A study on Forging of Spiral Bevel Gear

***Masaki WATANABE、Minoru MAKI,**

Sumio HIROKAWA、Yasuhiro KISHIMOTO

***** Department of Mechanical Engineering
Kanto-Gakuin University
236-8501、Mutuura、Kanazawaku、Yokohama,Japan
e-mail: maki@kanto-gakuin.ac.jp

Abstract: New idea for crowning of tooth surface to obtain point contact for forged gears is proposed. Tooth contact of proposed gearing are confirmed by 3D drawing of tooth surfaces. Based on the Idea, numerical dataset are calculated and used for CAD/CAM systems for manufacturing the electrodes to work metallic mold forging a pair of spiral bevel gears. Using the dataset, master gears of electrodes to work metallic mold to forge a pair of spiral bevel gears were made and contact mark coincide well with 3D contact mark calculated by the theory proposed in this paper.

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Keywords: Spiral Bevel gear, Forging ,Gleason type Spiral bevel, 3 D Expression of Tooth Surface, Electrode to work metallic mold

1. INTRODUCTION

This study report the theory of meshing and manufacturing of a pair of electrodes of spiral bevel gear. The electrodes are used to work metallic mold to forge a pair of spiral bevel gears. So, the pair electrodes have same shape with the forged gears. Numerical dataset are calculated and used for CAD/CAM systems for manufacturing the electrodes. New idea for crowning of tooth surface to obtain point contact for forging gears is proposed. Tooth contact of proposed gearing are confirmed by 3D drawing of tooth surfaces. Master gears of electrode to work metallic pattern to forge a pair of spiral bevel gears were made and contact mark coincide well with 3D contact mark calculated by the theory proposed in this paper.

2. BASIC THEORY

In the case of spiral bevel gear, line contact of pinion and gear tooth surface should be changed to point contact to avoid wrong performance of power transmission.

The authors made a new idea for crowning of tooth surface to obtain point contact for forging gears. Gear tooth surface enveloped by the crown gear contacts the pinion tooth surface with common contact lines with the cone surface of crown gear theoretically. The diameter of cone shaped tool to envelope real forged gear is designed slightly larger than that of theoretical crown gear. And two cones contact with the straight lines composing the cone surface. Then, theoretical gear tooth surface and real tooth surface for forging contact with curved line lies directions of top to bottom of tooth profile.

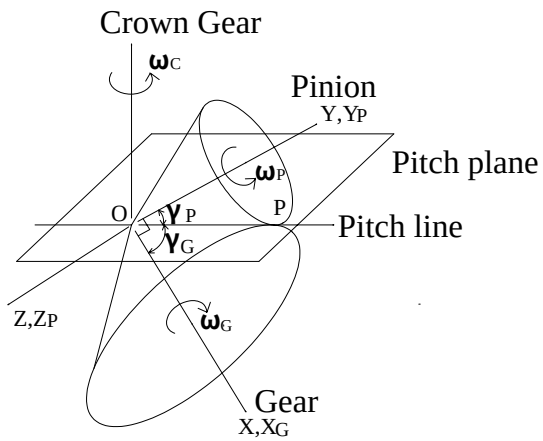

Fig.1 Relations among crown gear, pinion and gear.

Fig.1 shows the relations among crown gear, pinion and gear. Let O-X,Y,Z be a static co-ordinate $O\text{-}X_PY_PZ_P$ O and- $O\text{-}X_GY_GZ_G$ are moving co-ordinate fixed to pinion and gear respectively. Pitch cones of the pinion and the gear and pitch plane of crown gear rotate around their axes and roll with each other. γ_P and γ_G are the half cone angle of pitch cone of pinion and gear, respectively. ωc , ωp and ω_G are angular velocity of crow n gear, pinion and gear , respectively.

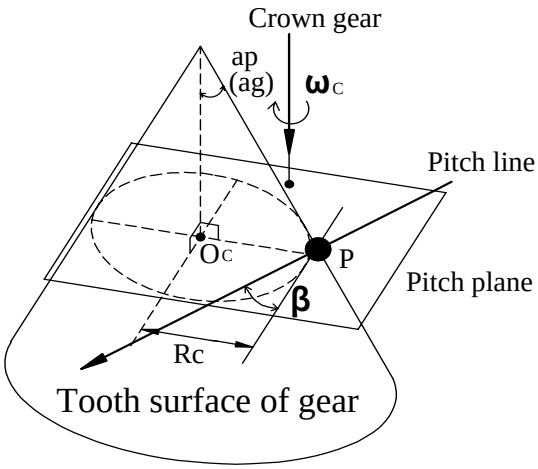

Fig. 2 Cone shaped tooth of Crown gear placed on Pitch plane

Fig.2. shows the cone shaped tooth of crown gear placed on Pitch plane. The cone shaped tooth of crown gear becomes the tool to cut the teeth surfaces of the pinion and the gear. The cone is lied perpendicularly to the pitch plane of crown gear and the distance between axis of the cone and pitch line is cutter radius Rc. β is skew angle of tooth surface of pinion and gear enveloped by the cone shaped tool. The half cone angle ap or ag of the cone tool becomes the pressure angle of the pinion and gear tooth. The tooth surfaces enveloped by the cone shaped tooth of crown gear contact with each other on a curved line which is so called contact line in the gear technology.

3. 3D EXPRESSION

Table 1 shows the dimensions of spiral bevel gear calculated and made in this report.

Fig.3. shows the pinion surface calculated and drawn by 3 dimensional cad systems. Contact lines between cone shaped tool and pinion are calculated under the condition of contact , and tooth surface of pinion is drawn by 3 D /CAD software by drawing surfaces between the contact lines. As shown in Fig.3, pinion surface has the edge of regression near the bottom cone of the teeth. This edge of regression is the same as spiral on base cylinder of involute helicoid. The edge of regression becomes the limit curve of the useful part of the pinion tooth.

Table 1 Dimensions of spiral bevel gear

	Pinion	Gear
Number of teeth	10	24
Pitch cone angle	22 ° 37’	6 ° 23’
Pitch cone diameter	33.0 mm	79.2 m m
Spiral angle	35 ° R	35 ° L
Face width	22 mm	22mm
Shaft angle	90 °	
Module	3.3 mm	

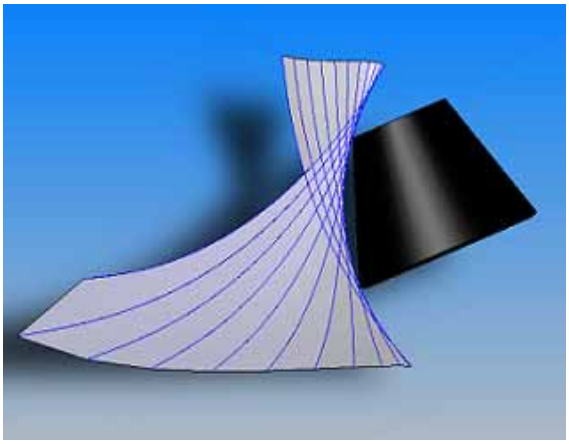

Fig.3 Pinion surface calculated and drawn by 3 dimensional cad software.

Fig. 2.

Fig. 4 3 D Expression of theoretical gear tooth surface and tooth surface for forging, under view of teeth surfaces.

Fig.4 and Fig.5 shows 3 D Expression of theoretical gear tooth surface and tooth surface for

forging with the top and bottom cone of gear blank. Gear tooth surface enveloped by the crown gear contacts the pinion tooth surface with common contact lines with the cone surface of crown gear theoretically.

Fig. 5 3 D Expression of theoretical gear tooth surface and tooth surface for forging, upper view of teeth surfaces.

4. MANUFACTURING AND TESTING

Fig. 6 3D expression of electrode of pinion drawn by 3D / CAD software.

Fig. 6 shows the 3D expression of electrode of pinion drawn by 3D/ CAD software. By calculating contact lines between cone of crown gear and pinion tooth surface, teeth surfaces are drawn by 3D /CAD software adding clearances and top and bottom cone of the pinion. Fig 7 shows manufacturing of the master gears for electrode by machining center using ball endmil. Fig.8 shows completed master pinion of electrode, and Fig.9 shows the completed master gear of electrode. The master pinion and gear are the steel model of the electrode to test the accuracy of the calculation and the performance of the power transmission.

Fig. 10 shows the testing of tooth contact by tooth contact testing apparatus. Fig. 11 shows the tested contact mark on the tooth surfaces of master pinion and gear. These contact marks coincide well with the theoretical contact pattern estimated by Fig.4 and Fig.5.

Fig 7 Manufacturing master gears for electrode by machining center using ball endmil.

Fig.8 Completed master pinion of electrode.

Fig.9 Completed master gear of electrode.

Fig.10 Testing the tooth contact of the master pinion and gear.

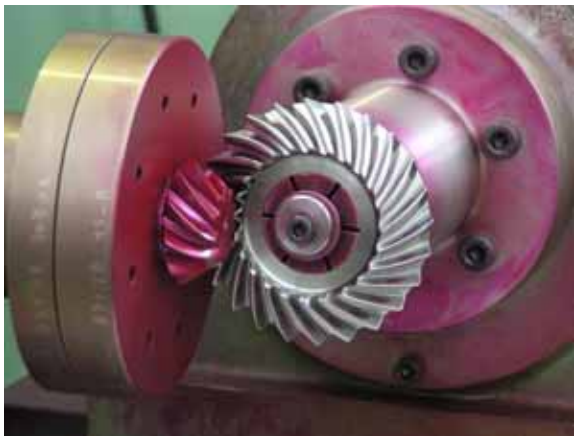

Fig. 11 Tested contact mark on the tooth surfaces of master pinion and gear .

5. CONCLUSION

The authors made a new idea for crowning of tooth surface to obtain point contact for forging gears. By this idea, tooth surface of pinion meshes with the gear tooth surface by conjugate point contact. And the trace of contact points on the gear tooth surface is perpendicular to the lengthwise direction of gear tooth, namely becomes the “square contact” so called in gear technology. By calculating contact lines between cone of crown gear and pinion tooth surface, teeth surfaces are drawn by 3D /CAD software. Numerical dataset are calculated and used for CAD/CAM systems for manufacturing the electrodes to work metallic mold forging a pair of spiral bevel gears. Using the dataset, the master gears for electrode were manufactured by machining center using ball endmil. The master pinion and gear are the steel model of the electrodes to test the accuracy of the calculation and the performance of the power transmission.

The tooth contact of master pinion and gear were tested by tooth contact testing apparatus. The contact marks coincide well with the theoretical contact pattern estimated by 3D/CAD expression.