DESIGN, MODELING AND STRESS ANALYSIS OF HIGH SPEED HELICAL GEAR ON BASIS OF BENDING STRENGHT AND CONTACT STRENGTH BY CHANGING FACE WIDTH AND HELIX ANGLE

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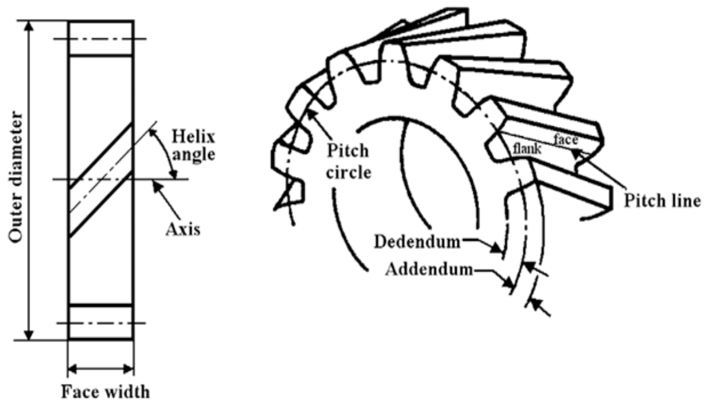
Abstract: This process is based on the helical gear under the title Design, modeling and stress analysis of high speed helical gear on basis of bending strength and contact strength by changing face width and helix angle in ANSYS environment. In this, simulation of helical gear by changing parameter to obtain result and efficient life of helical gear.
There are commonly two types of stresses in gear teeth
1. Bending stress
2. Contact stress
Because of these stresses the result failure of gear teeth. Fatigue fracture is due to the bending stress and pitting failure due to the contact stress at contact surface. Therefore bending stress and contact stress are to be considered for designing of gear. Most of heavy loaded gear are made from ferrous metal and that have infinite life for bending loads but it impossible to design gear with infinite life against surface failure. The principle of failure modes are studies based on the calculation of bending stress. For smoother and noiseless operation and for power transmission helical gear are widely used in Industries. For estimate the bending stress, three dimensional solid models for different face width and for estimate contact stress three dimensional solid model for different helix angle are generated in ANSYS. ANSYS is powerful and modern solid modeling software and the numerical solution is done by AGMA, which is a finite element analysis package. The analytical solution by using Lewis stress and Hertz stress formula. In this work the model and stress analysis of helical gear on ANSYS and than compare result of the procedures.
KeyWords: Gear design, Analysis, ANSYS, ANOVA etc.

I. INTRODUCTION

A mechanical engineer's work is to design, develop or modify new things that provide comfort for human race. Hence continuous evaluation, evolution and improvement are needed to move with the pace of the booming world. So to improve gradually or modify gradually, things are to be learnt from past experiences. The failures or the defects which lead to failure, also show the flaws of the design or manufacturing or quality or assembly department. Hence it can be concluded that analysis of failure gives an insight of the mistakes that can be minimized or rectified in future. This works as a feedback loop in the evolution process. Analysis of fault is the process of collecting and analyzing data to determine the cause of a failure. Failure investigations help clients prevent failures, extend component service life, and establish inspection intervals. Breakdown of any unit, system or equipment is an avoidable and costly occurrence and must be prevented or minimized. Analysis of such failures becomes a resourceful and affordable tool in addressing such unwanted occurrences.

Fig1: Nomenclature of helical gear



1) MODULE: Module of a gear is defined as ratio of diameter to number of teeth. m=d/N
2) FACE WIDTH: The width along the contact surface between the gears is called the face width.
3) TOOTH THICKNESS: The thickness of the tooth along the pitch circle is called the tooth thickness.
4) ADDENDUM: The radial distance between the pitch circle and the top land of the gear is called the addendum.
5) DEDENDUM: The radial distance between the pitch circle and the bottom land of the gear is called the dedendum.
6) PRESSURE ANGLE The angle between the line joining the centers of the two gears and the common tangent to the base circles.
7) HELIX ANGLE: It is a constant angle made by the helices with the axis of rotation.
8) AXIAL PITCH: It is the distance, parallel to the axis,

between similar faces of adjacent teeth. It is the same as circular pitch and is therefore denoted by pc. The axial pitch may also be defined as the circular pitch in the plane of rotation or the diametric plane.

9) NORMAL PITCH: It is the distance between similar faces of adjacent teeth along a helix on the pitch cylinders normal to the teeth. It is denoted by pN. The normal pitch may also be defined as the circular pitch in the normal plane which is a plane perpendicular to the teeth. Mathematically, normal pitch, pN = pc cos

Methodology for the process:

- For the process of improve the efficiency of helical gear and change some parameters by trial and error method.
- For that the maximum bending stress, contact stress and shear stress by changing face width and helix angle by keeping rest of parameters are constant.
- Change of face width and helix angle and analyse on ANSYS package and for maximum stresses.
- After get the value of ANSYS result it will be compare with taguchi method by arranging L9 array, design of experiment (ANOVA Analysis) and find best result.

II. DESIGN METHOD AND CALCULATION

In this work optimization of helical gear, according to this I change some parameters of helical gear like face width and helix angle for purpose of improve Bending stress, contact stress and shear stress according to AGMA.

A. BENDING EQUATION THEORY

This bending stress Equation derived from the Lewis

$$\sigma_b = \frac{Ft}{bY}Pd$$

formula. Bending Stress is given by

The AGMA equation for bending stresses given by,

$$\sigma_b = \frac{Ft}{bm_nj}k_vk_o(0.93k_m)$$

Where,

Ka = Application factor
Km = Load distribution factor
Kv = Dynamic factor
Ft = Normal tangential load
J =Geometry factor

B. HERTZ CONTACT STRESS THEORY

The surface compressive stress (Hertzian stress) is found from the equation.

$$\sigma_c = \sqrt{\frac{F_t}{\Pi B\cos\Phi} * \frac{\frac{1}{r_1}+\frac{1}{r_2}}{\frac{1-v_1^2}{\varepsilon_1}+\frac{1-v_2^2}{\varepsilon_2}}}$$

Where,

$$r_1 = \frac{d_p \sin\Phi}{2}$$

$$r_2 = \frac{d_g \sin\Phi}{2}$$

The AGMA equation for contact stress is given by,

$$\sigma_c = c_p\sqrt{\frac{F_t\left(\frac{\cos\Phi}{0.95CR}\right)K_vK_o\left(0.9K_m\right)}{BDI}}$$

Where,

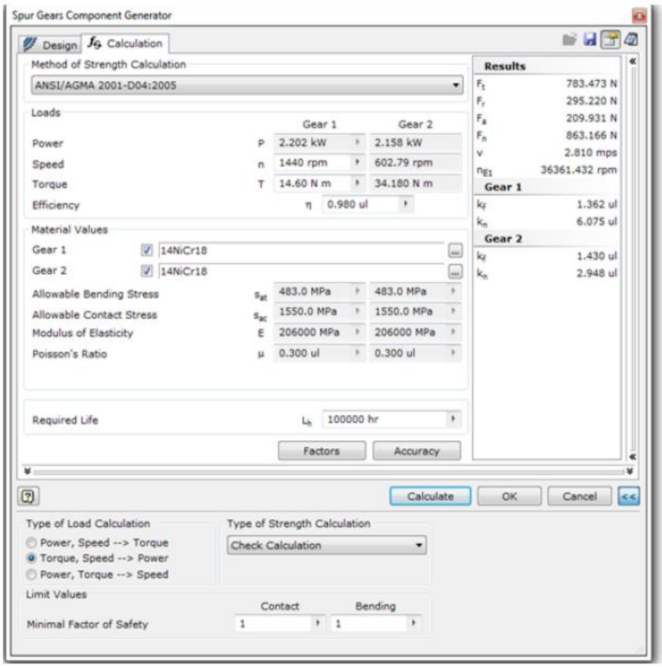
Cp = Elastic Coefficient (191 for steel by Bhandari)
CR = Contact Ratio
Kv = Velocity factor
Ko = Overload Factor

I used following data for optimization and analysis of existing helical gear of Pitroda Utility Industries (wadhwan-surendranagar).

Table: 1 data of existing gear

Sr No.	Decription	Value of pinion	Value of gear	Unit
1	No. of Teeth	18	43	
2	Module	2	2	mm
3	Pitch Diameter	36	86	mm
4	Pressure Angle	20^0	20^0	degree
5	Helix Angle	20^0	20^0	degree
6	Face Width	14	14	mm
7	Addendum	1.6	1.6	mm
8	Dedendum	2	2	mm
9	Modulus of Elasticity	$2.1 * 10^5$	$2.1 * 10^5$	MPa
10	Poission's Ratio	0.3	0.3	
11	Torque	14.60	14.60	N-m

By using this equation Autodesk Inventor give the perfect result of problem by inputting Different value of gear and pinion, that shows in below figure.



III. MODELING AND ANALYSIS

For given specification of helical gear, we have prepare model of exiting gear in cad software and after that by changing different face width and helix angle, static analysis is preformed using ANSYS 14.5.The modeling analysis of existing gear in ANSYS. (Face width 14mm, Helix angle 20 degree)

Fig 2: bending stress (face width 14mm, helix angle 20 degree)

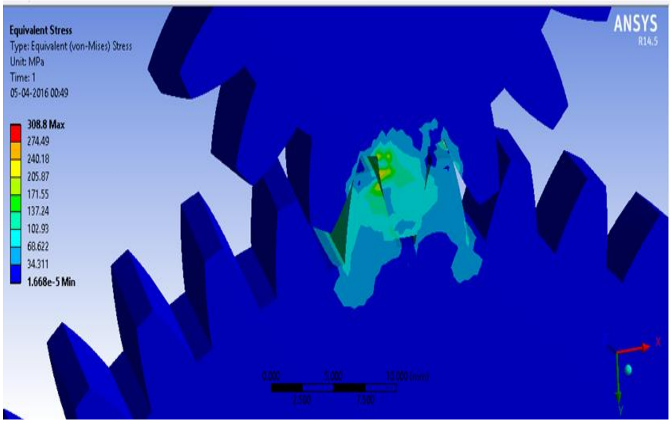


Fig 3: shear stress (face width 14mm, helix angle 20 degree)

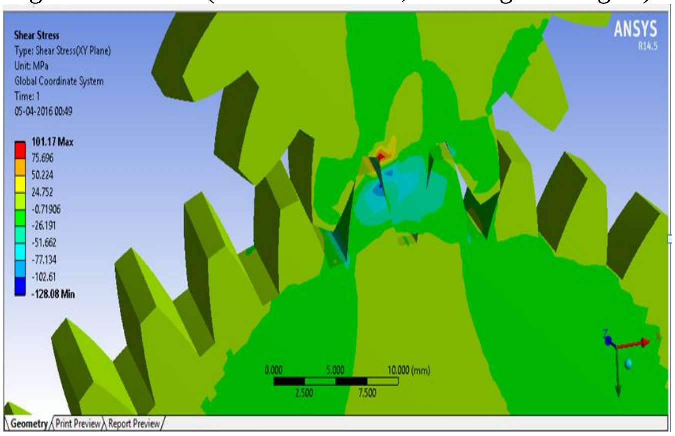
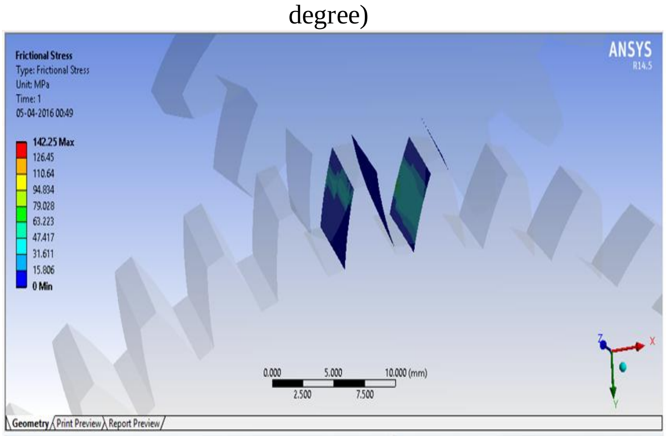


Fig 4: contact stress (face width 14mm, helix angle 20 degree)



The ANSYA analysis result of bending stress, contact stress and shear stress according to by changing different face width and helix angle is below.

Selection of the Orthogonal Array: As variables having three levels are being taken, so the

Degree of freedom associated with one variable is 2.The DOF associated with the two variables is 4.

An orthogonal array having at least 4 DOF is to be selected. In the present work, the OA selected

is L9. Data to be investigated is given in following table.

Table2: different stress values by ANSYS analysis

Sr No.	face width (mm)	helix angle (degree)	bending stress (Mpa)	contact stress (Mpa)	shear stress (Mpa)
1	10	10	328.54	130.67	96.56
2	10	15	308.8	142.25	101.17
3	10	20	287.58	71.65	104.678
4	12	10	308.95	142.35	101.18
5	12	15	304.34	159.6	105.94
6	12	20	292.68	81.701	109.63
7	14	10	306.28	71.34	87.834
8	14	15	265.66	73.904	91.121
9	14	20	235.3	45.256	95.453

From above all results select best result of face width 12mm and helix angle 15 degree.

Fig 5: bending stress (face width 12mm, helix angle 15 degree)

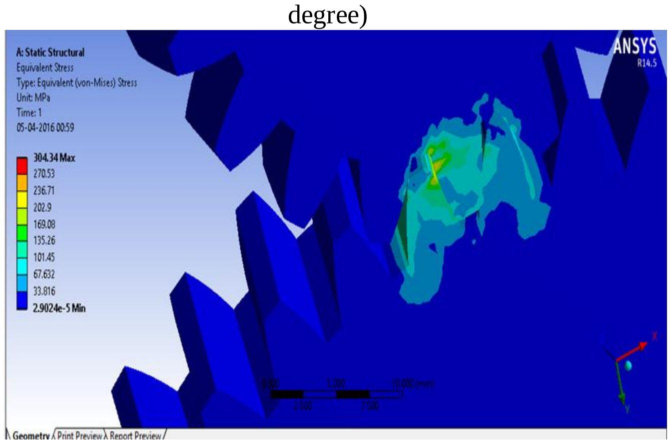


Fig 6: shear stress (face width 12mm, helix angle 15 degree)

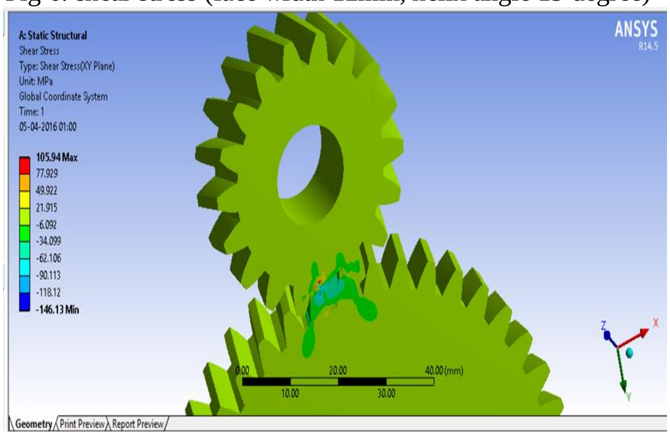
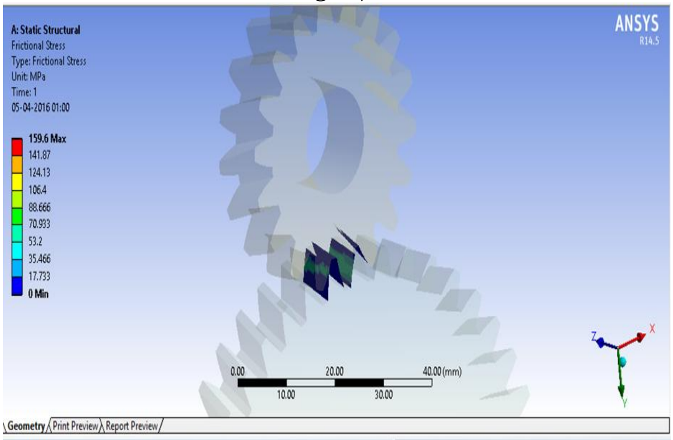


Fig 7: contact stress (face width 12mm, helix angle 15 degree)



IV. ANOVA ANALYSIS

Taguchi method

Design of experiment: Taguchi method is adopted for optimizing process variables as it is simple and easy. The method is popularly known as the factor design of experiments. This method uses a special set of arrays called orthogonal arrays. The orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. The L9orthogonal array is meant for understanding theeffectof4independent factors each having 3 factor level values.

Table3-SPIF Parameter and their Levels

Input Parameters	symbol	unit	Level 1	Level 2	Level 3
Face Width	t	mm	10	12	14
Helix Angle	Φ	degree	10	15	20

Table4-Orthogonal Array L9

Experiment no.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

ANOVA Results

1. General Linear Model: Bending Stress versus Face width, helix angle:

Table 5: ANOVA results for bending stress

parameters	process parameters	variance	test F	% of contribution
A	Face width	2661.1	6.85	43%
B	Helix Angle	2740.7	7.06	44%
Error		776.7		13%

2. General Linear Model: Contact stress versus Face width, helix angle:

Table 5: ANOVA results for contact stress

parameters	process parameters	variance	test F	% of contribution
A	Face width	6952.5	18.27	51%
B	Helix Angle	5956.7	15.65	44%
Error		761.1		6%

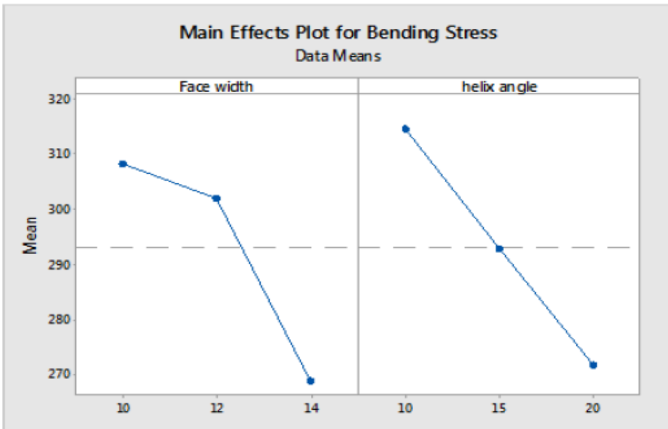
3. General Linear Model: Shear stress versus Face width, helix angle:

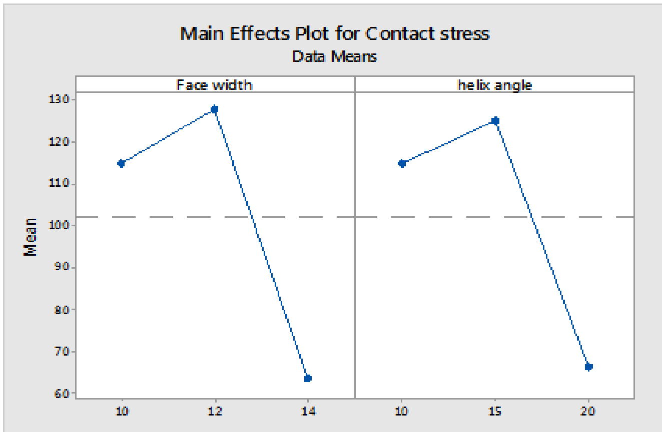
Table 5: ANOVA results for shear stress

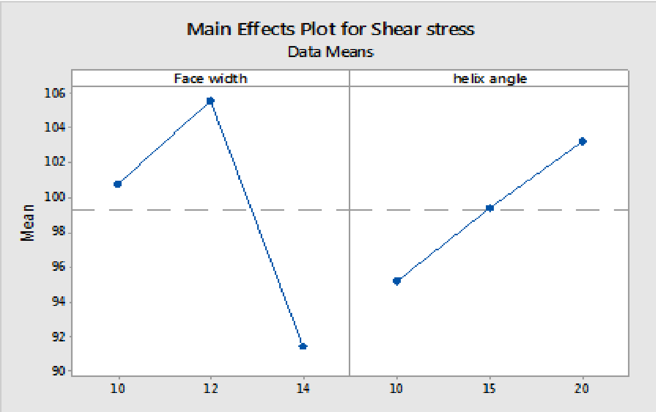
parameters	process parameters	variance	test F	% of contribution
A	Face width	309.171	909.83	76%
B	Helix Angle	97.572	287.14	24%
Error		0.680		0%

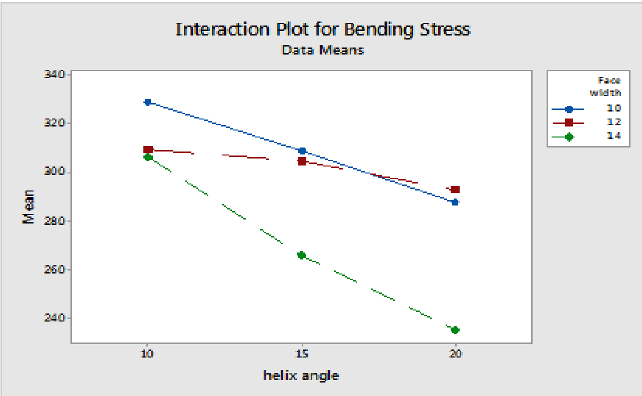
ANOVA Graphical Results

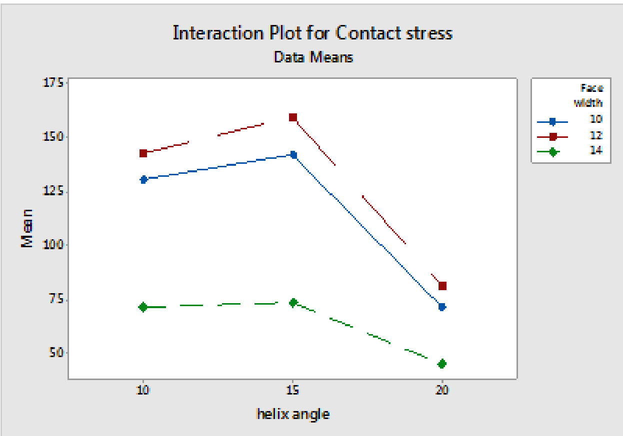
As below figure shown the graphical representation of bending stress, contact stress and shear stress by using ANOVA.

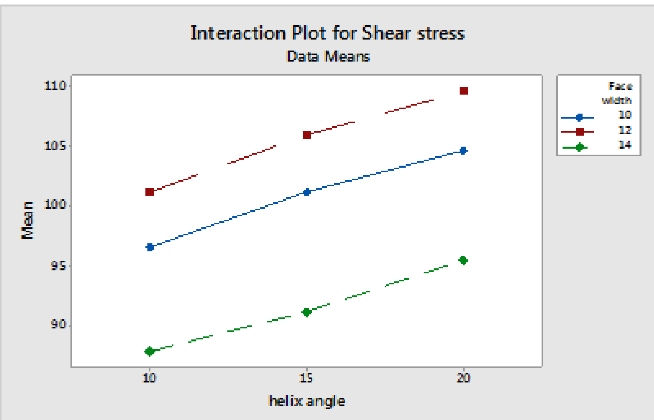












V. CONCLUSIONS

1. As compare to the existing gear less thickness and helix angle give better and maximum bending stress, contact stress and shear stress.
2. From ANOVA results it is
Concluded that Face width and helix angle 43% and 44% respectively contribute in bending stress variation.
Face width and helix angle 51% and 44% respectively contribute in contact stress variation.
Face width and helix angle 76% and 24% respectively contribute in shear stress variation.

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