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OPINION

about PhD thesis of. Anastasiya Vinakurava on
"Modeling of bone and biocompatible materials for biomechanic analysis of hip-implant considering micropolar elasticity"

commissioned by
the Dean of the Faculty of Mechanical Engineering and Aeronautics
Rzeszów University of Technology

Overall job assessment

The dissertation presents the modeling of human bones and bioceramic materials by using micropolar theory of elasticity by considering some relevant contact phenomena of the analyzed parts.

Indeed the phenomena occurring in the areas of bone contact with the implant are of great importance from the point of view of the technique of performing surgical operations and in the treatment process. They are also important in later years when natural bone age and diseases, such as osteoporosis, change the bone's properties, can, as a consequence, lead to damage of the implant, in particular at the interfaces between natural bone and artificial material.

The human bone from the engineer's point of view is a composite of several tissues. In terms of strength properties, the most important ingredients are calcium that gives bones the strength and collagen which increases bones flexibility and resistance to the dynamic loads. It is important that bone has a porous structure which changes with age or disease and that living cells are remodelling bone tissues.

The formulation of predictive models for bones requires more complex theories than those involving e.g. metals. In the presented research on modeling of bones and implants (which are also porous bodies) the micropolar theory of elasticity is used. In this approach it is assumed that the deformable body experiences displacements (3 components in 3D problems) and additionally microrotations (also 3 components). As a consequence of these assumptions, the strain and stress

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tensors are nonsymmetric and contain more components when compared to the classical theory of elasticity. In micropolar approach isotropic material is defined by six constitutive parameters (in the classical theory of elasticity we have only two constants). In conclusion: more degrees of freedom, greater number of strain and stress tensors, and more material constants allow for a better description of the phenomena occurring in deformable bodies with complex structure subjected to external loads.

In the dissertation the bone material parameters are taken from the literature. The continuous micropolar theory used in bones modeling can be regarded as equivalent to the bone models proposed by other researchers in which discrete elements (beams) are applied. Unfortunately, these models require more computational effort. In light of the above advantages of the micropolar approach its use in bones and implants analysis seems to be reasonable.

The work contains eight chapters and a careful list of references. Literature contains 171 records, most of which are published after year 2000. This shows the candidate's assessment of the achievements of the other researchers in the field of her interest.

Chapter 1 is the introduction to the work. Chapter2 provides an overview of the literature which is divided into subjects related to: tissue engineering, bone reconstruction with implants, and micropolar theory of elasticity.

After introduction and literature review the following chapter presents: motivation, objectives and scientific thesis (Chapter 3).

Chapter 4 discusses CT images capturing techniques and the creation of three-dimensional bone models. In the fifth chapter, the PhD student focused on the mechanical properties of bones and the properties of bioceramic materials. Selected technologies for the production of ceramic materials are also presented.

In Chapter 6, the basic equations of the micropolar theory of elasticity are presented. The numerical implementation of the micropolar approach in the finite element method code is presented. The patch test results confirm the convergence of solutions obtained for proposed hexahedral finite element. This chapter includes the results of several benchmark tests and comparisons of the micropolar results versus classical theory of elasticity ones.

Chapter 7 is the fundamental part of the job. Two practical cases of bone implants are analyzed here. The first example concerns the implant of the femur bone after resection, the second is the hip prothesis. Chapter 8 contains conclusions.

The present dissertation analyses problems of bone reconstruction with implants which are important from a practical point of view. The cases considered here can be improved in further researches. The results of these studies may be helpful, in the long run, to surgeons and for rehabilitators. The used approach (micropolar theory of elasticity) represents an original contribution of the candidate in the development of this type of applied research.

Critical remarks.
The Author of this thesis discussed the difference in the predictions obtained by using the Cauchy and the Cosserat continuum for some chosen values of material parameters. It will more convenient to analyse more deeply this difference by using various values of the micropolar moduli: this will make the understanding of their influence more detailed and definitively clearer.
For bone implants the contact conditions play an important role. So, it will be nice if author can discuss, may be in future work, the role of growth of the bone into implant at different stages of recovering.

Formal comments
In the thesis there are some misprints or badly presented figures. For example, in Fig 3.3. "Microstructure of different ceramics type and its composites" the scale should be given, it is not clear which elastic modulus is given in Tables 3.7 and 3.8, presentation of marks in Fig 5.25 "Pre-surgery planning" is not clear, in many figures the numbers are too small, etc.

Final remarks

Despite a number of critical remarks, considering the contribution of this work to a more extensive research program, I believe that the thesis submitted to me for review is a valuable resource for enhancing knowledge of strain and stress states in bones reconstructed by implants. The PhD student has showed sufficient skill in the subject of the dissertation, she was able to determine important scientific problems and applied modern research methods. The presented doctoral thesis "Modeling of bone and bioceramic materials for biomechanic analysis of the hip-implant considering micropolar elasticity" meets the requirements of the Law on Degrees and Scientific Title, and I request that it can be admitted to the public defense.

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