ANALYSIS OF POSSIBILITY OF APPLYING ATYPICAL MESHING IN DRIVING UNITS OF CARS

Bogdan Kozik, Grzegorz Budzik, Jacek Pacana

Rzeszów University of Technology
Faculty of Mechanical Engineering and Aeronautic
Powstańców Warszawy Av. 8, 35-959 Rzeszów, Poland
e-mail: bogkozik@prz.edu.pl, gbudzik@prz.edu.pl, pacanaj@prz.edu.pl

Abstract

A constant tendency in the development of gear transmission is aiming for increasing its load capacity and minimalizing its outside dimensions and weight. It is particularly important in automotive vehicles. In every type of transmission, among others in gear-boxes, mainly involute profile wheels are used.

The work presents analysis of possibility of applying atypical meshing in driving units of cars. This kind of meshing can be alternative to involute meshing which is most widely used in gear transmission. Among existing solutions of this type, Nowikow meshing is applied most often.

A different kind of concavo-convex gearing is BBW type gearing. The gearing is obtained by generation with a tool with reference profile in which tooth profile of a rack is an involute.

The analysis of possibility of applying has been carried out with the exemplary concavo-convex BBW type gearing. In BBW type gearing a wheel with a smaller number of teeth has a positive profile curvature, and a cooperating wheel has a negative curvature. Teeth profiles are conjugate ones, transverse contact ratio is higher than 1, so this kind of gearing may be used also in gears with straight teeth. What is more linear contact occurring along the whole width of mating teeth, in comparison to point contact in Nowikow meshing, creates possibilities of obtaining higher load capacity of gearing. BBW gearing based on involute-derivative tooth profiles is characterized by smaller sensitivity to the change of axle distance than Nowikow meshing.

Keywords: *gears, involute profile, atypical meshing*

1. Introduction

One of the ways of increasing the load capacity of gear transmission is replacing involute gearing with the gearing of concavo-convex tooth profiles [1- 5]. Among existing solutions of this type, Nowikow meshing is most widely used. However making gears requires applying cutting tools with complicated reference profiles. In case of applying rapid prototyping methods to make the gears this problem does not exist any longer. In Nowikow meshing mating of teeth is realised in point contact. Transverse tooth contact ratio equals zero, and in that case to ensure smoothness of the gearing, Nowikow meshings are made only as helical gears (overlap tooth contact ratio has to be higher than 1).

A different kind of concavo-convex gearing which can be applied in driving units is BBW type gearing [3]. Prototypes of gears with this kind of profiles can be made by means of rapid prototyping based on 3D-CAD model [5-7]. In case of lot production of wheels for driving units this kind of gearing can be obtained by generation with a tool with reference profile in which tooth profile of a rack is an involute. In BBW type gearing a wheel with a smaller number of teeth has a positive profile curvature, and a cooperating wheel has a negative curvature. Teeth profiles are conjugate ones, transverse contact ratio is bigger than one, so this kind of gearing may be used also in gears with straight teeth [8]. What is more linear contact occurring along the whole width of mating teeth, in comparison to point contact in Nowikow meshing, creates possibilities of obtaining higher load capacity of gearing. BBW gearing based on involute-derivative tooth profiles is characterised by smaller sensivity to the change of axle distance than Nowikow meshing with concavo-convex teeth.

2. Properties of BBW type gearing

The basic feature of BBW type gearing (Fig. 1) is involute profile of rack-type tool cutting edge, generating convex pinion teeth profiles and concave wheel teeth profiles.

In case of making profiles in CAD system a tool can be virtual one and is used to create 3D-CAD model of wheel's rim. This kind of modelling is realised by means of computer simulated gear generation [9-13].

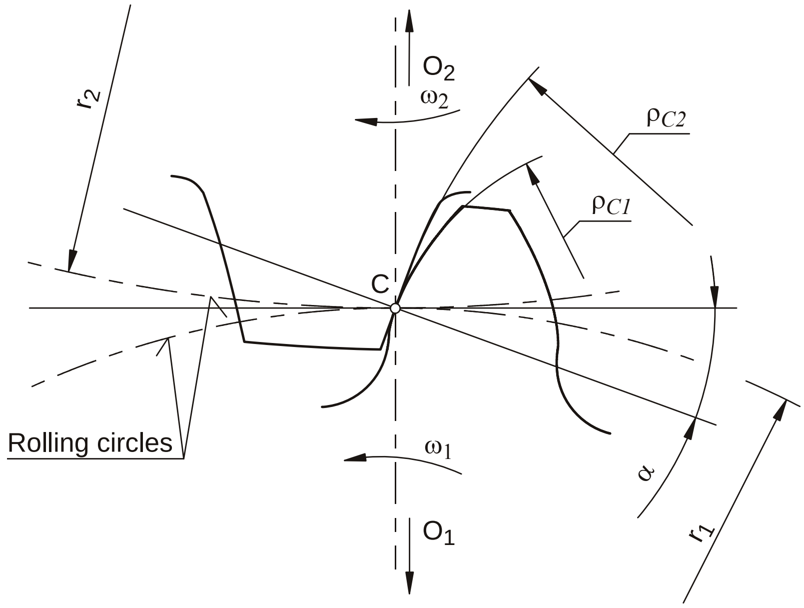

Fig. 1. The BBW type gearing

Involute is defined by the following parameters: module m, main pressure angle α_0 and apparent number of teeth z_0 - defining base circle d_b, from which involute is unrolled

$$d_b = z_0\ m\ \cos\alpha_0 . \quad (1)$$

Apparent number of teeth is defined according to the formula:

$$\frac{z_0}{z_2} = \cos\psi , \quad (2)$$

where:

z_2 - wheel teeth number,

ψ - angle taken for this type of gearing, which should be higher than 31° [1], to obtain cooperation of concavo-convex teeth.

The way of constructing cutting tool profile is given in works [1, 2, 4].

Introductory analysis of the BBW gearing showed, that in a general case (regardless of z_0 and z_2) the gearing should have teeth with a smaller height and so:

- dedendum of a pinion h_{f1} = (0,2 - 0,5) m_n,
- addendum of a gear wheel h_{a2} = (0,2 - 0,5) m_n,
- dedendum of a gear wheel h_{f2} = (0,8 - 1,2) m_n,
- addendum of a pinion h_{a1} = (0,8 - 1,2) m_n
- pressure angle on pitch circle α_0 = (18° - 24°).

For the analysis of the BBW type gearing cutting edge profile of tool for shaping a pinion in normal section presented in Fig. 2 has been assumed and analogical tool for shaping a gear (Fig. 3) [6].

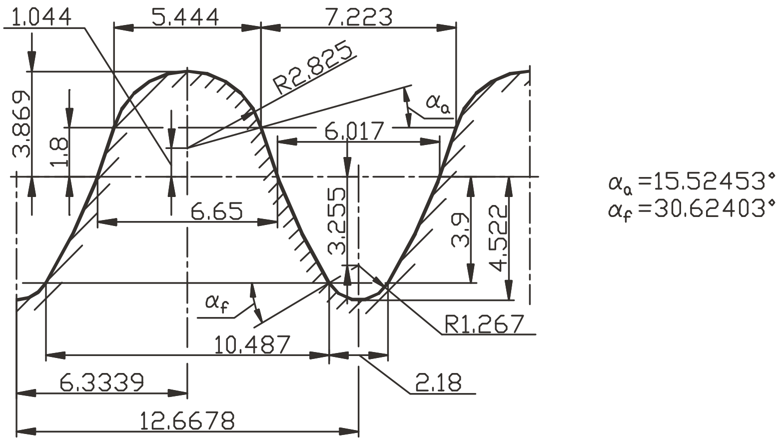

Fig. 2. Cutting edge profile of tool for shaping a pinion (in normal section)

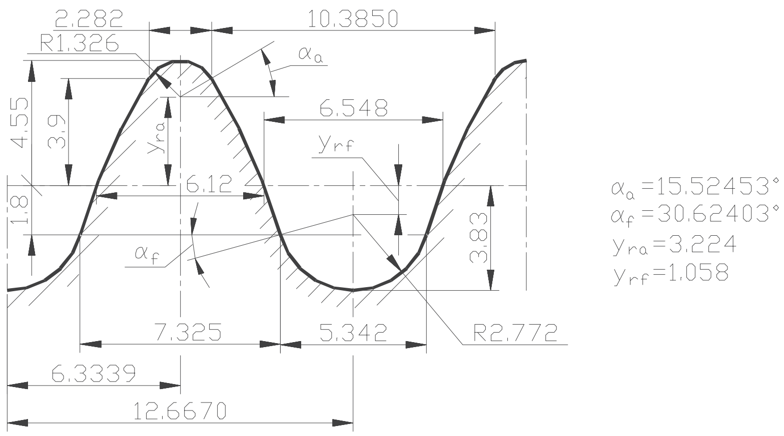

Fig. 3. Cutting edge profile of tool for shaping a gear wheel (in normal section)

Applying the above mentioned profiles of tool cutting edges, the profiles of BBW type gear wheels were generated by means of computer simulated gear generation process [9]. For analysis of the BBW gearing a pair of wheels with transmission ratio u=1.22 was taken. The other parameters are presented in Tab. 1.

Tab. 1. Parameters of the analysed pair of the BBW gearing

	Pinion	Wheel
Teeth number	27	35
Module	4	4
Pressure angle	21°	21°
Addendum	4.305	1.985
Dedendum	3.815	4.565

A pair of gears cooperation at entering the meshing, in pitch point and at demeshing is presented in Fig. 4. It is a case, when active tooth depth is nominal (tool- tip radiuses were not taken into account). After applying tool-tip radiuses from the technological point of view, contact ratio equals approximately 1.15.

The path of contact in discussed gearing is a curve determined by points A-C-E, where point A defines entering the teeth into meshing, whereas point E defines demesh (Fig. 4).

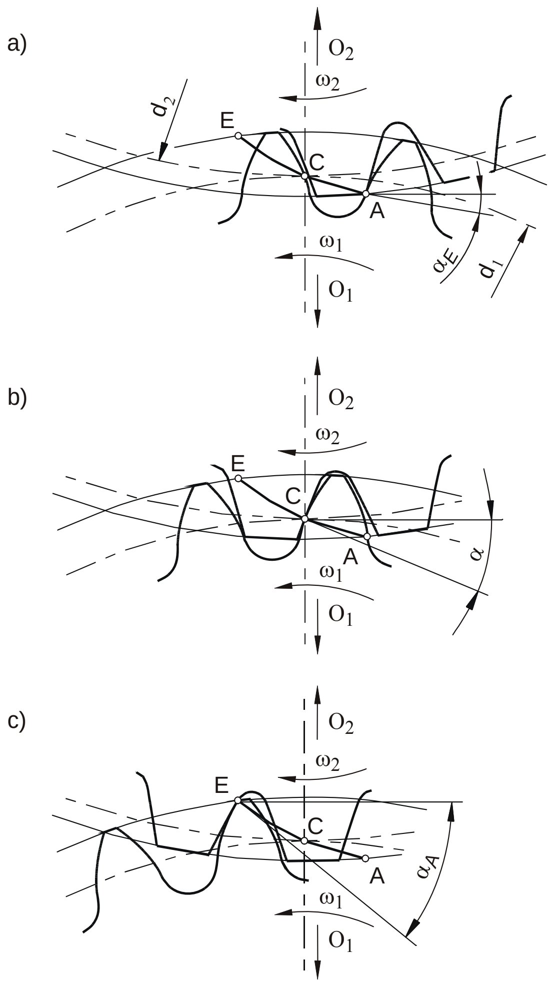

Fig. 4. Cooperation of BBW type gear wheels: a) in entering the meshing, b) in pitch point, c) at demeshing

Contact line is characterised by pressure angle decreasing in direction of tooth-root and increasing in direction of tooth point counting from the pitch point C.

3. Research prototypes of gears

Theoretical analysis allowed for creating 3D-CAD virtual models of gears to be made by means of rapid prototyping (Fig. 5). Cutting tools for creating metal research prototypes (Fig. 6) were also made. They were tested on circulating power stand (Fig. 7).

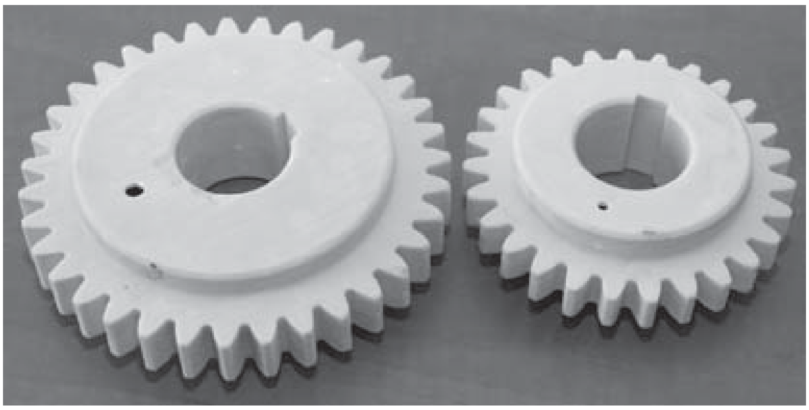

Fig. 5. Research prototypes of gears made by means of 3DP method

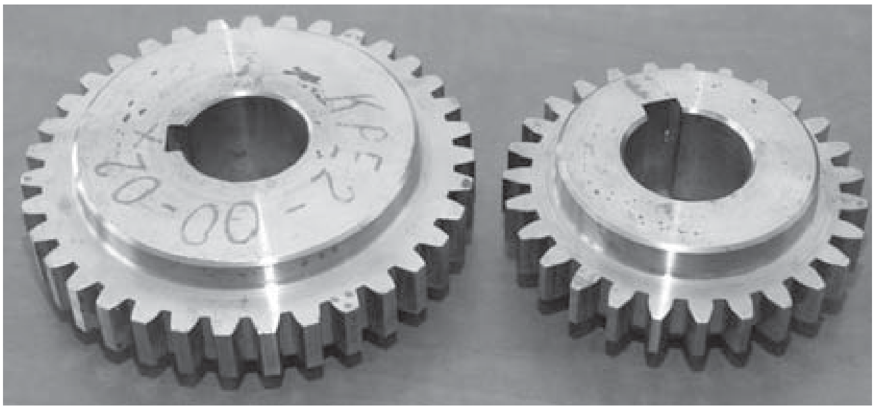

Fig. 6. Research prototypes of gears made by means of hobbing

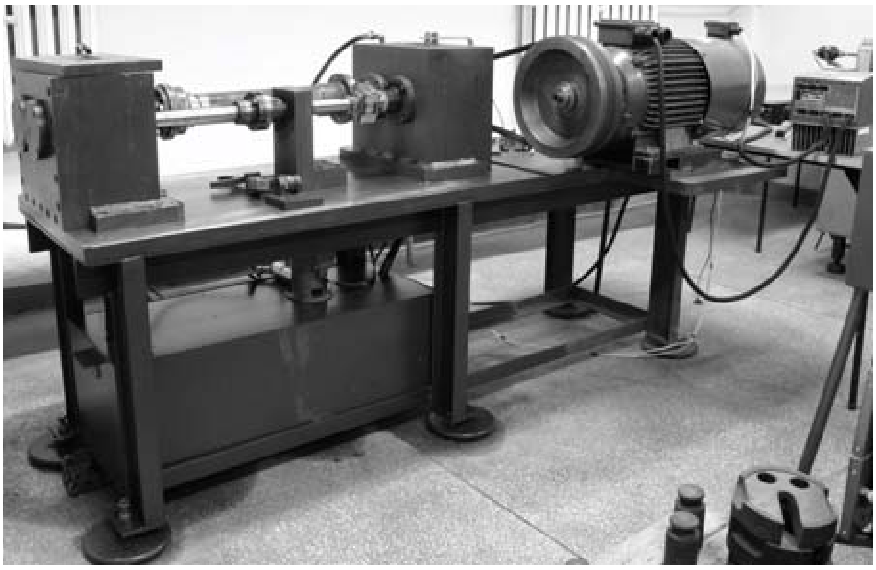

Fig. 7. Circulating power stand for examining gears

4. Conclusion

As a result of stand tests one can state that gears with BBW type profiles have better fatigue strength parameters in comparison to involute profile gears.

The load capacity of a gearing considering the pitting (according to Hertz) is determined by the greatest normal stress [5-6]. Taking that into account one can state that for a gearing with parameters: m_n = 4 mm, z_1 = 27, z_2 = 35 α_0 = 21° normal stress in case of involute gears are about 60% greater than normal stress that occurs in gears with concavo-convex meshing of BBW type. That is why the load capacity of the discussed gearing is bigger. Using the gearing with such a tooth profile enables to increase the gear load without increasing its size.

Therefore one can claim that using gears with BBW type profiles in driving units makes it possible to achieve greater load capacity having the same overall dimensions as gear transmission with involute profile wheels.

In case of given values of loading applying BBW profile wheels causes minimalizing size and at the same time weight of gear transmission. Consequently these factors influence minimalizing weight of the whole vehicle and what follows reducing the amount of fuel used by it.

This research work is financed from the funds allotted for science in 2007-2009, as a research and development project (R03 021 02) titled „Developing of innovative gear boxes with atypical teeth".

References

[1] Buczek, J., *Konstrukcyjne i technologiczne podstawy projektowania przekładni zębatych o zazębieniu wklęsło-wypukłym*. Rozprawa habilitacyjna, Wydawnictwo Naukowe Politechniki Lubelskiej, Mechanika 44, s. 1-294, Lublin 1990.

[2] Buczek, J., *Kształtowanie bocznych zarysów o podwyższonej nośności zazębienia*. Mechanik 3, s. 81-84, 1990.

[3] Buczek, J., Buczek, W., Warzybok, T., *Przekładnia zębata o zmiennym kącie przyporu oraz sposób obróbki zarysów zębów przekładni o zmiennym kącie przyporu*. Patenty Nr 245813, W-wa 1989, Nr 4, 825, 715 USA 1989.

[4] Buczek, J., Buczek, W., *Zewnętrzne walcowe przekładnie o zazębieniu wklęsło-wypukłym typu BBW. Konstrukcja zarysu zęba zębnika na przykładzie zębnika*. Biuletyn LTN, Sect E. Vol. 1, 1, s. 53-60, 1992.

[5] Budzik, G., Markowski, T., Sobolak, M., *Hybrid foundry patterns of bevel gears*. Archives of Foundry Engineering, Vol. 7, Iss. 1/2007, pp. 131-134.

[6] Budzik, G., Markowski, T., Sobolak, M., *Prototyping of Bevel Gears of Aircraft Power Transmission*, Journal of KONES Powertrain and Transport, Vol. 14, No. 2, pp. 61-66, Warszawa 2007.

[7] Budzik, G., Pacana, J., *Standaryzacja modelu 3D koła zębatego o zębach prostych w środowisku Unigraphics*, Zeszyty Naukowe Politechniki Rzeszowskiej Nr 217, Koła Zębate 2004, Oficyna Wydawnicza Politechniki Rzeszowskiej, s. 16-22, Rzeszów 2004.

[8] Dietrych, M., *Podstawy konstrukcji maszyn, T. IV*, PWN, Warszawa 1991.

[9] Kozik, B., Komputer Simulated Generation of Teeth in the BBW Toothing Wheels. International Scientific Conference Progressive Technologies and Materials PRO-TECH-MA '07, Bezmiechowa 2007.

[10] Kozik, B., Mijał, M., *Zarysy krawędzi skrawających narzędzi zębatkowych do obróbki zębów kół zazębienia typu BBW*. Zeszyty Naukowe Politechniki Rzeszowskiej, Rzeszów 1997.

[11] Sobolak, M., Budzik, G., *Prototypowanie kół zębatych z wykorzystaniem stereolitografii i odlewania próżniowego*, Zeszyty Naukowe Politechniki Rzeszowskiej Nr 217, Koła Zębate 2004, Oficyna Wydawnicza Politechniki Rzeszowskiej, s. 264-270, Rzeszów 2004.

[12] Sobolak, M., Budzik, G., *Experimental Method of Tooth Contact Analysis (TCA) With Rapid Prototyping (RP) Use*, Rapid Prototyping Journal, Vol. 14, No. 4, pp. 197-201, 2008.

[13] Sobolak, M., Budzik, G., *Two-Dimensional Simulation of Tool Geometry Mapping in Gear Machining in CAD Environment*, Progressive Technologies and Materials No. 2/2007, pp. 115-121, Rzeszów 2007.