. M. M. a. B. P, "Tensile and Fracture Toughness Properties of SiC Reinforced Al Alloys: Effects of Particle Size, Particle Volume Fraction, and Matrix Strength," JMEPEG, vol. 13, pp. 775-783, 2004.
47. K. K. ,. A. R. and V. S. L. Poovazhagan, "Characterization of hybrid Silicon Carbide and Boron Carbide nanoparticles- reinforced Aluminum alloy composites," Procedia Engineering, vol. 64, pp. 681-689, 2013.
48. Https://www.mathworks.com/discovery/finite-element-analysis.html