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Opponent review of the dissertation thesis

Ha Nguyen Van, M.Sc

Topic:

MODERN TRANSMISSION MECHANISM OF PRODUCTION MACHINES

Based on the request (ref. no. TUL-378790/2112) of prof. Dr. Ing. Petr LENFELD, dean of FE TUL, I developed this opponent review on the above-mentioned dissertation thesis.

a) Analysis of dissertation thesis

Ph.D. thesis Ha Nguyen Van: Modern transmission mechanism of production machines is composed of 7 chapters. Totally dissertation contains 109 pages of typescript, 57 figures, and 8 tables. Candidate for a doctor's degree quotes also 29 properly selected references presenting the international range.

b) Objectives

The main objectives of the dissertation have been set:

The target of the dissertation is to design a novel groove cam mechanism for converting the cam rotation to a desired rotary motion of the output shaft and proposes the ways to design optimization of the groove cam. To obtain the goal of the thesis three groove cam design models were introduced to study in this thesis. Based on the results of the optimization the groove cam mechanism has been selected.

In my opinion, it can be stated that all the objectives of the dissertation are solved successfully.

The analysis of the current state of the solved problems

For analysis of the current state, the author used scientific works, professional books, conference proceedings, publications in prestigious international scientific journals. He described the current state in a concise and comprehensible form. Discussion has been supported by appropriate references.

c) The theoretical benefits of dissertation thesis

- The Ph.D. student introduced three groove cam design models to study in this thesis based on different shapes of the grooves on the middle part and the output shaft in order to optimize the contact pressure between the balls and their grooves.
- Both Hertz theory and finite element methods were applied to determine the contact pressure between the balls and their grooves of the groove cam. The results have shown that the computational values were consistent with theoretical values.

d) The practical benefits of dissertation thesis

- The author has demonstrated the possibility to use simulation models to solve the design problems of the groove cam models and its results show the possibility of using numerical analysis for optimization of the groove cam mechanism.
- The design model can have a lot of potential applications in industries. Especially, in high-power drivers due to the small size and great reliability of the mechanism. Also, all vehicles due especially to high efficiency and power density, because in the design used the ball for transmitting motion. Therefore, the mechanism performed the pure rolling motion.

1) Suitability of methods of solutions

The solution process is logical and systematic. In the introduction, the author formulates the goals of his work, which are gradually fulfilled in the next chapters of the thesis. The materials and methods were appropriately chosen and suitably applied, which led to successful solution of the solved problem.

2) The way, how the scientific methods were applied

In this dissertation, the chosen methods and, above all, the proposed simulation tools have been applied appropriately and suitably following the logic of the development, design, and optimization of the groove cam mechanism.

3) Demonstration of adequate knowledge in the scientific field

The candidate for doctor's degree demonstrated good knowledge of the subject and proper formulation of the scientific thesis

4) Comments to the results and originality of the practical benefits of work

The dissertation is written incomprehensible way, it possesses the attributes of originality and brings in the new cognitive values with comparison to the past state of the art in scientific field Machine and Equipment Design. Also, the author used quoted sources and appropriately used his knowledge in the Machine design field.

5) Formal level of work

The Ph.D. thesis is systematically processed. Its language level and graphics processing have an appropriate level. Although in the text of this thesis there are also some minor formal irregularities that do not diminish the professional importance of the presented Ph.D. thesis. But it is a pity that the author did not pay attention to the proper marking of the chapters in accordance with the content –

page 5 – instead of 2.3.1.2 till 2.3.1.4 are to be 2.2.1.2 till 2.2.1.4

page 18 – instead of 1.2 is to be 1.1

page 41 – instead of equation number (2.45) is to be (2.46)

page 11 – unit for acceleration is not [mm].

And it would be more readable to use multiplication dots in equations.

6) Evaluation of the Ph.D. publications

Results of the thesis of the applicant Ha were published in scientific papers. He was attending several scientific conferences abroad and he is the coauthor of 9 presentations presented on international conferences.

7) Overall evaluation work

The Ph.D. student has demonstrated a high level of scientific qualifications and he has proven that he can apply his knowledge practically. The thesis brings new scientific knowledge.

Questions for the defense:

1) Can balls transfer torque (page 23)?
2) Can you display graphical dependencies of output rotational speed on constant input rotation for all 3 solutions?
3) Don't you think about the inverse solution in the future (finding the shape of the cams for the prescribed rotation $\omega_2 = f(\varphi_2)$ at the output)?
4) Was the reason for not using quality literature on cams from TU Liberec (Koloc, Václavík) a language barrier?

Concluding observations

Taking into consideration remarks mentioned above, I recommend the dissertation thesis of **Ha Nguyen Van** for the defence and in the case of a successful defence, I recommend to grant the academic degree doctor abbreviated as "**PhD.**"

In Ostrava 6.4. 2019

Prof. Dr. Ing. Miloš Němček

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Review of the dissertation

Ha Nguyen Van

with the title

„Modern Transmission Mechanism of Production Machines“

Study branch: 2302V010 – Machine and Equipment Design

University: Technical University of Liberec (TUL), Faculty of Mechanical Engineering

Analysis of work

The dissertation deals with methods suitable for designing an optimized design of a new cam mechanism. A cam mechanism with an eccentrically located circular groove on the cam driven shaft is proposed, in which the balls for the transfer of motion to the output shaft rotating in the required range. It is demonstrable, that all of the above correspond with the requirements of technical practice and therefore the Ph.D. student in his DisP deals just with this issue. Based on the analysis of the new cam mechanism, in the thesis are proposes dynamic models, procedures and methodologies that will enable the application of the principles of systematic design of technical systems directly into practice. The intention is to achieve flexible and rapid implementation of results obtained from CAD models and FEM computational analyses and analytical calculations made on the basis of Hertz's theory even in the process of designing the cam mechanism and thereby achieving optimized and efficient motion and force loading with simultaneous extension of cam mechanism life.

DisP is divided into the following chapters

- **Introduction** – In the introduction, the author comments what is the subject of DisP and states that currently, mechanisms for transformation and transfer of motion and load are used in many sectors industrial production. The author here conducts research in particular cam mechanisms. The author presents a number of reasons that indicate suitability for use balls as a transfer member in the cam mechanism. The author assumes that the proposed solution will achieve higher efficiency of motion transfer and thus a higher efficiency in the transfer of power load. Other positives are simple construction, low installation space and lower production costs.
- **Theory and model for cam mechanism design** – In this chapter, the author presents a preliminary design of a cam mechanism with balls and grooves and it analyses its organ structure and basic groove shapes in the individual parts of the mechanism. Furthermore, the author presents a cam mechanism model with one and two balls. It introduces the basic parameters of the cam mechanism and presents their computational model, suitable for determining the movements of individual parts of the mechanism, contact pressures at the interfaces and transmission parameters between the input and output members of the mechanism. At the end of the chapter it defines the target function, allowing to determine the maximum pressure angle at simultaneously minimizing the spatial build-up of the proposed cam mechanism.
- **Contact stress and damage** – In this chapter, the author deals with quite a bit in detail contact stress determined by Hertz's theory for elastic contact. Applies a mathematical model based on this theory to the proposed cam mechanism in DisP, proposes an analytical calculation of contact pressures between contact surfaces of grooves and balls.
- **Numerical method of contact stress calculation** – In this chapter, the author deals with FEM theory and deals with the definition of contact calculation using this method. The chapter also compares the

results obtained using the analytical calculation method and FEM. The resulting deviation in contact stress is 4.52% and in shear stress 11.5%. The chapter also lists the maximum contact pressures and their recommended values for different types of materials according to [4]. Allowable pressure for the refined steel is up to 2000 [MPa] and the maximum pressure obtained from the analyses is 2093 [MPa]. As recommended pressure is 800 [MPa], it was necessary to modify the design of the grooves so as to lower the pressure at the contact surfaces.

- **Optimization of cam mechanism** – In this chapter, the author deals with the optimization of the groove shapes of the output member and the optimization of the shape of the groove side surfaces and the overall design of the middle cam mechanism member to reduce contact pressure. The optimization process results in a reduction of the maximum contact pressure to 863 [MPa] when the recommended value is up to 800 [MPa]. It can thus be stated that this embodiment is already practically applicable.
- **Production of a newly designed cam mechanism** – In this chapter, the author commented on the process of verifying the manufacturability of the cam mechanism. However, the verification was carried out only for the first draft of the cam system with straight grooves and flat sides of the slots at the middle member. Also, the material used was an aluminium alloy and not a refined steel that corresponds to the proposed system solution. The whole process of verification was therefore greatly simplified.
- **Conclusion** – At the end of the work, the author summarizes the individual design variants of the cam mechanism, which was created by the design of the central member and the optimization of the grooves of the central and output members. It presents the advantages and disadvantages of the proposed mechanism by completing the envisaged theoretical and practical benefits of the proposed cam mechanism.

Achieving the goals set in the DisP

The primary goal of DisP was to develop suitable methods for designing an optimized design of the new cam mechanism. The secondary objective was to verify the manufacturability of the newly proposed cam mechanism design. It can be stated that the optimization process has reduced the maximum contact pressures in the mechanism while minimizing its space requirements and increasing reliability and durability. Based on the above facts it can be stated that the general objective is achieved by the DisP therefore optimisation of the proposed cam mechanism as well as demonstration and confirmation of the correctness of developed computational models and their applicability in numerical simulations of proposed cam mechanisms in industrial practice.

The objectives and sub-objectives of the dissertation I find it fulfilled

Level analysis of the current situation in DisP solved problems

The analysis of the current state of the solved issue is presented in the proposed DisP in a comprehensible and, in my opinion, sufficient way. The author focuses in DisP primarily on the analysis of the design of cam mechanisms and on the theoretical basics of FEM and its capabilities and suitability for investigating contact pressures between machine parts. DisP shows that the proposed design support methodology has considerable potential for deployment in industrial practice and thus at the DisP proposed cam systems, the features of which are more closely related to the required properties as specified by the requirements and which will ensure more efficient and effective motion and load transfer and load transfer.

Theoretical contribution of the dissertation

In the DisP, kinematic analyses of the newly designed cam mechanism were carried out and the methodology of the optimization process leading to the reduction of the cam system's spatial demands while simultaneously tuning the operating conditions and reducing the parasitic effects reducing its life and reliability. Another theoretical benefit is the fact that the suitability and usability of the ANSYS system for solving DisP problems, especially contact pressures, has been confirmed. Computations based on Hertz theory and FEM calculations were also compared and relatively good agreement was found. This implies that the results obtained by FEM analysis can be quite satisfactorily used during the optimization process of the cam system design.

Practical contribution of dissertation

The practical benefit of DisP is the creation of methodology and support tools and tools suitable for the design of optimized ball cam mechanisms. The author believes that in today's practice and also in the Czech Republic, which

is widely used in the automotive industry, less space-consuming mechanisms, with higher efficiency of motion transfer and higher efficiency of load transfer, can be in demand. It also contributes to practical use by extending the life and reliability of the DisP proposed cam system.
Finally, it can be stated that the results of DisP offers a significant possibility of their use by the industrial sphere, especially for designing optimized ball cam systems.

How the methods have been applied

The chosen methods and, in particular, the proposed mathematical and FEM models, were applied appropriately and correctly following the logic of the development process, design and optimization of the ball cam mechanism.

Proving of relevant knowledge in the field

I think that the author is very well oriented in the solved problems, which follows from the previously acquired both theoretical and practical knowledge and experience.
In the given field, he has unequivocally demonstrated the appropriate knowledge that he used for the design of DisP of his own solutions.

Formal level of work

DisP is elaborated in a logical sequence, but some non-systematic work and inconsistencies in chapters lead to some confusion and problems with a proper understanding and interpretation of the presented results. The language level of DisP is on an average level and the graphical processing has a level of corresponding commonly presented such works. There are only minor bugs in the pictures links, etc.

Dissertation queries

1. Why was investigated only manufacturability of the individual parts in the DisP proposed cam mechanism and why was the cam mechanism not produced according to the proposed optimized variant, on which its functionality could be demonstrated and unambiguously confirmed the expected properties and operating behaviour of the mechanism?
2. For what specific purposes could the proposed cam mechanism be used in practical applications?

Closing statement

Based on the above, I recommend the dissertation work of **Ha Nguyen Van** for the defence and in the case of a successful defence, I recommend to give the Ph.D. student an academic title

„Ph.D. "

doc. Ing. Václav Vaněk, Ph. D.

In Pilsen 9. 4. 2019

Prof. Ing. Vojtěch Dynybyl, Ph.D.
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Review of the dissertation thesis

MODERN TRANSMISSION MECHANISM OF PRODUCTION MACHINES

Ha Nguyen Van, M.Sc

Study programme: P2302 – Machines and Equipment
Study branch: 2302V010 – Machine and Equipment Design

This review of the dissertation thesis was carried out on base of the request of prof. Dr. Ing. Petr LENFELD, dean of the Faculty of Mechanical Engineering of the Technical University of Liberec.

a) **Analysis of the dissertation thesis**

The thesis is written on 109 pages and is divided into seven chapters. Chapter 1 is focused on the introduction to the transmission mechanisms, especially cam mechanism and objective research. Chapter 2 presented the fundamental of the cam design model. Also, the kinematics analysis of the groove cam design and deal with the cam size optimization of the groove cam are proposed in this chapter. Chapter 3 describes the Herzt theory and application of Herzt to solve the contact problems of the groove cam design. A Finite element method by using Ansys workbench is applied to investigate the contact problems between the balls and their grooves of the groove cam are conducted in Chapter 4. Chapter 5 the ways for the optimal design for the groove cam mechanism to obtain the recommended value of contact pressure for steel material is presented. The performance of the machining of the design is shown in chapter 6. Conclusion and recommendations are listed in chapter 7.

b) Objectives

In this Ph.D. thesis the main objectives of the research were:

- Design a novel groove cam mechanism for converting a rotary cam to a desired rotary motion of the output shaft by applying the steel balls.
- Due to the contact between the balls with their grooves on each part of the cam mechanism is very important can directly affect the lifespan and be ability working of the structure of the groove cam. Therefore, the research focus on determination of the contact stress between the balls and their grooves on the output camshaft, the middle part as well as the circular groove of the input camshaft by using both theory and fine element analysis methods.
- Based on the results of calculating simulations we suggested the ways to change the shape of the groove of the output shaft and the middle part to obtain the minimum contact pressure in contact between the balls and their grooves. Therefore, three groove design models were introduced to study in the thesis.
- Finally, the shapes of the groove on each part for the optimization of the groove cam are selected. The calculated result is matched nearly perfectly and the calculation can be used for the general design of the groove cam.
- A groove design model was fabricated successfully at the laboratory of the Department of Design of Machine Elements and mechanism, Technical University of Liberec.

In my opinion, it can be stated that all the objectives of this Ph.D. thesis have been successfully fulfilled.

c) **The theoretical benefits of dissertation thesis**

- Developed kinematic analysis of the groove cam and a methodology to deal with optimization of the groove cam size based on the most suitable cam operating conditions, namely in what concerns to the maximum allowed pressure angle, the radius of curvature based circle radius, ball radius, and eccentricity.
- An ANSYS software was developed to fulfill the calculating tasks in the research such as contact pressure, penetration, friction stress on the groove cam mechanism.
- Both Hertz theory and finite element methods were applied to determine the contact pressure between the balls and their grooves of the groove cam. The results have shown that the computational values were consistent with theoretical values.

d) **The practical benefits of dissertation thesis**

- This dissertation proposed and designed a new groove cam model that can be used in practical and very workable. Therefore, the design can have a lot of potential applications in industries. Especially, in high-power drivers due to the small size and great reliability of the mechanism. Also, all vehicles due especially to high efficiency and power density, because in the design used the ball for transmitting motion. Therefore, the mechanism performed the pure rolling motion.
- The dissertation brought out the newest idea design for designing cam mechanism by using the ball, where the ball plays the role of a follower in the cam mechanism. Until now there are very few references can be found in the literature that addresses the issue of the application of the ball for designing the cam field. So the research may help to open the new trend for designing cam mechanism in the years coming up.

e) **Suitability of methods of solutions**

The idea of the solution procedure is logical and systematic. The author organizes the chapter logically and proceeds the thesis in order to maintain continuity of operations. Used methods completely match the needs of the research. Ph.D. student uses modern computational methods and uses available mathematical tools.

f) **Comments to the results and originality of the practical benefits of work**

In this work, they are given quite specific initial results of methodical character. The literature cited in the text is properly identified. From a scientific point of view, theme is very interesting. The original results have been presented correctly.

g) **Formal level of work**

Formally, the work is processed on a good technical level. It is logically structured, and the text is written in the English language clearly and intelligibly. In this work, there are also a few formal errors.

h) **Evaluation of publications**

Ph.D. student presents 9 presentations presented on the international conferences, which is mostly listed as a co-author. His publications are quite worthy and good addition in the field of Machine Design.

Formal issues:

The candidate for a doctor's degree made few mistakes. I will quote some of them in presented review "the size of the text on the figure should be the same size with the text of the thesis (*Fig 2.1*)". Despite this and other mistakes and misinterprets, in my opinion, the dissertation presents an adequate level and deserves for positive opinion.

Concluding expression of opinion

I can state that all the objectives of the dissertation thesis have been fulfilled. On the base of the review described above, according to law no. 111/1998 Coll. Section 47, I can recommend dissertation thesis of Ha Nguyen Van, M.Sc for defense, and after a successful defense to grant Ha Nguyen Van, M.Sc Ph.D. degree "Doctor".

In Prague 31. 3. 2019

Prof. Ing. Vojtěch Dynybyl, Ph.D.