Fatigue Strength Analysis of Spur Gear of different Materials under Fully Reversible Loading using FEA

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Abstract - *Spur gear is the simplest gear used in power transmission system. It is generally subjected to bending stress, pitting due to fatigue stress which causes teeth failure. However performance of the spur gear can be improved using Composite materials which provide adequate strength with weight reduction. In this work, a metallic gear of Structural Steel is replaced by the Metal Matrix Composite (MMC) made of Aluminium AA6061 Matrix Composite Reinforced with Spherical Alumina Particles (Spherical PRMMC). Modeling of spur gear is carried out using CATIA V5 and fatigue strength analysis of spur gear is carried out using ANSYS V16.*

Key Words: Spur Gear, Fatigue strength, Fatigue life, ANSYS, Finite Element Analysis

1. INTRODUCTION

Gears are mechanical components used for transmitting motion and torque from one shaft to another. They are toothed members which transmit power/ motion by meshing without any slip. Spur gear is the simplest gear & widely used in power transmission system. However it is observed that performance of the spur gear is not satisfactory in certain applications and therefore it is required to explore some alternate materials to improve the performance of the spur gears. Composite materials provide adequate strength with weight reduction and they are emerging as a better alternative for replacing metallic gears. Such Composite material provides much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure.

2. Literature Survey

V. Siva Prasad in his paper describes design and analysis of spur gear and it is proposed to substitute the metallic gears of sugarcane juice machine with polymer gears to reduce the weight and noise. A virtual model of spur gear was created in PRO-E, Model is imported in ANSYS 10.0 for analysis by applying normal load condition.

Vivek Karaveer in his paper presents the stress analysis of mating teeth of the spur gear to find maximum contact stress in the gear tooth. The results obtained from finite element Analysis are compared with theoretical Hertz equation values. The spur gear are modelled and assembled in ANSYS and stress analysis of Spur gear tooth is done by the ANSYS 14.5 software. It was found that the results from both Hertz equation and Finite Element Analysis are comparable.

Abhay A Utpat in this work metallic gears of steel alloy and Aluminium Silicon Carbide composite have been manufactured Composites provide much improved mechanical properties such as better strength to Weight ratio, more hardness, and hence less chances of failure. Gears manufactured from composite provides almost 60% less weight compared to steel gear, while power rating of both gears remains almost same. FE Analysis also shows less chances of failure in Al-SiC gear. Almost 3-4% difference has been observed between theoretical and FEA values of bending stress.

3. Objective

1. Design of spur gear by using involute profile formulae in CATIA.
2. Assembly of the two gears and simulation of torque transmission in digital mockup kinematics in CATIA.
3. The model is subjected to meshing and appropriate boundary conditions are applied and then it is solved for von-mises stress, fatigue life, fatigue safety factor.
4. The solution is obtained for different cases by varying the moment for the spur gears made of Structural Steel and Aluminium AA6061 Matrix Composite Reinforced with Spherical Alumina Particles(Spherical PRMMC).
5. Comparison of results between the spur gears made of Structural steel and Spherical PRMMC.

4. Modeling of Spur Gear

The spur gear model is created in CATIA by using the mathematical formulae to generate the involute profile. Involute profile is the most important profile for any gear to transmit the torque at constant angular velocity ratio i.e., smooth transmission of the torque without any interruption. It is followed by creation of base shafts on which gears are to be mounted to transmit the torque. The spur gears are then assembled and finally simulated in digital mockup in CATIA.

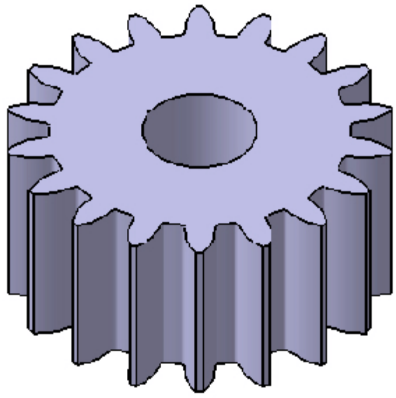

Fig-4.1: Spur Gear

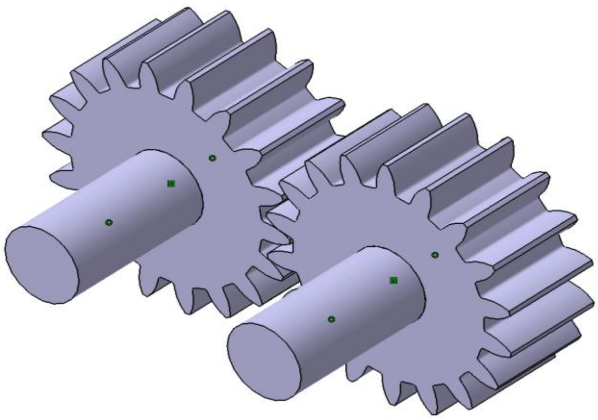

Fig-4.2: Spur gear assembly

5. Fatigue Analysis

Fatigue is the weakening of a material caused by cyclic loading that results in progressive and localized structural damage and the growth of cracks. For the above model, Fatigue analysis is carried out in ANSYS.

Initially, the model is meshed in ANSYS and then appropriate boundary conditions are applied which is then solved to obtain the results of Fatigue life, Fatigue safety factor and Von-mises stress.

Table-1: Material Properties used for Spur gear

Property	Structural Steel	Spherical PRMMC
Density (kg/m3)	7850	3250
Modulus of Elasticity (GPa)	210	150
Poisson's ratio	0.3	0.29
Tensile Strength (MPa)	460	413

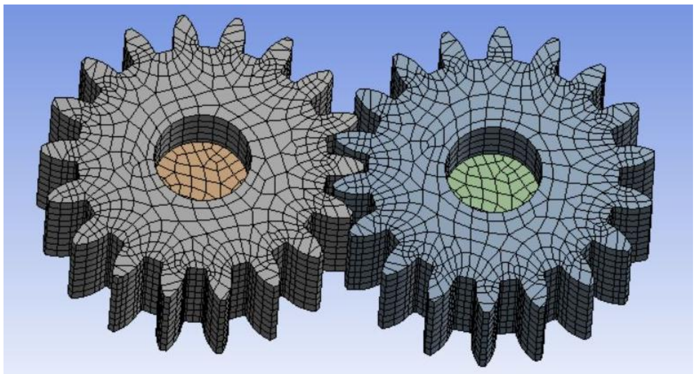

Fig-5.1a: Front view of meshed Spur gear

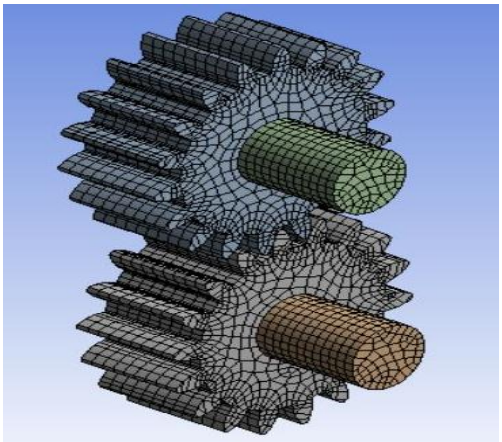

Fig-5.1b: Isometric view of meshed Spur gear

5.1 Von-mises stress at 100N-m moment

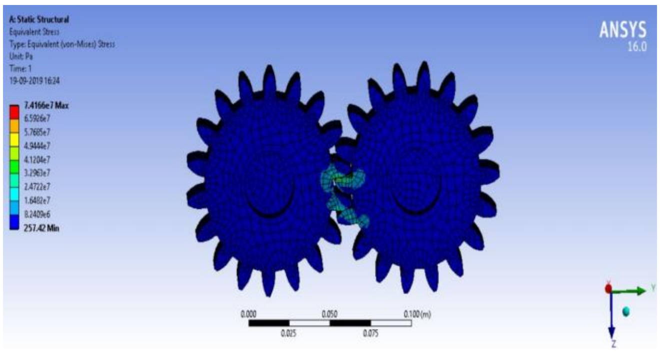

Fig-5.11: Von-mises stress in Structural steel

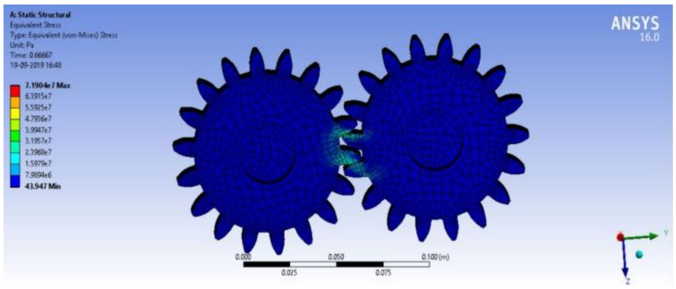

Fig-5.12: Von-mises stress in Spherical PRMMC

5.2 Fatigue Life at 100N-m moment

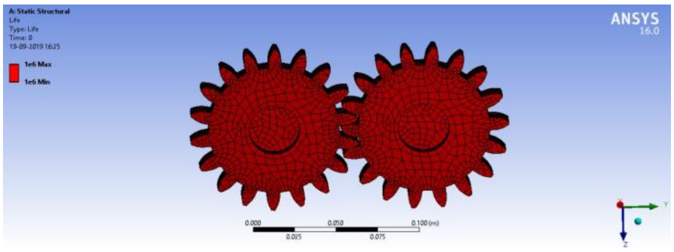

Fig-5.21: Fatigue Life in Structural steel

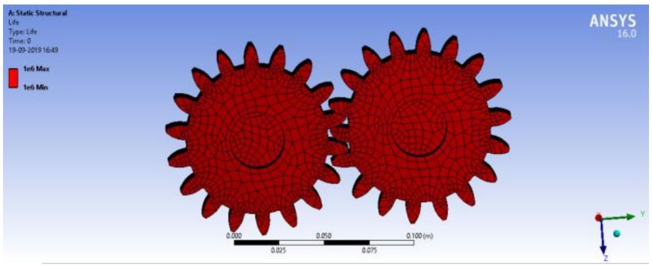

Fig-5.22: Fatigue Life in Spherical PRMMC

5.3 Safety Factor at 100N-m moment

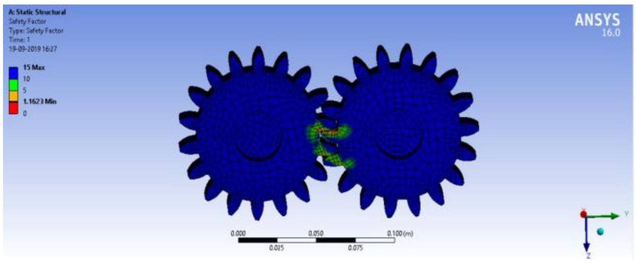

Fig-5.31: Safety factor in Structural steel

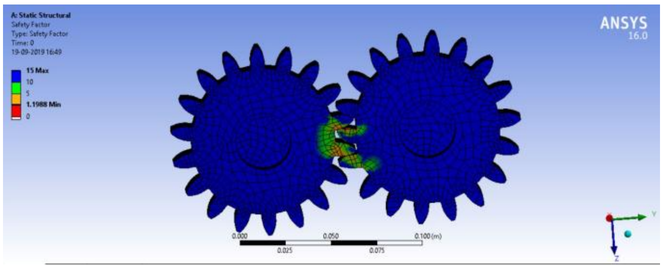

Fig-5.32: Safety factor in Spherical PRMMC

5.4Von-mises stress at 150N-m moment

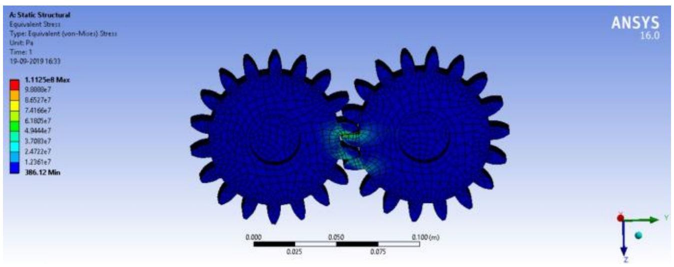

Fig-5.41: Von-mises stress in Structural steel

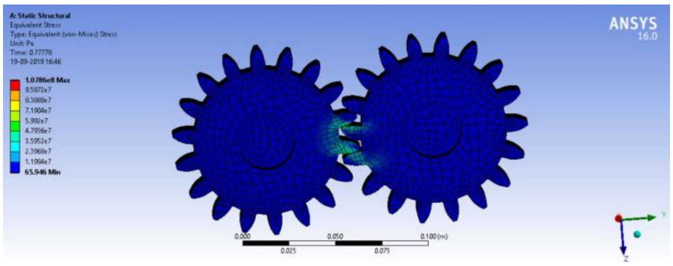

Fig-5.42: Von-mises stress in Spherical PRMMC

5.5 Fatigue Life at 150N-m moment

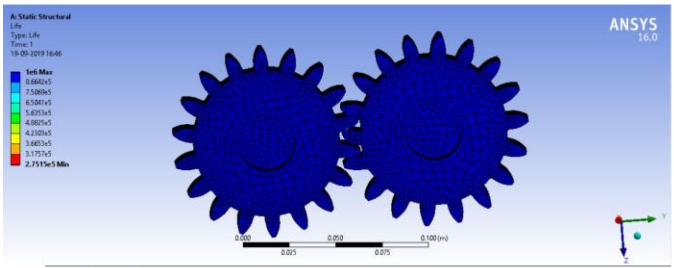

Fig-5.51: Fatigue Life in Structural steel

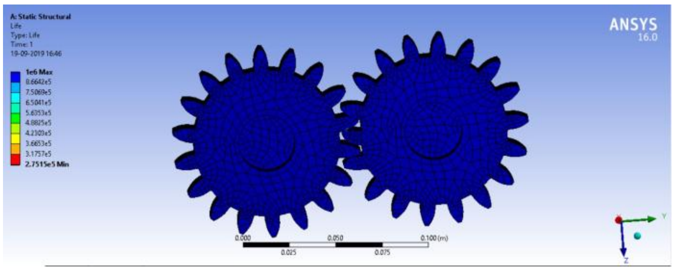

Fig-5.52: Fatigue Life in Spherical PRMMC

5.6 Safety Factor at 150N-m moment

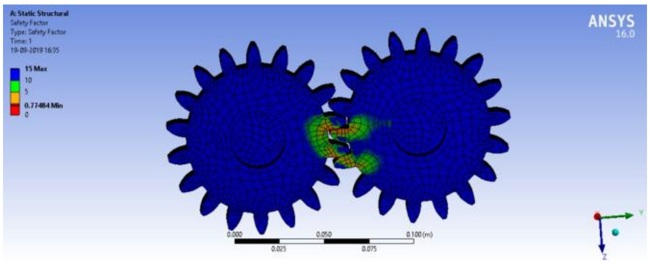

Fig-5.61: Safety factor in Structural steel

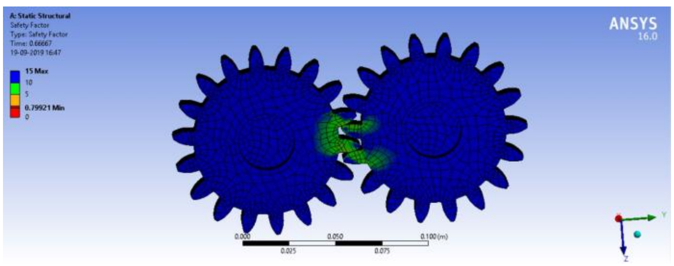

Fig-5.62: Safety factor in Spherical PRMMC

5.7 Von-mises stress at 200N-m moment

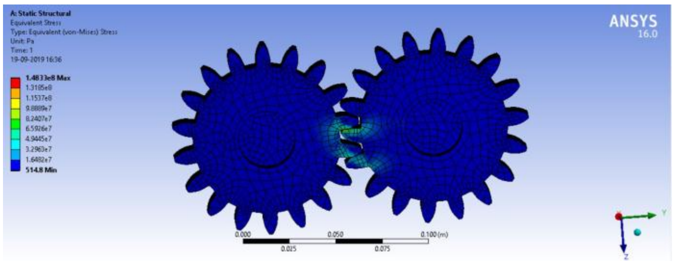

Fig-5.71: Von-mises stress in Structural steel

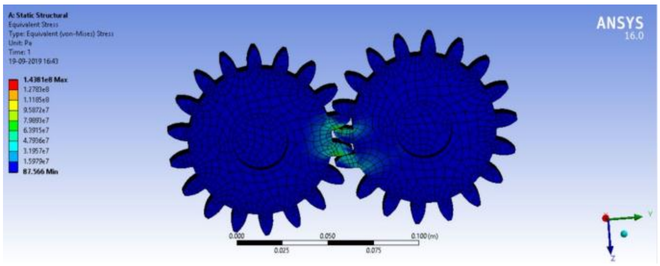

Fig-5.72: Von-mises stress in Spherical PRMMC

5.8 Fatigue Life at 200N-m moment

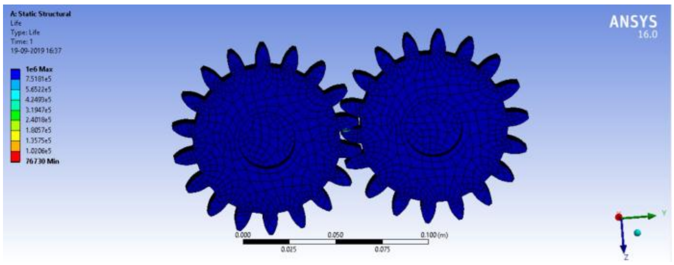

Fig-5.81: Fatigue Life in Structural steel

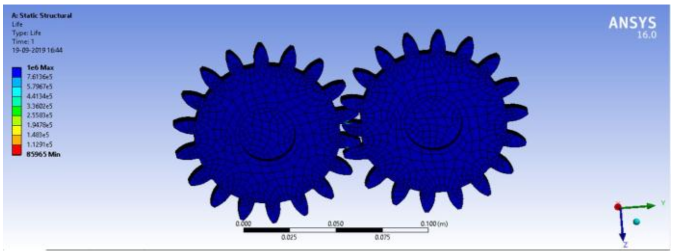

Fig-5.82: Fatigue Life in Spherical PRMMC

5.9 Safety Factor at 200N-m moment

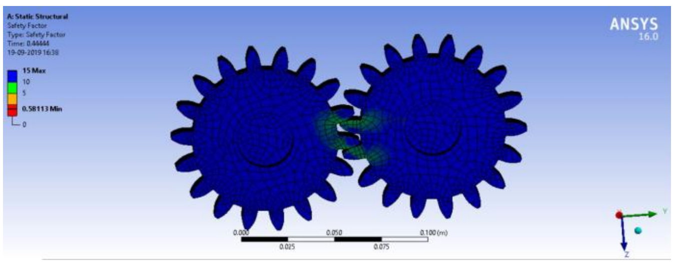

Fig-5.91: Safety factor in Structural steel

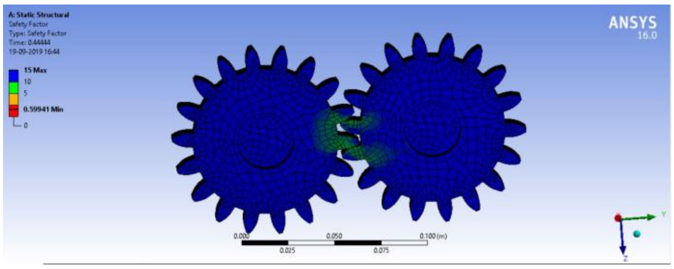

Fig-5.92: Safety factor in Spherical PRMMC

6. Results

Case 1:

Table-6.1: Case of applied moment at 100N-m

Material	Von-mises Stress(MPa)	Safety Factor	Fatigue Life
Structural Steel	74	1.1623	1e6
Spherical PRMMC	72	1.1988	1e6

Case 2:

Table-6.2: Case of applied moment at 150N-m

Material	Von-mises Stress(MPa)	Safety Factor	Fatigue Life
Structural Steel	111	0.775	2.3e5
Spherical PRMMC	107	0.799	2.7e5

Case3:

Table-6.3: Case of applied moment at 150N-m

Material	Von-mises Stress(Mpa)	Safety Factor	Fatigue Life
Structural Steel	148	0.58113	76730
Spherical PRMMC	143	0.59941	85965

7. Conclusions

- From the analysis we came to know that both the materials used for spur gears are safe when the applied moment is less than 100N-m.
- When the moment is 150N-m, the induced von-mises stress in both the materials is within their yield strength but however, the safety factor goes below 1 which is not a safe criteria for design.
- When the moment is 200N-m, the induced von-mises stress in both the materials is within their

yield strength but however, the safety factor goes below 1 which is not a safe criteria for design.

- For the applied moment of 150N-m and 200N-m, the fatigue life cycles reduced below 1e6 for both the materials.

- It can be observed that in all the three cases of varying the moment, the spur gears made of Spherical PRMMC has outperformed the spur gears made of structural steel in terms of Von-mises stress, Fatigue life and Safety factor.

- Since the safety factor goes below 1 for both the materials for the applied moment of 150N-m and 200N-m, it can be concluded that these two materials can be used when the applied moment is 100N-m and out of the two, spur gears made of Spherical PRMMC has better life than that of structural steel.

REFERENCES

[1] P.B. Pawara, Abhay A Utpat, “Analysis of Composite Material Spur Gear under Static Loading Condition” Elsevier(2014).

[2] Mrs.Shinde S.P., Mr. Nikam A.A. , Mr. Mulla T.S, Static Analysis of Spur Gear Using Finite Element Analysis.

[3] PB.Pawar, Abhay A. Utpat, “Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear”(2014).

[4] Krishankant Kankar, R.P. Singh, “Design of spur gear and its tooth profile for given power “(2015).

[5] V. Siva Prasad, Syed Altaf Hussain, V.Pandurangadu, K.Palani Kumar, “Modeling and Analysis of Spur Gear for Sugarcane Juice Machine under Static Load Condition by Using FEA” International Journal of Modern Engineering Research (2012).

[6] Claudio Bacciarini1,2 and Vincent Mathier1, “Aluminium AA6061 Matrix Composite Reinforced with Spherical Alumina Particles Produced by Infiltration: Perspective on Aerospace Applications”, Journal of Metallurgy.