

Development of Tooth Contact Pattern on Spiral Bevel Pinion

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ABSTRACT: The spiral bevel pinion has the requirement of developing a localized tooth contact between its mating member (i.e., pinion meshing with the main gear) under no load condition which progressively develop into a full area tooth contact located at the centre region without deviating towards the end of the tooth under full load condition. This localized tooth contact in the gear assembly ensures that no end thrust will be produced on the corner ends of the tooth which leads to the chipping of the spiral gear teeth. Development of a spiral bevel gear pair is the process of generating the pinion with a variety of combinations of profile and lengthwise mismatch to determine the one best suited for the job. Once after the development of the contact pattern is ensured, the tooth profile is saved as the master tooth profile which is used for the production purpose.

KEYWORDS: Spiral bevel pinion, tooth contact pattern, tooth contact analysis.

I. INTRODUCTION

The design and manufacturing of spiral bevel gears is a challenging research topic and is vital for application of such gears in helicopter transmissions, motorcycle gears, reducers, and in other branches of industry. The challenge in the design of spiral bevel gears is to reduce noise and increase its endurance limit. The basis of design of low-noise spiral bevel gears with localized bearing contact is shown in Figure1. The design of low-noise spiral bevel gear drives is based on application of the local synthesis algorithm and tooth contact analysis to achieve a favourable orientation of the bearing contact. The analysis of design is complemented with the investigation of the influence of errors of alignment on transmission and the shift of the bearing contact.

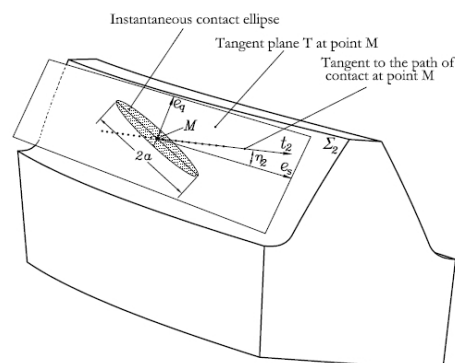


Figure1 Illustration of parameters η_2 and a applied for local synthesis

The tooth contact analysis (TCA) is a mathematical tool used for studying the tooth contact and motion transmitted by the gear teeth using GAGE software. TCA will accurately represent the motion of the gear teeth under any operational load by simulating the motion between the spiral bevel pinion and the spiral bevel gear. The main criterion of the spiral bevel pinion is to develop the desired tooth contact pattern as per TCA requirement. This is done to ensure a localized

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tooth contact on the tooth surface under no load condition which prevents the concentration of loads over the ends of the tooth during operation under full load condition.

II. RELATED WORK

Vilmos Simon, [1] has determined a method for the determination of optimal tooth modifications in spiral bevel gears based on improved load distribution and reduced maximum tooth contact pressure and transmission errors was presented. Fuentes, et al [2], proposed an integrated computerized approach for design and stress analysis of low-noise spiral bevel gear drives with adjusted bearing contact. Tetsu Nagata, et al [3] applied tooth flank form measurement of hypoid gears and tooth contact technology promoted mainly by automotive manufacturers to large bevel gears and a gear design method based on the tooth flank form standard instead of the conventional tooth contact standard has been developed. Robert F Handschuch, [4] described the recent progress for the analysis of spiral bevel gears. The foundation of this work relies on the description of the gear geometry of face-milled spiral bevel gears via the approach developed by Litvin.

III. DEVELOPMENT OF TOOTH CONTACT PATTERN

The main criterion of the spiral bevel pinion is to develop the desired tooth contact pattern as per tooth contact analysis (TCA) requirement. This is carried out to ensure a localized tooth contact on the tooth surface under no load condition thus prevents the concentration of loads over the ends of the tooth during operation under full load condition. The tooth contact is an indication of correct tooth shape both up and down of the tooth profile and length wise on the tooth. It is the actual portion of the gear tooth which makes the contact with its mating pair. Localized tooth contact is formed by grinding the pinion length wise or profile mismatch. A mismatch is the relative distance in the curvature between the profiles or length curves of the two mating teeth. This localized tooth contact between pinion and gear is obtained by grinding the required profile on the convex side of the pinion which is the working side. The proportional changes of the grinding machine setting are used during the development process to modify various parts of the tooth contact pattern or geometry.

IV. STEPS INVOLVED IN THE DEVELOPMENT OF TOOTH CONTACT PATTERN OF THE SPIRAL BEVEL PINION

1. Setting the grinding machine as per machine summary and grinding the concave and convex side in two different grinding wheels and different machine set up.
2. The working side of the pinion is the convex side. So, the required tooth contact development is done on the convex side alone.
3. The gear and the pinion are mounted in the angular hypoid tester after the gear grinding process is done as per the summary.
4. Marking compound is painted over the entire tooth surface of the pinion and the gear in certain areas. Then both the pinion and the gear are set to mesh and roll under no load condition.
5. The area in the flank of the tooth where the marking compound is swept away due to rolling motion is the tooth contact that is initially formed.
6. First order changes are carried out to position the tooth contact area in the central toe region. The first order proportional change used here is the spiral angle proportional change.
7. The desired tooth profile is generated using GAGE software.
8. On comparing the simulated profile with the original part, the GAGE software along with CMM creates the machine setting corrections.
9. Second order changes are carried out to alter the width, length and bias of the contact pattern.
10. Then finally the required tooth contact pattern and tooth profile is obtained and checked for correctness of the desired shape.
11. Several iterations of the above mentioned steps are required to finalize profile based on testing results if it is negative.

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V. BASIC MACHINE SETTING PARAMETERS FOR TOOTH CONTACT DEVELOPMENT

1. Radial distance – This is measured as the distance from centre axis of both X-Y planes to the cutter axis. It helps in both spiral and pressure angle changes.
2. Machine root angle – The angle to which the swinging base is set for cutting the gear. It controls the tooth depth.
3. Ratio of roll – It is the ratio of relative roll required between the imaginary generating gear and the gear being cut in order to generate a desired tooth profile curvature.
4. Centre roll position – It is the centre point between the start roll position and the end roll position. It is mandatory for all order corrections.
5. Work offset – It is the amount of vertical displacement of the work spindle relative to the horizontal plane through the centre of X-Y axis. It affects the profile/width of the tooth contact pattern.
6. Sliding base position – Sliding base can be advanced or withdrawn to meet the requirements of the depth of grinding. It also helps in indexing of the teeth.
7. Machine centre to crossing point – It is the horizontal distance between the vertical line of the machine center axis and the vertical line along the axis of crossing point of the bevel pinion and the grinding wheel. It helps in changing the bias nature of the contact pattern.
8. Wheel diameter – It is the specified diameter of the wheel formed due to dressing of the wheel using the diamond roller dresser. It affects the length wise curvature of the tooth contact pattern.

VI. CORRECTIONS MADE DURING THE TOOTH CONTACT DEVELOPMENT

The first order changes are carried out by visual inspection of the tooth contact pattern of the component mounted on the machine and the necessary spiral angle proportional change is used to position the pattern at central toe region. The contact pattern is moved from the heel region to toe region by changing the following proportional change. Table 1 shows the initial machine setting values which was used for machining the spiral bevel pinion.

Table1: Initial machine setting values

Machine setting	Initial values in mm
Radial distance	153.56977
Sliding base	0.66058
Machine centre to cross point	-4.33677
Ratio of roll	4.10514
Centre roll	38.84
Work offset	0
Inside pressure angle	23.67
Wheel diameter	219.6808

Spiral angle change

The machine setting value used for spiral angle change is the Radial distance. The change in value given to move the pattern inside is -6.2mm. To reverse the direction of contact pattern movement change the signs of the change values. After the first order correction, the following tooth contact pattern is formed as shown in the figure 2.



Pinion



Gear

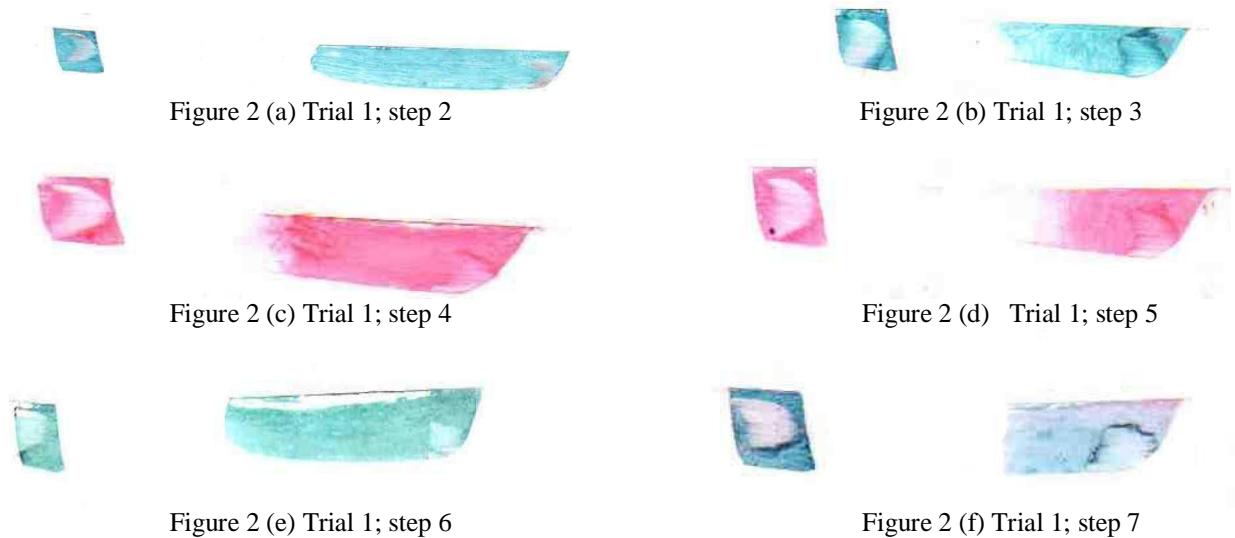
Figure 2 Progressive developments of tooth contact (Trial 1; step 1)

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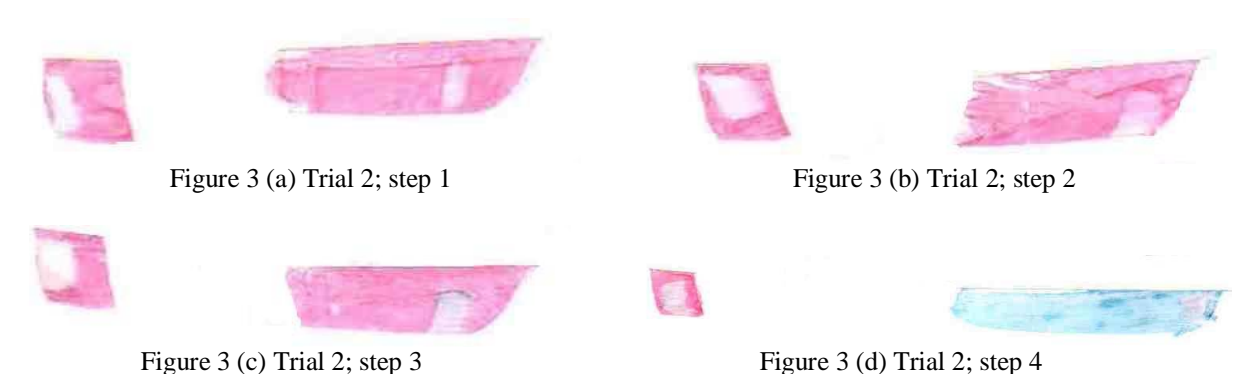
In Figure 2 the shape and size of the contact pattern is not as per the design and in the gear side the pattern is half outside the profile. In order to correct these, 2nd order proportional changes are used. The second order correction changes the size and shape of the contact pattern without affecting its position.



Figures 2 (a), (b), (c), (d), (e) & (f) are the patterns got by machining the component by using 2nd order proportional changes for each trial and measuring it in a universal hypoid testing machine. The main machine setting parameters used to change the shape and size of the contact pattern are Radial distance, Work offset, Wheel diameter, Centre roll, Ratio of roll and inside pressure angle. The final pattern obtained in step 7 after the correction was not satisfactory.

Hence, another set of correction were carried out by using the same initial values as given in Table 1 is used for the second trial with required changes.

Progressive developments of the tooth contact pattern in the second trial as shown in figures 3 (a), (b), (c), (d), (e), (f), (g), (h). In the second trial the main aim was to increase the length of the pattern and to move the contact pattern towards the heel region. The main machine setting parameters changed to get the final contact pattern as shown in figure 3 (h) Trial 2; step 8 are Radial distance, centre roll, wheel diameter, and change in length of machine cutter to sliding base.



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Figure 3 (e) Trial 2; step 5



Figure 3 (f) Trial 2; step 6



Figure 3 (g) Trial 2; step 7



Figure 3 (h) Trial 2; step 8



Final Tooth contact patterns obtained after three iterations are as shown in the figures 4 (a), (b) & (c). The Contact pattern is checked for consistency by using the final machine setting values by machining 3 numbers of spiral bevel pinion. The contact patterns obtained were all satisfactory and were saved as Master profile for further production purpose.

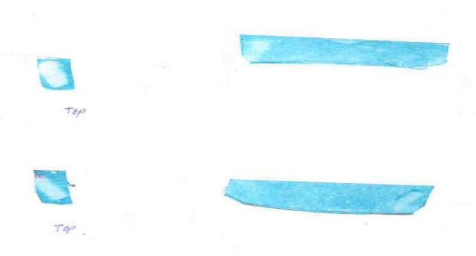


Figure 4 (a) First iteration

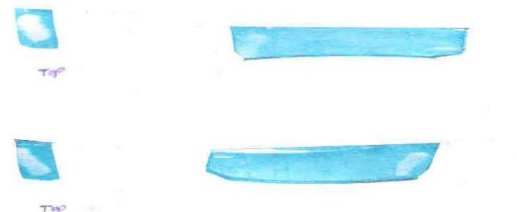


Figure 4 (b) Second iteration

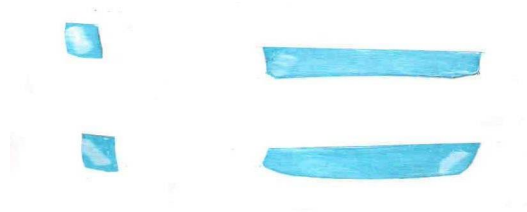


Figure 4 (c) Third iteration

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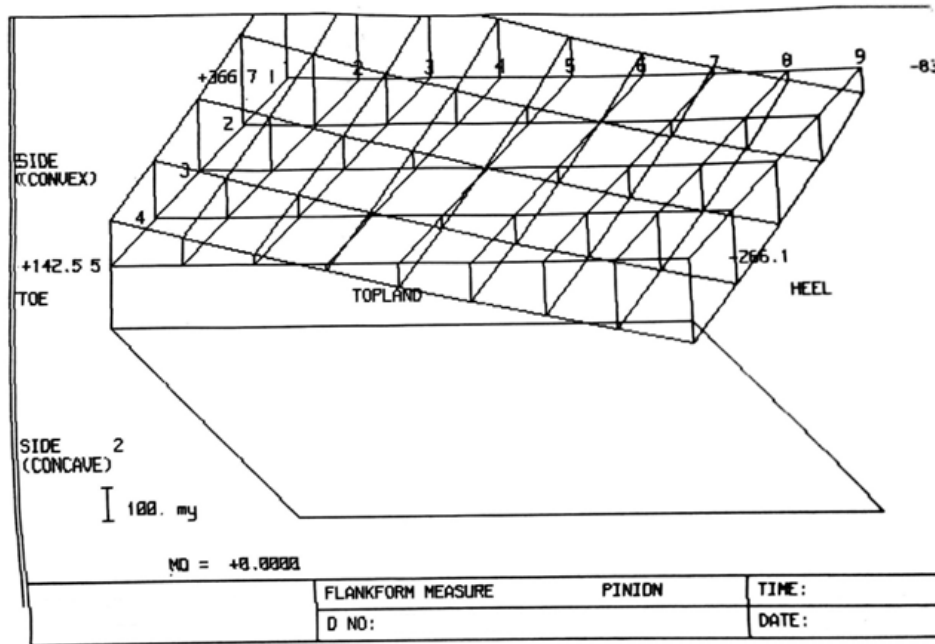


Figure 5: Flank form of the tooth after final contact pattern formed

VII. CONCLUSION

The localized tooth contact pattern developed for this pinion under no load condition progressively develops into the required full area contact pattern under full load operating conditions with no concentration of loads in the corner edges of the spiral teeth which results in improved efficiency of the gear and pinion with longer life.

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