IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Optimizing Spur Gear Assemblies: A Historical, Mathematical, And Finite Element Analysis Approach

Priyam Jaiswal[1st] S.S. Chauhan[2nd] Prakash Pandey[3rd]
[1]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal
[2]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal
[3]Department of Machine Design, Vaishnavi Group of Institutions, Bhopal

Abstract: Gears have played a crucial role in transferring power from one shaft to another throughout history, with their usage dating back to 2600 BC. This research paper delves into the historical evolution of gears, highlighting their significance in various applications and the challenges faced by designers and manufacturers. It categorizes gears based on axial arrangements and focuses on the description of spur gears, particularly their geometry and pressure angles.

The central objective of this study is to employ mathematical and finite element methodologies to optimize spur gear assemblies. The research concentrates on extending the fatigue life of gears and mitigating contact pressure between teeth by strategically modifying the gear's face width. This exploration aims to yield multifaceted results, including enhanced durability, reduced wear, and improved operational efficiency. By comparing traditional design paradigms with innovative alterations, this research provides insights into the tangible benefits that can be achieved.

***Index Terms* - Gears, Spur Gears, Gear Evolution, Gear Design, Finite Element Analysis, Contact Stress, Gear Geometry, Historical Development, Gear Optimization.**

I. INTRODUCTION

The power is transferred from one shaft to another shaft by means of gears, which are machine components. As early as 2600 BC, there were gears. Early records mention the Chinese using gears to gauge chariot speeds. In the year 250 BC, Archimedes used a screw to turn toothed wheels that were a part of war engines. Aristotle simulated astronomical ratios using gears in the fourth century BC. Gears are mentioned in Greek and Roman literature as being used in cathedral and ecclesiastical building clocks [Dudley's Handbook 2012]. Wood or stone teeth set in a wood base were used to develop gears in the early centuries. Following that, metals like iron, bronze, and tin were used in place of stone. A gear could not be made using any set practises or methods prior to 1835. The first gear manufacturing method, known as hobbing, was patented by Whitworth [Maitra Gitin M, Handbook 1994]. Pfauter introduced the first NC hobbing machine in 1975, the first basic all-six-axis gear hobbing machine in 1982, and the first gear hobbing machine that can cut both spur and helical gear in 1897. Designers and manufacturers continued to face difficulties with the failure of gear due to contact and bending stresses until 1892. Wilfred Lewis' presentation of stresses on the gear tooth was first acknowledged by the City of Brotherly Love Engineers Club in 1892, and it is still a good idea to see the gear stress [Prof. K. Gopinath Machine Design II].

1.1 Type of Gear

According to axial arrangements there are three categories of gears:

- Parallel Axes Gears
- Intersecting Axes Gears
- Nonparallel and Nonintersecting Axes Gears

Parallel axes gears include spur and helical gears. Bevel gears are gears with intersecting axes. The third category is handled by screw or crossed helical, worm, and hypoid gears. Table 1 shows the gear categories and theoretical efficiency ranges for the various gear types.

Table 1.1. Types of Gears and Their Categories *[Dudley's 2012]*

Categories of Gears	**Types of Gears**	**Efficiency (%)**
Parallel Axes Gears	• Spur Gear • Spur Rack • Internal Gear • Helical Gear • Helical Rack • Double Helical Gear	97 - 99.5
Intersecting Axes Gears	• Straight Bevel Gear • Spiral Bevel Gear • Zerol Gear	97 - 99.5
Nonparallel and Nonintersecting Axes Gears	• Worm Gear • Screw Gear • Hypoid Gear	50 - 90 70 - 95 90 - 98

1.2 Description of Spur Gear

The least expensive gear type for applications involving parallel shafts is the spur gear. Their straight teeth enable sliding shaft and clutch systems for running engagement or disengagement. Spur gears are frequently used in conveyor systems, electric motor gearboxes, timing mechanisms, machine tool drives, manual and automatic motor vehicle gearboxes, and power tool drives. (Gears) Peter R.N. Children, 2019. The tooth is shaped like an involute form. However, there are a few notable outliers. Since they have lower separation loads, generally work more smoothly than involute gears, and have fewer tendency to bind, cycloidal teeth are frequently used in precision mechanical clocks. Because cycloidal gears are difficult to manufacture, sensitive to little centre distance changes, and less sturdy and durable than its involute brethren, the cycloidal type is not employed for power gearing. 2012 [Dudley's guidebook] Gears are mechanical components that maintain a nearly constant instantaneous angular speed ratio while transferring power between two rotating axes by the meshing of conjugated profiles. Their unusual design presupposes the existence of a sliding/rolling contact situation, which can result in a number of failure modes (such as pitting, micro-pitting, and wear), as well as a recurrent pulse-like bending force acting on the tooth root. 2021 [L. Bonaiti] 14.5°, 20°, and 25° pressure angles are the most often employed angles for spur gears. In contrast to new designs, which typically do not use the 14.5° pressure angle, special designs and some replacement gears do. Due to the high profile contact ratio, lower pressure angles provide the benefit of quieter and smoother tooth action. Lower sliding velocities and improved load-carrying capacity are advantages of higher pressure angles, both in terms of strength and durability (thus better scoring and wear performance characteristics). Some unique slow speed gears with very high load capacity, when noise is not the primary concern, use very high pressure angles, for example, 28° or 30°, and in a few cases, as high as 45° [Dudley's handbook 2012]. The toothed wheels known as gears serve as power transmission components that control the torque, speed, and rotational direction of a machine's driving elements. They are used in a variety of industries, including mining, agriculture, aircraft, and autos. Due to the way these sectors operate, an unwarranted breakdown of the gears is undesired. Therefore, it is crucial that these gears be made to have a longer lifespan.

Figure 1.13: Spur Gear

1.3 Terminology of Spur Gears

The following is a list of different definitions for gear geometry that are shown in Fig. 14. The smaller gear in a pair of meshing gears is referred to as the "pinion," and the bigger gear is referred to as the "gear wheel" or just the "gear." 2019 Peter R.N. Childs (Gears)

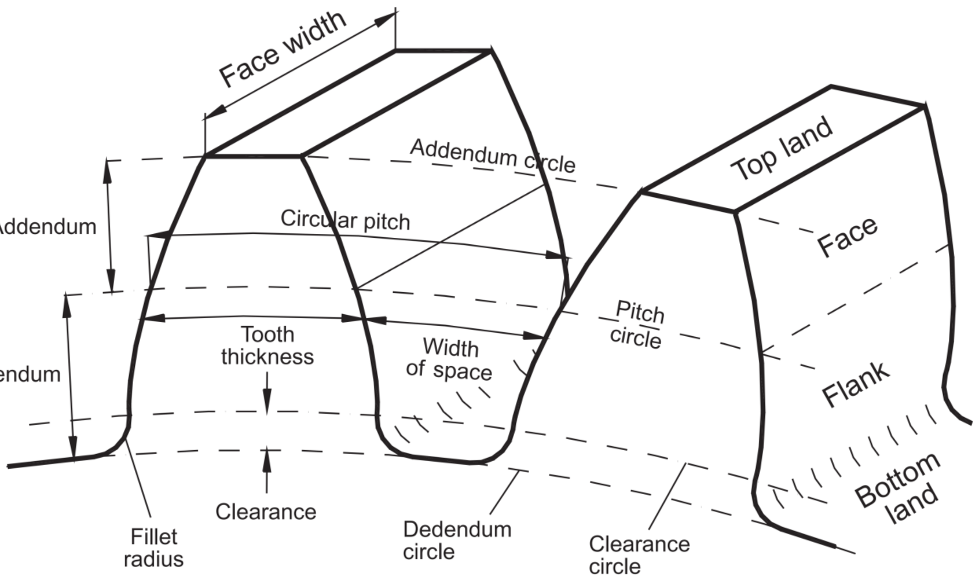

Figure 1.14: Principal terminology of spur gear. [Peter R.N.Childs 2019]

II LITERATURE REVIEW

Oguzhan Demir (2021) [5] This work presents a computational methodology for crack growth path and life prediction of constructions with cracks and its application to three different spur gear tooth case studies. Utilizing fully unstructured tetrahedral elements at the crack front and throughout the model, three-dimensional non-planar fatigue crack propagation analyses are performed using FRAC3D, a component of the Fracture and Crack Propagation Analysis System (FCPAS). Utilizing recently created crack growth criteria, which include various formulae for predicting crack deflection angle and calculating equivalent stress intensity factor, fatigue crack growth path predictions are made. The obtained fracture growth trajectories from numerical simulations and data from the literature are in extremely close agreement when compared. Therefore, it can be said that FCPAS can represent three-dimensional non-planar crack growth using entirely tetrahedral elements throughout the entire finite element model with less user involvement, time, and effort. Additionally, a three-dimensional crack growth analysis can be performed using the suggested methodology and recently created fracture growth criteria.

Sheng Li &Ahmet Kahraman (2021) [6] In this paper, a scuffing model for spur gear contacts is proposed. In order to assess gear bulk temperature, a heat transfer formulation is developed, with frictional heat flow coming from thermal mixed elastohydrodynamic lubrication (EHL) study. For the purpose of determining tribological behaviour inside the contact zone, including flash temperature, the bulk temperature is supplied back into the EHL simulation.. The total surface temperature is calculated after the bulk and flash components have stabilised, and its maximum is compared to a scuffing limit to determine failure. A series of simulations are run using the model to show how surface roughness and rotating speed affect scuffing load.

Yi Yang et al. (2021) [7] This work presents a thorough analysis of a spur geared rotor system with tooth tip chipping from the viewpoints of dynamic modelling and fault diagnosis. Along with a more accurate tooth tip chipping model, analytical equations of time-varying mesh stiffness (TVMS) for a chipped tooth are developed. A new idea dubbed "torsional rigidity" is added to the entire TVMS as a result of the chipping problem. These data are used to build a finite element dynamic model of a spur geared rotor system.. The dynamic model emphasises the mass unbalance brought on by the chipping flaw. To investigate the vibrational behaviours of the system, the nonlinear frequency responses of the geared rotor system are obtained. On the TVMS, time histories, and frequency spectra of vibration signals, the effects of chipping defects are shown. The fault conditions are assessed using a variety of statistical indicators at various rotating speeds. The impacts of imbalance excitations brought on by chipping defects on the system vibration responses are finally demonstrated through a comparison analysis. For the modelling, dynamic analysis, and fault diagnosis of gear transmission systems with local flaws, this paper may offer a thorough technique and some useful references.

Bilal El Yousfi et al. (2020) [8] One of the most frequent causes of gear failure is wear on the surface of the gear teeth. Spalling and pitting are the two primary mechanisms where surface fatigue develops. Pits are dispersed cavities throughout the entire teeth surface with tiny depths, as opposed to spalls, which are isolated cavities on the teeth surface with rather significant depths. In general, spalls and pits have irregular shapes, making it challenging for researchers to model them. Therefore, standard techniques for evaluating surface defects on gear mesh stiffness presume particular geometries (rectangles, triangles, circles, etc.). In this study, a novel potential energy-based method is provided to precisely determine the gear mesh stiffness of spur gears with surface imperfections. To take into account defect depth change in both the width and length directions of the gear tooth, a double discretization of the tooth surface was conducted. To identify actual contact locations throughout the meshing process, a contact detection algorithm is created. The deformation of the gear mesh stiffness caused by spalls and pits with irregular shapes was completely different from those with regular shapes, according to the simulation results, and it also relies on the degree of the defect. Results also indicated that the final deformation of the gear mesh stiffness is influenced by the spall size and position. The suggested approach allowed for the resolution of numerous issues that researchers had with simulating gear mesh stiffness of gears with tooth surface flaws.

Carl-Magnus Everitt& Bo Alfredsson (2020) [9] Thermal elastohydrodynamic fatigue simulations included measured shot peened, ground, and worn surfaces. Moderate negative slip was discovered to be more harmful than positive when taking into account transient temperature fields, shear limit, and metal to metal contact. Thus, surface roughness and the slide to roll ratio were used to describe the location of pitting in gears. Within each surface structure, the -ratio was connected with the probability of weariness. The surface skewness qualitatively ranked the fatigue risk between the surface structures as an addition to the -ratio.

FatihKarpat et al. (2020) [10] Due to the high operating speeds and rising power and torque requirements, the study of the dynamic properties of spur gears has expanded recently. One of the key determinants of the dynamic behaviour of the gear pairs, which varies continually during the meshing process, is tooth stiffness. Therefore, proper calculation of the spur gears' tooth stiffness is required.. Analytical equations are typically used to determine the tooth and mesh stiffness of spur gears. Experimental measurements of the involutes spur gear's single tooth stiffness were made in this work. An experimental method was suggested to evaluate the effects of drive side pressure angle on the stiffness, and a specific test rig was created for this purpose. The finite element method was used for this study's validation process. In ANSYS Workbench, the experiments were repeated, and the elastic deformations were computed. Results from experiments and calculations were discovered to be largely consistent. The single tooth stiffness increased by about 38% when the driving side pressure angle was increased from 20 to 35, according to the results. With the help of this technology, it is possible to conduct an experimental evaluation of the single tooth stiffness of gear types made using novel manufacturing processes, such as forged bimetallic gears and additive manufacturing.

Heli Liu et al. (2020) [11] Contact fatigue issues are being highlighted more and more in current gear anti-fatigue designs. Surface wear may inevitably lead to competition between micropitting and pitting, two contact fatigue failure types. In order to examine this rivalry mechanism during the wear process of a wind turbine gear pair, this work provided a model including the interface features, mechanical properties, and residual stress gradients. Results show that during the wear process, the critical damage position shifts from near-surface to subsurface, indicating that the most likely failure mechanism gradually shifts from surface-initiated contact failure to subsurface-initiated contact failure. This demonstrates that because the dominant failure mode may alter during operation, one-sided gear anti-fatigue designs may not fulfil the complicated contact circumstances.

Prithwiraj Jana (2020) [12] One of the most crucial choices in the best design of any manufacturing procedure and product is the choice of material. An efficient production system with outstanding product and process excellence combined with optimization relies heavily on proper material selection. A company frequently incurs significant costs as a result of poor material selection, which leads to immature product failure.. The manufacturing organisations must therefore be assisted in choosing the optimal material for a given application by an effective technique for material selection. To improve spur gear design with high efficiency, an analytical method and modelling process to assess stress distribution under velocity and moment would be developed. A three-dimensional finite element model of the spur gear system was created to examine stress distribution, based on the theories of gear engagement, contact analysis, and friction. Through rigorous comparisons to the theoretical database created in this study, the accuracy of a full-scale deformable-body model and a simpler discrete model were both demonstrated.

III. OBJECTIVE

The central objective of this research endeavor is to harness the power of mathematical and finite element methodologies to optimize spur gear assemblies, focusing on extending the fatigue life and mitigating the contact pressure between engaging teeth through strategic modifications to the spur gear's face width. Such a concentrated exploration into the domain of gear dynamics and mechanics is anticipated to yield multifaceted results. Beyond the evident benefits of heightened durability and reduced wear, the study seeks to provide an in-depth understanding of the correlation between gear face width and operational efficiency, potentially offering a blueprint for the design of future gear systems. Furthermore, by juxtaposing traditional design paradigms with these innovative alterations, the research hopes to delineate the tangible benefits that arise from such modifications. The insights gained could pave the way for not only more resilient gear systems but also cost-effective production and maintenance strategies, culminating in a comprehensive enhancement of gear assembly performance:

- Develop a range of three-dimensional CAD representations for spur gear assemblies.
- Undertake structural evaluation focused on the derived Von-mises or equivalent stress.
- Execute fatigue assessments to forecast fatigue longevity, safety margins, fatigue sensitivity graphs, and hysteresis representations.
- Perform contact evaluations to ascertain condition, inter-tooth contact pressure, and depth of tooth penetration.

IV. TRANSMISSION OF MOTION

Neuber's rule equalises the elastic material behaviour strain energy with the actual total strain energy at the notch tip.

Neuber's rule is used to calculate the uniaxial stress state.

$$\sigma_b.\varepsilon_b = \frac{(K_t.\sigma_{nominal})^2}{E}$$

Where

σ_b = Actual bending stress

ε_b = Actual bending strain

K_t = theoretical stress concentration factor

$\sigma_{nominal}$ = Nominal tress

E = young modulus or modulus of elasticity

$K_t.\sigma_{nominal} = \sigma_{b,elastic}$

$\sigma_{b,elastic}$ = bending stress for linear elastic material behavior

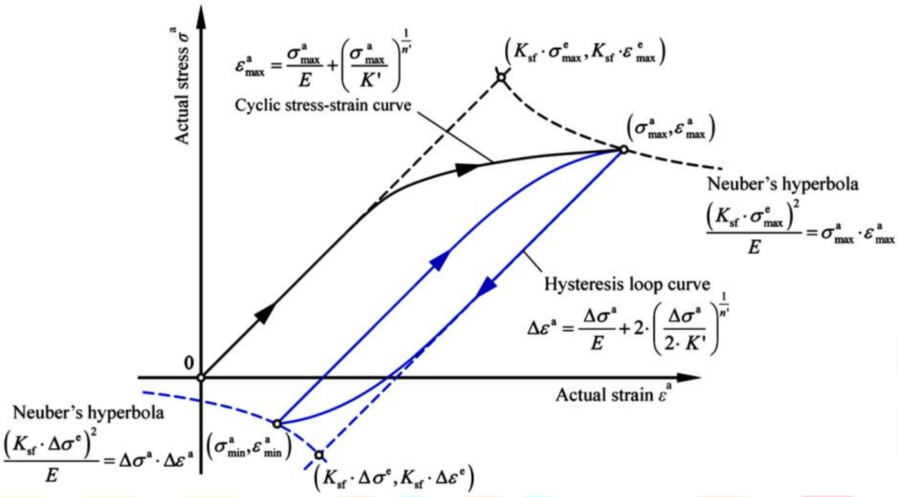

Figure 4.1: Neuber's rule for constant amplitude cyclic loading

4.1 Analytical Methods for Contact Stress Analysis

Contact Mechanics delves into the intricacies of how elements, when in contact, deform at specific points. The interaction zone between two engaging gears is, from a theoretical standpoint, delineated as a line. This, however, mirrors the interaction seen when two cylindrical bodies with ever-evolving radii of curvature come into contact. Although the theoretical model suggests a mere line of contact, the physical reality paints a different picture. The compressive forces at play widen this line, creating a tangible band of interaction along the tooth's length. This contact stress, brought about by the convergence of these elements, plays a pivotal role in the determination of the optimal dimensions for gears. It was Hertz, a luminary from Germany, who pioneered the formulation of expressions quantifying the stresses born out of the contact between two curved surfaces. These induced stresses, often referred to as contact stresses, hertzian stresses, or simply Hertz stresses, have become foundational in the domain of gear design and analysis.

The traditional contact hypothesis focused solely on non-staying contact where no pressure constraint is permitted to occur within the contact territory. In determining the arrangements of hertzian contact issues, a few assumptions are made:

- The strain is lower and the elastic limit is reached. The traditional contact hypothesis focused solely on non-staying contact where no pressure constraint is permitted to occur within the contact territory. In determining the arrangements of hertzian contact issues, a few assumptions are made.
- The surfaces are linear and non-conforming (implying that the area of contact is smaller than the characteristic dimensions of the contacting bodies).
- Each and every body can be considered an elastic half-space.
- The tooth surfaces are frictionless.

When all of these assumptions are violated, an additional problem arises, and these contact problems are commonly referred to as non-Hertzian.

Mathematical relation for cylindrical contact of spur gear:

Contact half-width

$$b = \sqrt{\frac{\frac{2F}{\pi l}\frac{(1-v_1{}^2)}{E_1}+\frac{(1-v_2{}^2)}{E_2}}{\frac{1}{d_1}+\frac{1}{d_2}}}$$

Maximum pressure

$$P_{max} = \frac{2F}{\pi b.l}$$

Known Parameters of Gear one Gear two

Pressure angle of driving & driven gear = 20º

Outside Diameter of driving Gear = 95.25 mm

Table 4.3 Mathematical relation for cylindrical contact of spur gear:

S. No.	Particulars	Mathematical Relation 20° full depth involute	driving & driven gear
1	Addendum	*1m*	*3.175*
2	Dedendum	*1.25m*	*3.969*
3	Working depth	*2m*	*6.35*
4	Minimum total depth	*2.25m*	*7.144*
5	Tooth thickness	*1.5708m*	*4.987*
6	Minimum clearance	*0.25m*	*0.794*
7	Fillet radius at root	*0.4m*	*1.27*

Finite Element Analysis

Finite element analysis is a relatively new concept that is used to solve various engineering problems in industrial applications. It's also used in calculations, models, and simulations to predict and understand how an object will behave under different physical conditions.

4.2 ANSYS Capabilities

In FEM (finite element analysis) ANSYS software is used that helps engineers for performing the following works:

- To build computer prototype, components, transfer CAD model structures in a system products.
- Enhances the profile of structural member with shape optimization.
- To study stress levels, temperature distributions.
- To reduce production costs design should be optimized in early development process.
- Testing of prototypes is done in normal condition where it otherwise would be undesirable or impossible (for example, biomedical applications).

In ANSYS, the graphical user interface (GUI) provides users with an easy, interactive way to access documentation, programme functions, commands, and reference material. Users use an intuitive menu system to navigate through the ANSYS programme. Data can be entered using a mouse, a keyboard, or a combination of the two.

B. Analysis Steps in ANSYS

The different analysis steps involved in ANSYS are mentioned below.

Preprocessor

The model setup is basically done in preprocessor. The different steps in pre-processing are

- Build the model
- Define materials
- Generation of element mesh

Solution Processor

In addressing the issue at hand, a meticulous aggregation of all pertinent data concerning the problem was carried out. This analytical juncture witnesses the computer assuming a pivotal role, deftly handling and solving the intricate equations birthed from the finite element method. The culmination of this computational endeavor is the extraction of values for the nodal degrees of freedom. These values are of paramount significance, as they embody the inaugural set of solution-derived metrics that delineate the component's geometric configuration and behavioral characteristics under various conditions. This computational phase is essential in bridging the gap between theoretical modeling and practical implications, ensuring the component's optimal performance in real-world scenarios.

C. Postprocessor

The general postprocessor completes the review of analysis results across the entire model. The capabilities of a postprocessor range from graphics displays and tabular listings to complex information manipulations such as the combination of load cases.

4.3 Structural Analysis of Spur Gear Assembly for Design-1

CAD modeling

The driving gear three-dimensional CAD model for design-1 was created in CATIA software and imported into ANSYS workbench for further analysis. The dimensions for making gear are as follows: As shown in the figure, the number of teeth is 28, the module is 3.175 mm, the face width is 6.35 mm, the pressure angle is 20o Outer, the addendum is 3.334 mm, the dedendum is 4.286 mm, and the tip diameter is 95.25 mm.

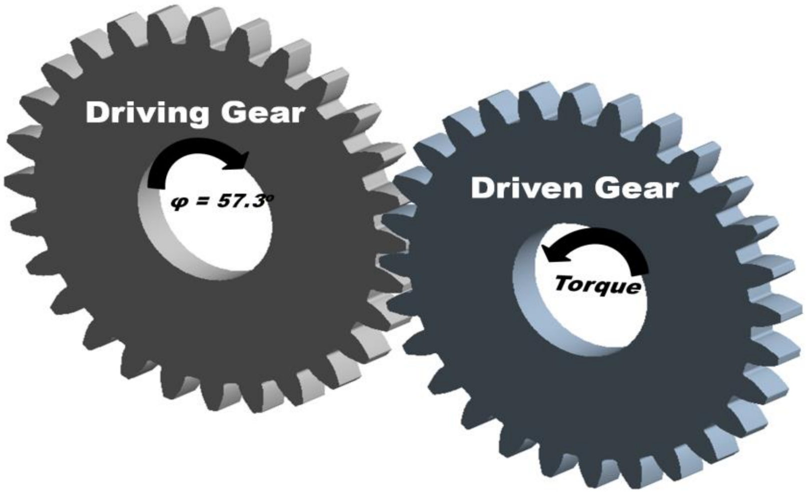

Figure 4.3: CAD geometry of spur gear assembly

V. RESULT AND DISCUSSION

This research endeavor centers on leveraging both mathematical and finite element methodologies to enhance the fatigue longevity and minimize contact pressures between mating spur gear teeth, specifically by adjusting the spur gear's face width. Utilizing CATIA, three distinct CAD models for the driving gear were conceptualized. Post design, these were converted into the Stp. format to facilitate in-depth analysis. The inaugural design, Design-1, was derived from dimensional parameters extracted from a foundational paper. Meanwhile, Design-2 hinged on mathematically determined parameters rooted in the gear module. In a bold approach, Design-3 was contrived by amplifying the geometrical parameters by a substantial 20% compared to the original base design. Each of these designs underwent rigorous evaluations encompassing steady-state structural scrutiny, fatigue analysis, and contact dynamics assessment. This chapter delves deep into the findings of the finite element model analysis, elucidating results through comprehensive visual aids like contour plots and illustrative graphs.

5 Comparative results of spur gear assembly for design-1

Torque [N_m]	**Von-mises stress [MPa]**	**Min. Life [Cycle]**	**Safety Factor**	**Max Life [Cycle]**	**Hysteresis Stress [MPa]**	**Hysteresis Strain [mm/mm]**	**Contact Pressure [MPa]**	**Penetration [mm]**
350	919.99	65861.0	0.1838	1.47E+6	389.18	0.0109	447.21	0.0188
400	1048.60	38734.0	0.1613	7.76E+5	408.74	0.0135	508.98	0.0214
450	1177.40	24439.0	0.1437	4.52E+5	426.53	0.0163	570.77	0.0240
500	1306.20	16270.0	0.1295	2.83E+5	442.92	0.0193	632.56	0.0266
550	1435.10	11301.0	0.1179	1.87E+5	458.16	0.0225	694.36	0.0290
600	1564.20	8123.6	0.1081	1.30E+5	472.42	0.0259	756.17	0.0318

Comparative results of spur gear assembly for design-2

Torque [N_m]	Von-mises stress [MPa]	Min. Life [Cycle]	Safety Factor	Max Life [Cycle]	Hysteresis Stress [MPa]	Hysteresis Strain [mm/mm]	Contact Pressure [MPa]	Penetration [mm]
350	1092.80	34768.0	0.1550	6.72E+5	412.77	0.0140	581.41	0.02100
400	1249.70	20478.0	0.1356	3.63E+5	433.51	0.0174	658.50	0.02379
450	1406.80	12932.0	0.1204	2.16E+5	452.40	0.0211	735.61	0.02657
500	1564.10	8613.9	0.1083	1.37E+5	469.80	0.0252	812.74	0.02936
550	1721.50	5984.6	0.0984	91617	485.99	0.0295	889.89	0.03214
600	1879.00	4302.3	0.0902	63913	501.15	0.0340	of 967.06	0.03490

Comparative results of spur gear assembly for design-3

Torque [N_m]	Von-mises stress [MPa]	Min. Life [Cycle]	Safety Factor	Max Life [Cycle]	Hysteresis Stress [MPa]	Hysteresis Strain [mm/mm]	Contact Pressure [MPa]	Penetration [mm]
350	838.74	1.02E+05	0.2020	2.47E+06	373.71	0.0091	397.24	0.0190
400	946.57	61985.0	0.1790	1.34E+06	391.29	0.0111	448.64	0.0220
450	1054.50	40086.0	0.1607	7.94E+05	407.37	0.0132	500.05	0.0240
500	1162.50	27211.0	0.1457	5.04E+05	422.24	0.0155	551.47	0.0265
550	1270.50	19200.0	0.1334	3.37E+05	436.11	0.0179	602.90	0.0290
600	1378.70	13982.0	0.1229	2.35E+05	449.13	0.0204	654.33	0.0315

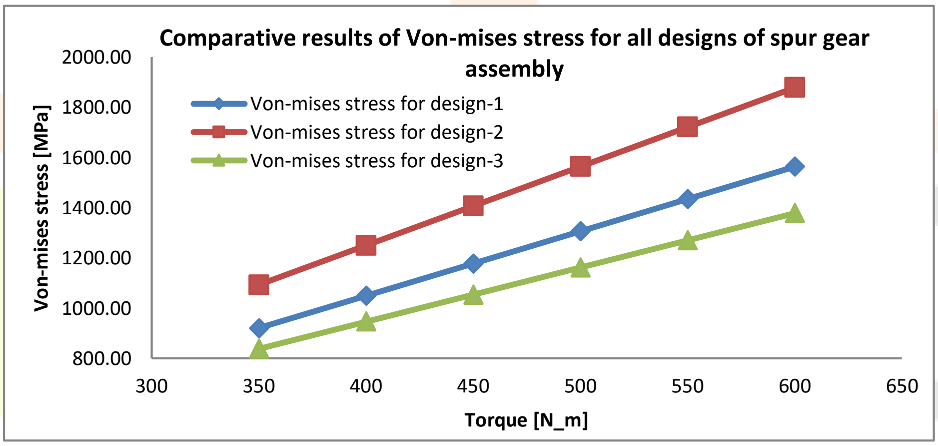

Figure 5.127: Comparative results of Von-mises stress for all designs of spur gear assembly

Based on the comparison of Von-Mises stress in the spur gear assembly, design-3 exhibits a reduction in equivalent stress by 9.69% at 350 N m and 13.45% at 600 N m relative to design-1.

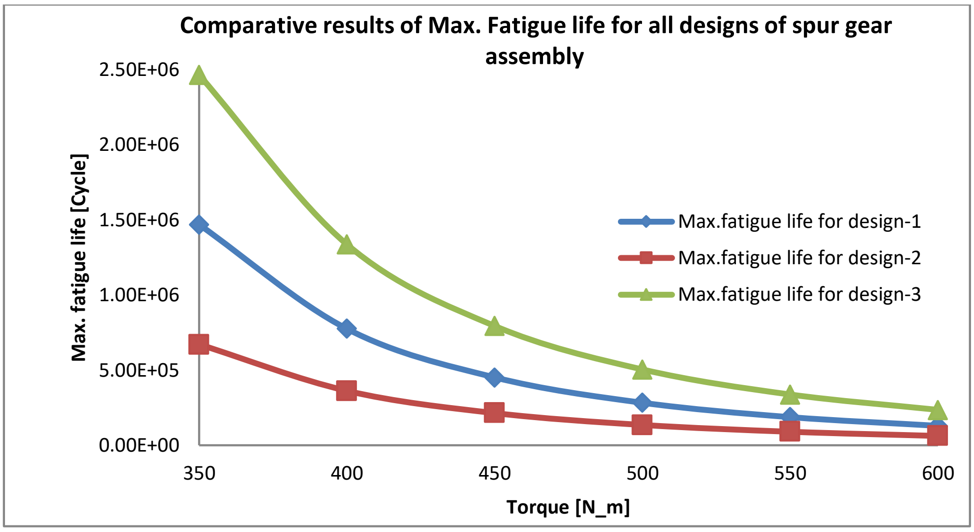

Figure 5.128: Comparative results of Max. Fatigue life for all designs of spur gear assembly

Based on the comparative analysis of maximum fatigue life within the spur gear assembly, design-3 demonstrates an increase in fatigue life of 67.7% at 350 N m and 81.59% at 600 N m compared to design-1.

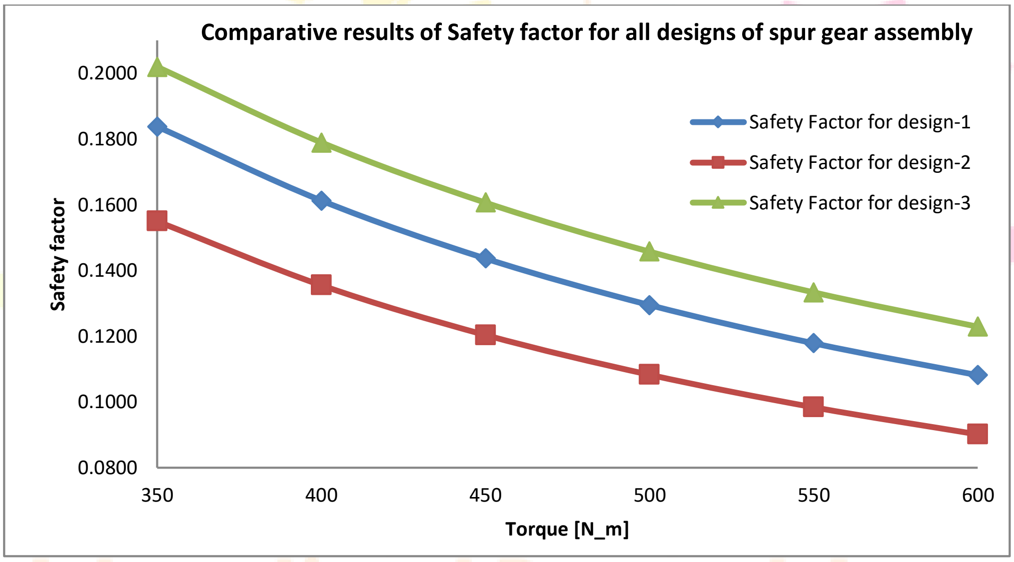

Figure 5.129: Comparative results of Safety factor for all designs of spur gear assembly

Based on the comparison of the safety factor in the spur gear assembly, design-3 showcases an enhanced safety factor by 9.88% at 350 N m and 13.65% at 600 N m compared to design-1.

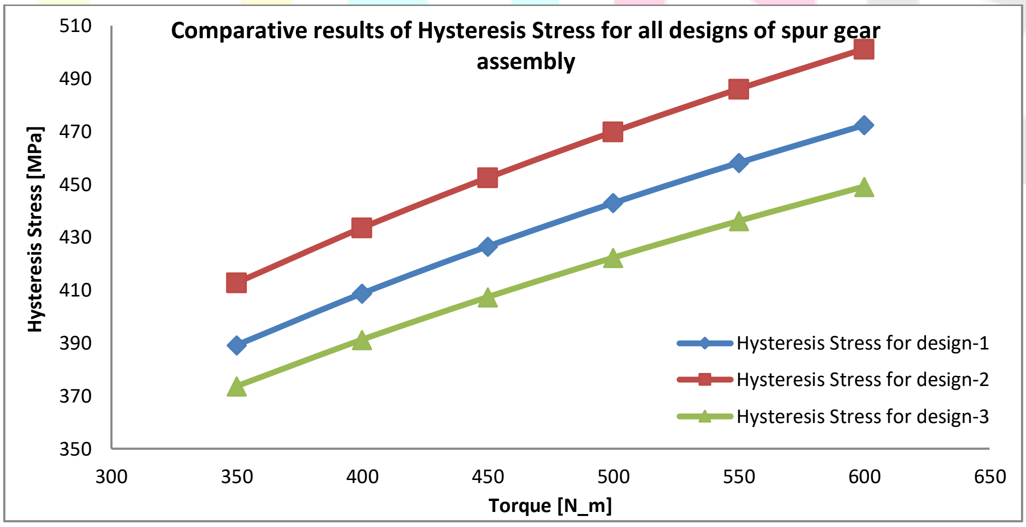

Figure 5.130: Comparative results of Hysteresis Stress for all designs of spur gear assembly

Based on the Hysteresis stress comparison within the spur gear assembly, design-3 exhibits a decrease of 4.14% at 350 N m and 5.19% at 600 N m relative to design-1.

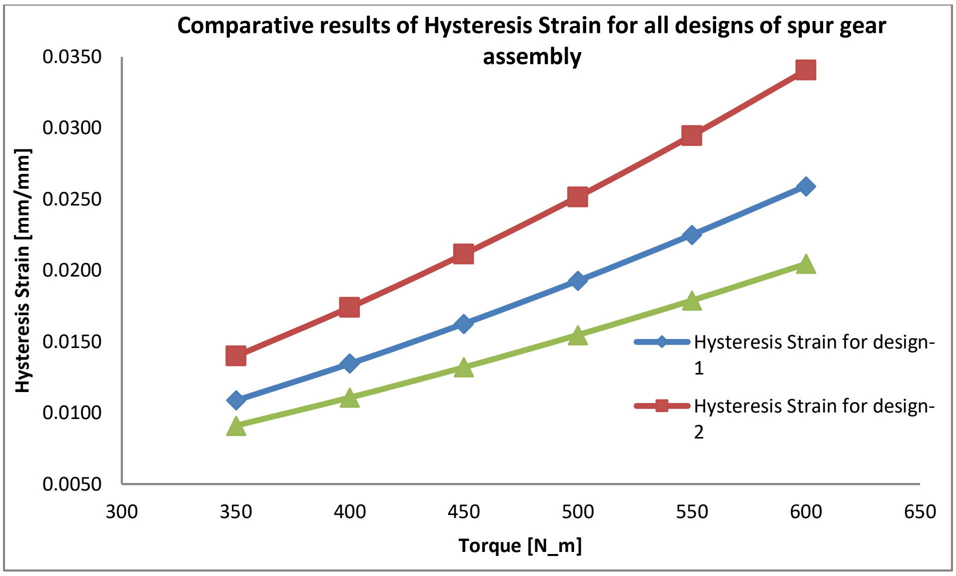

Figure 5.131: Comparative results of Hysteresis Strain for all designs of spur gear assembly

When comparing the Hysteresis strain in the spur gear assembly, design-3 demonstrates a reduction of 19.58% at 350 N m and 26.63% at 600 N m compared to design-1.

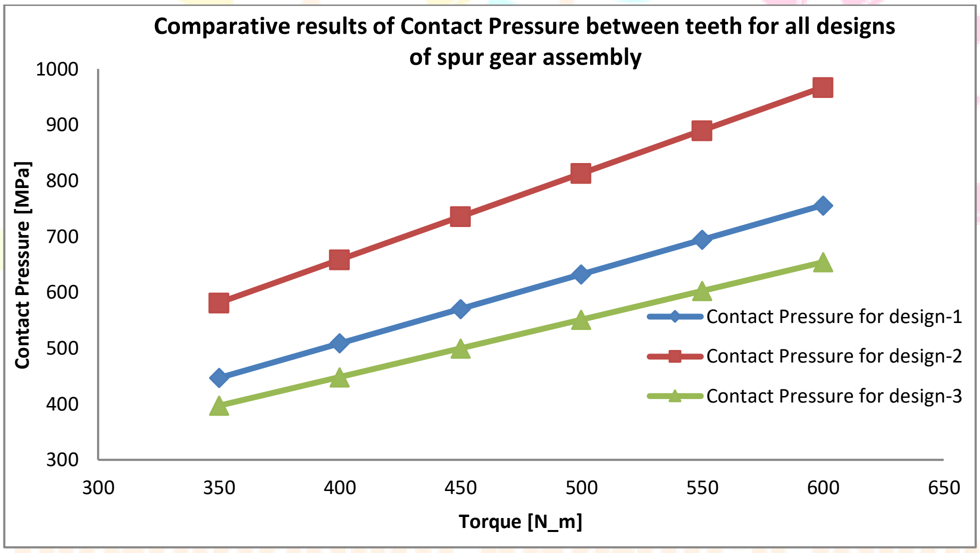

Figure 5.132: Comparative results of Contact Pressure between teeth for all designs of spur gear assembly

Based on the comparative analysis of the Contact Pressure between the teeth of the spur gear assembly, design-3 exhibits a reduction of 12.58% at 350 N m and 15.56% at 600 N m relative to design-1.

6. CONCLUSION

This research paper explores the historical evolution of gears and their significance across applications. It centers on the enhancement of spur gear assemblies through mathematical and finite element analysis techniques, particularly by adjusting the gear's face width. The study aims to achieve diverse outcomes, such as increased durability and operational efficiency. By contrasting conventional and innovative design methods, it offers valuable insights into the potential advantages of these alterations. This research contributes to our knowledge of gear systems and their optimization for improved performance and longevity.

REFERENCES

[1] Kresimir Vuckovi et al. 2021. Numerical model for bending fatigue life estimation of carburized spur gears with consideration of the adjacent tooth effect, International Journal of Fatigue 153 106515 https://doi.org/10.1016/j.ijfatigue.2021.106515.
[2] L. Bonaiti& C. Gorla 2021. Estimation of gear SN curve for tooth root bending fatigue by means of maximum likelihood method and statistic of extremes International Journal of Fatigue 153 106451; https://doi.org/10.1016/j.ijfatigue.2021.106451.
[3] Matthew E. Wagner et al. 2021. “Implementation of the Average-Log-Ratio ALR gear-damage detection algorithm on gear-fatigue-test recordings” Mechanical Systems and Signal Processing 154 107590 https://doi.org/10.1016/j.ymssp.2020.107590.
[4] OguzDogan et al. 2021. “Effects of rim thickness and drive side pressure angle on gear tooth root stress and fatigue crack propagation life Engineering Failure Analysis 122, 105260 https://doi.org/10.1016/j.engfailanal.2021.105260.
[5] OguzhanDemir 2021. Three-dimensional modeling of non-planar fatigue crack growth in spur gear tooth using tetrahedral finite elements. Engineering Fracture Mechanics 252, 107857; https://doi.org/10.1016/j.engfracmech.2021.107857.
[6] Sheng Li &AhmetKahraman 2021. A scuffing model for spur gear contacts” Mechanism and Machine Theory 156, 104161 https://doi.org/10.1016/j.mechmachtheory.2020.104161.

[7] Yi Yang et al. 2021. Dynamic analysis for a spur geared rotor system with tooth tip chipping based on an improved time-varying mesh stiffness model, Mechanism and Machine Theory 165, 104435 https://doi.org/10.1016/j.mechmachtheory.2021.104435.
[8] Bilal El Yousfi et al. 2020. New approach for gear mesh stiffness evaluation of spur gears with surface defects, Engineering Failure Analysis 116 2020. 104740 https://doi.org/10.1016/j.engfailanal.2020.104740.
[9] Carl-Magnus Everitt& Bo Alfredsson 2020. The influence of gear surface roughness on rolling contact fatigue under thermal elasto hydrodynamic lubrication with slip, Tribology International 151, 106394 https://doi.org/10.1016/j.triboint.2020.106394.
[10] FatihKarpat et al. 2020. Experimental measurement and numerical validation of single tooth stiffness for involutes spur gears" Measurement 150. 107043 https://doi.org/10.1016/j.measurement.2019.107043.
[11] Heli Liu et al. 2020. "Study on gear contact fatigue failure competition mechanism considering tooth wear evolution" Tribology International 147, 106277 https://doi.org/10.1016/j.triboint.2020.106277.
[12] Prithwiraj Jana 2020. Determination the Fatigue Life of Spur Gear through Stress Analysis with Optimization Methodology International Journal for Research in Applied Science & Engineering Technology (IJRASET) https://doi.org/10.22214/ijraset.2020.31976.
[13] Qi Wen et al. 2020. Analytical calculation of the tooth surface contact stress of spur gear pairs with misalignment errors in multiple degrees of freedom" Mechanism and Machine Theory 149, 103823 https://doi.org/10.1016/j.mechmachtheory.2020.103823.
[14] B. Cerne et al. 2019. Thermo-mechanical modeling of polymer spur gears with experimental validation using high-speed infrared thermography, Mechanism and Machine Theory 146, 103734 https://doi.org/10.1016/j.mechmachtheory.2019.103734.
[15] Kangkang Chen et al. 2019. Calculation of mesh stiffness of spur gears considering complex foundation types and crack propagation paths" Mechanical Systems and Signal Processing 130, 273–292 https://doi.org/10.1016/j.ymssp.2019.05.014.