IJE TRANSACTIONS B: Applications Vol. 34, No. 02, (February 2021) 556-563

International Journal of Engineering

Journal Homepage: www.ije.ir

The Prediction of Stress and Strain Behaviors in Composite Gears using FEM

M. Bigdeli, V. Monfared*

Department of Mechanical Engineering, Zanjan Branch, Islamic Azad University, Zanjan, Iran

PAPER INFO

Paper history:
Received 03 October 2020
Received in revised form 31 October 2020
Accepted 05 November 2020

Keywords:
Alloys
Composites
Metal Matrix Composite Gears
Strain
Stress

ABSTRACT

Metal matrix composite (MMC) gears are used as a major component in the industry and are responsible for providing high-quality power transfer at high speeds. High quality, including high strength and impact-resistance, low brittleness, and long lifetime, is very important and needed in the industry. Gears are made of different materials, and, nowadays, researchers and industrialists have turned to designing, manufacturing, and using composite gears more than other gears due to their low weight, high hardness and strength, and better mechanical properties. In this research, the stress and strain behaviors are predicted in the composite gears made of aluminum silicon carbide with 3 different SiC volume fractions, namely 55 vol.%, 40 vol.%, and 30 vol.%, and with specifications of (Al45/SiC55, Al60/SiC40, and Al70/SiC30) and gears made of aluminum oxide with 3 different alumina weight fractions, namely 94 wt.%, 96 wt.%, and 99.5 wt.% to evaluate and compare the stress behavior due to different forces exerted on a single gear tooth in MMC gears. The Al45/SiC55 composite experienced the largest stress compared to other composites such as Al60/SiC40 and Al70/SiC30. The strain values (unlike the stress values) reduced with increasing in the volume fraction of the SiC reinforcement. Moreover, 94% aluminum oxide composite showed larger stress compared to 96% aluminum oxide and 99.5% aluminum oxide. The spur gear is designed and analyzed using SOLID WORKS and ANSYS Workbench softwares.

doi: *10.5829/ije.2021.34.02b.29*

1. INTRODUCTION

Gears are different in terms of type (spur, helical, bevel, worm, and rack and pinion) and material (gray cast iron, alloy cast iron, steel, brass, bronze, plastic, etc.). One of the simplest types of gears is spur gears, which have straight teeth that are parallel to the gear axis. For example, one of the important industrial applications of the composite "Al-SiC" is in internal combustion engine, like piston crown, cylinder liners where alumina and carbon fiber reinforced aluminum have shown a suitable substitute for cast iron. Also, the composite of "Al/SiC" has many applications in structural and industrial aims, where suitable weight and high strength-to-weight is required. In addition, the obtained results show and prove that the composite "Al/SiC" considerably increased the mechanical properties. So, it can be concluded that the mentioned composite can be the best-suited engineering material with characteristics in the application of the engine cylinder liner to get the modern demands of the automotive industries in the world. The teeth are tasked with transferring force between two parallel shafts. These gears are easy to design and manufacture and are used in a wide range of applications, such as trains, agricultural machinery, motorcycles, automobiles, aircraft, and similar applications [1, 2]. Nowadays, MMC gears have drawn the interest of researchers and industrialists due to their features such as improved hardness, low weight, and high tensile strength [3, 4]. Composites consist of a matrix and reinforcement. They can be divided into several categories in terms of the types of the matrix and reinforcement. Metal Matrix Composites (MMC's) are lightweight materials composed of a metal matrix and hard reinforcement particles that provide suitable strength and stiffness. Recently, researchers and manufacturers have shown interest in using MMCs in automotive, airplane, helicopter, and spacecraft industries due to their good physical and mechanical properties. MMCs have better characteristics such as resistance to high heat, high thermal conductivity, high

*Corresponding Author Institutional Email: vahid_monfared@alum.sharif.edu (V. Monfared)

Please cite this article as: M. Bigdeli, V. Monfared, The Prediction of Stress and Strain Behaviors in Composite Gears using FEM, International Journal of Engineering, B: Applications Vol. 34, No. 02, (2021) 556-563

strength and stiffness, resistance against erosion, and high strength to weight ratio, Composites with aluminum alloy matrices have attracted most research and development programs and commercial applications. Reinforcements used for aluminum composites include alumina, aluminosilicate, silicon carbide, and graphite. Reinforcements can be in the form of particles, continuous and discontinuous fibers, and whiskers and constitute 10% to 60% of the volume of the composite. Continuous fibers MMCs include carbon, silicon carbide, boron, alumina, and refractory metals [5–7]. In this research, the aim is to examine the stress and strain behaviors in an aluminum silicon carbide composite gear with different SiC volume fractions (55 vol.%, 40 vol.%, 30 vol.%) and an aluminum oxide composite gear with weight fractions of 94 wt.%, 96 wt.% and 99.5 wt.%. Among the available research works published in this field, one can name the paper by Singla et al. [8] in which the authors made a silicon aluminum part by casting and concluded from the test that hardness and impact-resistance increase with an increase in the SiC weight fraction [8]. MMCs have been used in power transmission gear applications, and the results show that aluminum oxide gears are also noteworthy for power transmission [9, 10]. In other cases, aluminum oxide has been used in dentistry to replace teeth and dental implants and in various fields such as artificial joints, artificial bones, and the electronic industry due to such features as high mechanical strength, high hardness and resistance, high thermal conductivity, and high erosion-resistance [11, 12], and other types of composites particularly Al/SiC's composites in many industries [13–21]. Also, recently applied and interesting research works have been done about composite materials analysis [22–29]. It should be mentioned that it has been used from MatWeb's searchable database of material properties includes data sheets of many material data for simulations. In this research, a spur gear has been modeled in 3D in the SOLIDWORKS software, and the mechanical data of the metal composite materials, including aluminum silicon carbide with the specifications (Al45/SiC55, Al60/SiC40, and Al70/SiC30) and aluminum oxide with the specifications (94% Aluminum Oxide, 96% Aluminum Oxide, and 99.5%Aluminum Oxide) have been defined in the ANSYS Workbench software. Then, we exerted various forces on a gear tooth and evaluated the stress corresponding to each force and gear material.

2. MATERIALS AND METHODS

2. 1. Composite Materials Composites consist of matrix and reinforcement. They can be divided into several categories in terms of the types of matrix and reinforcement. In terms of the matrix type, they are classified into metal, polymer, ceramic, and intermetallic matrix composites. Metal matrix composites have drawn the most attention among the various types. Methods of manufacturing metal matrix composites include powder metallurgy, spray deposition, mechanical alloying, and various casting techniques such as squeeze casting, slip casting, and compo casting. All of these techniques are based on the addition of reinforcement particles, in powder or molten form, to the matrix [7, 13].

2. 2. Aluminum Silicon Carbide Most metal matrix metals have commercial and industrial applications with an aluminum matrix, i.e., most of them are focused on an aluminum matrix. Aluminum matrix metals feature low weight, high strength, and very good mechanical properties, which have made the alloys of this metal popular. It is easy to fabricate this composite due to the low melting point of aluminum. Examples of reinforcements used in aluminum composites are alumina, aluminosilicate, silicon carbide, and graphite. Similar to silicon carbide (SiC) reinforcement particles, MMCs are a famous group of composites due to their characteristics such as stiffness, hardness, strength, erosion-resistance, and availability. Casting is a common method of producing these MMCs [14–16]. Here, three different SiC volume fractions, namely 55 vol.%, 40 vol.%, and 30 vol.%, are used to analyze three types of Al-SiC MMC. The mechanical properties of aluminum silicon carbide composites (Al45/SiC55, Al60/SiC40, Al70/SiC30) composites are shown in Table 1.

2. 3. Aluminum Oxide Aluminum oxide has the chemical formula Al_2O_3 and is commonly known as alumina. Alumina has strong ionic inter-atomic bonds. Moreover, it represents a family of engineering ceramics that feature availability and a low price. Among the different and prominent properties of alumina are such mechanical properties as high compressive strength, hardness, and refractoriness. Due to the high hardness and erosion-resistance of alumina, it is used in various applications such as erosion-resistant coatings for pipes and conduits, pumps, and valves. Also, due to its high hardness at high temperatures, it is utilized as a tooltip material in metal cutting [17–19]. Three different weight fractions of aluminum oxide, namely 94 wt.%, 96 wt.%, and 99.5 wt% have been used here for analysis. For high-temperature use, a purity of 94% to 99.5% is available. The mechanical properties corresponding to each purity level of alumina are provided in Tables 2-4.

2. 4. Gear Design Gears are among the most common power and motion transmission tools. A gear mechanism is a system composed of at least two gears working as a pair. Gears have various types, such as spur, helical, bevel, worm, and rack and pinion [1, 20]. Since the goal of this research is comparing and analyzing

TABLE 1. Mechanical Properties of Al70/SiC30, Al60/SiC40, Al45/SiC55*

Property	SI	Al70/SiC30	Al60/SiC40	Al45/SiC55
Composition (vol. %)	-	Al70/SiC30	Al60/SiC40	Al45/SiC55
Density, ρ	(g/cm^3)	2.78	2.87	2.96
Poisson's Ratio, ϑ	-	0.29	0.28	0.25
Young's Modulus, E	(GPa)	125	150	200
Thermal Conductivity, k	(W/m.K)	160	160	160
Specific Heat	(J/kg.K)	820	750	730
Ultimate Tensile Strength	(MPa)	370	370	340
Flexural Strength	(MPa)	NA	NA	NA
Fracture Toughness	($MPa.\sqrt{m}$)	15	14	13
Damping Factor	(%Zeta)	0.26	---	0.58
Specific Stiffness, (E/ρ)	GPa. g/cm^3	45	52	68
Thermal Stability, (k/α)	$J/K.m^3$	11	13	14

* Adapted from http://www.mmmt.com/resources/standard-materialproperties.html

TABLE 2. Mechanical Properties of 94% aluminum oxide*

Mechanical	Units of measure	SI/Metric	Imperial
Density	gm/cc (lb/ft^3)	3.69	230.4
Flexural Strength	MPa ($lb/in^2 \times 10^3$)	330	47
Elastic Modulus	GPa ($lb/in^2 \times 10^6$)	300	43.5
Shear Modulus	GPa ($lb/in^2 \times 10^6$)	124	18
Bulk Modulus	GPa ($lb/in^2 \times 10^6$)	165	24
Poisson's Ratio	---	0.21	0.21
Compressive Strength	MPa ($lb/in^2 \times 10^3$)	2100	304.5
Hardness	Kg/mm^2	1175	---
Fracture Toughness $\mathbf{k_{Ic}}$	$MPa.m^{1/2}$	3.5	---
Maximum Use Temperature(no load)	℃ (°F)	1700	3090
Specific Heat	J/kg.°K (Btu/lb.°F)	880	0.21
Thermal Conductivity	W/m.°K (BTU.in/ft^2.h.°F)	18	125
Coefficient of Thermal Expansion	10^{-6}/°C (10^{-6}/°F)	8.1	4.5

* Adapted from http://www.matweb.com/

TABLE 3. Mechanical Properties of 96% aluminum oxide*

Mechanical	Units of measure	SI/Metric	Imperial
Density	gm/cm^3 (lb/ft^3)	3.72	232.2
Flexural Strength	MPa ($lb/in^2 \times 10^3$)	345	50
Elastic Modulus	GPa ($lb/in^2 \times 10^6$)	300	43.5
Shear Modulus	GPa ($lb/in^2 \times 10^6$)	124	18
Bulk Modulus	GPa ($lb/in^2 \times 10^6$)	172	25
Poisson's Ratio	---	0.21	0.21
Compressive Strength	MPa ($lb/in^2 \times 10^3$)	2100	304.5
Hardness	kg/mm^2	1100	---
Fracture Toughness $\mathbf{k_{Ic}}$	$MPa.m^{1/2}$	3.5	---
Maximum Use Temperature(no load)	℃ (°F)	1700	3090
Specific Heat	J/kg.°K (Btu/lb.°F)	880	0.21
Thermal Conductivity	W/m.°K (BTU.in/ft^2.h.°F)	25	174
Coefficient of Thermal Expansion	10^{-6}/°C (10^{-6}/°F)	8.2	4.6

* Adapted from http://www.matweb.com/

TABLE 4. Mechanical Properties of 99.5% aluminum oxide*

Mechanical	Units of measure	SI/Metric	Imperial
Density	gm/cc (lb/ft^3)	3.89	242.8
Flexural Strength	MPa ($lb/in^2 \times 10^3$)	379	55
Elastic Modulus	GPa ($lb/in^2 \times 10^6$)	375	54.4
Shear Modulus	GPa ($lb/in^2 \times 10^6$)	152	22
Bulk Modulus	GPa ($lb/in^2 \times 10^6$)	228	33
Poisson's Ratio	---	0.22	0.22
Compressive Strength	MPa ($lb/in^2 \times 10^3$)	2600	377
Hardness	Kg/mm^2	1440	---
Fracture Toughness $\mathbf{k_{Ic}}$	$MPa.m^{1/2}$	4	---
Maximum Use Temperature(no load)	℃ (°F)	1750	3180
Specific Heat	J/Kg.°K (Btu/lb.°F)	880	0.21
Thermal Conductivity	W/m.°K (BTU.in/ft^2.hr.°F)	35	243
Coefficient of Thermal Expansion	10^{-6}/°C (10^{-6}/°F)	8.4	4.7

* Adapted from http://www.matweb.com/

MMCs, the spur gear has been used for the analysis. Spur gears have a simple design and are widely used in the industry due to their ease of manufacture. The methods of manufacturing gears include machining, forging, casting, stamping, powder metallurgy, and plastic injection molding. The most common gear manufacturing method is machining, which is divided into gear hobbing and form milling [20, 21].

In this study, the spur gear along with its shaft was designed in the SOLIDWORKS 2016 software. The design procedure can be seen in the figures below. Figure 1 shows the design of a single gear tooth.

As shown in Figure 2, the number of teeth was increased to 20 using the Circular Pattern command.

Finally, the 3D model of the gear was completed by adding the shaft, as shown in Figure 3.

2. 5. Analysis using ANSYS Workbench After designing the gear, the mechanical properties of aluminum silicon carbide and aluminum oxide composites with the specifications [Al45/SiC55, Al60/SiC40, and Al70/SiC30] and [94% aluminum oxide, 96% aluminum oxide, and 99.5% aluminum oxide] were defined in the Engineering Data Sources of ANSYS Workbench software. Then, fine meshing was performed on the gear geometry for stress and strain analyses, as shown in Figure 4.

After the meshing, a gear tooth is selected, and [100 N, 200 N, 300 N, 400 N, 500 N] forces are applied to a (Al45/SiC55, Al60/SiC40, Al70/SiC30) aluminum silicon carbide tooth. Moreover, [100 N, 350 N, 600 N, 800 N, 1000 N] forces are exerted on a (94% Aluminum Oxide, 96% Aluminum Oxide, 99.5% Aluminum Oxide) aluminum oxide tooth. An example of a force (350 N) applied to a gear tooth is shown in Figure 5.

In the final part of modeling, the stress and strain results of the composite gears in terms of the exerted forces are derived so that they could be analyzed and compared. An example of this stress computation process for the Al45/SiC55 with Force=400 N is displayed in Figure 6.

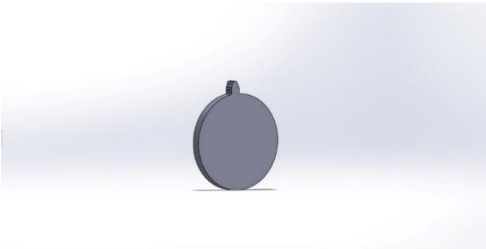

Figure 1. Design of a simple gear tooth in SOLIDWORKS 3D environment

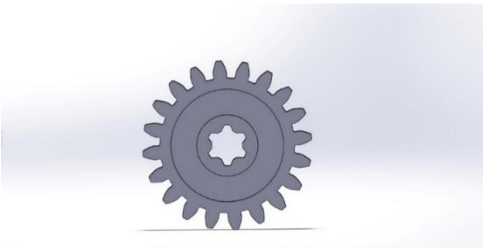

Figure 2. Modeling of 20 gears in SOLIDWORKS 3D environment

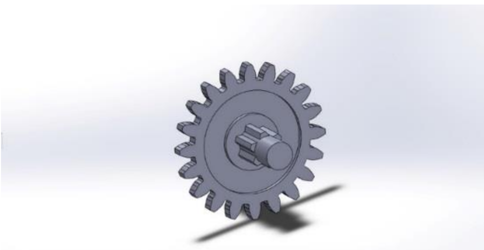

Figure 3. Spur gear model with the shaft in SOLIDWORKS 3D environment

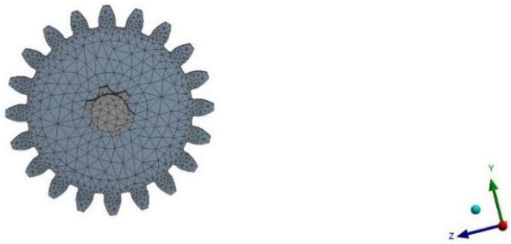

Figure 4. Meshing on the gear geometry

Figure 5. Application of 350 N force on a gear tooth

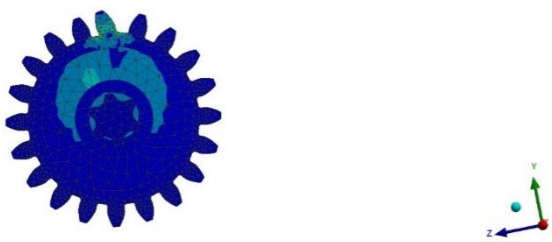

Figure 6. Al45/SiC55 gear analysis with Force = 400 N

Also, the stress analysis for the 94% aluminum oxide composite gear with Force = 350 N is presented in Figure 7.

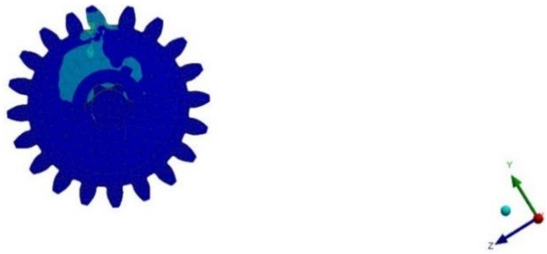

Figure 7. Stress analysis for the 94% aluminum oxide composite gear with Force = 350 N

3. RESULTS AND DISCUSSIONS

After applying force on a single gear tooth, the stress and strain results for aluminum silicon carbide gears with 3 different SiC volume fractions, i.e., 30 vol.%, 40 vol.%, and 55 vol.% and with the specifications (Al45/SiC55, Al60/SiC40, Al70/SiC30) and aluminum oxide gears with 3 different alumina weight fractions, i.e., 94 wt.%, 96 wt.%, and 99.5 wt.%, were analyzed and compared. The stress and strain results of each gear in terms of the exerted forces have been shown in Tables 5-12, and the stresses of the gears relative to each other are displayed in Figures 8 and 9. These tables and figures show good results for aluminum silicon carbide and aluminum oxide metal matrix composites. According to the results, the gears made of aluminum silicon carbide of the type Al45/SiC55 exhibited less stress compared to 2 other gears made of Al60/SiC40 and Al70/SiC30 under forces of [100 N, 200 N, 300 N, 400 N, 500 N]. Hence, the Al45/SiC55 gears can be used in sensitive applications in the industry where gears must bear larger pressures.

The stress (strength) and strain (elongation and deformation) values increase with an increase in the applied forces (Table 5). The combination of "SiC" (reinforcement) and Al (matrix) significantly increases the stress values, such as the yield strength, compressive strength, ultimate tensile strength, Young's modulus, yield and fracture stresses, hardness, and wear properties and decreases the elongation, strain (ductility and strain rate), and toughness of the composites in comparison with those of the matrix alloy. Moreover, the "SiC" reinforcement particles are the most effective strengthening particulates for higher strength, hardness, and grain size reduction. Also, Table 6 indicates the maximum stress and strain results for the Al60/SiC40 gear.

According to the obtained results for the "Al/SiC" composite, it is concluded that the strain values decrease with an increase in the volume fraction of the "SiC" reinforcement particles (unlike the stress values). Table 7 shows the maximum stress and strain results for the Al70/SiC30 gear.

The stress results for each of the aluminum silicon carbide composite gears with SiC volume fractions of (55 vol.%, 40 vol.%, 30 vol.%) are shown in Figure 8. The results of Figure 8 and the following table show that the stress has increased with an increase in the volume fraction of the SiC reinforcement. In other words, the strength of the gear increases with an increase in the volume fraction of SiC.

Given the obtained stress values, the results of Figure 8 indicate that the Al45/SiC55 composite gear has experienced higher stress compared to Al70/SiC30 and

TABLE 5. Stress and strain results for Al45/SiC55 gear

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.0701	5.66×10^{-6}
2	0.2	2.1402	1.13×10^{-5}
3	0.3	3.2103	1.70×10^{-5}
4	0.4	4.2804	2.27×10^{-5}
5	0.5	5.3506	2.83×10^{-5}

TABLE 6. Stress and strain results for Al60/SiC40 gear

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.0653	7.52×10^{-6}
2	0.2	2.1305	1.50×10^{-5}
3	0.3	3.1958	2.26×10^{-5}
4	0.4	4.2611	3.01×10^{-5}
5	0.5	5.3263	3.76×10^{-5}

TABLE 7. Stress and strain results for Al70/SiC30 gear

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.0637	9.01×10^{-6}
2	0.2	2.1274	1.80×10^{-5}
3	0.3	3.1911	2.70×10^{-5}
4	0.4	4.2548	3.61×10^{-5}
5	0.5	5.3185	4.51×10^{-5}

TABLE 8. Results for Al45/SiC55, Al60/SiC40, Al70/SiC30

Stress maximum (MPa)				
Number	Force (KN)	Al45/SiC55	Al60/SiC40	Al70/SiC30
1	0.1	1.0701	1.0653	1.0637
2	0.2	2.1402	2.1305	2.1274
3	0.3	3.2103	3.1958	3.1911
4	0.4	4.2804	4.2611	4.2548
5	0.5	5.3506	5.3263	5.3185

Al60/SiC40 composite gears. Hence, Al45/SiC55 can be employed to manufacture gears with good mechanical properties and high impact-resistance.

The stress and strain results for the 94% aluminum oxide composite gear are shown in Figure 9. The strain results in Tables 9-11 indicate that the stress under different forces has decreased with a decrease in the weight fraction of alumina. For example, for Force = 1 KN, the stress in the composite gear with a weight fraction of 94 wt.% is 12.727, which is larger than those corresponding to composite gears with weight fractions of 99.5 wt.% and 96 wt.%.

The stress and strain results for the 96% aluminum oxide composite gear are shown in Table 10.

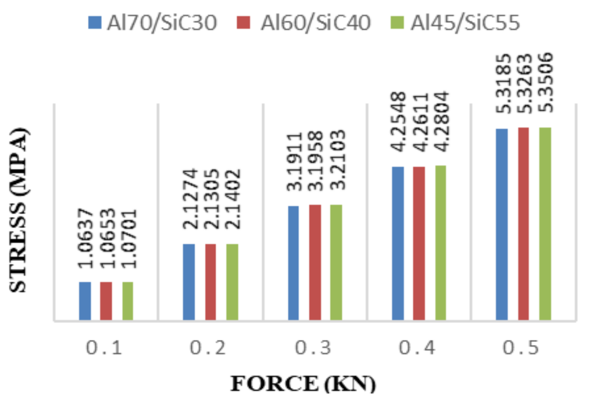

Figure 8. Stress results for Al45/SiC55, Al60/SiC40, Al70/SiC30 composite gears

TABLE 9. Stress and strain results for 94% Aluminum Oxide composite material

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.2727	4.51×10^{-6}
2	0.35	4.4543	1.58×10^{-5}
3	0.6	7.636	2.71×10^{-5}
4	0.8	10.181	3.61×10^{-5}
5	1	12.727	4.51×10^{-5}

TABLE 10. Stress and strain results for 96% Aluminum Oxide composite material

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.266	4.29×10^{-6}
2	0.35	4.431	1.50×10^{-5}
3	0.6	7.5959	2.57×10^{-5}
4	0.8	10.128	3.43×10^{-5}
5	1	12.66	4.29×10^{-5}

The stress and strain results for the 99.5% aluminum oxide composite gear are shown in Table 11 The results show smaller stress for the composite gear with a weight fraction of 99.5 wt.% compared to those for weight fractions of 94 wt.% and 96 wt.%.

The stress results for 94% Aluminum Oxide, 96% Aluminum Oxide, 99.5% Aluminum Oxide are shown in Table 12 and Figure 9. According to Figure 9 and the obtained results, the composite gear made of 99.5% aluminum oxide has the lowest stress and the composite gear made of 94% aluminum oxide has the highest stress under different forces. In other words, the 94% aluminum

TABLE 11. Stress and strain results for 99.5% Aluminum Oxide composite material

Number	Force (KN)	Stress maximum (MPa)	Strain maximum (m/m)
1	0.1	1.2592	3.33×10^{-6}
2	0.35	4.4072	1.17×10^{-5}
3	0.6	7.5552	2.00×10^{-5}
4	0.8	10.074	2.67×10^{-5}
5	1	12.592	3.33×10^{-5}

TABLE 12. Stress results (MPa) for 94% aluminum oxide, 96% aluminum oxide, and 99.5% aluminum oxide composite material gears

Number	Force (KN)	94% aluminum oxide	96% aluminum oxide	99.5% aluminum oxide
1	0.1	1.2727	1.266	1.2592
2	0.35	4.4543	4.431	4.4072
3	0.6	7.636	7.5959	7.5552
4	0.8	10.181	10.128	10.074
5	1	12.727	12.66	12.592

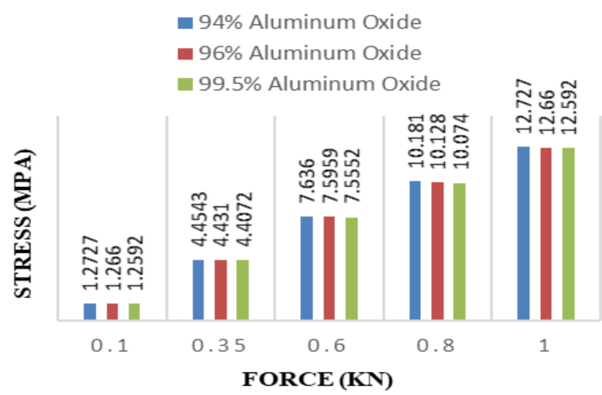

Figure 9. Stress results for 94% aluminum oxide, 96% aluminum oxide, and 99.5% aluminum oxide composite material gears

oxide composite gear can be employed where the teeth are required to carry larger loads.

According to Figure 10, the teeth can fracture or fail under forces greater than the load capacities of the gears. Therefore, reinforcing the regions of the teeth under the highest pressure can reduce the probability of failure or fracture.

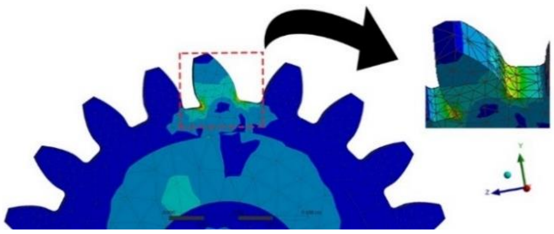

Figure 10. Strengthening specified areas to reduce the failure probability

4. CONCLUSION

The (Al45/SiC55, Al60/SiC40, Al70/SiC30) aluminum silicon carbide composite with (55 vol.%, 40 vol.%, 30 vol.%) SiC volume fractions and aluminum oxide composite with (94 wt.%, 96 wt.%, 99.5 wt.%) weight fractions were analyzed and compared, and the following results were obtained,

- The Al45/SiC55 composite material experiences higher and larger stresses compared to Al60/SiC40 and Al70/SiC30 composite materials.
- An increase in the volume fraction of SiC reinforcement particles in the aluminum silicon carbide composite gear, increases stress under different forces, thus improving the strength of the gear is resulted.
- The results of the investigation on the aluminum oxide composite gears showed that the 94% aluminum oxide experienced higher and larger stress values under different forces compared to the 95% aluminum oxide and 99.5% aluminum oxide composite materials. In other words, the stress has increased with a decrease in the weight fraction of alumina.
- The higher stresses in the Al45/SiC55 and 94% aluminum oxide gears under different forces compared to the composite gears studied in this research are remarkable and can satisfy the needs of industrialists in many industries for gears with high fracture-resistance.
- The strain values decrease with an increase in the volume fraction of SiC reinforcement particles.
- Reinforcing the tooth areas under can reduce the probability of fracture and failure. Finally the engineers and researchers can trust to the ANSYS results for predicting the composite gear behaviors in the practical and academic fields.

5. REFERENCES

1. Radzevich, S., Dudley's Handbook of Practical Gear Design and Manufacture, (2012) CRC press.
2. Mayuram, M., and Gopinath, K., Machine Design II, (2008) Indian Institute of Technology, Madras.
3. Karthik, J. P., Sai, T. R., and Praneeth, S. S., "Design and Optimization of Metal Matrix Composite (MMC'S) Spur Gear", ***International Journal of Advanced Design & Manufacturing Technology***, Vol. 9, No. 3, (2016), 49–56.
4. Pawar, P. B., and Utpat, A. A., "Analysis of Composite Material Spur Gear Under Static Loading Condition", ***Materials Today: Proceedings***, Vol. 2, Nos. 4–5, (2015), 2968–2974. doi:10.1016/j.matpr.2015.07.278
5. Karl, U., Metal Matrix Composites: Custom-Made Materials for Automotive and Aerospace Engineering, (2006) Basics of Metal Matrix Composites, Wiley.
6. Haghshenas, M., "Metal–Matrix Composites", Reference Module in Materials Science and Materials Engineering, (2016) Elsevier. doi:10.1016/b978-0-12-803581-8.03950-3
7. Chawla, K. K., "Metal Matrix Composites", ***Composite Materials***, (2012), 197–248. doi:10.1007/978-0-387-74365-3_6
8. Singla, M., Deepak Dwivedi, D., Singh, L., and Chawla, V., "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite", ***Journal of Minerals & Materials Characterization & Engineering***, Vol. 8, No. 6, (2009), 455-467.
9. Ganesan, N., and Vijayarangan, S., "A static analysis of metal matrix composite spur gear by three-dimensional finite element method", ***Computers and Structures***, Vol. 46, No. 6, (1993), 1021–1027. doi:10.1016/0045-7949(93)90088-U
10. Sharma, A., Aggarwal, M. L., and Singh, L., "Experimental investigation into the effect of noise and damping using composite spur gear", ***Materials Today: Proceedings***, Vol. 4, No. 2, (2017), 2777–2782. doi:10.1016/j.matpr.2017.02.156
11. Ratner, B., Hoffman, A., Schoen, F., and Lemons, J., Biomaterials Science: An Introduction to Materials in Medicine, (2004) Academic Press.
12. Ishikawa, K., Matsuya, S., Miyamoto, Y., and Kawate, K., "Bioceramics", ***Comprehensive Structural Integrity***, Vol. 9, (2007), 169–214. doi:10.1016/B0-08-043749-4/09146-1
13. Kar, K., Composite Materials: Processing, Applications, Characterizations, (2016) Springer.
14. Loos, M., "Composites", Carbon Nanotube Reinforced Composites: CNR Polymer Science and Technology, (2015), 37–72 Elsevier Inc. doi:10.1016/B978-1-4557-3195-4.00002-3
15. Agnihotri, R., and Dagar, S., "Mechanical Properties of Al-SiC Metal Matrix Composites Fabricated by Stir Casting Route", ***Research in Medical & Engineering Sciences***, Vol. 2, No. 5, (2017), 178–183. doi:10.31031/rmes.2017.02.000549
16. Poovazhagan, L., Kalaichelvan, K., Rajadurai, A., and Senthilvelan, V., "Characterization of hybrid silicon carbide and boron carbide nanoparticles-reinforced aluminum alloy composites", ***Procedia Engineering***, Vol. 64, (2013), 681–689. doi:10.1016/j.proeng.2013.09.143
17. McKeen, L. W., "Pigments, Fillers, and Extenders", Fluorinated Coatings and Finishes Handbook, (2006), 59–76. doi:10.1016/b978-081551522-7.50008-x
18. Park, S. J., and Seo, M. K., Element and Processing, Interface Science and Technology, Vol. 18, (2011) ,. doi:10.1016/B978-0-12-375049-5.00006-2
19. Ebnesajjad, S., "Surface Treatment and Bonding of Ceramics",

Surface Treatment of Materials for Adhesive Bonding, (2014), 283–299 Elsevier. doi:10.1016/b978-0-323-26435-8.00011-3

20. Goldfarb, V., Trubachev, E., and Barmina, N., New Approaches to Gear Design and Production, Vol. 81, (2020) Cham, Springer International Publishing. doi:10.1007/978-3-030-34945-5
21. Watson, H. J., "Methods of Manufacture", ***Modern Gear Production***, (1970), 117–129 Elsevier. doi:10.1016/b978-0-08-015835-8.50010-9
22. Monfared, V., Mondali, M., and Abedian, A., "Steady-state creep analysis of polymer matrix composites using complex variable method", ***Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science***, Vol. 227, No. 10, (2013), 2182–2194. doi:10.1177/0954406212473391
23. Monfared, V., "A displacement based model to determine the steady state creep strain rate of short fiber composites", ***Composites Science and Technology***, Vol. 107, (2015), 18–28. doi:10.1016/j.compscitech.2014.11.019
24. Aswad, M. A., Awad, S. H., and Kaayem, A. H., "Study on Iraqi Bauxite ceramic reinforced aluminum metal matrix composite synthesized by stir casting", ***International Journal of Engineering, Transactions A: Basics***, Vol. 33, No. 7, (2020), 1331–1339. doi:10.5829/IJE.2020.33.07A.20
25. Mekonnen, B. Y., and Mamo, Y. J., "Tensile and flexural analysis of a hybrid bamboo/jute fiber-reinforced composite with polyester matrix as a sustainable green material for wind turbine blades", ***International Journal of Engineering, Transactions B: Applications***, Vol. 33, No. 2, (2020), 314–319. doi:10.5829/IJE.2020.33.02B.16
26. Vosough, M., Sharafi, S., and Khayati, G. R., "Co-tio2 nanoparticles as the reinforcement for fe soft magnetic composites with enhanced mechanical and magnetic properties via pulse electrodeposition", ***International Journal of Engineering, Transactions A: Basics***, Vol. 33, No. 10, (2020), 2030–2038. doi:10.5829/IJE.2020.33.10A.21
27. R., B., Al Madhani, M., and Al Madhani, R., "Study on Retrofitting of RC Column Using Ferrocement Full and Strip Wrapping", ***Civil Engineering Journal***, Vol. 5, No. 11, (2019), 2472–2485. doi:10.28991/cej-2019-03091425
28. Hanoon, A. N., Abdulhameed, A. A., Abdulhameed, H. A., and Mohaisen, S. K., "Energy Absorption Evaluation of CFRP-Strengthened Two-Spans Reinforced Concrete Beams under Pure Torsion", ***Civil Engineering Journal***, Vol. 5, No. 9, (2019), 2007–2018. doi:10.28991/cej-2019-03091389
29. Song, J.-H., Lee, E.-T., and Eun, H.-C., "Shear Strength of Reinforced Concrete Columns Retrofitted by Glass Fiber Reinforced Polyurea", ***Civil Engineering Journal***, Vol. 6, No. 10, (2020), 1852–1863. doi:10.28991/cej-2020-03091587

Persian Abstract

چکیده

چرخ دنده‌های کامپوزیتی MMC به عنوان یکی از قطعات اصلی در صنعت به کار می‌روند و وظیفه اصلی آنها کیفیت انتقال قدرت در سرعت‌های بالاست. نیاز به داشتن کیفیت بالا اعم از استحکام و مقاومت بالا در مقابل ضربه و شکنندگی کمتر و عمر طولانی بسیار حائز اهمیت و نیاز صنعتکاران است، چرخ دنده‌ها از جنس‌های مختلفی ساخته می‌شوند و امروزه محققان و صنعتکاران روی به سوی طراحی، ساخت و استفاده از چرخ دنده‌های کامپوزیتی نسبت به دیگر چرخ دنده‌ها آورده‌اند به دلیل وزن پایین، هزینه کمتر، سختی، استحکام بالا و خاصیت مکانیکی بهتر. در این پژوهش پیش‌بینی تنش را در چرخ دنده‌های کامپوزیتی از جنس Aluminum Silicon Carbide با سه درصد حجمی مختلف از SiC یعنی 55 vol.% , 40 vol.%, 30 vol.% با مشخصات (Al45/SiC55, Al60/SiC40, Al70/SiC30) و همچنین چرخ دنده‌هایی از جنس Aluminum Oxide با سه درصد وزنی مختلف از alumina یعنی 94 wt.% , 96 wt.%, 99.5 wt.% مورد ارزیابی قرار دادیم تا رفتار تنش در نیروهای مختلف وارده بر یک دنده چرخ دنده را درچرخ دنده‌های کامپوزیتی MMC مورد مقایسه و بررسی قرار دهیم. ماده کامپوزتی Al45/SiC55 بیشترین مقدار تنش را نسبت به دیگر ماده‌های کامپوزیتی نظیر Al60 SiC40 و Al70SiC30 داشت، نتایج مقدار کرنش (برخلاف نتایج مقدار تنش) با افزایش درصد حجمی تقویت‌کننده 'SiC' کاهش یافت، همچنین ماده کامپوزیتی 94% Aluminum Oxide بیشترین مقدار تنش را نسبت به ماده‌های کامپوزیتی 96% Aluminum Oxide و 99.5% Aluminum Oxide نشان داد. طراحی چرخ دنده از نوع ساده با استفاده از نرم‌افزار Solid Works 2016 و تعریف داده‌های مکانیکی مواد به چرخ دنده وتحلیل تنش و کرنش در نرم‌افزار ANSYS Workbench 16.1 انجام گردیده است.