A Review Paper on Static Structural Analysis of Spur Gear with Different Materials

Amit Kumar Shah[1], Mrs. Priyanka Jhavar[2]

Mechanical Department, SSSUTMS, Sehore, M.P./466001, India1

Mechanical Department, SSSUTMS, Sehore, M.P./466001, India2

ABSTRACT

Present research work focuses on static analysis of spur gear under different materials. For the purpose of research, first of all a spur gear of standard dimensions, provided by a customized machine manufacturing firm, was designed, and four properties, namely, Von misses stresses, total deformation and total equivalent strain were investigated, with four materials, namely, PLA, Ceramic ZrO2, Epoxy and ABS. Results of static analysis, with an applied load of 1000 N showed the suitability of PLA material for the gear. The software used were Creo 3.0 and SimScale. Following were the results of the research

Keyword:- *Spur gear, Creo 3.0, Sim Scale, material, Structural analysis.*

---

1. Introduction

The spur gear is simplest type of gear manufactured and is generally used for transmission of rotary motion between parallel shafts. The spur gear is the first choice option for gears except when high speeds, loads, and ratios direct towards other options. Other gear types may also be preferred to provide more silent low-vibration operation. A single spur gear is generally selected to have a ratio range of between 1:1 and 1:6 with a pitch line velocity up to 25 m/s. The spur gear has an operating efficiency of 98-99%. The pinion is made from a harder material than the wheel.

Spur gears are simple in construction, easy to manufacture and cost less. They have highest efficiency and excellent precision rating. They are used in high speed and high load application in all types of trains and a wide range of velocity ratios. Hence, they find wide applications right from clocks, household gadgets, motor cycles, automobiles, and railways to aircrafts. Typically spur gears are used in internal combustion engine gear boxes (for producing small torques). gears are usually subjected to fluctuating loads. Due to these loads bending and compressive stresses will be developed in the gears. While designing the gear it is very important to analyze the stresses for safety operation, and weight reduction of gear is also one of the design criteria.

1.2 Overview of Spur Gears

Figure 1.1: Basic Gear Terminology

In present research work, a spur gear has been designed for a customized machine manufacturing and as per the requirements provided by the firm, 3 properties, namely, Von misses stresses, total deformation and total equivalent strain has been investigated for 4 materials, namely, PLA, Ceramic ZrO2, Epoxy and ABS. For the purpose of simulation a SAAS software, simscale has been used.

2. Literature review

Tian et al. (2022), Present research work focuses on the concept of dynamic modeling and stability analysis of a spur gear system considering bearing clearance and gear backlash. [2]

Wang et al. (2022), In the research work, investigations on loading capacities of high contact ratio based internal spur gearing system with arc path of contact have been made. [3]

Zhao et al. (2021), In present research work, considering the influence of roughness on the normal contact stiffness of gears, a fractal contact model suited for gear pair contact has been established. [4]

Yilmaz et al. (2021), In this study, the effect of rim thickness of hybrid gears on the root stress, joint stress, tooth stiffness, natural frequency, and dynamic behavior are examined numerically. [5]

Zheng et al. (2021), this study focuses on the wear performance of the gear generated by modified cutter. Numerical results show that the wear resistance can be enhanced through proper cutter modification. [6]

Demet & Ersoyoğlu (2021), In this study, the fatigue performances of symmetrical and asymmetrical spur gears were analyzed by performing single tooth bending fatigue tests. The gears tested were determined to be symmetrical spur gears with a 20°/20° pressure angle, asymmetrical spur gears with a 20°/22° pressure angle, and asymmetrical spur gears with a 20°/25° pressure angle. It was observed that the formation of tooth flank damage negatively affected the fatigue performance. [7]

Lin et al. (2021), in the present research work, distributed cumulative wear and wear at various test stages are quantitatively evaluated. The method is experimentally validated and agrees with the previous simulation. [8]

Zhang et al. (2020), the use of 3D printing to manufacture nylon polymer gears is evaluated in this paper. More specifically, Nylon spur gears were 3D printed using Nylon 618, Nylon 645, alloy 910 filaments, together with Onyx and Markforged nylon proprietary materials, with wear rate tests performed on a custom-built gear wear test rig. The results showed that Nylon 618 provided the best wear performance among the 5 different 3D printing materials tested. [9]

Pleguezuelos et al. (2020), this paper presents a study on the influence on the quasi-static transmission error of symmetric long profile modifications on high contact ratio spur gears. [10]

Karpat et al. (2020), in this study, single tooth stiffness of involute spur gear was measured experimentally. A special test rig for this purpose was designed, and an experimental technique was proposed to investigate the effects of drive side pressure angle on the stiffness. The validation process of this study was performed using the finite element method. The experiments were repeated in ANSYS Workbench, and the elastic deformations were calculated. Experimental and numerical results were found to be generally consistent. Results showed that, the single tooth stiffness increase nearly 38% with the increase in drive side pressure angle from 20° to 35°. Single tooth stiffness of gear types manufactured by non-traditional methods, including additive manufacturing and forged bimetallic gears, can be investigated experimentally with this technique. [11]

Chen et al. (2019), the complex gear foundation types and the crack propagation paths are considered in the proposed method, and the effects of various foundation types, crack propagation paths and crack lengths on the mesh stiffness are analyzed. [12]

Feng et al. (2019), According to the researchers, gear wear introduces geometric deviations in gear teeth and alters the load distribution across the tooth surface. Wear also increases the gear transmission error, generally resulting in increased vibration, noise and dynamic loads. This altered loading in turn promotes wear, forming a feedback loop between gear surface wear and vibration. Having the capability to monitor and predict the gear wear process would bring enormous benefits in cost and safety to a wide range of industries, but there are currently no reliable, effective and efficient tools to do so. This paper develops such tools using vibration- based methods. [13]

Doğan & Karpat (2019) in this research work, the researchers reported that gears are one of the most important power transmission elements in every area of the industry. Because of its importance, the gear design must be carefully performed. Unfortunately, due to the changing of the boundary conditions, gears are exposed to failures such as cracks, pitting, tooth missing etc. during the operation. Thus the gear diagnostic and monitoring become a very critical phenomenon for the gearboxes. A dynamic transmission error based numerical fault detection model is proposed. [14]

Singh and Singh (2018), This study investigates the potential of three different thermoplastic materials viz. Acrylonitrile Butadiene Styrene (ABS), High Density Polyethylene and Polyoxymethylene to be used in plastic gearing applications. [15]

Singh et al. (2018). This article presents a comprehensive review of the research on polymer spur gears operating under low (0–8 Nm) and moderate (>8 and ≤17 Nm) loading conditions. Different polymers and polymer composites used till date for the fabrication of such gears are included along with different operating conditions. [16]

Diez-Ibarbia et al. (2018), in this proposal, the effect of the friction coefficient on the efficiency of spur gears with tip reliefs was analyzed. For this purpose, the efficiency values using an average friction coefficient along the mesh cycle were compared with those obtained implementing an enhanced friction coefficient formulation, which is based on elasto hydrodynamic lubrication fundamentals. In this manner, it can be established the differences between both formulations in the efficiency and friction coefficient values, as well as the advantages of using this enhanced friction coefficient with respect to formulations implemented in traditional approaches of efficiency calculation. In addition to studying the impact of the friction coefficient choice on efficiency, the profile modifications influence on the friction coefficient and efficiency was also assessed. [17]

3. Objectives of the Research Work

During survey of available literature, following gaps are being observed.
1. The is very limited research which uses different materials for modeling a gear; and
2. There is very limited research which tells about ranking of different materials used for making gears.
On the basis of these gaps, objectives of the proposed research work are formulated. Following are the objectives of present research work:
a) To determine different mechanical properties of the gears made up of different materials; and
b) To rank different gear materials in accordance with the properties shown by them.

3.1 Problem Identification

On the basis of investigated gaps in the research, it has been found that there is an utmost need of analysis of spur gear with different materials.

3.2 Problem Defination

For the present research work, a gear needed by a customized machine making firm wastargeted, for which static structural analysis was requested by the firm, under a load, with four different materials, and four mechanical properties. On the basis of the requirements put by the firm, the research problem was defined

4. CONCLUSIONS

Present research work is devoted to the selection of a gear material for the design of a machine, and involves four different types of materials, namely, ABS, ZrO2 ceramic, Epoxy and PLA, and three mechanical properties, namely, Von misses stresses, total deformation and total equivalent strain. In order to select the best material for the application, static analysis was done on SimScale, and rankings of materials for different properties were investigated. Finally, overall rankings of materials were investigated. Following points represent the conclusion of the research work:

a) Material Ceramic ZrO2 is considered as the best material for the application;

b) Material PLA is considered as the second best option;

c) Material Epoxy is considered as the third best option for the gear manufacture.

5. REFERENCES

[1] Keerthi, M., Sandya, K., &Srinivas, K. Static & Dynamic Analysis of Spur Gear using Different Materials. International Research Journal of Engineering and Technology, Volume 3(1), 2016, Pages 694-699.

[2] Tian, G., Gao, Z., Liu, P., & Bian, Y. (2022). Dynamic Modeling and Stability Analysis for a Spur Gear System Considering Gear Backlash and Bearing Clearance. Machines, 10(6), 439.

[3] Wang, Y., Liu, P., & Dou, D. (2022). Investigation of Load Capacity of High-Contact-Ratio Internal Spur Gear Drive with Arc Path of Contact. Applied Sciences, 12(7), 3345.

[4] Zhao, Z., Han, H., Wang, P., Ma, H., Zhang, S., & Yang, Y. (2021). An improved model for meshing characteristics analysis of spur gears considering fractal surface contact and friction. Mechanism and Machine Theory, 158, 104219.

[5] Yılmaz, T. G., Doğan, O., & Karpat, F. (2021). A numerical investigation on the hybrid spur gears: Stress and dynamic analysis. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 0954406220982007.

[6] Zheng, F., Zhang, J., Yao, L., & Tan, R. (2021). Investigation on the wear of spur gears generated by modified cutter. Friction, 9(2), 288-300.

[7] Demet, S. M., & Ersoyoğlu, A. S. (2021). An analysis of the effect of pressure angle change on bending fatigue performance in asymmetrical spur gears. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, 235(9), 2142-
2150.

[8] Lin, J., Teng, C., Bergstedt, E., Li, H., Shi, Z., & Olofsson, U. (2021). A quantitatively distributed wear-measurement method for spur gears during micro-pitting and pitting tests. Tribology International, 157, 106839.

[9] Zhang, Y., Purssell, C., Mao, K., & Leigh, S. (2020). A physical investigation of wear and thermal characteristics of 3D printed nylon spur gears. Tribology International, 141, 105953.

[10] Pleguezuelos, M., Sánchez, M. B., & Pedrero, J. I. (2020). Control of transmission error of high contact ratio spur gears with symmetric profile modifications. Mechanism and Machine Theory, 149, 103839.

[11] Karpat, F., Yuce, C., & Doğan, O. (2020). Experimental measurement and numerical validation of single tooth stiffness for involute spur gears. Measurement, 150, 107043.

[12] Chen, K., Huangfu, Y., Ma, H., Xu, Z., Li, X., & Wen, B. (2019). Calculation of mesh stiffness of spur gears considering complex foundation types and crack propagation paths. Mechanical Systems and Signal Processing, 130, 273-292.

[13] Feng, K., Borghesani, P., Smith, W. A., Randall, R. B., Chin, Z. Y., Ren, J., & Peng, Z. (2019). Vibration-based updating of wear prediction for spur gears. Wear, 426, 1410-1415.

[14] Doğan, O., & Karpat, F. (2019). Crack detection for spur gears with asymmetric teeth based on the dynamic transmission error. Mechanism and Machine Theory, 133, 417-431.

[15] Singh, P. K., & Singh, A. K. (2018). An investigation on the thermal and wear behavior of polymer based spur gears. Tribology International, 118, 264-272.

[16] Singh, A. K., Siddhartha, & Singh, P. K. (2018). Polymer spur gears behaviors under different loading conditions: A review. Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 232(2), 210-228.

[17] Diez-Ibarbia, A., Fernandez-del-Rincon, A., De-Juan, A., Iglesias, M., Garcia, P., & Viadero, F. (2018). Frictional power losses on spur gears with tip reliefs. The friction coefficient role. Mechanism and Machine Theory, 121, 15-27.