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Study of Contact Examination of the Teeth Automotive Gear and Its Numerical Analysis: A Literature Review

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Abstract –*Gear tooth contact analysis is the subject of this review study, which includes a review and a comparative numerical analysis approach. In gear, working transmission error is investigated in both static and dynamic conditions. Transmission fault is a major cause of gearbox noise. The transmission error has been minimized as a result of a final gear manufacturing setting that has been proposed and analyzed. We attempt to address several numerical analytical methods of tooth contact analysis of a spiral bevel gear in this study, as well as a review of the FEM methodology and experimental prediction contact pattern in gear teeth. In this field of the overall contribution of the literature investigated, strengths, weaknesses are discovered. The potential missing and this study be used by other future studies is evaluated. The next steps for research are suggested. These next steps should address explicitly how the gaps and weaknesses will be corrected.*

Keywords*-Spiral bevel gear, Tooth contact analysis, Transmission error.*

I- INTRODUCTION

For transmitting motion and power from the engine to the wheel gear is used. Three complimentary characteristics of gear behavior under load are highlighted. The gear's elastic behavior. The point at which the pinion and the gear come into contact. The load is shared amongst the teeth that are in contact at the same time. Facing a problem of failure before the gear's expected life. The goal was to improve the transmission system's efficiency. Reduce noise and vibration during spiral bevel gear meshing in the workplace. Reduce the production lag time.

II - SPUR AND HELICAL GEARS

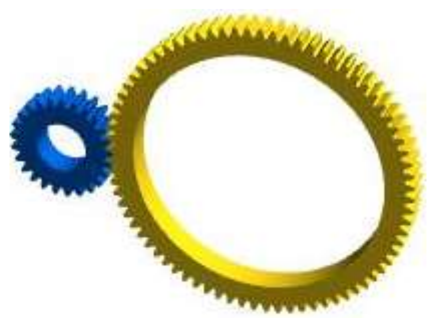

Fig.1- Spur Gear

This shows axes of gear are parallel to teeth.

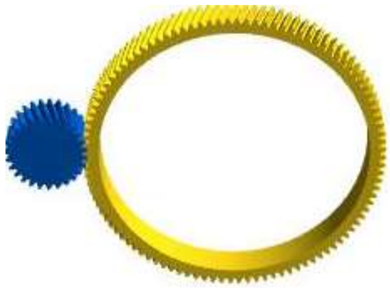

Fig.2- Helical Gear

This shows axes of gear are inclined to teeth.

Litvin et al. develop an analytical approach for kinematic inaccuracy in spiral bevel gear [1]. Drago R. and Mack J. tested the Heavy Lift Helicopter Endurance Test was completed with all engines running and one engine operating working at 95 percent of design loads [2]. Sasaoka identified the transmission error, a spur gear measurement approach has been devised at high speeds and loads [6]. Spur gear module 3.738 was used in an experiment using the Heidenhain 36000 line encoders corner contact to determine transmission error at various torques by Munro[9]. The Harmonic Analysis was done by Rao and Yoon of the helical gear of module 5 at various loads [10]. To discover dynamic transmission error, tangentially mounted accelerometers, and Laser torsional vibration meters were used to perform tooth contact analysis on a spur gear with 44,21 teeth. The transmission error and Sound Pressure Level were determined using experimental analysis with Load and Profile Error on a spur gear with the number of teeth of 55,34 [14]. For discovery transmission error, a spur gear with a module of 2 and two models with the same number of teeth of 24 is generated with CAD and tiff relief is studied at constant load [19]. Spur gear with the module of 3 and three pairs (2, 40) (41, 53) (41,53) of teeth generated the computer programs by Podzharov et al. Tooth contact analysis of a high contact ratio has been obtained the low dynamic transmission error and static transmission error [22]. Helical gear of module 4.44 and pair with teeth of 34,32 performed experiment on Test Rig with considering Lead error and Profile modifications to the invention of Transmission error, Contact Stress and Sound Pressure Level [23]. Spur gear has been modeled and simulated with FEM calculation and KISSsoft software with Profile Correction shows an effect on a peak to peak transmission error [26]. Helical gear with the module of 3.5 number of teeth are (49,36) and (65,36) experiment with the same load at increased speed and same speed at increase load to result from Transmission error increase with the increase of the input load, accurate at high speed [29].To find the maximum deflection, maximum bending stress, and stiffness of a helical gear with the module of 8 and number of teeth are 94,24. Ansys software was used to determine the maximum deflection, maximum bending stress, and stiffness [35]. Virtual marking compound thickness (VMCT) discrete triangular meshes, degree of refinement to obtain desired contact patterns, contact routes, and transmission mistakes are used in the spur gear of module 1, and teeth are 34,20. Spur gear with a tooth count of 75,25 was used in an experiment by Banodiya and Karma.. Use of defective and precise gear at a specific RPM to determine the transmission error (in rpm) [42]. ERN 460 encoders have been used to measure the torque on a spur gear with 21 teeth. Compare the results to those obtained using Matlab software by Kucera et al.[45]. Models of helical gears with 100 and 25 teeth were constructed and simulated by Narayanan in KISSsoft software using parameters such as end relief, helix angle error, profile crowning, and pressure angle to produce Stress distribution and line load distribution over the face width [50].

III -SPIRAL GEARS

Types of Bevel Gears are as follows

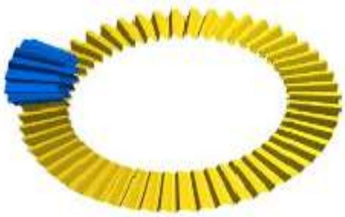

Fig.3- Straight Bevel Gear

This figure shows the mating gear axes are at 90 degrees. Teeth are straight.

Fig.4- Spiral Bevel Gear

This figure shows the mating gear axes are at 90 degrees. Teeth are curved in shape

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Due to improper Machine setting: Blank offset, Sliding base setting, Machine center to back, Machine root angle, Basic cradle angle, Basic radial, Ratio of roll variation.

Profile errors produce like crowning, Profile Crowing (Barreling), Pressure Angle Modification, Eccentric Profile Crowing,

Twist, Helix Angle Modification, Eccentric Crowing, Topological Modification.

Types of Profile errors in Spiral Bevel Gear

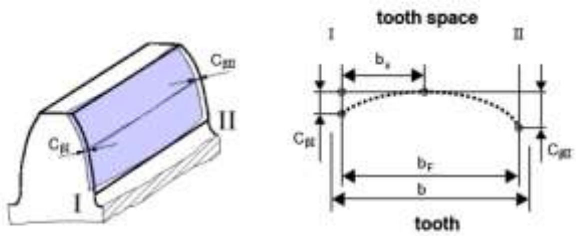

Fig.5- Crowning

This shows surface deviation along the width of teeth of the gear

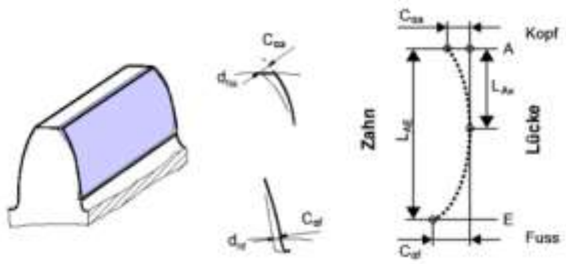

Fig.6- Profile crowning (Barreling)

This shows surface deviation along with the depth of teeth of the gear.

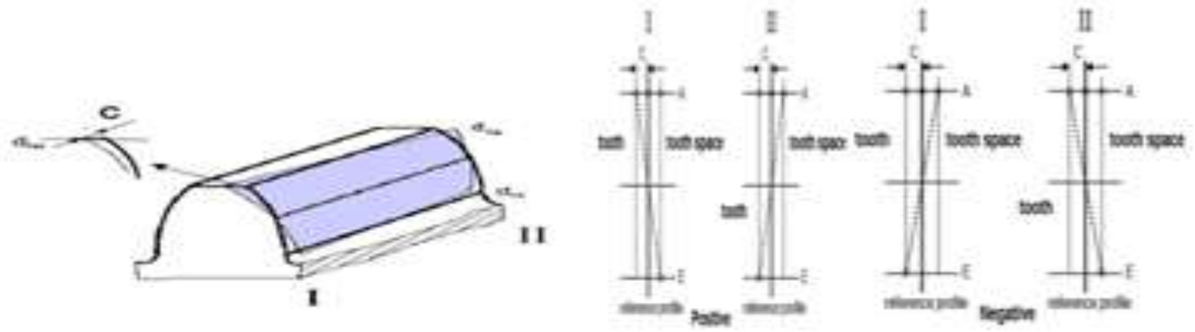

Fig.7- Twist

This shows surface deviation along with depth and width in Positive and Negative of teeth of the gear.

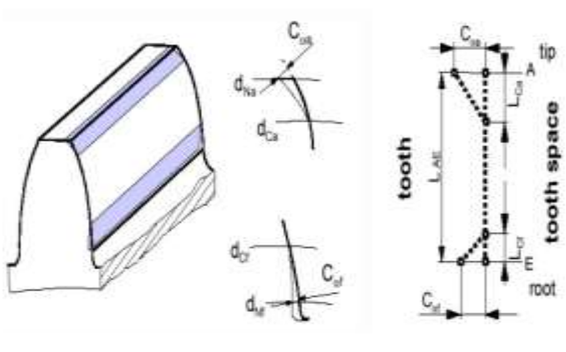

Fig.8 -Tip / Root Relief, Linear

This shows surface deviation at the tip and root of gear in linear.

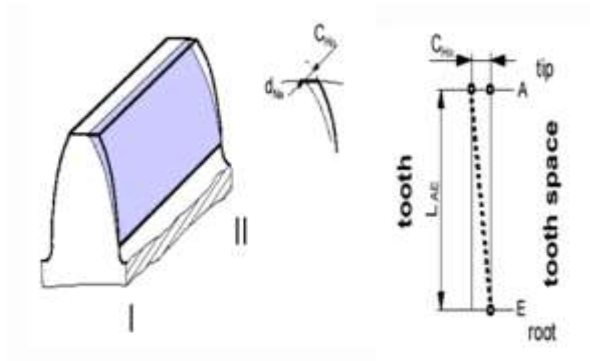

Fig.9 - Pressure Angle Modification

This shows surface deviation along with the tooth profile.

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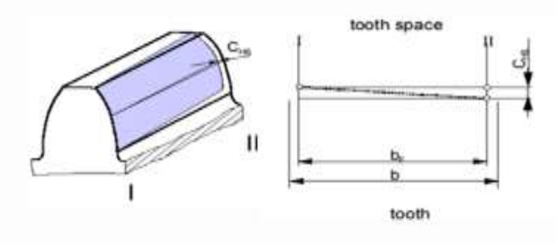

Fig.10 - Helix Angle Modification

This similarly shows helix angle correction as end relief. Surface deviation along the width of gear.

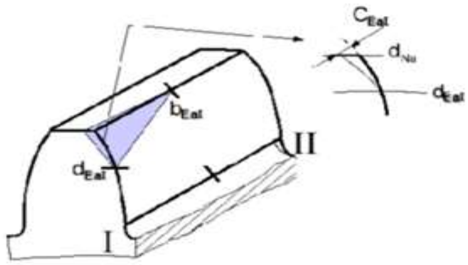

Fig.11 - Triangular End Relief

Surface deviation at End Relief of gear. Triangular surface area.

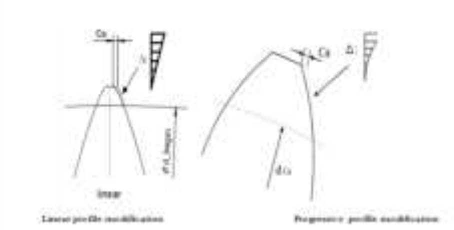

Fig. 12- Comparison of Linear and Progressive Profile Modification

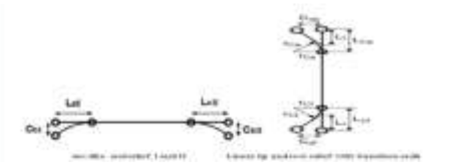

Fig. 13- Comparison of Arc like end relief and Linear tip and root relief with transition radii Profile Modification

Table 1- Comparative Numerical Analysis of Spiral Bevel Gear

References	**Gear Size (Module, No. of teeth of Gear, Pinion)**	**Method**	**Parameters Considered**	**Crucial observation**
1	40,20	Analytical method	Pinion and gear eccentricity, axial pinion/gear, displacements	Kinematic error
2	Heavy Lift Helicopter	Endurance Test, Dynamic Testing	All Engine operating, One engine In operating	95 percent of design loading, Alternating stresses
3		Direct Drive Tester	Under Load and Speed	Transmission error under load, measuring the errors at operating speeds,2 methods for optical encoders, and 2 methods for torsional accelerometers
4	31,28	EPG test machine, the mathematical model	Loaded tooth contact Analysis, machine-tool settings	Kinematic errors and contact patterns
5		General Formulation	Under Load	Load Shearing and TE
7	5,25,25	Numerical and experiment	Contact ratio	Theoretical and actual contact patterns
8	8.24,37,6	Analog Encoder,	Different torque	Simulation and Measurement of

		Optical Encoder		Bearing Patterns,TE
11	6.5,44,13		Edge contact, Negative Offset	Contact trace Lines, TE
12	4.83,33,9	The computer program for simulation	Machine-tool settings and mean contact point not known	Path of Contact Lines, TE
15	5.11,44,15	Load, No Load, Gleason T2000	Misalignment, Different Load	Contact Pattern, Contact pressure, TE, Optimum Condition, Stress
16	5.8,44,15	Magnetic and optical encoders, numerical simulations	Load 65,130Nm	TE
17	3.9 ,34,17	Algorithm for a geometrical and kinematical analysis	Hertz, Non-Hertz	Contact patterns, TE, Max. Pressure
18	5, 50, 17	Computer simulation	Influence of machine setting	TE, the path of contact, contact lines,
20	4.25,86,23	Phoenix 800PG Grinding	Machine tool-settings	TE, Contact Pattern
21	5,50,13	Computer program	Machine tool-settings	Path of contact, T.E.
24	5,50,13	Gleason Phoenix	Machine tool-settings	TE, contact pressure
25	5.5,26,16	0,50,100 Nm, MATLAB	Modified (pinion +0.026), unmodified experiment T.E.	Meshing performance of modified is better
27	35,40	Light, heavy	Effect of mean mesh stiffness, khm2 change	Stiffness for the drive side has more effect on the dynamic response, vibration characteristic for the heavily loaded case is far better.
28	1.8,38,43		Width,height,ratio,x,y	TE, tooth face contact trace
30	4.941,36.12	Computer program	Radial machine tool setting variation, tilt distance, roll ratio variation, tilt and swivel angles, head-cutter profile radii, the difference in head-cutter radii	Unbalanced separations, edge contact, and considerable transmission errors
31	Bevel 2.9,19.42	Simulation	Shaft angle, the mounting distance of the crown	The greater error increases Transmission error
32	12.7,51,15	Simulation, Actual	Machine setting (grinding)	Value of profile is same
33	Dump Truck	Unload, load, test, Analysis	Load increase	Contact pattern change, Comparison, deflection
34	6.5,60,46		Original machine	Transmission error, the contact

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			setting, optimization	area
36	4,61,61	Load, speed, NI Labview	Dynamic transmission error test	Peak to Peak Transmission error
37	9,25,11	UG Software	Radii of the generating arcs of circles, Coefficient	Transmission ratio error
39	2.6548,41,12	The experiment of actual SFT	PSFT and actual SFT, Position of pinion	Transmission error and the contact pattern
40	5.5,32,25		Assembly misalignment	Contact area, transmission error
41	4,39,7	Experiment	Machine settings	LTCA
43		Experiment, Romax	Static analysis, Modal Analysis	Deflection, von Mises Stress, Moment along axes
44	30,10	FEA, Ansys14, Experiment	Different Load, speed	Max bending stresses, Max Contact Stress, Transmission efficiency
46	2.5(30,32) 2(26,28)	Loading experimental	Different Load, assembly errors	RMS- DTE,
47	3.4884,47,11	Load, Abaqus, Masta,	Misalignment, System Deflection(Shell stiffness, Bearing Stiffness, Bearing Location)	Contact pattern, Angular TE
48	34,11	Load, Abaqus	Mesh frequency	Angular TE, Mesh deflection, Mesh force
49	3.9,65,23			HTE, PTE,RMS oscillation
51	6,46,15	ANSYS, KISSsoft, Test	Different Load	Maximum bending stresses, Transmission error
52	7,65,23	Simulation	Sensitivity of gear to Misalignment, modified cutter for pinion, gear	Compare the contact paths of the original gear and the changed gear.
53	3.15,55,47	Simulation	Machine tool setting modification	Transmission error
54	3 ,55,47 3,48,43	Simulation, Test	Pinion and gear rotation angle, Misalignment	Loaded Transmission error
55	3.85,74,27	Numerical	Load, Meshing Point	Loaded Transmission error

IV-CONCLUSION

In spur gear profile errors like end relief, helix angle error, profile crowning, and pressure angle are considered in tooth contact analysis. Different methods are investigated for finding the transmission error with misalignment. Due to the effect of misalignment and loading changes occurring in contact pattern has been observed. System Deflection like Shell stiffness, Bearing Stiffness, Bearing Location is considered after applying load. In loaded tooth contact analysis mid-position of mesh gear is changed due to elasticity. In above, most of the literature survey found that experimental analysis is done. That result should be compared to the simulation result.

In the above profile error in spiral bevel gear has not been considered in tooth contact analysis, misalignment, and different load and unloading conditions. The change of material of gear and its comparison of tooth contact analysis has been considered for future study. A comparison of transmission error and contact pattern with and without profile hasn't been considered. The tooth contact analysis of hypoid gear hasn't been considered. The combination of profile error with misalignment at different loads is the research gap found in the investigated literature review. To find optimal torque at which peak to peak transmission error is low and contact ratio should be high. The use of KISSsoft software and experiment setup is recommended to find Transmission error, Contact pattern, Bending stress in the root area, Wear along the tooth flank, Safety against scuffing, Contact lines, Contact temperature, Single contact stiffness, Safety against tooth flank fracture in Tooth contact analysis.

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