Ilkogretim Online - Elementary Education Online, 2021; Vol 20 (Issue 4): pp. 3675-3692
http://ilkogretim-online.org
doi: 10.17051/ilkonline.2021.04.406

The Effect Of Profile Error In Tooth Contact Analysis Of Spiral Bevel Gear

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Abstract -This paper uses a simulation method to tooth contact analysis in spiral bevel gear. Transmission error at different value of profile error condition are investigated in gear working. Geometric modelling contains number teeth of pinion and gear is 13 and 50. The module of gear is 5. Transmission error is key factor for making noise in gearbox. Experimental Analysis has been performed at particular load. The experimental contact pattern compare with simulation result shows well agreement. The Peak to Peak Transmission Error is directly proportional to the value of profile Crowning used in the modification of geometric design of pinion and gear. The profile crowning value is increased; it's found more elongated elliptical shape area of contact pattern. Minimum Peak to Peak Transmission Error is 1.40μm with modification of Profile Crowning 15 μm in Pinion and Profile Crowning 15μm in Gear at Load 268Nm.In this research, the methods of simulation have been developed for tooth contact analysis of a spiral bevel gear with profile error using KISSsoft Software.

Keywords – Peak to Peak to Transmission Error, Profile error, Transmission error, Tooth contact Analysis etc

1. INTRODUCTION

Gear is definite as a device used to transmit motion from one shaft to another shaft by direct contact. The gear teeth permit the force to be fully transmitted without slippage and depending on their configuration can transfer forces at different speeds, torque and even different direction

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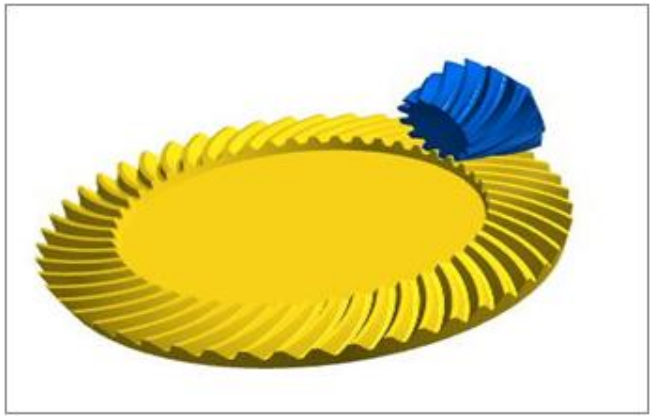
Spiral bevel gears: In this type of bevel gears, the tooth elements are curved in the shape of a spiral so that the contact between the inter-meshing teeth begins gradually and continues smoothly from one end of teeth to the other. The contour of the spiral be determined by the particular create circular arc for the Gleason system.



Figure(1) Spiral bevel gear and pinion in mesh

In the figure the number of teeth of pinion is 13, number of Teeth of Gear is 50 and Module is 5

Objective

The objectives of the proposed research work are as follows:

- To measure the transmission error with effect of Profile error (Profile Crowning).
- To measure the performance of the contact pattern under applying load conditions.
- To validate the experimental analysis with simulation contact pattern conditions.

2. MATERIALS AND METHODS

Generate solid model with parameter (number of teeth in gear, pinion, pressure angle, spiral angle, module). Based on the misalignments and Solid model LTCA model has been generated. The procedure to predict the mesh behaviors for face-hobbed spiral Bevel gear considering without misalignments which are caused by system deformation. The mesh behavior analysis can be carried out in Kisssoft software based on the LTCA model. Output of analysis is Transmission error and Contact pattern.

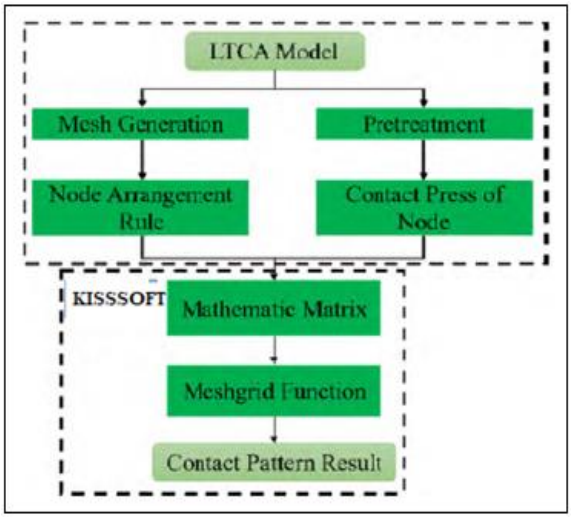


Figure (2) Flowchart of contact pattern calculation procedure in LTCA

Table (1) Geometric data of the example case. (modified slot width Gleason system)

		Pinion (A)	Gear (B)
Number of teeth	T	13	50
Normal module	m	5	
Shaft angle	**Σ**	90°	
Mean Spiral Angle	β_m	35°	
Pressure Angle		20°	
Hand of Spiral		LH	RH
Facewidth (mm)	b	55	
Tip Diameter(mm)	da	76.8	251.3
Addendum(mm)	h_a	6.06	2.46
Dedendum (mm)	d_f	3.40	7
Profile shift coefficient		0.2308	-0.2308
Reference Diameter(mm)	d	65	250
Reference Cone Angle	δ	14.59°	75.41°
Material		Steel grade 2, HRC58-64(AGMA) Case Carburized steel, Case hardened, AGMA 2003	
Lubrication		Oil :ISO –VG 150	
Cutter Radius		(Chosen) d_c = 95 mm	
Angle Cut Path		57°	
Quality (ISO 17485)		7	
Contact ratio		1.1648	2.0276
Operation Mode		Drive side	

Effect of Profile Crowning (Barrelling)

A standard lengthwise crowning is between face width/250 and face width/600 (for normal misalignment) or face width /350 and face width/800 (for low misalignment).

Table (2) Profile Crowning Value

	Profile Crowning	ΔE(mm)	ΔP(mm)	ΔG(mm)
Base	0	0	0	0
1	70	0	0	0
2	100	0	0	0
3	157	0	0	0
4	200	0	0	0

Profile Modification:

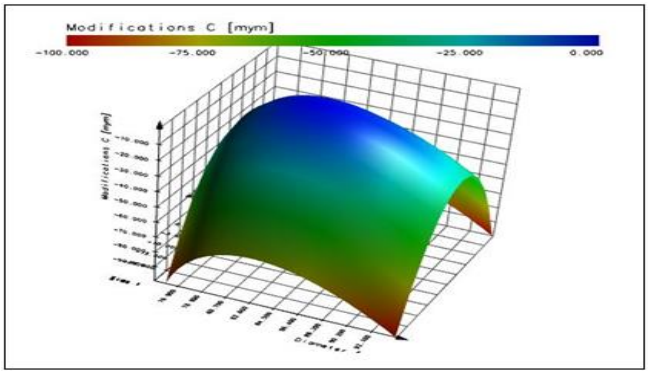


Figure (3) Pinion with Crowning 30 µm, Pinion of Profile crowning 70µm

In this figure, the number of Teeth of Pinion is 13, Module of Pinion is 5, Pinion of Profile crowning is 70µm and Pinion of Crowning is 30µm. The Pitch circle diameter of Pinion is 65mm.

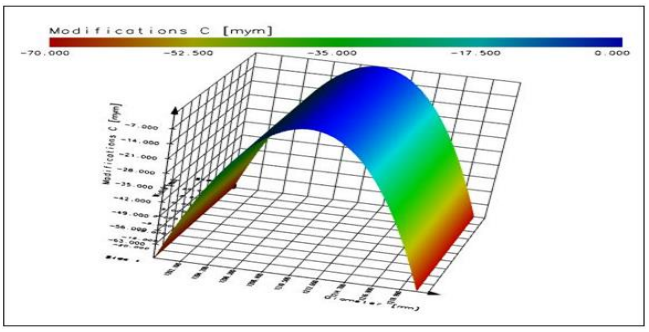


Figure (4) Gear of Profile crowning 70µm

In the figure, the number of Teeth of Gear is 50, Module of Gear is 5, Gear of Profile crowning is 70µm. The tiff diameter of Gear is 251.225mm.

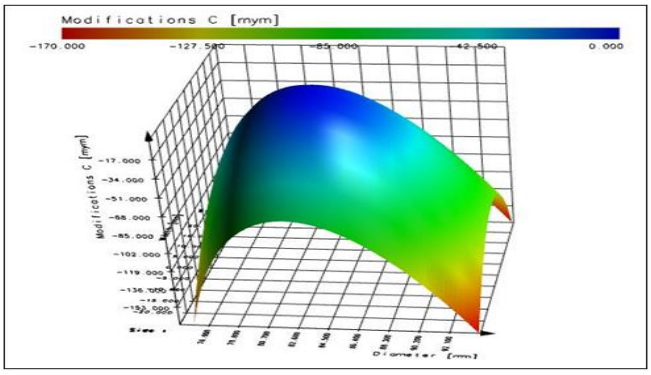


Figure (5) Pinion with Crowning 70 µm, Profile crowning 100µm

In this figure, the number of Teeth of Pinion is 13, Module of Pinion is 5, Pinion of Profile crowning is 100µm and Crowning is 70µm. The Pitch circle diameter of Pinion is 65mm.

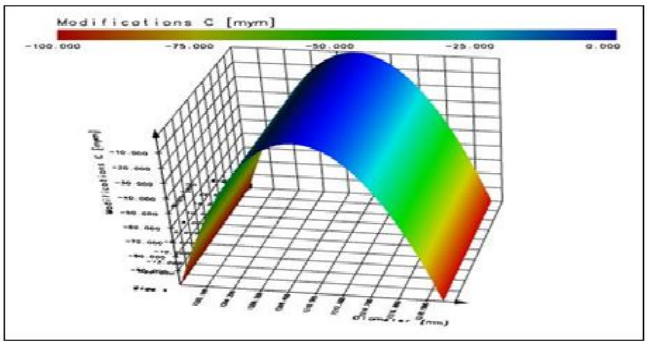


Figure (6) Gear with Profile crowning 100µm

In this figure, the number of Teeth of Gear is 50, Module of Gear is 5, Gear of Profile crowning is 100µm. The tiff diameter of Gear is 251.225mm.

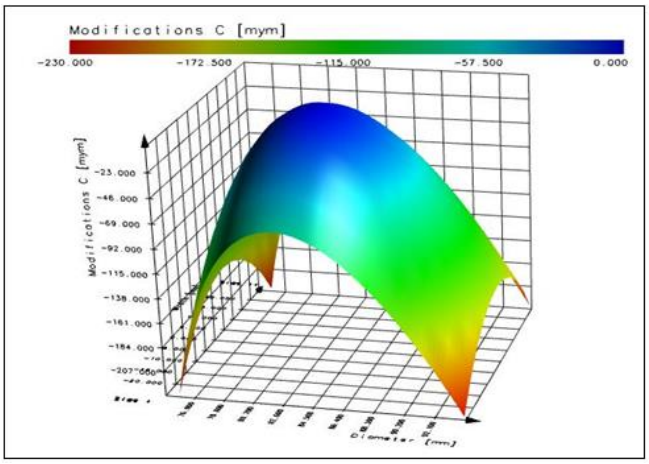


Figure (7) Pinion with Crowning 70 µm, Profile Crowning 157µm

In this figure, the number of Teeth of Pinion is 13, Module of Pinion is 5, Pinion of Profile crowning is 157µm and Crowning is 70µm. The Pitch circle diameter of Pinion is 65mm.

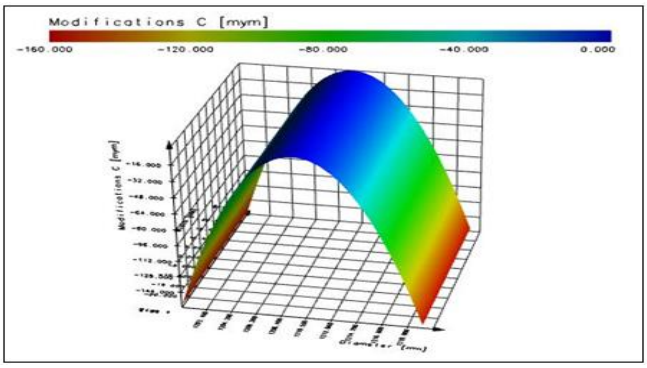


Figure (8) Gear with Profile Crowning 157µm

In this figure, the number of Teeth of Gear is 50, Module of Gear is 5, Gear of Profile crowning is 157µm. The tiff diameter of Gear is 251.225mm.

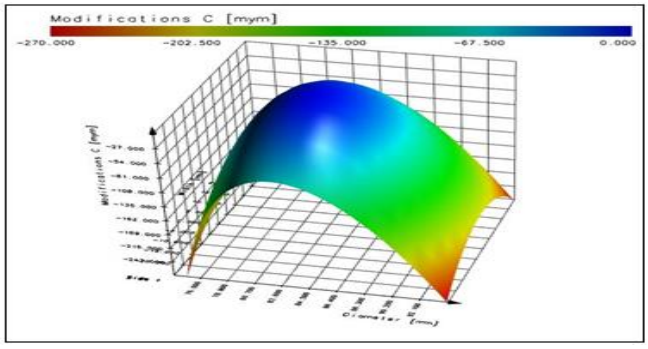


Figure (9) Pinion with Crowning 70µm, Profile Crowning 200µm

In this figure, the number of Teeth of Pinion is 13, Module of Pinion is 5, Pinion of Profile crowning is 200µm and Crowning is 70µm. The Pitch circle diameter of Pinion is 65mm.

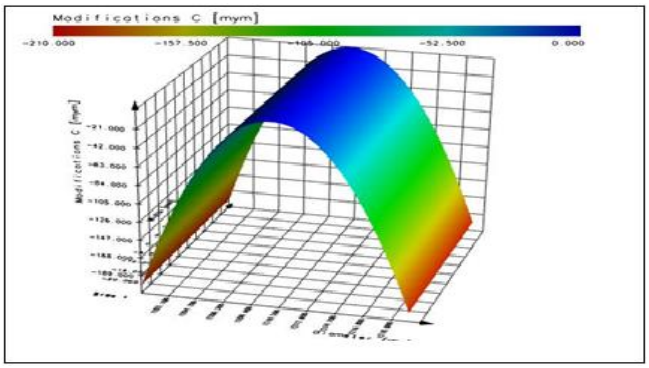


Figure (10) Gear with Profile Crowning 200µm

In this figure, the number of Teeth of Gear is 50, Module of Gear is 5, Gear of Profile crowning is 200µm. The tiff diameter of Gear is 251.225mm.

Transmission Error

Angle through which the Gear turn=Length of arc of contact x 360°/Circumference of Gear.

Angle through which the Gear turn=Length of Path of contact x 360°/ (3.14x Pitch circle diameter of Gear x cos20).

Length of Path of Contact or Transmission error (µm)=Angle through which the Gear turn x (3.14x Pitch circle diameter of Gear x cos20)/360.

Transmission error in degree or Angle through which the Gear rotate = Actual rotation of gear in degree – Theoretical rotation gear with respect to pinion in degree.

SIMULATION IN KISSsoft SOFTWARE:

Effect of Profile Crowning (Barreling)

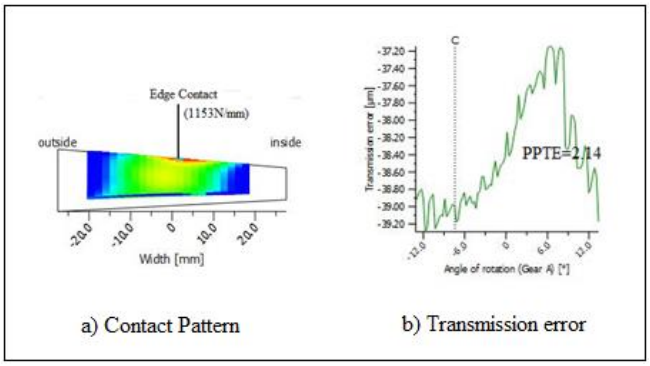


Figure (11) TCA at Profile crowning (0µm)

In this figure has been shown the contact pattern and transmission error. Tooth Contact Analysis has been done at Profile crowning is 0µm. The value of Peak to Peak Transmission Error comes about 2.14. Edge contact is shown and Maximum Line Load is 1153N/mm.

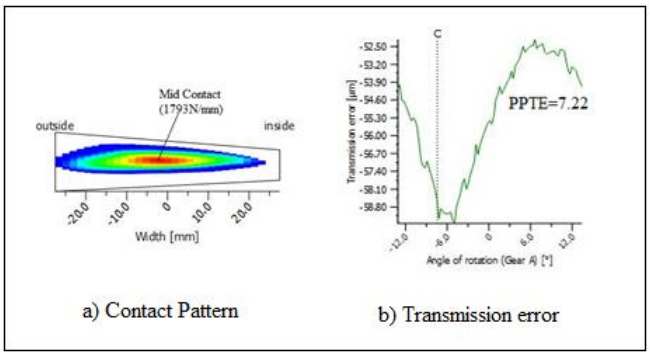


Figure (12) TCA at Profile crowning (70µm)

In this figure has been shown the contact pattern and transmission error. Tooth Contact Analysis has been done at Profile crowning is 0µm. The value of Peak to Peak Transmission Error comes about 7.22. Maximum Line Load is 1793 N/mm. Mid contact Red color is shown 1793 N/mm.

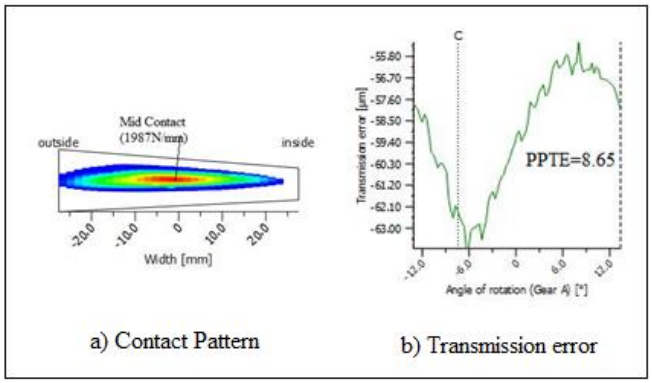


Figure (13) TCA at Profile crowning (100µm)

In this figure has been shown the contact pattern and transmission error. Tooth Contact Analysis has been done at Profile crowning is 100µm. The value of Peak to Peak Transmission Error comes about 8.65. Mid contact Red color is shown 1987 N/mm.

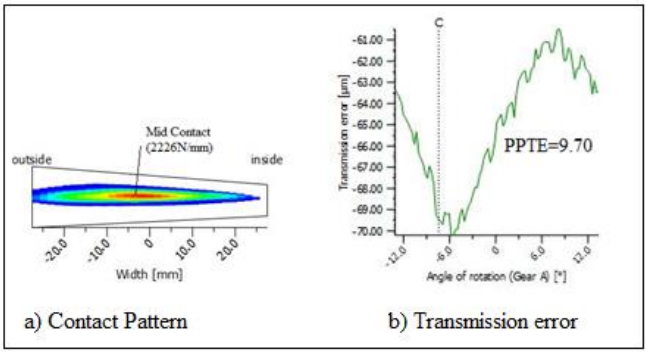


Figure (14) TCA at Profile crowning (157µm)

In this figure has been shown the contact pattern and transmission error. Tooth Contact Analysis has been done at Profile crowning is 157µm. The value of Peak to Peak Transmission Error comes about 9.70. Mid contact Red color is shown 2226 N/mm.

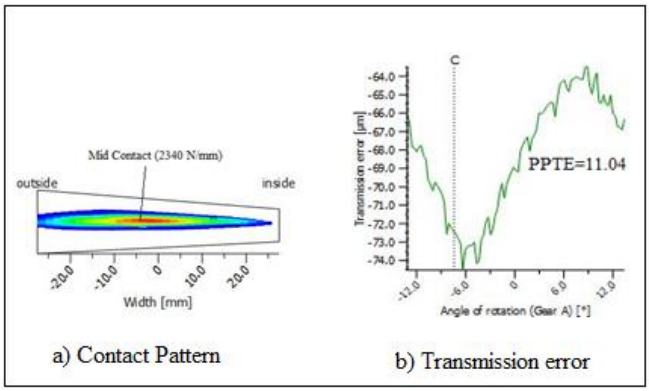


Figure (15) TCA at Profile crowning (200 µm)

In this figure has been shown the contact pattern and transmission error. Tooth Contact Analysis has been done at Profile crowning is 200 µm. The value of Peak to Peak Transmission Error comes about 11.04. Mid contact Red color is shown 2340 N/mm.

Effect of Shaft Angle Deviation

Table (3) Shaft angle deviation value

	ΔΣ(°)	ΔE(mm)	ΔP(mm	ΔG(m

			)	m)
Base	0	0	0	0
1	-2			
2	-1.2	0	0	0
3	+0.7	0	0	0
		0	0	0
4	+1.1	0	0	0

SIMULATION IN KISSsoft SOFTWARE:

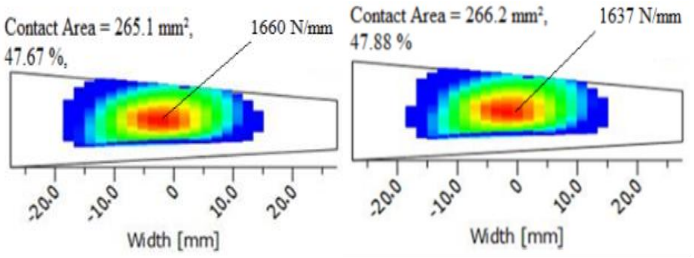


Figure (16) Shaft Angle Deviation -2° and -1.2°

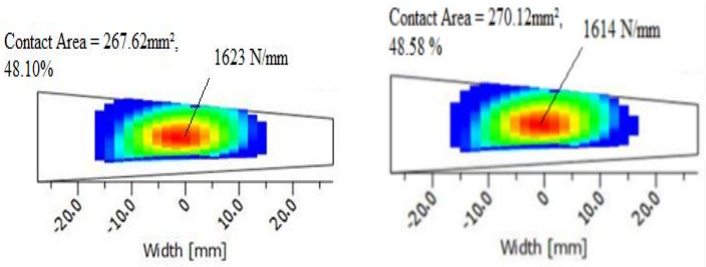


Figure (17) Shaft Angle Deviation 0° and 0.7°

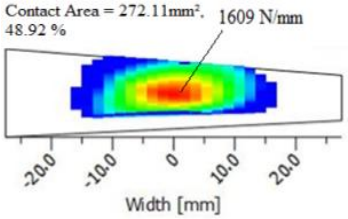


Figure (18) Shaft Angle Deviation 1.1°

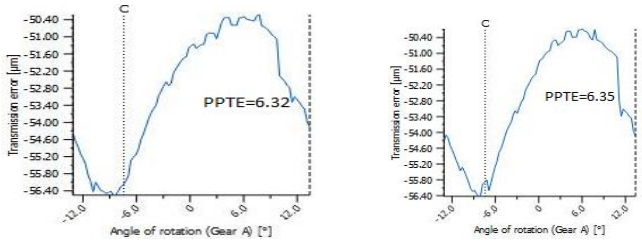


Figure (19) Transmission error at Shaft Angle Deviation -2° and -1.2°

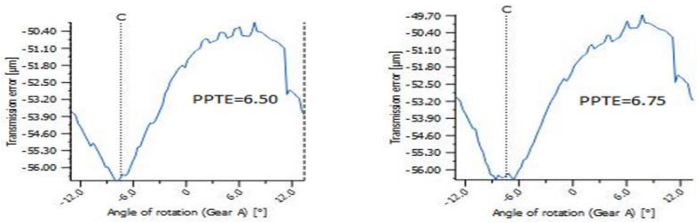


Figure (20) Transmission error at Shaft Angle Deviation 0° and 0.7°

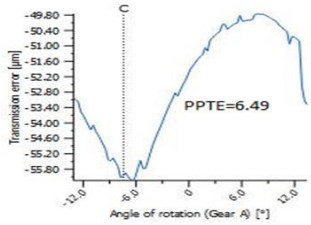


Figure (21) Transmission error at Shaft Angle Deviation 1.1°

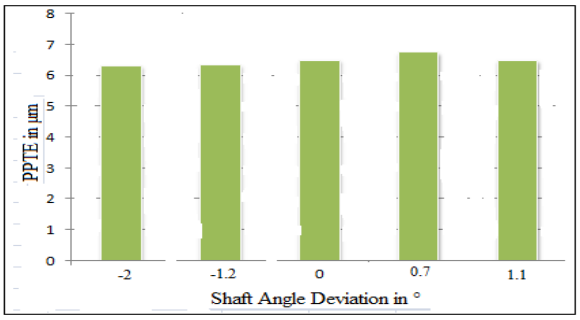


Figure (22) PPTE vs Shaft Angle Deviation in°

Result:

Edge contact is shown as shaft Angle Deviation is increased.

Interpretation:

1] Edge contact under load can be prevented by length corrections and profile crowning flank modifications.

2] Use the pressure angle and helix angle flank modifications to set the position of the contact pattern.

Experimental Analysis:

The Input torque is applied to the pinion**.** Rotation of pinion and gear is noted at angular scale. Performance Analysis has been done with module 5 of spiral gear pair at Profile Crowning (70µm) and 640Nm. Gear marking compound use at meshing of teeth of gear.

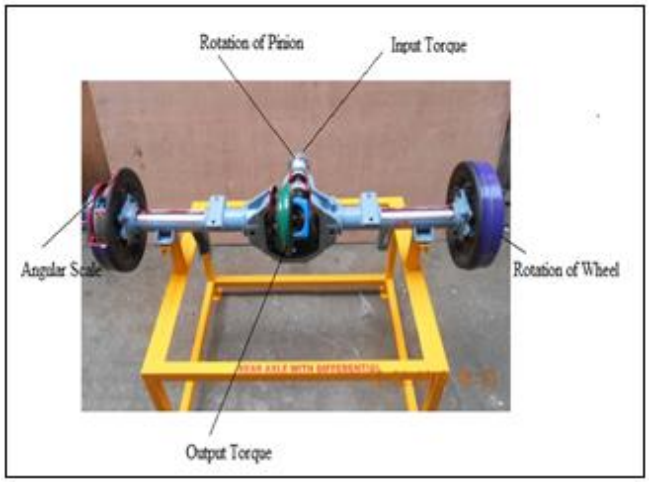


Figure (23) Experimental Setup

Figure (24) Contact Pattern at Profile Crowning (70µm)

Contact Pattern has been shown in elliptical shape. The position of origin of ellipse at mean of flank of gear. Experimental contact pattern compare with simulation result shows well agreement.

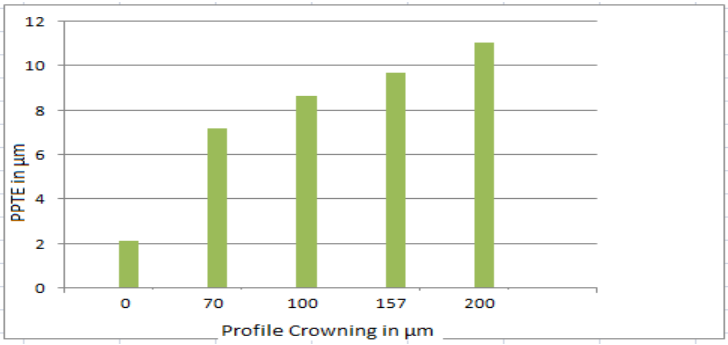


Figure (25) Profile Crowning vs PPTE

In this figure has been shown Graph Chart for Profile Crowning Verses Peak to Peak Transmission error. As shown in the graph, it is Predicted that the Peak to Peak transmission error is directly Proportional to profile crowning value.

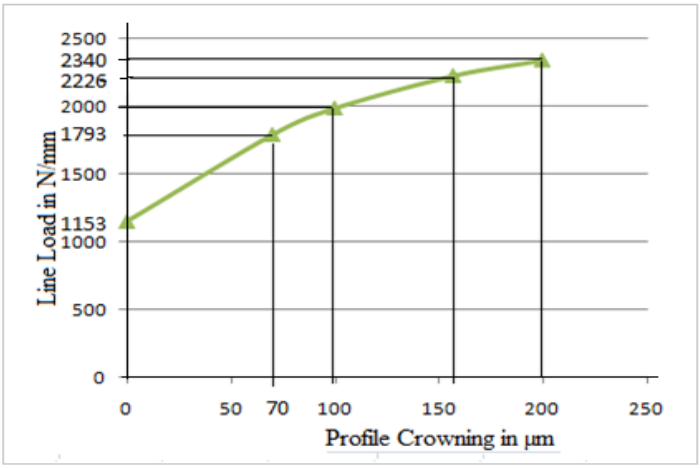


Figure (26) Graph chart for Profile Crowning Vs Line Load

In this figure has been shown Graph Chart for Profile Crowning Verses Maximum Line Load. As shown in the graph, it is Predicted that the Maximum Line Load is directly Proportional to profile crowning value.

3. RESULTS

1] PPTE (Peak to Peak Transmission Error) is directly proportional to the value of profile Crowning.

2]The Line load increases as value of the profile crowning is increased.

3] The profile crowning value is increase; it's found more elongated elliptical shape area of contact pattern.

4] At 0µm profile crowning edge contact is shown at the tip of teeth of spiral bevel gear. Which generates the sudden pressure peak at meshing.

Design Optimization

Tooth contact analysis due to effect of different value of profile error at different load.

Table(4) Geometric data of the available model case. (Uniform depth klingelnberg system)

		Pinion (A)	Gear (B)
Number of teeth	T	11	54
Normal module	m	5	
Shaft angle	**Σ**	90°	
Mean Spiral Angle	β_m	30°	
Pressure Angle		20°	
Hand of Spiral		LH	RH
Facewidth **(**mm)	b	50	
Outer pitch diameter (mm)	da	73.489	360.763
Addendum(mm)	h_a	7	3
Dedendum (mm)	d_f	4.25	8.25

Table (5) Misalignment

S.N.	Misalignment				Profile Crowning (μm)		Torque[Nm]
	ΔΣ(°)	ΔG[mm]	ΔE[mm]	ΔP[mm]	Pinion	Gear	
1	0	0	0	0	15	15	940
2	0	0	-0.508	0.280		20	772
3	+0.8	0.125	-0.420	0.314	20		604
							436

					25	25	268 100

SIMULATION IN KISSsoft SOFTWARE:

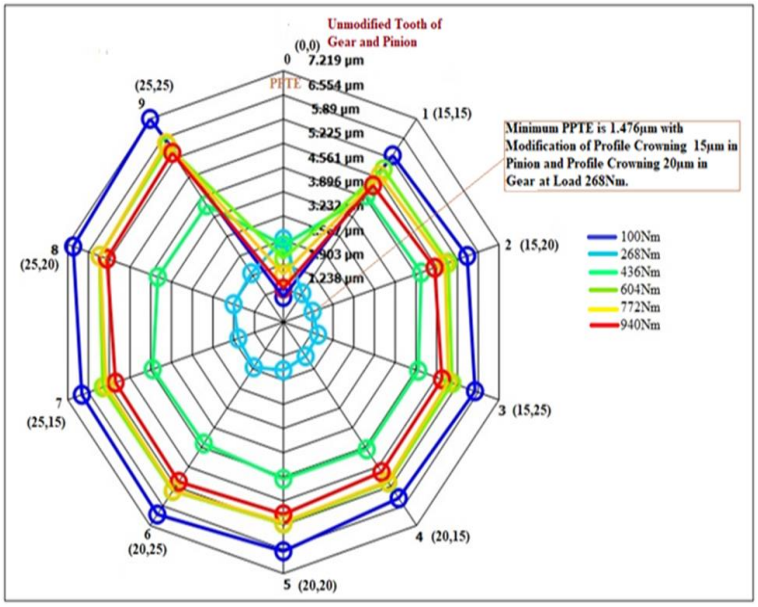


Figure (27) ΔΣ=0°, ΔG=0mm, ΔE=0mm and ΔP=0mm

Minimum Peak to Peak Transmission Error is 1.476µm with modification of Profile Crowning 15 µm in Pinion and Profile Crowning 20 µm in Gear at Load 268Nm.

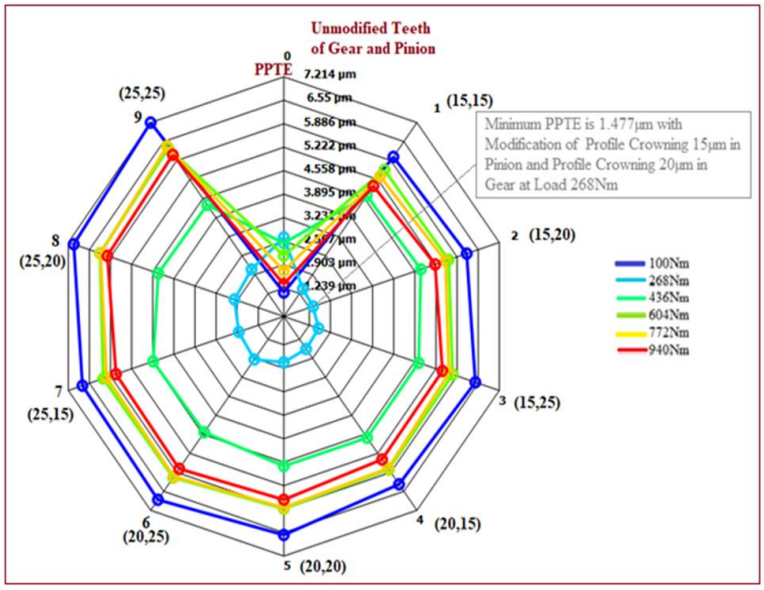


Figure (28) ΔΣ=0°, ΔG=0mm, ΔE=-0.508mm and ΔP=0.280mm

Minimum Peak to Peak Transmission Error is 1.477µm with modification of Profile Crowning 15 µm in Pinion and Profile Crowning 20 µm in Gear at Load 268Nm.

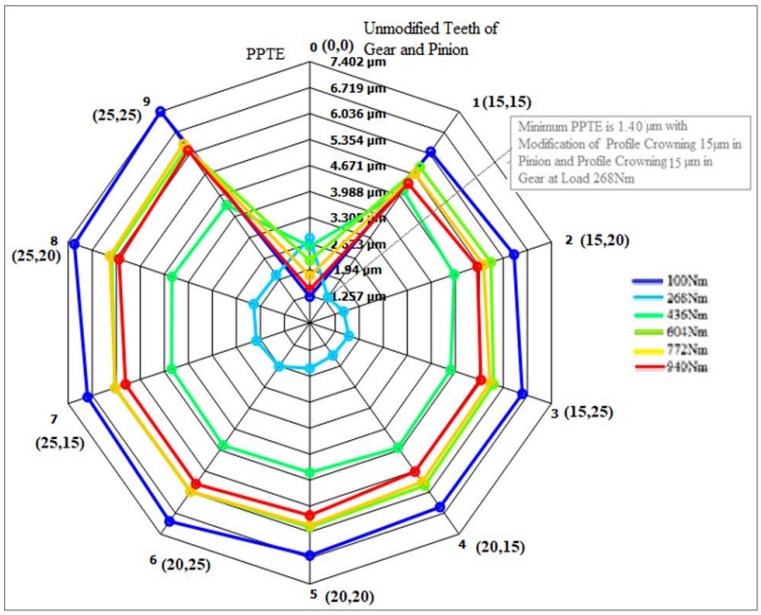


Figure (29) ΔΣ= 0.8°, ΔG= 0.125mm, ΔE= -0.420mm and ΔP= 0.314mm

Minimum Peak to Peak Transmission Error is 1.40µm with modification of Profile Crowning 15 µm in Pinion and Profile Crowning 15µm in Gear at Load 268Nm.

4. CONCLUSION

From this analysis, it has been concluded that, if the value profile crowning is increased, the value of peak to peak transmission error also increases. The mid of flank of pinion and gear with elliptical shape area of contact pattern is formed. If the profile crowning value is very less, the edge contact between pinion and gear is shown. Unmodified tooth of gear create low noise as compare to modified gear. PPTE (Peak to Peak Transmission Error) is directly proportional to the value of profile Crowning. Minimum Peak to Peak Transmission Error is 1.476µm with modification of Profile Crowning 15 µm in Pinion and Profile Crowning 20 µm in Gear at Load 268Nm.

FUTURE WORK

1) Matlab programming can be used to determine the transmission error in Spiral Bevel Gear.
2) Profile modification, i.e. twist and topological modification can be used for future analysis of the spiral bevel gear.
3) Tooth contact analysis can be used to determine the transmission error and contact pattern in hypoid gear.

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