14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

CONSTRUCTIVE AND TECHNOLOGICAL DEVELOPMENT OF HYPOID GEARS

Gyenge Csaba
Technical University
Cluj-Napoca
Romania

Kismihaly Janos
Emuge Franken Tools Romania
Cluj-Napoca
Romania

ABSTRACT
In this paper we present a new method for analyzing and developing the hypoid gears in order to improve their constructive and technological particularities.. The first part describes the methodologies for optimization the backlash. Then, the variation of the normal vectors and curvature is analyzed in the neighbourhood of the contact point. In the final part is presented a method for modelling and manufacturing these type of gears.
Keywords: gears, hypoid gears, gear manufacturing

1. CONSTRUCTIVE OPTIMIZATION

It has been well understood that the pitch surfaces of the hypoid gear are hyperboloids of revolution (fig.1), and the reference surfaces used for processing the wheels are cones. One may conclude that an infinity of hypoid gears satisfy the same conditions regarding the transmission ratio and distance between axes as a given hyperbolically gear. The authors aim to establish by calculation which of these gears is the most efficient from the technological and constructive points of view [1]. The use of conical surfaces as reference surfaces causes *a deformation of the tooth* in the cross section.

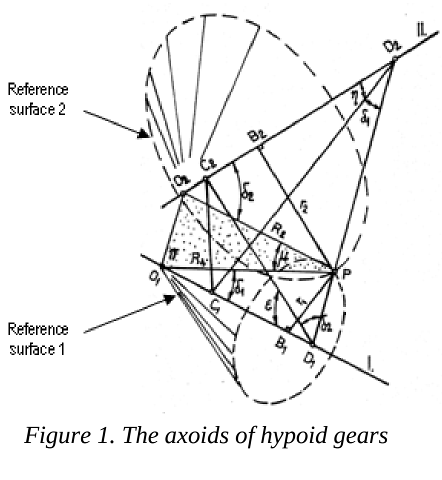


Figure 1. The axoids of hypoid gears

From the kinematical point of view, the wheels of the hypoid gear perform a relative helical motion identical to the motion of the hyperboloids. Their machining should be made by using a proper helical surface. Due to the fact that such a machine-tool does not exist, the wheels of the hypoid gear are processed on machines reproducing the flat generation gear. As a consequence, a backlash is obtained at the tooth ends.

By using the concepts of the differential geometry, one may prove the following relationship between these two gears:

$$\mathrm{tg}\Delta\alpha = \left(R_1 \sin\beta_1 - R_2 \sin\beta_2\right) / \left(R_2 \mathrm{tg}\delta_2 + R_1 \mathrm{tg}\delta_1\right) = f_1\left(k, \delta_2\right) \approx 0 \quad (1)$$

$$1/\rho = 1/\left(\mathrm{tg}\beta_1 - \mathrm{tg}\beta_2\right)[1/\left(R_1 \cos\beta_1\right) - 1/\left(R_2 \cos\beta_2\right) - \mathrm{tg}\Delta\alpha(\mathrm{tg}\beta_2/R_2\mathrm{tg}\delta_2 + \mathrm{tg}\beta_1/R_1\mathrm{tg}\delta_1)] = f_2\left(k, \delta_2\right) = 1/r_{CPC} \quad (2)$$

where: R_1, R_2 are the reference cone distance;
β_1, β_2 are the helix angles;
δ_1, δ_2 are the reference cone angles;
r_{CPC} is the radius of the standard cutting head;
$k=\cos(\beta_2)/\cos(\beta_1)$ is the modification coefficient.

The contact between the tooth flanks is optimal if, for the parameter $\Delta\alpha$ given by Eq. (1), the teeth get a curvature radius given by Equation (2). The optimization process consists in two stages and is performed by a specialized software developed by the authors. The software is dedicated to hypoid gears with circular teeth having constant height. Analyzing the results obtained for a specific gear one may conclude that:

- The optimal curvature radius greatly increases along with the reference cone angle of the wheel for a constant k coefficient;
- The non-symmetry of the tooth profile ($\Delta\alpha$) increases form negative to positive values along with the reference cone angle, for a constant value of k parameter;
- The condition of machining with symmetric tools ($\Delta\alpha=0$) is realized at greater curvature radii when the k parameter is increased.

2. ANALYSIS OF THE CONTACT BETWEEN THE FLANKS OF THE TEETH

The study of the contact between the tooth flanks implies the accurate modelling of the contact surfaces by using a 3D CAD software. Using the method of the reciprocity winding [1], the parametric equation of the tooth flanks $\bar{r} = \bar{r}(p, u)$ is established, generating a 3D mesh allowing the definition of an interpolating B-spline surface.

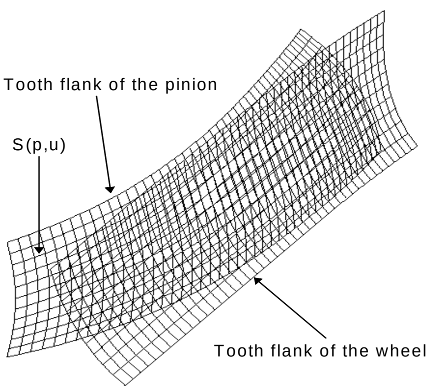
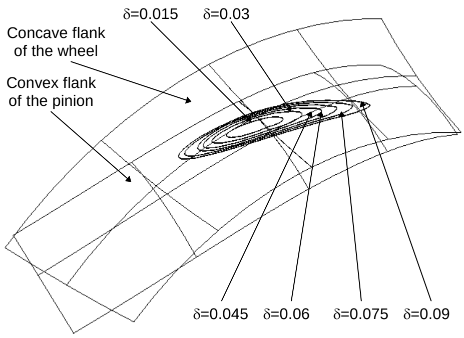


Figure 2. Conjugate flanks in contact.

Using the flanks of the teeth (Figure 2) modelled as B-spline surfaces, the current contact surfaces associated to different distances between the corresponding surfaces have been established. The distances are associated to different loads acting the hypoid gear. The model of the leaded flank is considered as fix in space, while the model of the leading flank performs an incremental motion (the angular increments are very small and correspond to different distances of the tooth surfaces). The intersection curve between these surfaces is then found. A series of intersection curves is thus obtained. Each of these curves is the boundary of the contact surface for an imposed distance δ between the tooth surfaces (Figure 3).

The tooth bearing is the surface swept by the intersection curves of some order along the contact path. The model of the tooth surfaces also allows the analysis of the variation of the normal vectors and curvature radius for different sections located in the neighbourhood of contact point of the hypoid gear [3]).

One may notice that the curvature radii of the convex flank are oriented towards the same side of the flank, their direction does not change (Figure 4). The curvature radii of the concave flank are oriented to the opposite sides of the flank, their direction thus changes. The variation of the curvature radius both for the pinion and wheel flanks are shown in Figure 5.



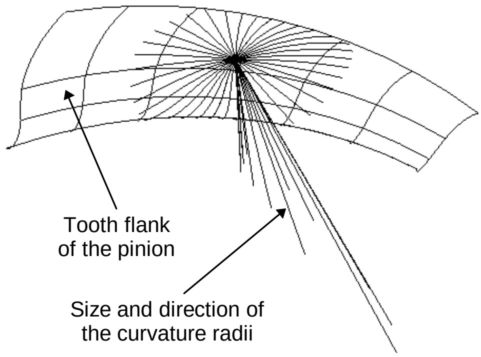


Figure 3. Intersection curves of different orders. *Figure 4. Curvature radii in the main point.*

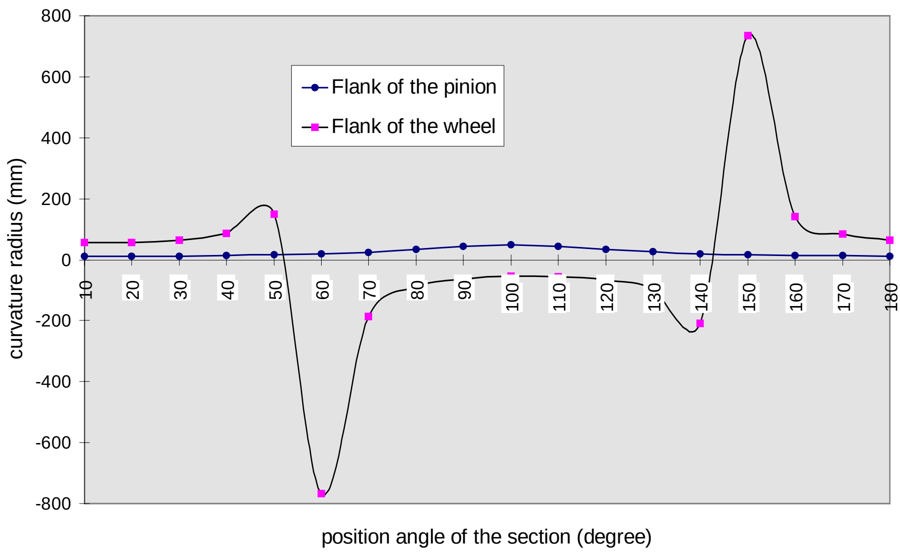


Figure 5. Variation of the curvature radius in the neighbourhood of the main point

3. MODELLING THE GEAR MANUFACTURING PROCESS

When modelling the two technological gears, the flanks of the hypoid wheels are cut by the solid models of the cutting head as the model of the raw material rolls over the flat generation gear (Fig. 6). In order to get a localization of the contact path, the teeth of the pinion are machined by using two cutting heads with different set-up. In the process of successive cutting of the work piece by the model of the cutting head, the tooth flank results as a discontinuous surface.

In order to obtained an approximation as good as possible, the following conditions will be imposed in the case of the (pinion) generation:

- The angular increment of the pinion rotation: 1°
- The angular increment of the cutting head rotation: 2,5995094°
- The height of the roughness generated at successive passes: 0,011 mm (Ra=2,7 µm)

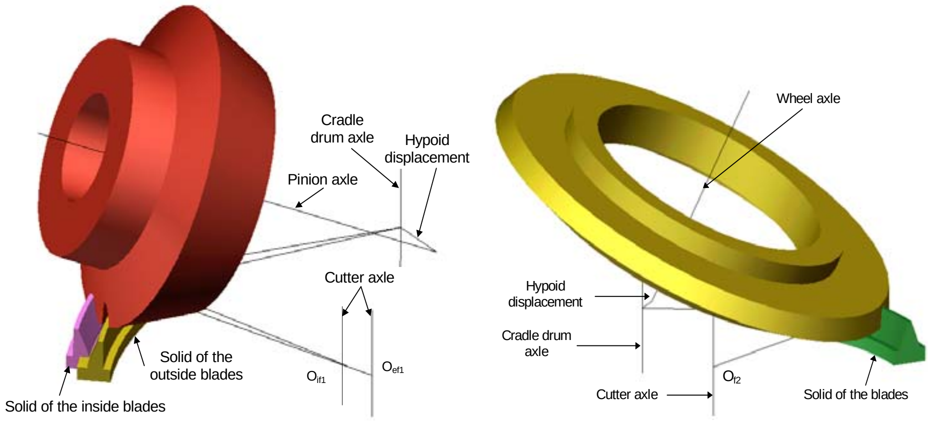


Figure 6. Generation of the hypoid wheels using solid models.

The procedure presented above is more than a simulation of the gearing process, as at the end the CAD system generated the solid model of a wheel. This model may be materialized on appropriate equipment (for example, Rapid Prototyping machines).
Also , Using parameters determined by numerical, have conducted a series of pairs of hypoid gears (fig.7.) on the the hobbing machine 5S280P

Figure 7. The manufactured hypoid gears

4. CONCLUSIONS

The end result of the modelling process developed is a 3D model solid identical to the real one that may make studies of contact and can be used to develop technologies for manufacturing process, by different methods
The methodology presented above, consisting in the use of software packages for calculating and optimizing the gears, the facilities offered by the CAD systems and the modern Rapid Prototyping machines, represents a global frame for studying the hypoid gears.

5. REFERENCES

[1] Gyenge, Cs. Contribuții asupra îmbunătățirii preciziei frezelor-melc pentru executarea angrenajului melcat duplex. Teză de doctorat, IPCN, 1979.
[2] Kismihaly, J. Cercetări legate de îmbunătățirea tehnologiei de fabricație a angrenajelor hipoide. Teză de doctorat, UTCN, 1999.
[3] Dudas, I. The theory $ Practice of Worm Gears Drives. Penton Press, London, United Kingdom, 2000, ISBN 1 8571 8027 5
[4] Matra Datavision. Euclid. Advance Surface, vol 1. (1997).
[5] Levai, I.: Hipoid hajtasok tervezesenek alapjai. University Press Miskolc, 1994