

Miloš NĚMČEK *

DESIGN OF A NON STANDARD INTERNAL GEAR PAIR
NÁVRH SOUKOLÍ S NESTANDARNÍM VNITŘNÍM OZUBENÍM

Abstract

Design of internal gear pairs is the common designer's task. Gears with an internal gearing are today more exploited for their indisputable advantages. There are some problems when they are designed (for example various types of interferences) for standard pairs too. Non standard profiles for internal gears were not ordinarily utilized till this time. The main reason was first of all very complicated meshing conditions. Mathematical procedures for checking of these conditions are complicated (usually numerical ones). This article brings the method how to design these non standard internal pairs easy way. Even application of a High Contact Ratio (HCR) gearing for an internal gearing will be easy when this method will be used.

Abstrakt

Návrh soukolí s vnitřním ozubením je běžnou prací konstruktéra. Kola s vnitřním ozubením jsou dnes hojně využívaná pro jejich nesporné výhody. Samozřejmě existují taky určité problémy i při návrhu vnitřního soukolí se standardním základním profilem (například různé druhy interferencí). Nestandardní základní profil pro kola s vnitřním ozubením se dosud moc nevyužíval. Hlavním důvodem byly poměrně komplikované záběrové podmínky. Matematické postupy pro kontrolu těchto podmínek jsou komplikované (obvykle numerické metody). Tento článek přináší návod, jak snadno navrhovat tyto nestandardní soukolí s vnitřním ozubením. Dokonce návrh HCR vnitřního ozubení při použití popsaného postupu bude snadný.

1 DESIGN OF A NON STANDARD INTERNAL GEAR PAIR

This chapter deals with a design of a non standard internal toothed pair (for example with HCR gearing). It shows to present practices for its design and their disadvantages when non standard gearing is using. The chapter refers to restrictions given in the standard DIN 3993 at the same time. It summarizes a set of tools suitable for a design of such a gearing as well.

The designer battles with a lot of problems when is designing an internal gear pair. The main problems are various types of interferences though. In addition they have published that it is impossible to design an internal gear pair with small difference between teeth numbers of a pinion and a ring gear. And for rest cases they have recommended using an additional addendum cutting-down of a ring gear. Nevertheless such combinations of gear parameters exist which make a safe design possible, even when no a ring gear addendum cutting-off is used. DIN 3993 is dealing with this problem (unfortunately with limitations) and some Russian authors too. There are a lot of manually calculated diagrams of boundary addendum modification coefficients (Blocking Contours Diagrams - BCD) in their books. The most famous of them is in [1]. All of these works and standards concern only to standard gearing regrettably.

1.1 How to design

It is very complicated to design HCR internal gearing (it is often impossible also). If by chance number of teeth of pinion and ring gear match to some of published diagrams [1] and [4], the problem is solved only partly. These diagrams are created only for standard gearing. When HCR gearing is used, its blocking contours diagram can be diametrically different one. Moreover there is no an approximate base for its design. But for a geometric design suitable DIN 3993 markedly restricts an area for a choice of suitable addendum modification coefficients.

* prof. Dr. Ing. VŠB – TU Ostrava, Department of Machine Parts and Mechanisms

1.2 Solving using Blocking Contours Diagrams

From the previous chapter it results that all common basis of design for an internal gearing are unsatisfactory ones and they can't be utilized. In addition they are designated only for the standard basic tooth profile. Diagrams in the standard DIN 3993 are very restricted in the area of negative addendum modification coefficients for ring gear beside (see [4]).

For correct design of HCR internal gearing it is necessary to find out an all functional area of existence of pair pinion – ring gear. This task is very complex and the only one possibility is drawing of these diagrams by using PC. There are many numerical calculations to do when they are drawing.

What is necessary to observe are fatal conditions for a gear pair existence and a basic serviceability :

- working transverse pressure angle equals to zero
- interference at a pinion fillets
- interference at a ring gear fillets
- interference between the tips
- truncating of wheel tips by a Fellow cutter tips
- truncating of wheel tips by a Fellow cutter roots
- wheels tips going by in a bottom position
- undercut of pinion
- allowable undercut of pinion (no shortening of a transverse ratio)
- equality between basic and tip diameters of a ring gear
- pointed pinion
- pointed ring gear
- transverse ratio equals to one
- acceptable value of specific sliding at roots and tips.

Very useful are some optimization criteria :

- balanced specific sliding
- required crest width of pinion and ring gear
- required value of transverse ratio (for example equals to an integer number)
- required working centre distance or working transverse pressure angle
- required tip diameters of pinion and ring gear

To get all these curves to one output window online means to perform a lot of simply or more complicated numerical calculations and tricky techniques concern to geometric and meshing parameters of mating gears. Also it is very important for designers to have user friendly input form for a data entry. So there is necessary a close cooperation among a designer, a mathematician and a software engineer when this software is creating.

The result of this effort is an electronic version of noted diagrams (BCD). But this electronic BCD are on the higher level than forementioned ones (in paper form). The electronic version of BCD was developed on the department of Machine parts and mechanisms of Technical university of Ostrava. This software is a part of the software package for a geometric design and a making-up data for FEM calculations. The core of this package is just an electronic version of BCD, see [3].

The figure 1 is an output of this software. Marked area is the operational area for solved HCR internal gearing even without a ring gear tip cutting-off ! There are the curve and the line passing through this area. The curve passing through this area is the curve of balanced specific sliding. From that we can see how easy is to do important optimization tasks in electronic BCD. There are no suitable recipes or templates for these parameters in known books or standards. Method using educated guess is a time consuming and often doesn't guide to any solution (for extremely parameters it is impossible). But using an electronic BCD for the finding of the operational area is a simple and quick question.

1.3 Practical demonstration

The solved HCR internal gearing with extended addendum ($h_{a1,2} = 1.2 \cdot m_n$) and with numbers of teeth $z_1 = 20$, $z_2 = -40$ has its BCD on figure 1. Another restriction are tip widths ($s_{a1,2} = 0.25 \cdot m_n$), transverse contact ratio ($\varepsilon_\alpha \geq 1.2$), required working centre distance ($a_w = 10.5$ mm) and reaching of balanced specific sliding would be an advantage. Used Fellow cutter has 35 teeth and its addendum modification coefficient x_0 is just equals zero. The operational area for demanding parameters is fulfilled gray. Two intersect lines in the bottom part of the fulfilled area – the straight line is for required working centre distance and the curve means balanced specific sliding.

Coordinates of their intersection is searched solution ($x_1 = 1.148$, $x_2 = -1.729$), see zoomed look on figure 2, this point is marked with a circle. In real program has each of curves its own color and it is possible to display curves one by one (see figure 3).

Obtaining of the two values of addendum modification coefficients means that the task is finished. But an experienced designer always will perform a complex geometric checking for these parameters. A lot of suitable programs are available. For example it is on figure 4 detail of meshing area of this solved gear pair.

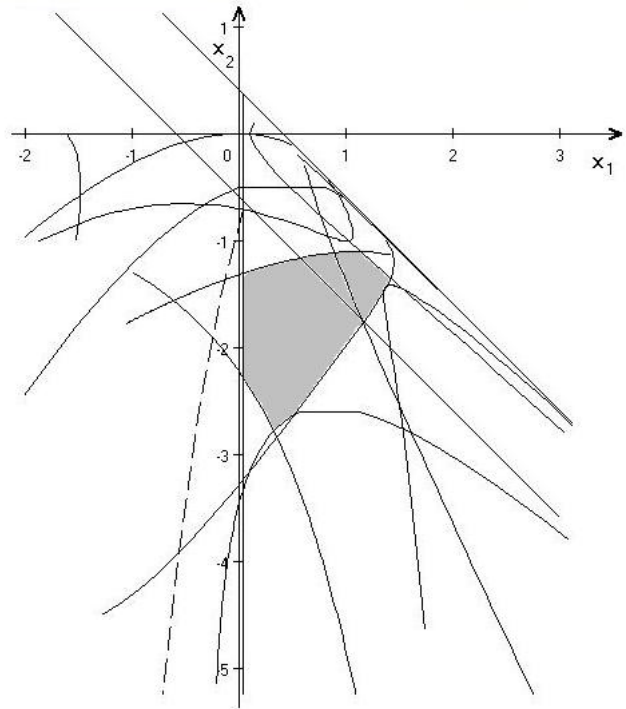


Fig. 1 Output window of the program "BCD"

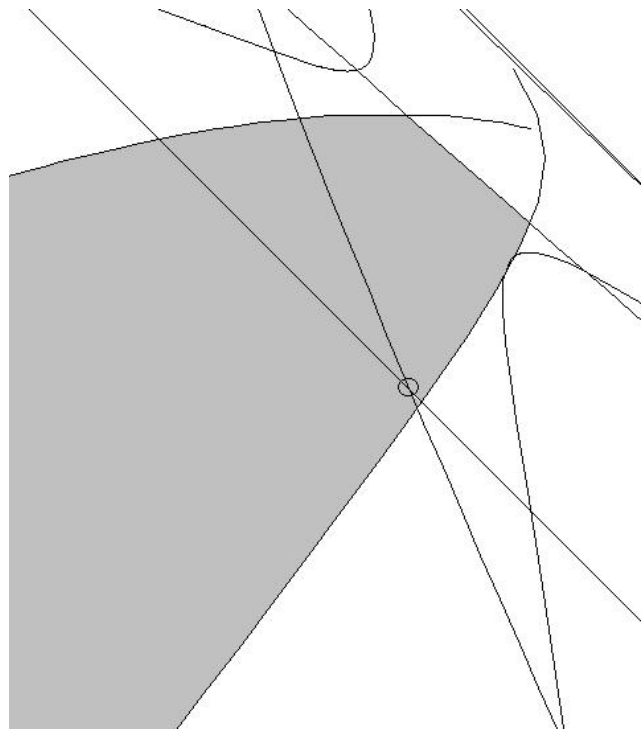


Fig. 2 Zoomed look at operational area

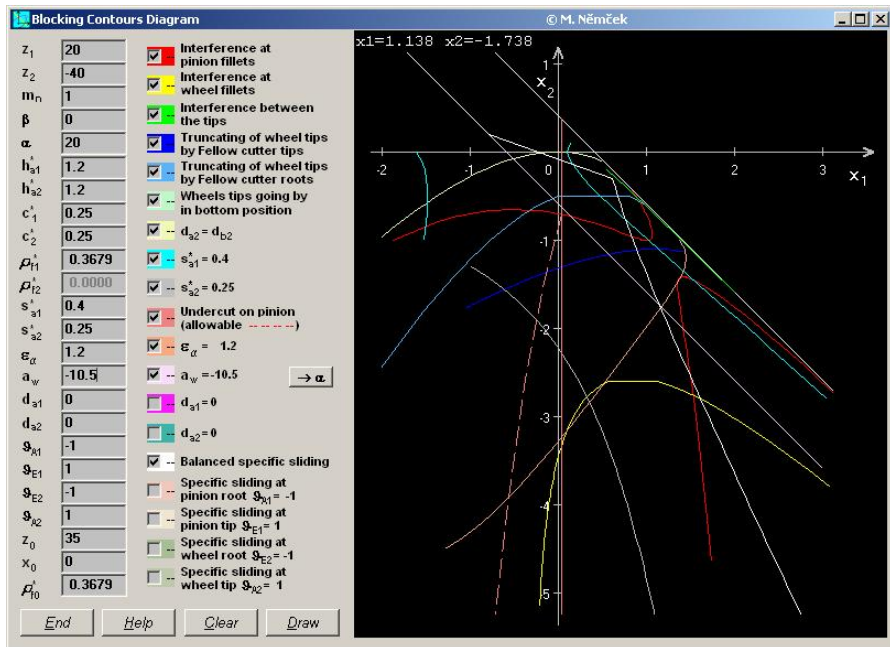


Fig. 3 Full view on BCD program

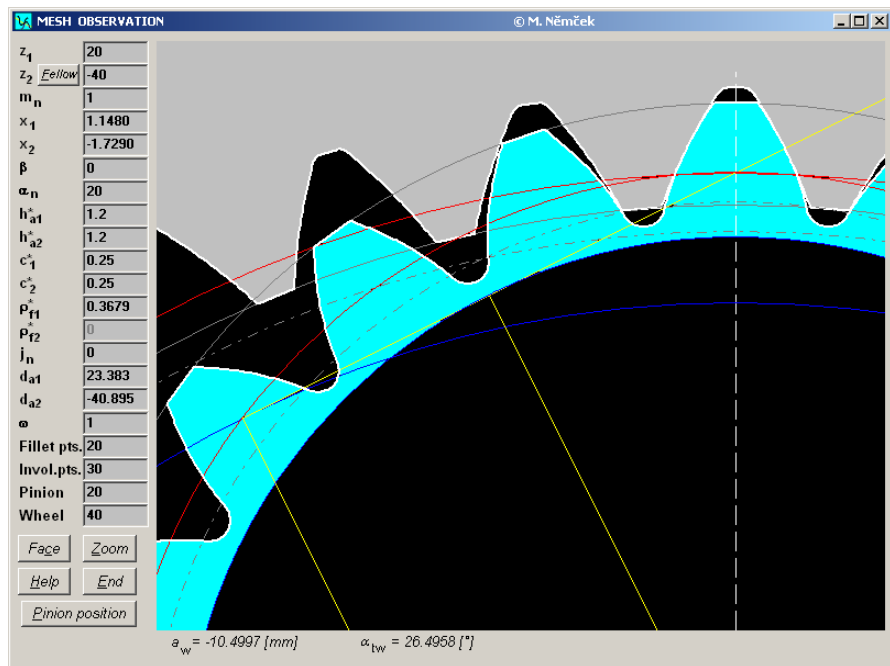


Fig. 4 Detail of meshing area

2 CONCLUSIONS

Final point of the all design is a loading capacity calculation using known standards or FEM calculations. There is also a good generator of data file describing teeth and fillets shape for a pinion and a ring gear among set of programs mentioned above.

Using the electronic BCD gives to a designer a higher order speed and quality of his decision making. In some cases a design by an old techniques is beyond possibility or extremely tough. It is valid mainly for non standard gearing or gear pairs with a small difference between teeth numbers. The electronic BCD gives good results for all extreme parameters promptly.

3 ACKNOWLEDGMENTS

This contribution was elaborated with the support of the project 1M0568 – Josef Bozek Research Center of Engine and Automotive technology (Czech republic). The author gratefully acknowledges it.

REFERENCES

- [1] Болотовский, Б. Справочник по геометрическому расчету эвольвентных зубчатых и червячных передач. МАШИНОСТРОЕНИЕ, Москва 1986.
- [2] Moravec, V. Konstrukce strojů a zařízení II. čelní ozubená kola. MONTANEX a.s. Ostrava 2001. ISBN 80-7225-051-5.
- [3] Němček, M. Vybrané problémy geometrie čelních ozubených kol. MONTANEX a.s. Ostrava, 2003 ISBN 80-7225-111-2.
- [4] DIN 3993 Geometrische Auslegung von zylindrischen Inneradpaaren

Reviewer: prof. Ing. Horst Gondek, DrSc , VŠB-TU of Ostrava