# Opponent review of the dissertation thesis

Title: **New possibilities for gearwheels of automotive gearboxes**
Author: Ing. Ondřej Miláček
Scope of work: 121 pages
Date of publication: 2021
Review author: prof. Dr. Ing. Miloš Němček, VŠB-TU Ostrava

Based on the request (ref. no. 175/12921/O/2023) of prof. Ing. Tomáš Jirout, vice dean for VVČ of FS ČVUT.

***The analysis of the current state of the solved problems***

The issue addressed is topical. Constant pressure from the EU authorities to reduce emissions and noise in transport vehicles forces manufacturers to look for various measures to meet these, sometimes almost impossible, goals. One of them is optimization in the field of gears. The effort is to increase their carrying capacity and reduce noise. All this while simultaneously reducing their dimensions (weight) and, if possible, lower costs. An interesting direction is the use of additive manufacturing possibilities and the associated use of new metal materials. This work also aims in this direction. From this follows the topicality of the topic worked on by the author.

***Objectives of the doctoral thesis***

The doctoral student set two main goals of the work:
- to determine the loading capacity of gears made of PM material, which were additionally treated with a special technology (HIP). This was solved for real car transmission gears,
- to determine the loading capacity of these wheels (PM), but with a new, asymmetrical tooth profile. The strengthening was carried out using a special technology – rolling.

These goals are demanding and require a considerable amount of both theoretical and mainly experimental work. Of course, all this in cooperation with a number of not only testing facilities, but also specialized foreign manufacturers.

***Dissertation thesis description***

In the introduction, the author describes the current technologies used in the production of car transmission gears. It deals in more detail with the rolling of gears. The following is an overview of materials and a detailed description of so-called powder metallurgy (PM). It also describes the so-called HIP process (Hot Isostatic Pressing), which significantly improves the mechanical properties of PM products. The following is an overview of the gearing in terms of the geometry of the tooth profile. Here, the author decided to use an involute non-symmetric gear profile.

The author also deals with tests of these gearboxes. He describes in detail the types of test benches and shows which devices he will test his designs on. At the same time, he describes his own design for the Labview software application. Here you can see that the student has considerable experience with these tests. In connection with these tests, he performs an analysis of energy losses in test circuits. This part is very valuable and precisely done. Its outputs are very important for further progress.

The following passage describes the theory of asymmetrical gearing. The author decided to create software for its geometric control and also for displaying the tooth profile. The result is successful. Loading capacity calculation is also related to the creation of geometry. This is done both according to the DIN standard and with the help of MKP. A lot of work is done here as well.

. The core of the work is in the seventh chapter. Here the author describes the production of gear test sets using PM technology and their testing. He does this for a symmetrical profile. The asymmetric profile used for other tests is applied this time to PM wheels, but rolling is used instead of HIP technology. He did a great job here. This chapter also includes an evaluation of the experiments. All with decent agreement between experiment and model.

***Methods used in the work***

The doctoral student mastered the geometry of involute gears very well. During his work, he programmed a lot (Python, Labview, MKP). He rationally used cooperation with experienced companies in the field (Höganäs, Profiroll). He performed measurements on test equipment very well and verified the obtained data using FEM.

***Benefits of dissertation thesis***

From a formal point of view, the dissertation is correctly structured (only a minor error in the numbering of chapters 4.2.1 to 3). The author expresses himself clearly and comprehensibly. The creation process is illustrative and clear. The pictures are clear. Table headings belong above the tables, aligned to the left. The text between the headings of some chapters is missing (pages 10, 13, 30). On page 47, the bottom two lines should be at the top. The main contributions to theory and practice include:

- an attempt to use PM material for gear wheels for the transmission of a passenger car,
- application of gear rolling method instead of HIP technology,
- testing these gears on closed loop test benches,
- methodology for determining losses for devices for continuous load change in a closed loop test benches.

***Overall publication activity of the author***

The list of publications at the end of the thesis shows that the doctoral student is actively working in the field of gear transmissions. This activity of his is expressed in nine publications. This number is completely satisfactory for doctoral students.

***Comments on work***

- Anotace, line 2 – instead of *vyrobeného* should be *vyrobeným,*
- Klíčová slova – instead of *otzubení* should be *ozubení,*
- Symbols – instead of *i* should be $z_w$ ,
- Symbols – *addendum* is different from *tip,*
- Symbols – $\varepsilon_\beta$ is properly the *overlap contact ratio,*
- Symbols – instead of $\varepsilon_\chi$ should be $\varepsilon_\gamma$ ,
- Page 10 – instead of $\varepsilon_\alpha \in (1,2)$ should be $\varepsilon_\alpha \in (1..2)$,
- Page 21 – at the TU Ostrava equipment, deformations are measured dynamically (when rotating the shafts),

- Page 48 – instead of *spider* should be *carrier,*
- Page 48 – in Equation 5-3 for the $M_{TECH}$ calculation do not agree with the efficiencies,
- Page 48 – in Equation 5-4 and 5-5 are undefined unknowns,
- Page 56 – at equiv. torque must be worked with equiv. number of cycles (revolutions),
- Page 60 – in Equation 6-16 – a slightly confusing simplification,
- Page 71 – finding exactly the involutes intersections is not that complicated,
- Page 75, tab.6-3 – tip rounding radius of the tool is different for both sides of the tooth,
- Page 75, tab.6-3 – instead of $\sigma_I$ should be $\sigma_F$,
- Page 79, line 6 – instead of *flak* should be *flank,*
- Page 83 – the heading under Figure 7-5 is on the next page,
- Page 119 – ISO 6336 (2003) already has two newer versions,
- The whole work - it is necessary to distinguish between the parameters of the gear tooth and its basic profile (index P), and between the parameters of the tool (index 0) and its basic profile (index P0).

***Questions for the defense:***

1) Would it make sense to apply the HIP method for 3D printed wheels?
2) How did the author find the ratio $M_{coastside}$ / $M_{driveside}$ ?
3) Can residual pores on the surface (after the HIP method) be the cause of pitting?
4) Did the author also consider checking specific slidings (mainly on the coast side)?
5) Asymmetric gearing has been described for more than 40 years, why hasn't its use spread?

***Concluding observations***

It is clear from the submitted dissertation that the author has done a great deal of work. He fulfilled all the set goals (with minor problems with the second point). The work is clear and easy to read, appropriately supplemented with pictures and tables. It can be seen that the doctoral student has been dealing with this issue for a long time. He made very good use of his previous outputs and progressed the development even further. It has a wide scope (gearing theory, programming, modeling, FEM, experiment preparation, experiment execution and its evaluation). However, it is worth considering whether a certain limitation of the scope of work and a more detailed focus on one area would not be more effective. But still, all the results are interesting and useful.

The content of the work itself is not purely theoretical or, on the contrary, experimental, but the doctoral student well connected both methods. As I have already stated, he could afford it based on his long-term research and publication activities. The work will definitely be an asset in the field. I would like to appreciate the diligence and interest in the student's field. It is certain that this work will also contribute to further development in this area. I believe that the student does not intend to stop researching in the field of gear transmissions of cars (and not only cars) to increase the competitiveness of our companies in the very important automotive industry.

Because the doctoral student in the submitted thesis fulfilled the conditions set by Act No. 111/1998 Coll. about universities,

**I recommend,**

that Ing. Ondřej Miláček was allowed to defend his doctoral thesis and after successful defense he was awarded the scientific rank of Ph.D. in the field of study "Dopravní stroje a zařízení".

In Ostrava on 5.2.2023 prof. Dr. Ing. Miloš Němček