



## Review of Doctoral Thesis

<b>1. PhD candidate</b>
Ing. Matúš Ranuša / Matus.Ranusa@vut.cz
<b>2. Name of PhD programme</b>
Design and Process Engineering
<b>3. Title of PhD thesis</b>
Volumetric Wear Analysis of Hip Joint Implants by Optical Methods

<b>4. Principal supervisor</b>
doc. Ing. Martin Vrbka, Ph.D. / Martin.Vrbka@vut.cz
<b>5. Co-supervisor</b>
/

<b>6. Reviewer</b>
Dr Michael Bryant / M.G.Bryant@leeds.ac.uk
School of Mechanical Engineering, University of Leeds

<b>7. Overview of the scope of PhD thesis<sup>1</sup></b>
<b>Satisfactory</b>
The thesis addresses a topic with a set of clear objectives that has the potential to infer some societal benefit. The theses aims can be split into two with the main aim of the thesis to develop a new method to assess the wear of PE implant materials. The second was to further expand this analysis and link the wear, degradation and time dependant processes. This is clearly stated. However the objectives, or steps as given in the thesis, to achieve the project aims are not well articulated and could be better articulated. These should be expanded upon to be specific, measurable, achievable, realistic and timely. By doing this, it would better demonstrate the candidates understanding of how the different analysis techniques contribute to understanding the multi-factorial degradation mechanisms.

<b>8. Significance of the topic and clarity of problem statement</b>
<b>Good</b>
Wear, and an understanding of the degradation mechanisms, of polymer components used in THR and other areas of orthopaedics is and continues to be a significant problem. The ability to effectively engineer surfaces and interfaces to reduce these processes would have a significant impact for patients and healthcare providers by reducing the need for future revision and longer lasting implant materials. The

<sup>1</sup> Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.



problem that the thesis looks addresses, the accurate measurement of components, is a current and timely issues given the current scrutiny in the preclinical and surveillance of medical implants. The thesis effectively addresses these points and articulates the key drivers of this research.

#### **9. Knowledge of existing literature**

##### **Satisfactory**

The literature review presents a general overview of the current state of the art in the area of orthopaedics and PE wear. It covers all the expected topics with some critical assessment (mainly for the measurement methods) of the literature made. In places the literature review lacks clarity and accuracy in the writing. For example, this is particularly the case where measurement methods are been discussed for both in-vivo and in-vitro literature, but not stated. Furthermore a full critique of the pre-clinical literature and the associated assessment methods. For example, a brief literature review on hip simulation methods is presented. However this is limited to the discussion of one simple and now out of date approach. A discussion and critique of the literature pertaining to the current tribological principles of MoP articulations is not included and limited to a simple analysis of wear mechanisms. A thorough review of the current concepts of wear and lubrication of MoP THRs, and the associated literature, would be expected as one of the main aims is link the understand the links between wear and degradation of the polymer. An annotated copy of the thesis is available if required.

#### **10. Choice of methods and technical soundness**

##### **Good**

The thesis makes a good use of a combination of different methods to address the aims and objectives. The use of optical hi resolution optical metrology measurement methods to assess the wear of PE implant materials in its self is novel. The use of RAMAN, SEM and surface profilometry to resolve the local changes in material properties and topography further add to the novelty. The simulation methods used to generate wear are limited. However was not the focus of study in this thesis. One aspect that did not receive much consideration in the thesis was the consideration of the algorithm used to assess wear or the factors that may influence wear measurements. The accurate measurement of the surfaces is not technically challenging, as highlighted by the thesis. However the identification of work areas and fitting of data to well defined geometries is an area of significant challenge. For example, a thresholding process is applied with a value of 3um. A thorough analysis of this parameter is not presented or how this may be effect the overall wear measurement, particular in the case of the reference surfaces where there will be some manufacturing deviations. Furthermore the use of geometrically perfect fitting algorithms has a number of limitations. The algorithms for fitting data, both commercial and home code, have not been assessed or critiqued. It would have also benefitted from the use of CMM methods to compare and validate against. Details of the metrology methods are detailed. Details of the Raman, including preparation of samples (ie were the lipids removed?) and data fitting methods, nano-indentation and analysis of the data and SEM prep and imaging conditions is limited.

#### **11. Quality, originality and significance of the results**

##### **Good**

The quality and originality of the results are as expected from a PhD thesis and are in line with other literature. The methodology and framework developed is novel and the key strength of the thesis. In my opinion the thesis would have benefitted from a thorough analysis of the results and the algorithm used to assess the results to demonstrate the robustness of the measurement. Due to the small number of implants it is difficult to draw any conclusions on the mechanisms of wear from the retrieved components,



although the framework for high thru-put analysis is now in place. With respect to the hip simulator results, there are some comments and limitations of the measurements in the absence of static load control surfaces which would be needed for the deconvolution of creep and wear.

#### **12. Quality of attached papers**

##### **Good**

The papers attached are of good quality and published in recognised peer-reviewed journals in the area of tribology and biomaterials. The papers present data that addresses the main research aim. One comment is that it is still not made overly obvious how the results presented can be used for future implant designs or inform the current tribological models. For example, the oxidation paper shows differences between the OI or fresh and implanted materials. However the changes in properties are not obviously linked to the tribology or wear data. It is obvious that a methodology has been used to measure the wear and existing techniques has been used to assess degradation. How this contributes to a mechanistic understanding of the degradation is not obvious. There are also some issues with the use of friction data obtained in this study.

#### **13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)**

##### **Good**

Overall the thesis highlights and addresses a current issue in the preclinical and clinical evaluation of PE implant materials. It proposes a new framework for the assessment of wear of PE components and observations of degradation on a select number of implants. One limitation of the thesis is limited number of implants used or stratification of groups to enable a well-defined retrieval wear study to be completed. There is a nice attempt to de-convolute wear and creep processes in hip simulation. There are some issues with the simulator approach used, the numbers analysed and the appropriate use of controls, as highlighted above. The written thesis would benefit from a thorough proof read and critical evaluation to ensure consistency and accuracy (both grammatically and scientifically) of the content.

#### **14. Other comments**

An annotated copy of the thesis is available for review if required.

#### **15. Conclusion**

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES

#### **16. Date and signature**

01/01/2019



- A. Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.
- B. E-mail the completed form to: [Klara.Javorcekova@vut.cz](mailto:Klara.Javorcekova@vut.cz)



## Review of Doctoral Thesis

<b>1. PhD candidate</b>
Ing. Matúš Ranuša / ranusa@fme.vutbr.cz
<b>2. Name of PhD programme</b>
D4Z-P Machines and Equipment, Branch: Design and Process Engineering
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<b>5. Co-supervisor</b>
Title and name of co-supervisor / E-mail

<b>6. Reviewer</b>
Dr. Prashant Kumar Sharma / p.k.sharma@umcg.nl
University Medical Centre Groningen, The Netherlands

<b>7. Overview of the scope of PhD thesis<sup>1</sup></b>
<b>Good</b>
The thesis concerns development of a new optical scanning method (OSM) to quantify creep and wear volume for retrieved acetabular cups made of UHMWPE or HXPE. This is an important area of research still open to improvement, thus the scope of the thesis is good. In absence of the knowledge of the original contour of the acetabular cup it is important to have many measurement points (possible by the OSM) to reconstruct the original contour from the unworn regions. Use of Raman spectroscopy made it possible to related the surface changes to wear mechanism.

<b>8. Significance of the topic and clarity of problem statement</b>
<b>Very good</b>
The area of research is significant because of its multifactorial nature i.e. creep, change in composition and wear taking place simultaneously and affecting each other in real time. The research aim of the thesis is clear i.e. development of a new scanning method and its use in combinations with surface composition to predict creep and wear.

<sup>1</sup> Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.



**9. Knowledge of existing literature**

**Very good**

The PhD students has shown a very good understanding of the existing literature. Latest literature along with classic old literature papers are cited in the thesis.

**10. Choice of methods and technical soundness**

**Good**

The hardware and software chosen for developing the OSM are latest. The self-made hip gait simulator was also made to allow the wear tests to be performed according to the ISO standards. The use of facilities at university of Arkansas are complementary to what is available at University of Brno and relevant to this PhD study.

**11. Quality, originality and significance of the results**

**Good**

The techniques used and results obtained are original. The results have significant contribution towards understanding of the creep, wear and surface changes of UHMWPE acetabular cups.

**12. Quality of attached papers**

**Very good**

The 3 published articles are in journals which belong to the Q1 category i.e. belong to the top 25% journals in their respective category. These are well written papers with good potential to be cited in this relevant field of research.

**13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)**

**Good**

See above

**14. Other comments**

The figures used for the thesis are low resolutions, text on the axis used are very small and would be good to be enlarged before final printing.

**15. Conclusion**

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES



**Faculty of Mechanical Engineering  
Brno University of Technology**

<b>16. Date and signature</b>	
28/12/2018	

Please note

- A. Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.
- B. E-mail the completed form to: [Klara.Javorcekova@vut.cz](mailto:Klara.Javorcekova@vut.cz)



## Principal supervisor's final report on the PhD study

<b>1. PhD candidate</b>
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<b>2. Name of PhD programme</b>
D4Z-P Machines and Equipment, Branch: Design and Process Engineering
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Doc. Ing. Martin Vrbka, Ph.D. / Martin.Vrbka@vut.cz
<b>5. Co-supervisor</b>
Title and name of co-supervisor / E-mail
<b>6. Stays at other institutions (min. 7 days)</b>
Waterloo University / Canada / 11/06/2016 / 27/08/2016 Anglia Ruskin University / Great Britain / 26/01/2017 / 04/02/2017 Rush University / USA / 15/06/2018 / 16/12/2018
<b>7. Teaching activities</b>
Machine Design - Machine Elements (5KS) / 208 Machine Design - Mechanical Drives (6KT) / 208 Team Project (ZKP) / 130 Mechanical Design Project (ZIP) / 104 Aventics Pneumobil Racing (OZP) / 104 Tribology (ZTR) / 16
<b>8. List of main publications</b>
RANUŠA, M., J. GALLO, M. VRBKA, M. HOBZA, D. PALOUŠEK, I. KŘUPKA and M. HARTL. Wear Analysis of Extracted Polyethylene Acetabular Cups Using a 3D Optical Scanner. Tribology Transactions, 2017, 60(3), 437-447. (IF 1.723) RANUŠA, M., J. GALLO, M. HOBZA, M. VRBKA, D. NEČAS, and M. HARTL. Wear and Roughness of Bearing Surface in Retrieved Polyethylene Bicon-Plus Cups. Acta Chirurgiae Orthopaedicae et Traumatologiae Cechoslovaca, 2017, 84(3), 159-167. (IF 0.645) CHOUDHURY, D., M. RANUŠA, R. A. FLEMING, M. VRBKA, I. KŘUPKA, M. G. TEETER, J. GOSS and M. ZOU. Mechanical wear and oxidative degradation analysis of retrieved ultra high molecular weight



polyethylene acetabular cups. Journal of the Mechanical Behavior of Biomedical Materials, 2018, 79, 314-323. (IF 3.239)

ZEMAN, J., M. RANUŠA, M. VRBKA, J. GALLO, I. KŘUPKA and M. HARTL. UHMWPE Acetabular Cup Creep Deformation during the Run-in Phase of THA's Life Cycle. Journal of the Mechanical Behavior of Biomedical Materials, 2018, 87, 30-39. (IF 3.239)

#### **9. Assessment of the supervision process**

##### **Very good**

The supervision process was friendly. The process was based on one-month main meetings and on-demand discussions with supervisor and colleagues from tribology research group. The candidate was always well prepared to discuss the issue of the dissertation including reflection of critical comments. The final thesis and research papers were prepared in time and in sufficient quality. The candidate was also active in attending conferences and internships. His teaching activity, arising from the PhD study, was excellent. The candidate was leader of the student team which developed the car powered by compressed air. This project was awarded by the Rector of Brno University of Technology.

#### **10. Assessment of the candidate's ability to work independently**

##### **Very good**

The candidate worked independently, based on discussion with supervisor and other experts from the field of biotribology and clinical practice. The candidate himself designed a methodology of experiments based on the state of the art, performed experiments and according to results analyses, he formulated conclusions. The candidate independently co-operated with master and bachelor degree students. Also supervised six bachelor and two diploma theses in the relevant research topics. Most of the publications were prepared by himself, where he is listed as the main or second author. The candidate has completed three internships, while one of these was in duration of six months.

#### **11. Assessment of the contribution that the research makes to knowledge in the field**

##### **Good**

In the first part of the work, the candidate introduced a new experimental approach for determination of volumetric wear of extracted polyethylene cups (liners) of THR using optical scanning method. This method is less time consuming than conventionally used CMM method and provides complex geometry with larger number of points for reconstruction of original (unworn) geometry. This new approach shifts knowledge in the area of fundamental research and can be extended into applied research or clinical practice. This is supported by publication in Tribology Transactions, Q2 IF journal targeting on the papers with the highest scientific quality. Next part of the work was focused on wear analyses of retrieved samples in terms of mechanical-chemical properties and acetabular cup positioning. Both these issues were published through two papers in IF Journal of the Mechanical Behavior of Biomedical Materials. It should be noted that the second paper used a method of evaluation wear based on micro-CT data instead of developed scanning method introduced in the first paper.

#### **12. Other comments**

none



**13. Conclusion**

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES

**16. Date and signature**

04/01/2019

Please note

- A. Evaluate categories 9 to 11 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent.
- B. In each category 9 to 11 explain reasons for evaluation using between 100–200 words.
- C. E-mail the completed form to: [Klara.Javorcekova@vut.cz](mailto:Klara.Javorcekova@vut.cz)