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Research Article

The Design and Analysis of the Helical Gear in the Car Gear Box for the Slag Port Transfer

Anandan Kanagaraj*, Senthilkumar Marakkanappatti Pandurangan, Saravavan Durai, Arunkumar Gopi

Department of Mechanical Engineering, P. S. V College of Engineering and Technology, Krishnagiri, India

Abstract

The design and analysis of helical gears with involutes profiles is the primary focus of this study. The most widely utilized gearing system in use today is the involutes gear profile. Power and torque are typically transmitted through them. When compared to other forms of transmission, the efficiency of power transmission via gears is extremely high. Bending and contact stress are the main causes of gear tooth failure. The current study examines helical gear, which has to do with slag transfer in the steel production sector. The most affected stress concentrated location of any set of gears in the slag port transfer car (SPTC) gear box is identified by examining the contact stresses for the current design set of gears. The high stress concentration gear set was redesigned with a constant (45mm) face width at various Helix angles (14, 15, 16, 17, 19^, 20˚, 25^, and 30˚) and a constant pressure angle (20). To calculate the contact stresses between two gears that are mating. The robust and cutting-edge solid modeling program AUTODESK FUSION 360 creates a three-dimensional solid model. The ANSYS Workbench module was utilized to do the numerical analysis. The outcomes of the workbench module for ANSYS. The current study is helpful in quantifying the previously mentioned factors, which aids in the safe and effective design of the helical gear in the SPTC Gearbox.

Keywords

Power, Torque, Helical Angle, Pressure Angle, Gear, Fusion 360, ANSYS

1. Introduction

In all contemporary gadgets, gears are the most often utilized type of power transmission mechanism. The speed [6] or power between input and output can be adjusted using these toothed wheels. They are now widely accepted in a variety of applications and are heavily utilized in high-speed marine engines. The gear design of today's high- tech world has advanced to a very high level of perfection. With very little noise, vibration, or other undesired characteristics of gear drives, gears that can transmit incredibly large loads at extremely high circumferential speeds have been made possible by the design and production of precision-cut gears made from materials of high strength. Power is transferred from one shaft to another by way of the consecutive engagement of teeth in a gear, which is a toothed wheel with a unique tooth space of profile that allows it to mesh easily with other gears.

Gears work in pairs, with the bigger gear being referred to as the "gear" and the smaller one as the "pinion." Typically,

*Corresponding author: anandandmeena@gmail.com (Anandan Kanagaraj)

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the system serves as a torque converter and speed reduction while the pinion drives the gear. Up until now, gear makers have focused on failures brought on by high surface pressures, high root stresses and hardening cracks [5] they haven't looked at the relationship between mild wear and more serious types of damage [8]. Surface fatigue is a recognized issue that has been addressed with improved and purer materials, smoother surfaces, heat treatments, and other techniques.

There would be significant benefits if the wear distribution could be determined throughout the design process as this would provide insights into the intended product's functionality and longevity. While many researchers have studied gear wear, few have compared wear simulation studies in contrast to actual tests [11]. Typically, wear is handled carelessly, with crude approximations and no consideration for how wear may affect the gears' ability to function. A scale is typically used to represent the degree of wear during wear analysis of tested gears. Variations in mesh stiffness are caused by variations in the effective length of the line of contact, which is a result of the number of teeth in contact changing as the gears spin [12].

2. Objective

The primary goal of this study was to employ several models to conduct static-structural analysis on a high- speed helical gear used in a gear box for automobile engines.

After comparing the findings from various analytical sections with the static analysis results, a determination has been made regarding the material [3] that should be used for the gear.

To calculate the bending stress applied to the helical gear 3-D solid model. Utilizing the ANSYS software suite [2], the twisting stress is examined.

3. Current System and Methods

Pitting, or surface fatigue failure brought on by repeated exposure to high contact stresses [1] in the gear tooth, is one of the primary causes of gear tooth failures. This research aims to decrease the contact stress that frequently occurs on gears by adjusting the various face width values. By using the AGMA [4] (American Gear Manufacturing Association) equation to calculate the contact stress and ANSYS for analysis, contact failure in gears can be anticipated. Solid Works software is utilized to construct the helical gear pair model, while ANSYS is employed for numerical analysis [13]. In the end, the ANSYS findings are shown and contrasted with theoretical values. Due of its lower weight, the face width of 21 mm, with a von-Mises stress of 493.27 MPa, was chosen for this investigation.

3.1. Techniques

AUTODESK FUSION 360 software was used to model the SPTC gearbox. Reverse engineering is used to get each component's dimensions from the construction site.

Basic equipment such as a Verniercaliper, steel rule, protractor, tape, and others are used in reverse engineering. Sketching is the process of processing data collection.

FUSION 360software is used to transform this sketch data into 3D objects. A created model of the helical gear assembly set is imported in the IGES format into the static structural module of ANSYS Workbench in order to perform contact analysis on the helical gear assembly.

With the exception of cases module 3 and module 4, the contact stress at the module 7 assembly - which consists of the output gear and second pinion shaft-exceeds the yield [7] strength limit.

Therefore, a safe design of the helical gear will be made by reducing the concentration of stress on stage 3.

The helical gear redesign of the module 7 gear set as detailed in the preceding section to maintain a steady module and pressure while changing the helix angle in order to lessen the concentration of stress on module 7.

3.2. Depiction of Helical Gears with Variable Helix Angles

The FUSION 360 models a redesign of a helical gear set with different helical angles.

Gears with different helix angles were developed and constructed in AUTODESK FUSION 360 in order to determine the range of helix angles for the redesign with the aid of finite element method of design. [7, 16].

After that, the assembled models are imported into ANSYS however the models are not correctly meshed due to the helix angle [6] below. As a result, the helix angle design above 14 degrees is appropriate and should be applied to the corresponding modeled parts.

Following meshing, the maximum pressures that can be achieved on a gear set's tooth are represented by post- processing.

3.3. Purpose

Autodesk Fusion 360 Designed 3D Model

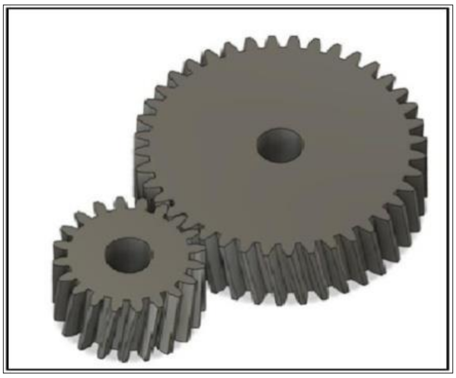

Figure 1. *3DModel for Meshing Gear Set.*

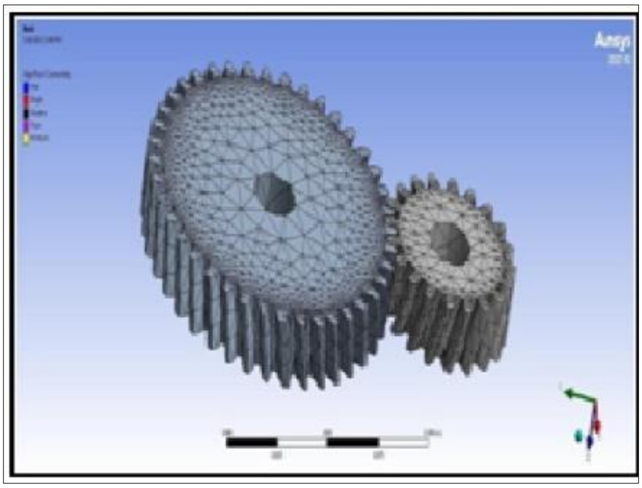

Figure 2. *Simulation Diagram for Proposed System.*

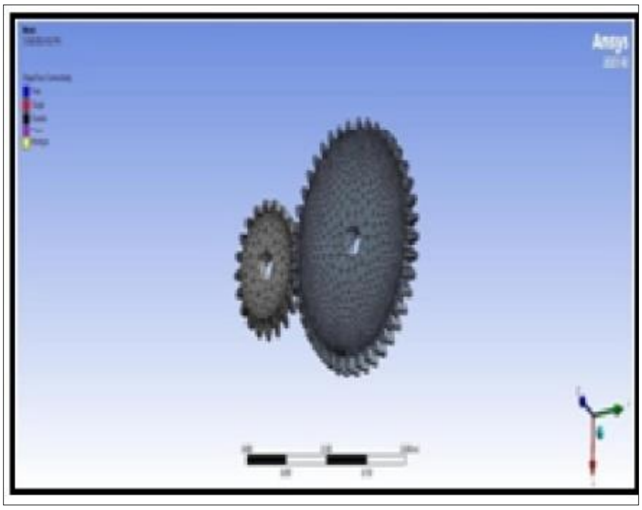

Figure 3. *3D Model for Module 4 Helical Gear.*

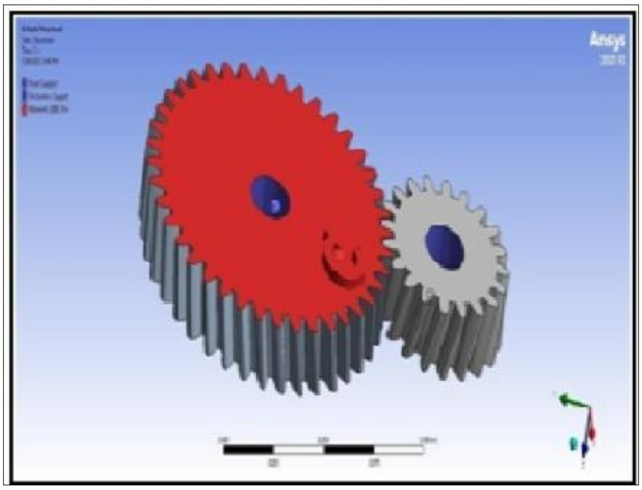

Figure 4. *Meshing Gear Set 3D Model.*

Figure 5. *Proposed System's Simulation Diagram.*

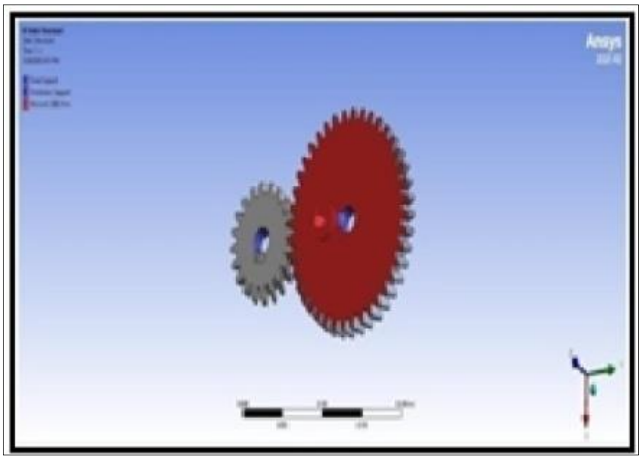

Figure 6. *Module 7 Helical Gear 3D Model.*

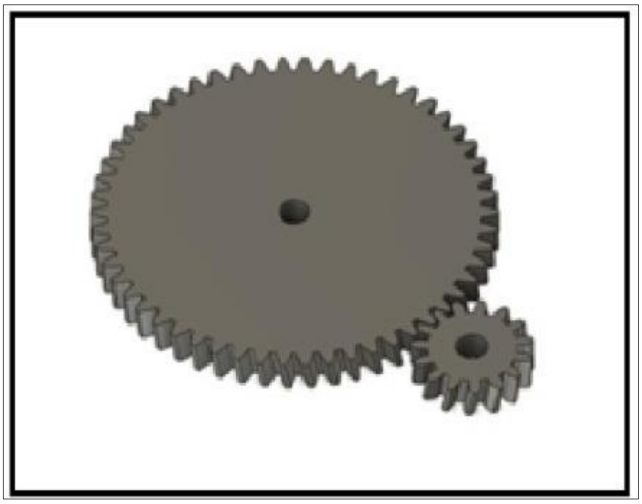

Figure 7. *Meshing Gear 3D Model Assign.*

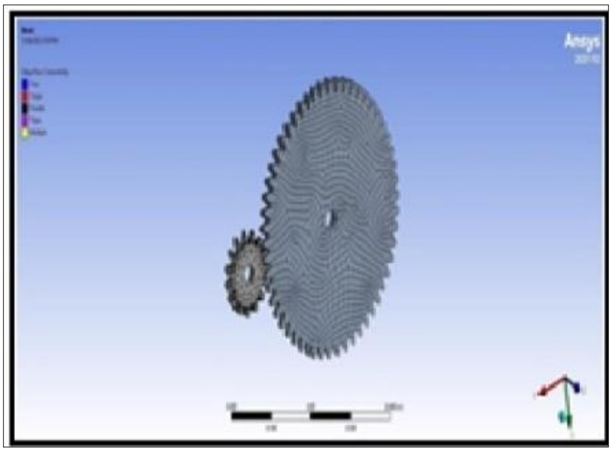

Figure 8. Meshing Gear 3D Model Assign.

Table 1. System Specifications.

System Description	
Specifications for Hardware	Processor type: Intel Core i5 RAM: 8 GB of 64-bit RAM 1 TB of storage
Display	20-inch color LCD
Specifications for software	Fusion 360 Autodesk Workbench ANSYS 2021 R2 Fusion 360 Autodesk

Fusion 360 is a CAD/CAM [15] solution for teamwork in product creation that runs on the cloud.

Fusion 360 facilitates product ideation exploration and iteration as well as distributed product development team cooperation.

Fusion 360 is a comprehensive program that integrates mechanical design [14] manufacturing, and organic shape modeling.

3.4. Overview of Fusion 360

Fusion 360 is a CAD/CAM solution for teamwork in product creation that runs on the cloud. Fusion's technologies facilitate cooperation among members of a product development team as well as the investigation and refinement of product concepts. Fusion 360 is a concept-to-production toolkit that makes it quick and simple to explore design concepts. Fusion enables you to concentrate on the design, engineering, and construction of your goods. Utilize the modeling tools to add final touches and the sculpting tools to investigate shape.

You may swiftly iterate over design [9] concepts using these tools. After deciding on a design, you can make assembly to check that it fits and moves properly, or you can make photo-realistic renderings to confirm how it looks. Making your design a reality is the last step. Utilize the CAM workspace to design tool paths for your components' machining, or the 3D print workflows to quickly produce a prototypeCombination.

Additionally, 360 foster team collaboration in design teams for joint product creation. Since all of your designs are kept on the cloud, you and your group may always access the most recent information. Versions of your design are also tracked by Fusion while you work. With Autodesk A360, you can promote an older version to the most recent version and view each version in your web browser. Lastly, track design activities and share your designs [10] using Fusion and A360. Fusion 360 offers a hybrid environment that leverages the power of the cloud when appropriate and allows you to grant controlled access to your creations without having an Autodesk ID.

When appropriate, makes advantage of local resources. For instance, each time you save an updated version of your design, the design data is rendered and saved in the cloud, producing breathtaking visuals. While you are working locally on your machine and developing and revising designs, this is happening concurrently. This enables you to simultaneously utilize the power of the cloud and your computer. You study these Fusion 360 sections during this course. This course helps you learn how to create using Fusion and shows you how it can streamline your design workflows.

3.5. Helical Gear Parameters and Material Properties

The Parameters of Helical Gears

The helix angle of helical gears ranges from 7 to 30 degrees. These gears can operate at higher speeds and silently while transmitting greater power. The helix angle needs to match for the pinion and gear to mate. The normal module and the number of teeth on each gear and pinion are required in order to calculate the helical gear specifications. The table below lists the calibrated values for the SPTC helical gears.

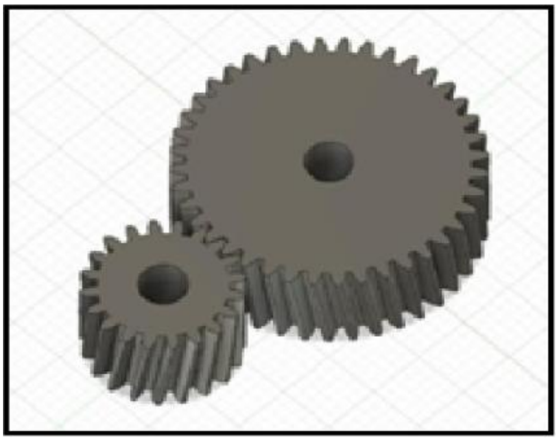

Figure 9. Helical Gear Set Design.

Module 3 helical gear

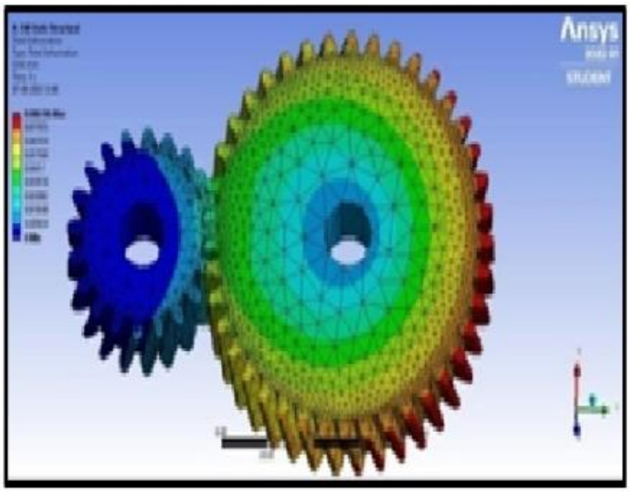

Figure 10. *Totaldeformation.*

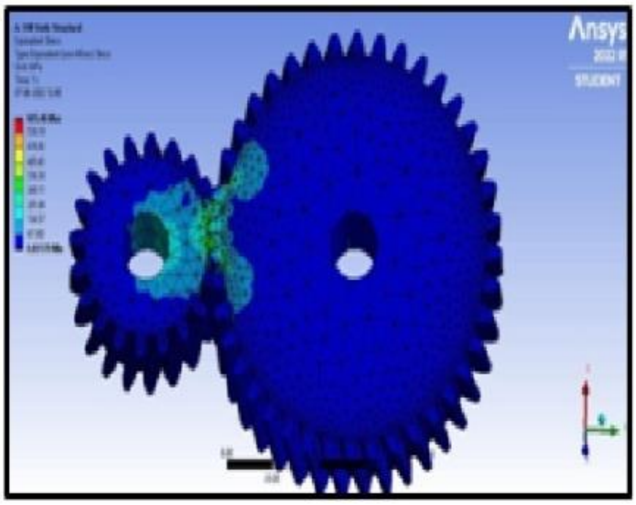

Figure 11. *Equivalent stress.*

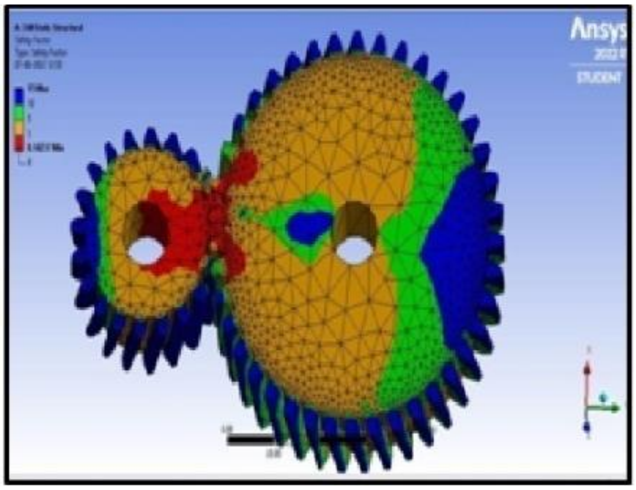

Figure 12. *Factor of safety.*

Helical gear in Module 4

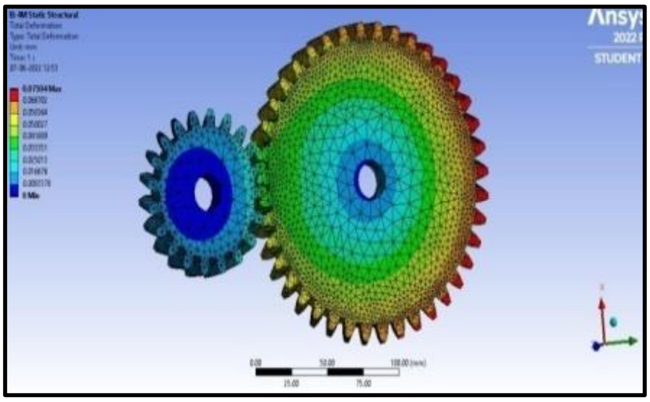

Figure 13. *Total deformation.*

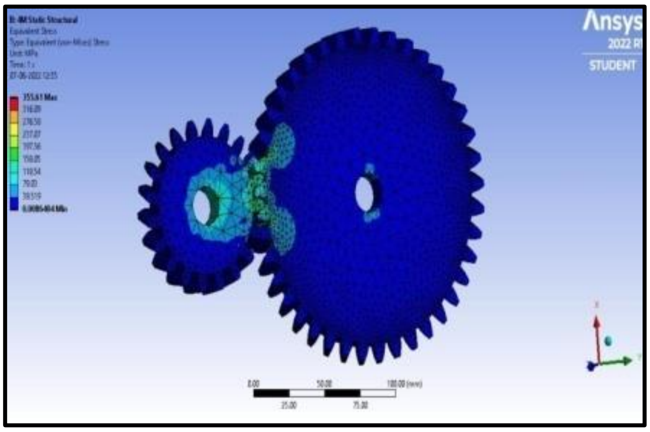

Figure 14. *Equivalent stress.*

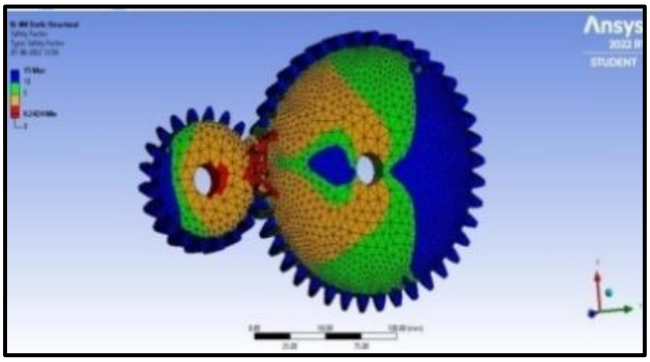

Figure 15. *Factor of safety.*

Helical Gear in Module 7.

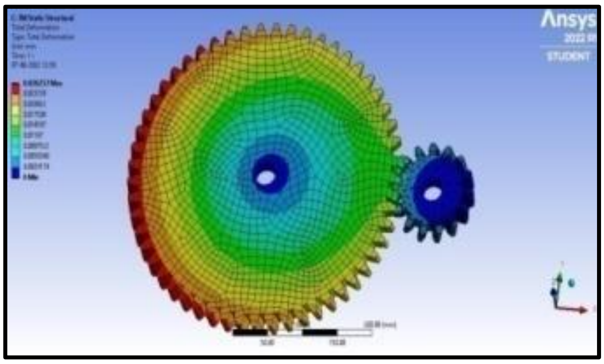

Figure 16. Total deformation.

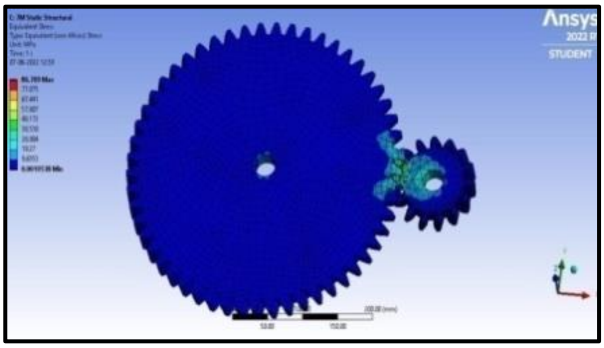

Figure 17. Equivalent stress.

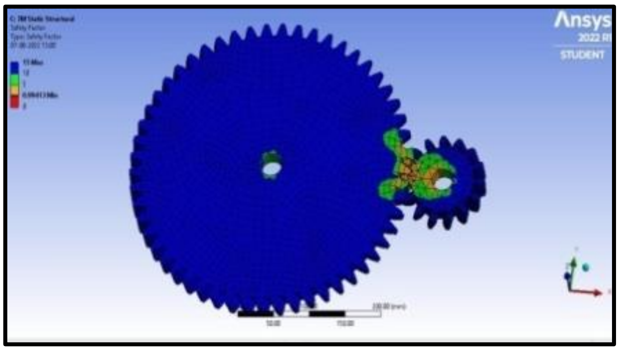

Figure 18. Factor of safety.

Helical Gear with 14 Helix Angle in Module 7

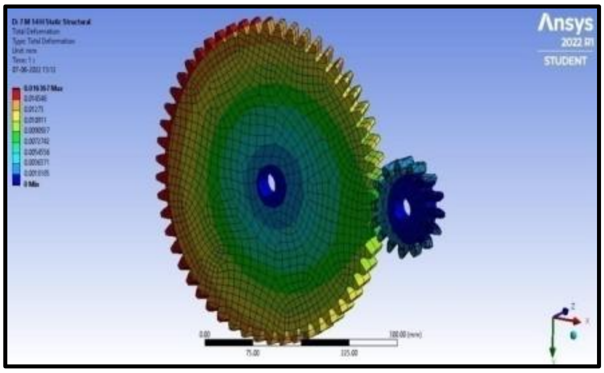

Figure 19. Total deformation.

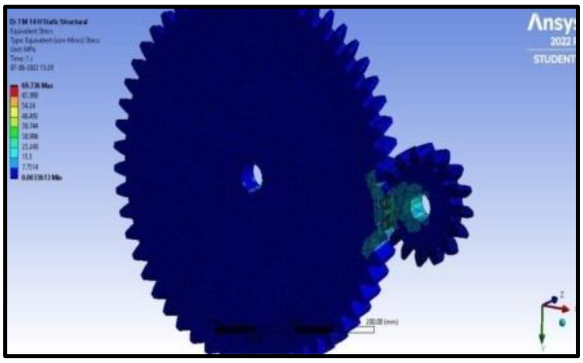

Figure 20. Equivalent stress.

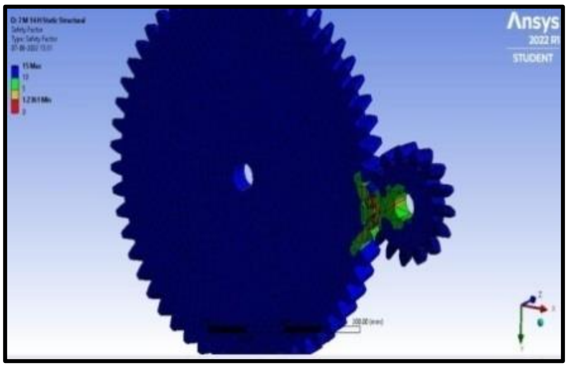

Figure 21. Factor of safety.

Module 7, 15 Helix Angle Helical Gear Total

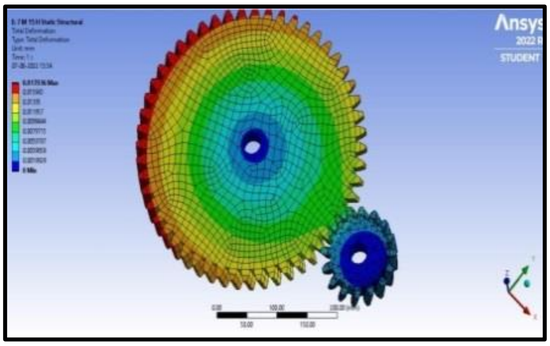

Figure 22. Total deformation.

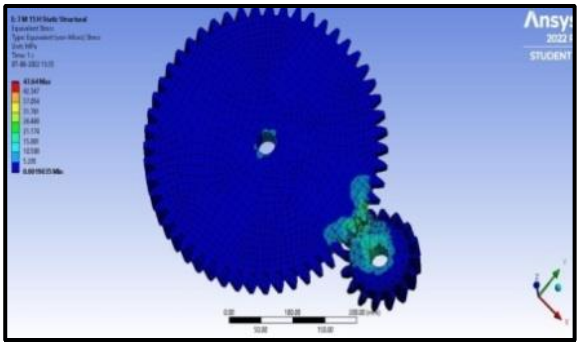

Figure 23. Equivalent stress.

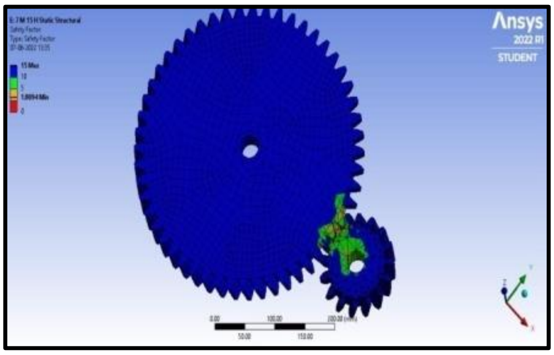

Figure 24. Factor of safety.

Module7, 16-HelixHelicalGearHelixAngle

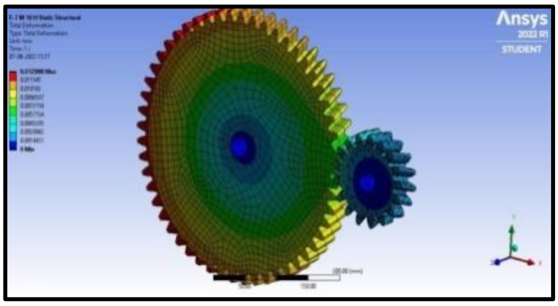

Figure 25. Totaldeformation.

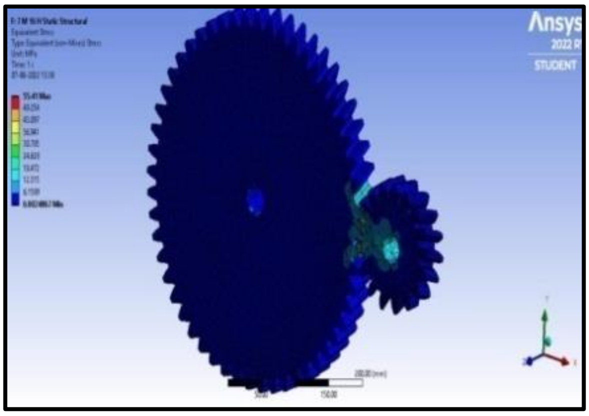

Figure 26. Equivalentstress.

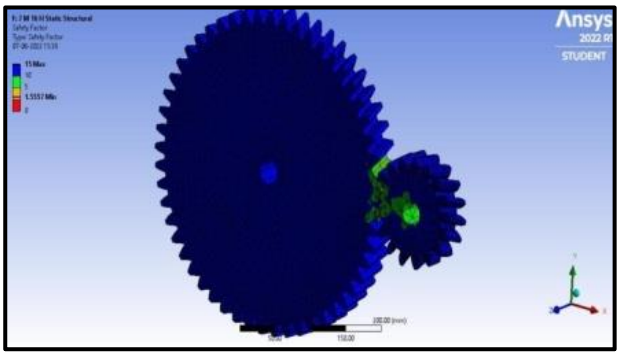

Figure 27. Factorofsafety.

HelixAngleHelicalGearinModule7and17

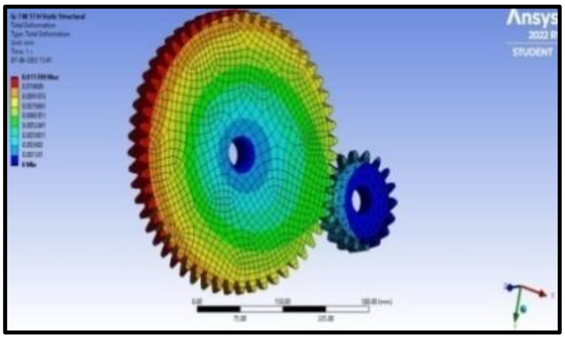

Figure 28. Totaldeformation.

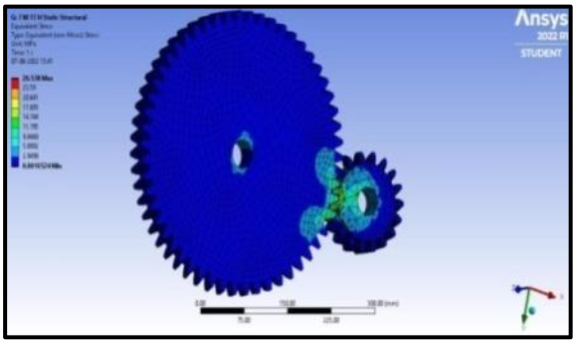

Figure 29. Equivalentstress.

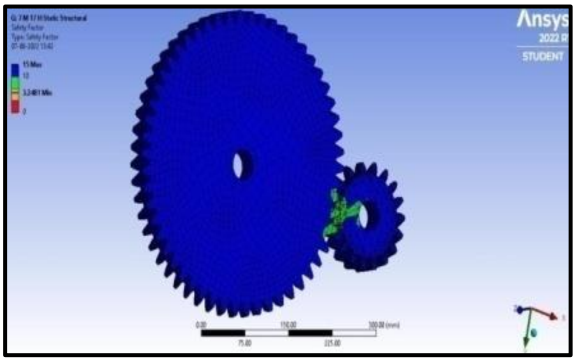

Figure 30. Factorofsafety.

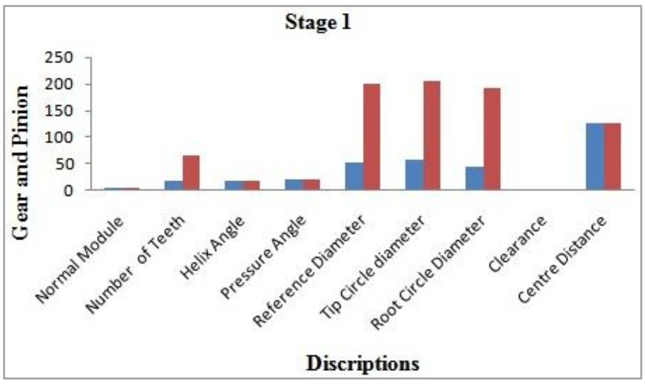

Figure 31. Stage I.

Table 2. Calibration of Helical Gear Parameters for Every Gear Set in the SPTC Gearbox.

S.No	Description	Stage 1		Stage 2		Stage 3	
		PINIO N	GEAR	PINIO N	GEAR	PINIO N	GEA R
1	Normal Module	3		4		7	
2	Numberof Teeth	16	64	16	71	15	54
3	Helix Angle	16.26		14.835		14.983	
4	Pressure Angle	20		20		20	
5	Reference Diameter	50	200	66.21	293.79	108.70	391.30
6	Tip CircleDiameter	56	206	77.41	298.59	127.60	400.40
7	Root Circle Diameter	42.50	192.50	59.41	280.59	96.10	368.90
8	Clearance	0.75		1		0.35	
9	Centre Distance	125		180		250	

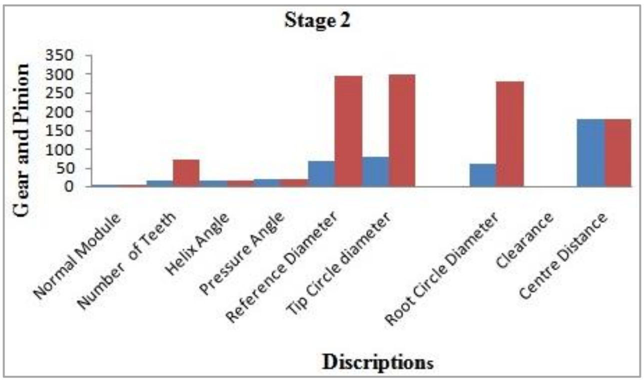

Figure 32. Stage II.

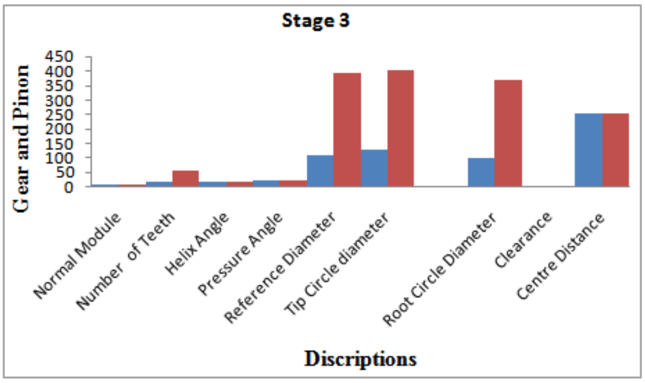

Figure 33. Stage III.

3.6. The Helical Gear's Material Properties

All of the aforementioned gears have the same material qualities. The table below lists the gear's properties in tabular form.

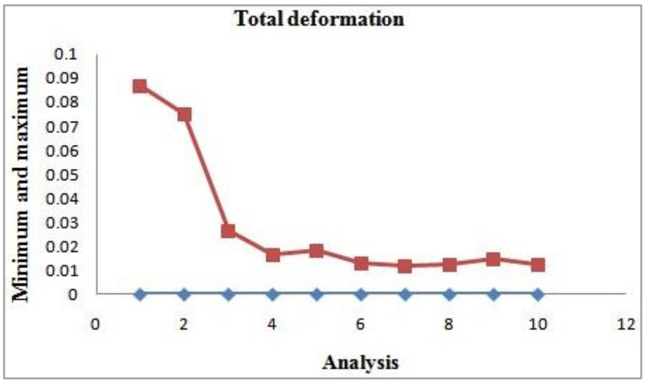

Figure 34. Factor of safety.

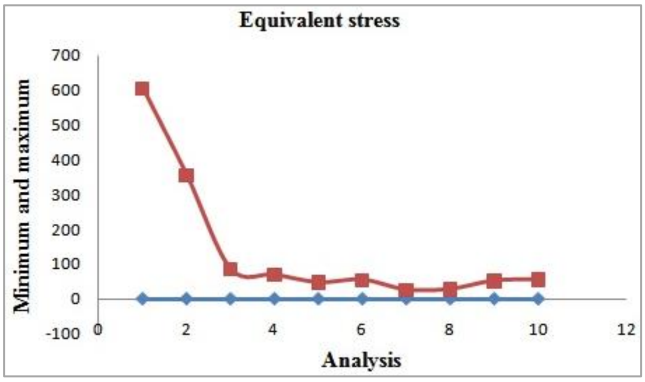

Figure 35. Factor of safety.

Table 3. Structural Steel's Mechanical and Chemical Properties.

ChemicalComposition		Properties		Mechanical Properties of Structural Steel	
Carbon	0.22	Density	7850 g/m^3	Tensile Strength (MPa)	320
Silicon	0.280	Specific heat capacity	486 J/(kg*K)	Young's modulus (MPa)	210
Manganese	1.03	Electric resistivity	1.62*10-7 ohm*m	Elongation	38
Phosphorus	0.040	Electrical Resistivity	0.72 x 10^{-6}Ω.m	Poisson's ratio	0.3
Sulphur	0.050			Yield strength (MPa)	250

Table 4. Overall Result.

S.No	Analysis	Total deformation		Equivalent Stress		Safety Factor	
		Min	Max	Min	Max	Min	Max
1	Load on static structural 3 helical gear	0	0.086706	0.03179	605.46	0.14237	15
2	Impact on static structural 4 helical gear	0	0.07504	0.086404	355.61	0.2424	15
3	Impact on static structural 7 helical gear	0	0.026257	0.0010538	86.709	0.99413	15
4	Impact on static structural 7 helical gear 14 angle	0	0.016367	0.0033613	69.736	1.2361	15
5	Impact on static structural 7 helical gear 15 angel	0	0.017936	0.0019035	47.64	1.8094	15

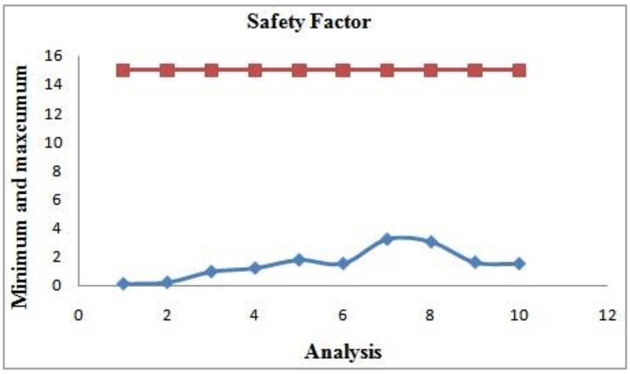

Figure 36. Factor of safety.

4. Conclusions

ANSYS Workbench and AUTODESK FUSION 360 are used for analysis and modeling, respectively. When designing gears, the condition of stress is determined in part by pressure angle, helical angle, and face widths. The stress values obtained are smaller than their yield stress, as can be shown by looking at the analytical findings. The design is safe to use under working conditions, it may be inferred. Under safe operating conditions, the designs at Modules 3 and 4 are within permissible bounds; nevertheless, Module 7 demonstrates that the stresses exceeded the yield stress. Therefore, fusion 360 is used to redesign the helical gear at module 7 with a constant module, face width, constant pressure angle of 20, and changing helix angles (14, 15, 16, 17, 20, 25, and 30). The stresses for the examination of the remodeling gears are calculated at various helix angles while maintaining a constant face width. It can be observed that under the identical module and SPTC gear box operating circumstances, the contact stress at 14 degrees is comparatively lower.

Conflicts of Interest

The authors declare no conflicts of interest.

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