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Design Modelling and Analysis of Helical Gear using FEA for various materials

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ABSTRACT:
Gears play one of the vital role in mechanical power transmission systems. It is a rotating components consists of tooth part in order to transfer torque. Helical Gears, Spur Gears, double helical Gears, crown Gears, Bevel Gears, Rack Gear, Worm Gears and Epicyclic Gears are some of the various types exists. Our paper relies on computational and finite element analysis to design and modelling to stresses and pressure distribution for the properties of an active helical gear network. One of the key component to the bending of the fault and surface tension of the gearbox is established. Therefore, It is of concern to mitigate the loss of machinery and to maximize the measurement of stresses of the gear configuration. A three dimensional solid model of a series of gears is created using ansys Program to estimate and define the various stresses and other essential parameters of helical gears.
This paper also cover the analysis and detailed study of stress generated in between two Gears. During our study a pair of two Helical Gears are used and result are shown by using FEA Software using the following two conditions for the same power output.

- Gear Pair made of stainless steel.
- Gear Pair made of Nylon Material.

The tests from ansys Software explore the usage of Nylon as a substitute medium for conventional devices, such as steel for strength and/or motions. Helical Gears are common types of Gear. Two kinds of cyclical tension are involved in the operation of a set of gears. Bending Stress and Contact Stress; At the same level of exhaustion, all tension cannot reach their optimum values. Through identifying the issue at the preparation stage and creating a suitable tooth surface profile with appropriate manufacturing processes, these forms of failures may be reduced. We are also trying to calculate the Bending Stress, Static Load and Contact Stress on the tooth of Helical Gear[4].

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I. INTRODUCTION

Due to rapid growth in Industry and globalization competition among the industry is increasing day by day. Alternative technologies for producing materials used for gears is more and more important in today's world. The high volume production sector, such as the automobile industry, is distinguished by a range of processing products utilized, such as metal removal, casting and shaping, which is more desirable than convection that involve finishing processes, efficient usage of the raw materials, shorter-cycling periods and better energy use. There are too many processes involving load and a part tension need to be learned[13]. We often incorporate processes and tension and are closely interlinked. Helical Gear is the simplest type of gear that has been cut to the tooth in parallel with the shaft axis. Power movement between parallel shafts is achieved by pinion gears. The operating performance of Helical Gear is 98-99 per cent. In filled and revolving gear teeth, there are increasing types of pressures. We have to consider all the possibilities into consideration, so that the gears have a balanced arrangement to sustain all the pressures[9].

In general terms, stresses measured in the gear configuration process are not a direct stress, it may be complicated for the right solution in gear-tooth tension, because it cannot be understood whether the load is distributed equally around the face width and whether the two or three sets of teeth that are in the mesh at the same time

coordinate correctly. We will also find the best path to issues such as tension, lingering pain, ineptitude and tooth misalignment.

FIGURE NO – 1: STRUCTURAL ANALYSIS OF HELICAL GEAR

To handle and study failure mechanism, we have considered two theoretical formulas as follows:

1. ***Hertz Equation:*** to calculate the total amount of Bending Stress. The system of finite element models may provide this knowledge, but it's time to generate such a model. The software can be used to reduce modelling[1]. FEA workbench is one of these versions.

2. ***Finite Element Method:*** The finite element process is the scientific computational analysis with possible solutions to a broad variety of engineering problems. Due to its complexity as an analysis tool, we find it essential to obtain approximate solutions to the problems instead of being exact similar to solutions, because it cannot be obtained in an analysis tool in the engineering school and in the business, because of the more and more engineering problem. An empirical approach is a mathematical concept that considers every spot in the body of the need uncertain substance and is thus true for an unlimited number of locations in the body[6]. The engineer's tool to quantitative approach offers the estimated solution for the question concerning complicated material properties and boundary conditions.

II. RELATED WORK

Experimental tests and research include the assessment of the material fringe nature of the Finite Element substance for testing, the detection of stresses in a sample and test scaling. In the entire question of elastic visual stress analyses, the precision of the Finite Element Model has a great impact on the results obtained, so planning the model is critical. The next steps are the planning of the concept of the finite element.

- Pattern making: For moulding 3D model, it is necessary to make pattern either of metal or wood. In previous work, prototype of a helical gear itself is used as a pattern.
- Design the Pattern in Rubber Mould and install in wooden Frame: In proportion of 100: 2.4. Silicon rubber vulcanizing at the room temperature was produced from Sylartivi-11 & catalyst. Casting pattern & scale disk. The device was constructed of Araldite CY203-1 IN epoxy resin in a proportion of 100:7 combined with HY-951 hardener. The reference disk was shaped in the same way to define the content fringe interest.

Praveen M Kinge [1], observed in his stress analysis experiment using ANSYS on gear box which is used in the sugar Manufacturing Companies and he was found that, the failure for Gearbox was teeth edges due to wear of teeth. This is primarily because of the elevated tension pressure on teeth surfaces. Three improvements have been introduced to minimize these pressures. The three improvements were firstly the teeth edges tapered by angles to 20, secondly the wheel groove, and lastly, the teeth root holes[8]. When analysing this, it was noted that the existing design of the gearbox isn't at the safe limit. Life is improved after the adjustment of the gearbox by strengthening safe controls.

M Prashant [2], On Analysis and Design of Helical Gear using AGMA and ANSYS standards quoted in his paper at any point of time only one teeth was in contact and take the total load. The necessary torque can be transferred with the aid of a loading frame via the loading worm & wheel and fringe method. That transitions torque from worm to worm wheel and stresses are pushed into the wheel as the wheel movement finishes. The loading frame has been designed and developed to load the calibration disk. This passes torque from worm to worm wheel and stresses are forced into the wheel as the wheel movement ceases. The loading frame has been designed and developed to load the calibration disk. The following parameters are needed for the design of loading frame and for load prediction of the model. Worm wheel speed (n) = 1439 rpm Worm gear transmission torque = 33257.27 N.mm Power transmitted by gearbox (P) = 5.0 kW Tangential components, acting on wheel, = 16732.57 N Appropriate fringes load of 2 kg was required.

Rati Jain, Pratik Goyal [3], conducted research on Spur Gear Box using SCM415 and 15NiCr1Mo15 Material using Contact Stress Technique on Gear Box and found different results. Deformation type of Model has been used using ANSYS as Software for Analysis purpose[7].

S Sai Anusha et al. [4], carried out an experiment at helix angles, face width and different pressure angle using ANSYS and AGMA Software to carry out Contact Stress Analysis of Helical Gear. The ANSYS app utilizes a strong 3D model built with ProE app, as well as the numerical tension solution. The results achieved are measured with the AGMA stress calculation, according to specific parameters, which can help to design helical gears in a safe and efficient way[10].

Design and Modelling Gear System is one of the critical and challenging part of in Mechanical Industries, several proposal and papers are published which are under research. The study of gear tension, transmission faults, the estimation of gear dynamic loads, transmission noise and optimal configuration of gear sets also constitute major issues in gear architecture[2].

III. PROPOSED WORK

The main objective of the project is to design and analysis a three-phase cyclical planetary helical gear reduction unit which is designed to meet the 64:1 reduction ratio performance specifications. The assembly and interference function is designed in ANSYS. All the parts. For the measurement of its strength, the modelled components are used. Our goal is to obtain a 64:1 reduction ratio for a cyclical three-stage planetary gear reduction. The steps involved in Design and Analysis of Helical Gear are as follows

- Designing.
- Modelling.
- Analysis of Modelling of the Helical Gear using ANSYS Software.

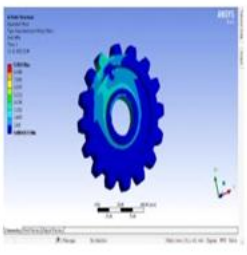

Fig No. 3 : Stresses Distribution in Helical gear made of Cast Iron

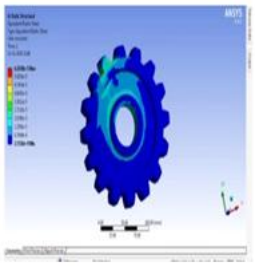

Fig No. 4 : Total Deformation on Helical Gear made of Structural steel

HELICAL GEAR MODEL SPECIFICATION

Helical Gears are more precise compare to Spur Gear. The teeth 's leading edges are not in line with the moving direction, but at an angle[3]. This angling is a segment of the helix since the gear is curved. In parallel or crossed paths, helical gears may be meshed. The first applies to the parallelness of the shafts and this is the most famous instruction. The shafts are not parallel to the latter. Winked teeth gradually become more smooth and silent than spurred gear teeth. With parallel helical gears, each pair of teeth first contact on one side of the gear wheel at a single point; then a moving contact curve gradually grows across the face of the tooth to maximum level then retreats into contact until the teeth break in a single spot on the other side. Helix Angle, Angle between a tangent to the helix and the gear axis. Is zero in the limiting case of a Spur Gear.

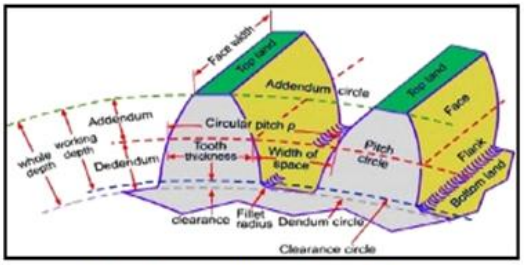

Fig No .5 : Helical Gear Nomenclature

Helical Gear Geometric Proportion

P = Circular pitch = $d\ g.p/z_g = d_p.p/z_p$

P_n = Normal circular pitch = $p.\cos\beta$

P_n = Normal diametrical pitch = $P/\cos\beta$

P_x = Axial pitch = $p_c /\tan\beta$

M_n = Normal module = $m/\cos\beta$

α_n = Normal pressure angle = $\tan^{-1}(\tan\alpha.\cos\beta)$

β = Helix angle

d_g = Pitch diameter gear = $z_g.m$

d_p = Pitch diameter pinion = $z_p.m$

a = Centre distance = $(z_p + z_g)* m_n /2\cos\beta$

a_a = Addendum = m

a_f =Dedendum = $1.25*m$

The spur gear unexpectedly adds tension and noise to a linear touch over the whole range. Spur gears produce a distinctive high speed whine and cannot torque as much as Helical Gears[6]. In situations where noise control is a problem, where spore gears are used for low speed applications, the use of Helical Gears is indicated if high speeds, high power transmission or the reduction of noise are important for applications. The speed is called a strong one because the velocity of the pitch line is over 25m/s Very sometimes helical gears are used with the helix angle of one with the negative helix angle of the other, a pair of a right-handed helix and an equivalent left-handed helix. The two angles are identical but opposite: the angle of the shafts is negative, i.e. the shafts are parallel. Where the total or gap is not nil the shafts are crossed, as mentioned above. The shafts. The helix corners are on the same hand with shafts crossed at the correct angle as they would reach 90 degrees.

IV. DESIGN METHODOLOGY

Spur Gear are widely used by experts because they are very easy to manufacture, if you want to transmit power in between parallel shafts. In case of some operations such as Smoother Engagement, Noiselessness, Meshing of Teeth Helical Gears are preferred[2]. When parallel Helical Mesh with each other, the following condition must be satisfied.

- Both the Gear should maintain equal Helix Angles.
- Teeth of the Gear must have the equal design and Module.
- One gear should have left handed helices and opposite one right handed helices angle.

In this paper, Based on different categories of Gear tooth, Design equation and assumption from variables the transmission ratio analysed and calculated. Let us assume Full Dept Profile = 20^0 ; Helix Angle (β) = 17^0 ‘ Max No:of teeth on pinion (Zp) = 21; and Normal Module (Mn) = 5.

Geometric Property	Gear	Pininon
No: of Teeth	51	19
Diameter of the Pitch Circle	261	105
Standard Design	6	6
Helix Angle	60^0	60^0
Width of the Phase	65mm	65mm
Angle of the Pressure	21	21
Diameter of addendum	271	114
Diameter of Dedendum	248	91

Table 1 : Analysis of Gear Dimension

SOLID FRAMEWORK MODELING OF HELICAL GEAR

The project engineer will use our structure to direct the creation of the component in its characteristic parameters. The key parameters specifying the built gear may be used as criteria for determining the equipment during gear construction, for example the modulus, the pressure angle and the number of teeth. The equation modelling and relation is utilised, The relation is used to communicate relations between the dimensions required to determine the specific model parameters. In this work the plates, the pressure angle, the number of teeth, and the helix angle are known as the input parameters for the gears with various geometric properties to be modeled from the current models by just changing the few parameters upon which the gears depend.

In accordance with its property, the Skilled Engineer uses these criteria to establish the structure of the helical equipment and all details required to construct the layout[12]. The exact three-dimensional helical gear designs are built using the relation equation in Pro / Engineer. The installation of the equipment requires the left and the right helical gear into account. The file is then stored in the folder of IGES. In order to plan schematic model of machinery, the proportions derived from theoretical study have been used.

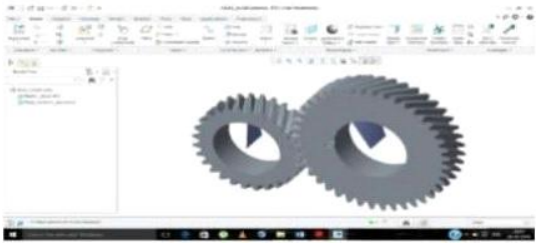

Fig No. 6 : Solid 3D Module of Helical Gear

CALCULATION OF HELICAL GEAR STRENGTH

To avoid the failure and damage of the gear during its life span a standard prerequisite are strictly maintained, a complete knowledge of individual gear teeth required to calculate the load carrying capacity. The most significant stress we are considered during design of gear are :

- Stress generated during teeth Bending process.
- Stress generated due to contact pressure (Hertz).

To calculate total bending stress in helical gear system, Hertz Equation is used which was introduced in 1892 and still remain same for most of the Gear Design System. In our paper, we have considered, Helical Gear system as Cantilever Beam as shown in figure[7]. The tangential force variable (Ft) induces the moment of bending across the tooth 's foundation.

ASSUMPTIONS:

1. The full pressure is distributed in static state on the tip of a single tooth.
2. The minute Radial Component is utilized.
3. The load is distributed over the whole facial width evenly.
4. Powers are negligible regardless of slipping friction.
5. The tooth fillet pain concentration is negligible.

The total bending stress is calcuted using standard Lewis Bending Equation according to AGMA Norms[11]. The values which are obtained during experiments are as follows

σ_b = Ft Kv Ko (0.93Km) b m J Where,

- Face width (b) = 21mm
- Load distribution factor = 1.3

- Geometry factor (J) = 0.593
- Dynamic Factor (Kv) = 1.17
- Overload factor (Ko) = 2.0

SL NO	RATING OF TORQUE	BENDING STRESS (σ_b)
1.	351	92
2.	401	405
3.	421	111

Table No.2 : Bending Stress for Different torque condition

HELICAL GEAR ANALYSIS USING FEM (FINITE ELEMENT ANALYSIS)

Finite element analysis is a computer-based computational tool for the calculation in the defined boundary state of structural strength and behavior. The arrangement of the FEM is defined as finite elements and joined of different sections, known as the nodefinite element analysis is the numerical solution of the mechanical components obtained by the discretification of the mechanical components into a limited number of building blocks (identified as elements). Fem is an simple way to measure the tension produced in a pair of gears opposed to theoretical approaches. Therefore FEM is widely used for the stress analysis of mating gears.

The FEM research is performed with the aid of an analytical method ANSYS 14.0 for which we evaluate quantities such as absolute deformation, relative of lost force, maximal shear tension, normal frequencies and mode types in real boundary conditions[6]. Numerical models in Creo 3.0, which were imported into ANSYS as IGES to be further evaluated, were planned. The typical figure shows the Gear Analysis using FEM Technique.

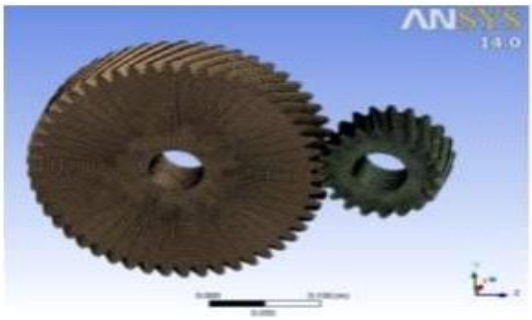

Fig No. 7: Gear Analysis Using FEM Technique

STRENGTH OF MATERIAL AND PROPERTIES

This project is designed to analyze, in contrast with standard steel alloy gear assembly, the structural and vibrator properties of composite type gear for the heavy duty device. We have considered the following materials to calculate the strength of material.

- The Metal matrix composite composite (MMC) materials.
- Carborized steel 10c4 with case hardening.
- Composite selected have AL 6061 matrix with 18% SiC reinforcedment materials.
- Carbon fibre reinforcement in epoxy resin.
- Caron fibre reinforcement in silicon carbide matrix.

Substituting the composite material for the gear have benefit of higher specific strength, less weight, better damping power, longer life, lower critical speed and greater torque carrying ability which can results in substantial amount of weight reduction as opposed to steel The composite material have the orthotropic elastic behavior rather than linear elastic properties. The research state was believed to be unchanged. The FEA research estimates technically the devices made by a hybrid Yung modulus and Young's alloy steel element and Poisson ratio are drawn from a concept database[5]. Young composite material module (varies with direction) is anisotropic and can be calculated by law of blend. The various mechanical properties of the selected material were given in the table below

Property	**Unit**	**Materials**			
		STEEL 10C4.0	ALSIC (21% SIC)	CARBON	CVI-C/SIC
Young Modulus	GPa	211	151	451	96
Poison Ratio		0.35	0.35	0.35	0.35
Tensile Strength	MPa	501	421	51	310
Density	Kg/m^3	7851	2811	1801	2101

Table No.2 : Strength Properties of different materials

MESHING OF GEAR ASSEMLY

The 3-D model for the gear-building was developed in creo 3.0 and was imported as an iges file format in ansys analytic software for the study of its structural actions at a specific load information condition[3]. After the model had been imported in ansys the appropriate material was added to the model and then meshed in ansys which split the whole body into a tethydral unit connected with nodes[8]. The total Nodes and Table are given below

	PART 1	PART 2
Nodes	92860	312726
Elements	20527	71962

Table No.3 : Meshing of Gear Assembly

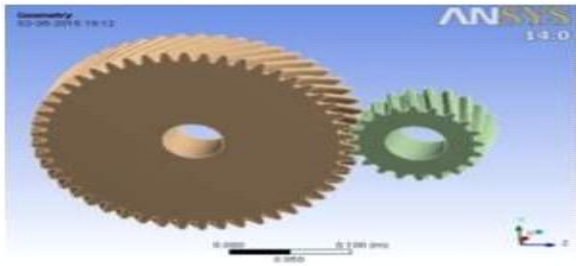

Fig No. 8 : Solid Modelling using Ansys

BOUNDARY CONDITION OF HELICAL GEAR

The frictional support is less added to the inner rim of a pinion gear to evaluate and model the actual situation as well as the frictionless support on the internal rim of the gear is added to facilitate its tangential rotation but to limit the radial transition. Period of moment relative to the torque in N-m, applied in clockwise direction as a moving location on the inner rim of the pinion.

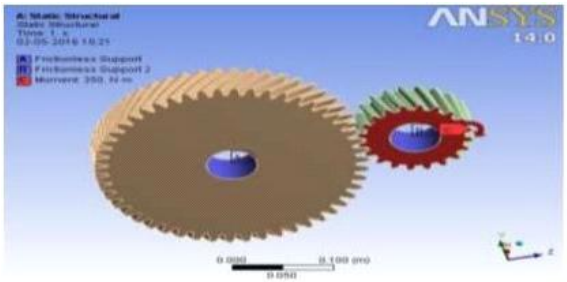

Fig No. 9: Boundary Condition of Helical Gear

STATIC STRUCTURAL ANALYSIS

To order to study the action of the system under the constant load pressures, static structural research has been performed thus considering inertia and damping effects as well as load-variable loads. All non-linearity forms, such as large deformations, plasticity, creeping, stress rigidity, contact elements etc. are allowed. This outcome defines how the system avoids the external loads applied. When the stress values measured in this study exceed the acceptable levels, the system itself would collapse. Such study is important to avoid such a loss. The FEA-based analysis method has been used in this project to investigate the structural behavior, for each composite material, of various compositing materials under the defined boundary conditions, by evaluating overall deformation, equivalent of lost stress for each composite material and then the relation.

The structural tests focused on FEM were shows as: AT TORQUE = 350 N-M AT 4000RPM1. Simulation findings of steel alloy and Al-SicC composites were shown below. Stuff for traditional steel[6].

AT TORQUE = 350 N-M AT 4000 RPM

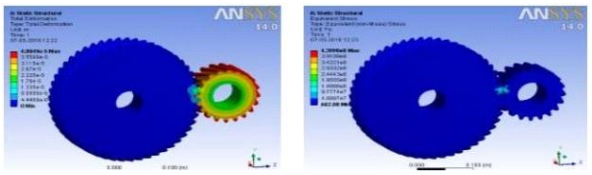

Figure No.10 : Convetional Steel Material

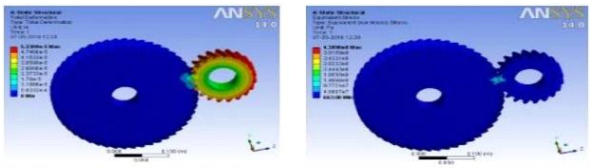

Figure No. 11 : The Aluminium silicon carbide composite

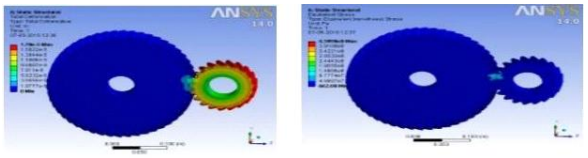

Figure No. 12 : For the 50% carbon fibre reinforced in epoxy resin

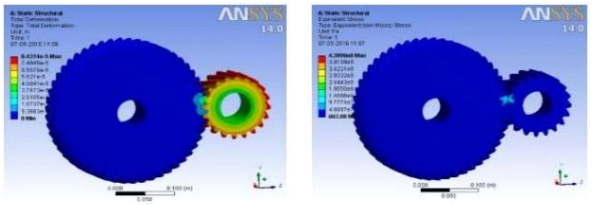

Figure No. 13 : For carbon reinforced silicon carbide ceramic composite

V. FINAL ANALYSIS AND RESULT

The comparison of results both numerically and analytically obtained from existing design for SPTC Gearbox of each gear set of Helical Gear are presented in the table no (4).

TORQUE CONDITION	EQUIOVALENT STRESS (VON - MISSES) MPa				TOTAL DEFORMATION (m)			
	steel	Al-SiC	c-epoxy	C-SiC	steel	Al-SiC	c-epoxy	C-SiC
350 Nm	439.2	438.64	439.98	438.7	$4e^{-5}$	$5.3\ e^{-5}$	$1.78\ e^{-5}$	$8.43\ e^{-5}$
400 Nm	562.5	562.125	562.83	563.5	$4.5e^{-5}$	$6.1\ e^{-5}$	1.93e-5	$9.69\ e^{-5}$
420 Nm	590.6	589.9	590.25	587.2	$4.8\ e^{-5}$	$5.5\ e^{-5}$	$2.13\ e^{-5}$	$10.2\ e^{-5}$

The helical gear reconstruction carried out at stage 3 found that such stresses were strong because of the point touch between the gear teeth regardless of decimal angles at the helical angle between the knotted gear. Table no (4) demonstrates the contrast of the findings obtained from the re-design of SPTC gears in both numerical and theoretical terms. A constant package is used to rebuild the helical gear as the diameter of the gear and other parameters are depending on the sensor. Touch pressures are caused by increasing helix angles.

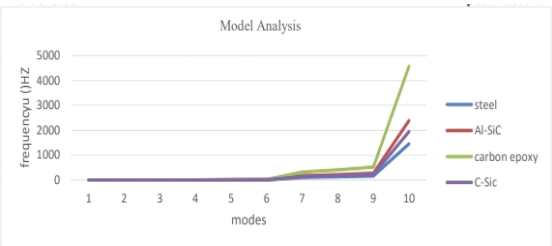

Fig No. 14 : Final Analysis

VI. FUTURE SCOPE OF WORK

Recommendation and future work In the light of this work, the following areas should be investigated further.

- In the field of bending in all forms in gears, such as spur, bevel or other dental designs, three dimensional statistical approaches may be researched and tested.
- Numerical research and study methods may be performed in all gearboxes, including gear boxes and bearing, with all elements in the system.
- Numerical methods for testing and analysis may be done with and without breaking teeth, surface pitting or strain on machines in mesh under complex conditions.
- More results can be achieved with different parameters like module, facet width, no. of teeth and helix angle.

VII. CONCLUSION

The project aims to decrease the distribution of stress, deformation and weight of the spur gear by using composite materials when applying the gearbox. The solid model of the gears was developed in Creo 3 for this purpose. A 0-cad-software analysis was conducted to classify the stress produced at different loading conditions relative to each other by means of relations and parameters for five different transmission ratios and a theoretical and software dependent impedance analysis.

The method used for testing composite and steel appliances is ANSYS In order to figure out the absolute deflection, equal of misses of stress and free vibrational natural frequencies up to 10 modalities, both the content and the different assumptions, research is carried out under the static and rigid framework for the three torque levels.

- For the gearbox application, the comparison was successful between the conventional steel gear material and the composite materials for different load conditions.
- Of specific stresses determined by the Lewis bending method, the bending stress for the substance was below the allowable bending stress.
- The static study performed by Fem under specific load environments reveals that the overall deformation and stress caused in the composite are smaller in the carbon epoxy composite than other composites.

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