To study their behavior and performance characteristics of spur Gears by analytical and finite element analysis

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Abstract - *Finite Element Method (FEM) models were utilized to analyze contact stresses, deviating from the traditional approach of employing Hertz's equations, originally designed for contact between two cylinders, to compute gear contact stresses. This study places a preference on investigating contact challenges through FEM.*

To facilitate this analytical approach, a stiffness relationship is established between the two contacts areas using a spring element positioned precisely at the point of contact. The outcomes of the two-dimensional FEM analyses, performed using ANSYS software, are detailed in this thesis. The resultant contact stress values from these analyses are then juxtaposed against theoretically computed values. Remarkably, both datasets exhibit a high degree of alignment, underscoring the FEM model's precision in simulating gear contact stresses.

In this thesis, an exhaustive examination is conducted on the influence of gear body rotation on the overall stiffness of the gear body. This phenomenon is attributed to bending deflection, cutting off displacement, and radial deformation. Thorough investigations are carried out across multiple positions within the gear meshing cycle. The central focus revolves around an in-depth exploration of the contact stress characteristics inherent in spur gears. This exploration takes into account Buckingham's Dynamic Load and the dynamic load formulation as per the Lewis Equation.

Key Words: Spur gear, hertz-contact stress, bending stress, finite element analysis, contact stress, Dynamic Load

1. INTRODUCTION

Function: Gears assume a pivotal role within an array of mechanical systems, facilitating the seamless transmission of power, motion, and positional accuracy. They serve as conduits for the efficient conversion of rotational motion between shafts, enabling adjustments in speed and direction, and guaranteeing meticulous alignment among disparate components.

Advantages: Gears yield a multitude of benefits in the realm of power transmission.

1. Optimal Power Transmission Efficiency: Gears exhibit an impressive power transmission efficiency, typically hovering at around 98%. This signifies a minimal power loss during the transfer process, resulting in a remarkably effective conveyance of power from one element to another.

2. Space-Efficient Design: Gears excel in transmitting substantial power within a confined spatial framework. Their compact configuration proves advantageous in scenarios with limited space availability, promoting efficient power transmission.

3. Robust High-Speed Capability: Gears boast the capacity to withstand elevated rotational speeds without incurring noteworthy wear or performance deterioration. This attribute renders them eminently suitable for applications necessitating swift power transmission.

4. Exquisite Timing and Alignment: Gears deliver meticulous timing and precision in alignment. The interlocking teeth of gears ensure precise synchronization and harmonious alignment of components. This attribute is indispensable in contexts demanding meticulous timing and accurate positioning, as observed in automotive engines and industrial machinery.

Disadvantages: Nonetheless, gears exhibit certain drawbacks when juxtaposed with alternative power transmission mechanisms such as belts and chains.

1. Elevated Cost: The manufacturing of gears tends to entail higher expenses compared to belts and chains. The gear production process entails intricate machining and often mandates employment of premium-grade materials. The heightened intricacy and material expenses contribute to escalated manufacturing costs.

2. Complexity in Manufacturing: The intricacy of gear manufacturing escalates in tandem with heightened precision requisites. Gears designated for high-speed applications, robust systems, or those necessitating low noise levels necessitate manufacture with exceedingly stringent tolerances. The attainment of such exacting specifications can substantially elevate manufacturing expenses.

3. Increased Mass: Gears can augment the total mass of a system in certain instances. The supplementary weight attributed to gears could pose a drawback in contexts where minimizing weight is of paramount significance, as exemplified in the aerospace or automotive sectors.

4. Sound Emission: Gears can generate operational noise as a consequence of teeth engagement. While strides in gear design and material enhancement have mitigated noise production, it might remain a consideration in scenarios where noise mitigation holds significance, as seen in consumer electronics.

2. RESEARCH GAP

The aforementioned literature underscores the significance of high-quality research in facilitating thorough analyses encompassing mechanical stress, mechanical vibration, motion, and fatigue. Such analyses play a pivotal role in the judicious selection of appropriate materials for gear manufacturing. Among the myriad Finite Element Analysis (FEA) techniques, several can be harnessed for the purpose of material selection in gear production. This process entails intricate considerations like geometry assessment, integration of diverse material properties, and meticulous capture of localized effects, which might necessitate nuanced adjustments in discretization approaches, such as h-version, hp-version, x-FEM, or is geometric analysis. Notably, the FEA algorithm reigns as the predominant choice within widely adopted simulation software, typified by ANSYS.

Commercial simulation tools like ANSYS are remarkably versatile, encompassing functions that extend to conducting comprehensive tests encompassing vibration, impact, durability, strength, and gearbox design optimization.

The current study addresses critical gaps in existing research:

1. Despite the extensive prior investigations into gear analysis and design, a notable void persists concerning a holistic numerical methodology capable of precisely predicting the ramifications of variations in gear geometry, contact stresses, bending stresses, torsional mesh stiffness, and transmission errors. The fundamental objective of this study is to bridge this gap by formulating a comprehensive numerical approach that accomplishes this task with a high degree of accuracy.

2. This study's specific focal point revolves around the computation of bending stress within spur gears, employing two distinct methodologies: the modified Lewis dynamic load approach and Buckingham's dynamic load approach. These methodologies strive to furnish more precise and dependable outcomes when evaluating the bending stress experienced by spur gears.

3. RESEARCH METHODOLOGY

3.1 Methodology flow chart

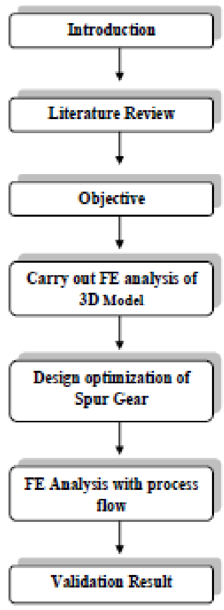


Figure 3.1Methodology flow chart

4. RESULT

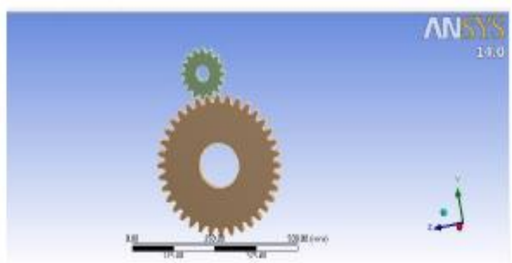


Figure 1 illustrates the gear and pinion assembly's geometry, seamlessly transferred from CATIA V5 to ANSYS 14.0 workbench. The choice of CATIA for geometry modeling is driven by its capability for parametric modeling, allowing for flexible design adjustments. Additionally, CATIA's product design module ensures precise assembly placement, contributing to the seamless depiction of the assembly in the context of this study.

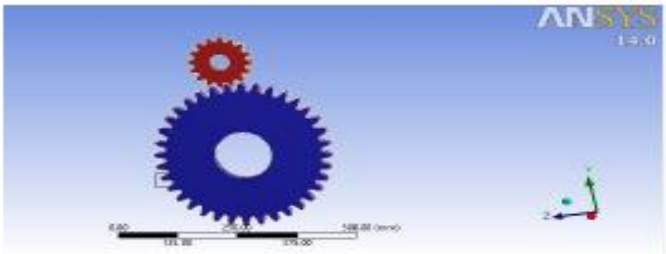
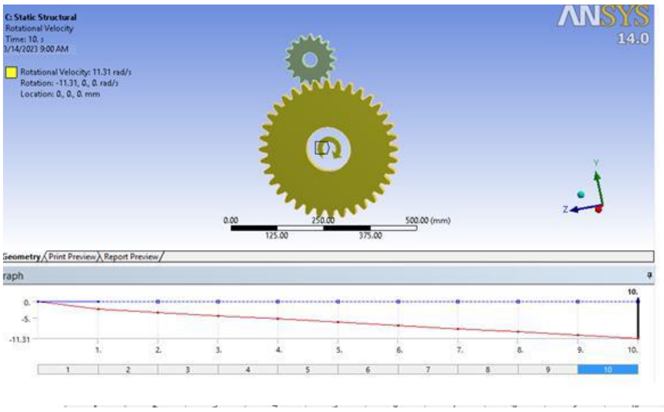


Figure 2 depicts the bonded contact established between mating surfaces, seamlessly integrated into ANSYS through automatic interpretation of the contact definitions from CATIA. This integration is facilitated by the accurate alignment of mating surfaces within CATIA, ensuring a seamless transition of contact definitions to the ANSYS environment.



In Figure 4, it can be observed that the gear is imparted with a clockwise rotational velocity of 11.31 m/s.

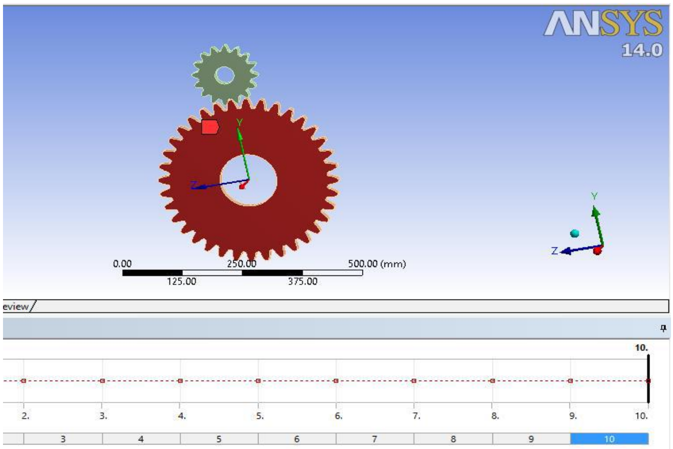
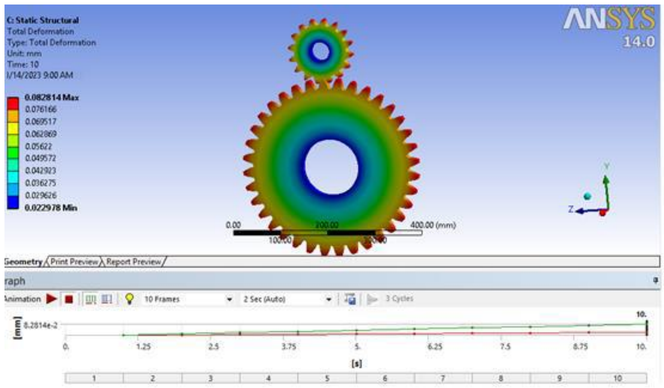
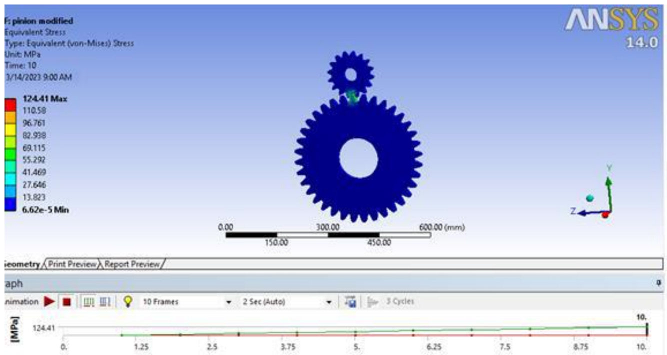


Figure 5.5 illustrates the gear under specific boundary conditions, enabling its movement along the y and z directions while restricting motion along the x direction.

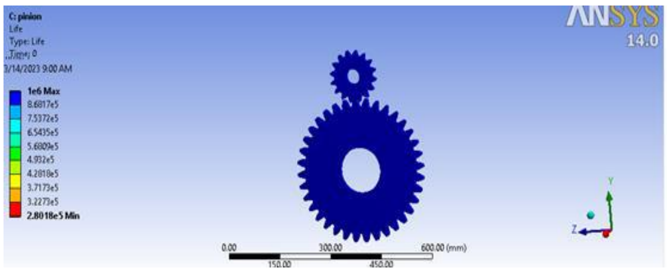
Figure 5 depicts the prescribed boundary conditions for the gear and pinion assembly. Notably, the gear's boundary conditions should facilitate exclusive rotation around its axis and be supported by a frictionless hub.



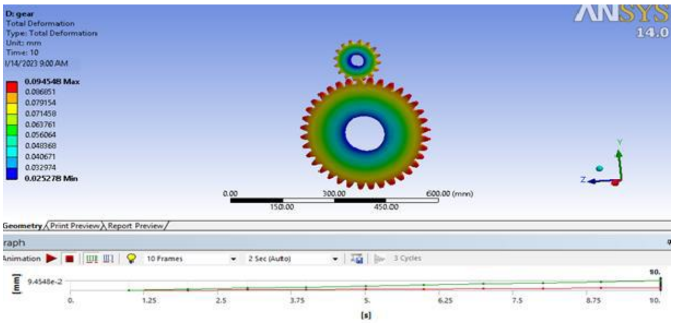
In Figure 5.10, the deformation of the pinion and gear assembly, taking into account the applied torque on the pinion, is presented. The analysis reveals that the overall maximum deformation is 0.08 mm, which is insignificant in relation to the gear mesh requirements.



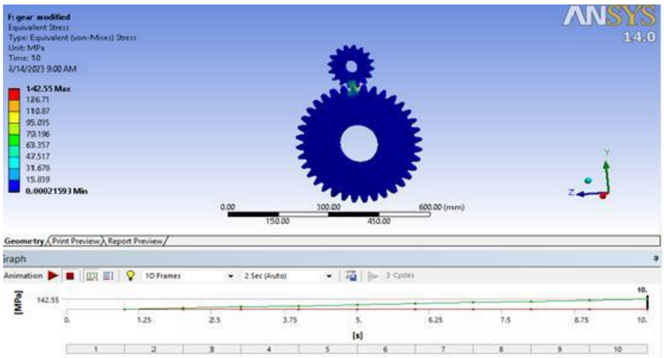
In Figure 5.11, the Equivalent Von Mises stress of the gear and pinion assembly, taking into consideration the torque applied to the pinion, is depicted as 124.41 N/mm^2. This value slightly deviates from the numerically obtained data of 139.1 N/mm^2, potentially attributed to environmental influences such as gear friction and the assumption of a frictionless support at the hub.



In Figure 5.12, the longevity of the gear-pinion assembly is illustrated, taking into account the applied torque on the pinion. This depiction portrays the fatigue life or durability of the meshing gears within the specified boundary conditions, determined to be within the range of 106 cycles.



In Figure 5.14, the deformation of the pinion and gear assembly resulting from the applied torque on the gear is presented. The analysis indicates that the overall maximum deformation is 0.09 mm, a value of minimal significance in relation to the requirements of the gear mesh.



In Figure 5.15, the Equivalent Von Mises stress of the gear and pinion assembly, taking into account the torque applied to the gear, is showcased as 142.55 N/mm^2. This value is slightly lower than the numerically obtained data of 166.556 N/mm^2, and this disparity can be attributed to environmental factors such as gear friction and the assumption of a frictionless support at the hub.

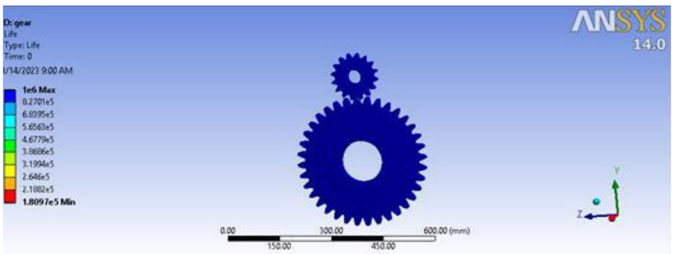


Figure 16, depicted as Figure 5.16, portrays the fatigue life or endurance of the gears under varying boundary conditions, with a particular focus on the influence of torque applied to the gears. The figure illustrates the quantity of cycles (falling within the range of 10^6 cycles) that the gears can sustain before encountering fatigue-induced failure. A careful examination of Figure 5.16 enables the evaluation of how torque affects the durability of the gear system. Notably, higher torque levels contribute to heightened stress and an elevated likelihood of fatigue failure.

TABLE 5.3: Comparative von misses stress between numerical and FEA results

Sr. No.	Parameter	Numerical Result	FEA Result	% Difference
1	Stress generated for pinion	139.1 N/mm^2	124.41 N/mm^2	10.5%
2	Stress generated for gear	160.556 N/mm2	142.55 N/mm^2	11.21 %

5. Conclusion:

The stress obtained numerically for the pinion is 139.1 N/mm^2, while the software-based solution yields 124.41 N/mm^2, demonstrating a proximity of approximately 89.5% to the numerical value.

1. For the gear, the stress calculated numerically is 160.5 N/mm^2, whereas the software-based solution results in 142.5 N/mm^2, exhibiting an approximate 88.79% convergence with the numerical outcome.

2. The design proves safe with nearly negligible deformation.

3. Numerically determined fatigue life falls within the range of 107 cycles, a prediction corroborated by software simulation which estimates fatigue life at around 106 cycles.

4. Deviations from the numerical data may arise due to factors such as the omission of friction in our gear assembly simulation. Additionally, while we utilized a fine mesh size, further refinement could potentially yield improved results.

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