Estonian Higher Education Accreditation Centre

Evaluation of Research in Mechanics in Estonia

Institutes evaluated

Tallinn Technical University Department of Mechanics,

Institute of Cybernetics of Tallinn Technical University,

Estonian Energy Research Institute at Tallinn Technical University

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Report to the Estonian Higher Education Accreditation Centre

I. Introduction

At the request of the Estonian Higher Education Accreditation Center, Tallinn (EHEAC), an evaluation team (hearafter named the "Evaluators") visited institutes and departments in Estonia carrying out research activities in mechanics. The evaluation team consisted of Prof. Dan Henningson (KTH, Sweden), Prof. Bengt Enflo (KTH, Sweden), Prof. Vitauts Tamuzs (Latvian University) and Prof. Gabor Stepan (Budapest University of Technology and Economics, Hungary).

The institutions evaluated were:
Institute of Cybernetics (IoC) at Tallinn Technical University (TTU),
Department of Mechanics at Tallinn Technical University,
Estonian Energy Research Institute at Tallinn Technical University.

The evaluators were provided in advance with self-evaluation reports from each of these institutions, prepared by the members of these groups.

After a brief orientation meeting at EHEAC, the evaluators visited the different institutions in Tallinn. At these occasions staff members presented their works as well as engaged in discussion about their research activities. Copies of papers and other documents related to the research activities were also made available to the evaluators during these visits.

In their work the evaluators followed the guidelines established by the EHEAC for research evaluation. This means that separate ratings are given for *quality of research* and for *overall capability* of the research groups. The evaluators were asked to give assessments on a four-point scale (*excellent, good, satisfactory, unsatisfactory*). In this report, the evaluators have in addition made various recommendations.

The rest of this report is divided into sections describing our general impressions and comments (section II) and then more detailed comments for the different institutions (section III-V).

II. General comments

A. Introduction

Research in mechanics has long traditions in Estonia. It can be mentioned that famous Kolosov´s equations of plane theory of elasticity were derived and published in 1910 in Tartu University. However, the modern research in mechanics started at the end of fifties by the efforts of Prof. Alumae. From this time research in mechanics was permanently developed mainly in dynamics of solids, photoelasticity, fluid mechanics and wave propagation. In 1992, just after the restoring of independence Estonia joined to IUTAM and since this time has very good contacts with societies and researchers in field of mechanics throughout the world.

After1995 the reorganization of the research system started in Estonia in order to obtain closer integration of research and education. At the same time a need for closer coordination of research in mechanics appeared. For this aim the "Centre for Nonlinear Studies" (CENS) was established. CENS is included into the list of "Centres of excellence" in Estonia and is doing an excellent job in coordination and consolidation of research in mechanics and integration of research and education in the field of mechanics.

B. General recommendations

1. The Centre for Nonlinear Studies (CENS) is a good focal point for mechanics and applied mathematics research in Estonia. The activity of this centre should be maintained or even extended in the future by the inclusion of experts also from chemical and mechanical engineering, and also from economics.

2. We also suggest to consolidate, co-ordinate, and on long term, merge the departments of mechanics at IoC and TTU. There exists an age problem at TTU, while young and ambitious people at IoC with international experience need to be given opportunities. Also, teaching should be integrated better with research and given to civil engineering, mechanical engineering and technical physics students. At present there seems to be no connection between teaching and research in mechanics for mechanical engineering students. The courses may have different level for different students, the same course that is prerequisite for 2^{nd} year technical physics students can be an elective course for 4^{th} year mechanical or chemical engineering students.

3. Computer facilities need to be drastically upgraded in each institution and modern computational techniques have to be used to a higher degree (particularly outside of IoC). There are two major directions of developments suggested. On one hand, local networks should be developed with regularly upgraded computers. On the other hand, the access to supercomputers should be provided to the groups, either by establishing a national centre, or by co-operating with the Finnish supercomputer centre CSC in Helsinki.

4. Target Funding is an important element of research funding in the field of mechanics. These funds provide more integrated financial support to certain fields of research as opposed to the smaller and more specific Estonian Science Foundation projects distributed for basic research. The two financing systems, together with the Innovation Foundation, give a wide range for the distribution of research resources. We have two observations that could improve the distribution of Target Funding further.
a) Since target funding tends to support larger research groups, the presence of MSc and/or PhD students in the research groups must be an essential requirement.
b) Although some Target Funding supports basic research, and direct industrial involvement may not always be desired, the project proposals should show the interest of either local or international industries.

5. The scientific capacity of the research groups in mechanics makes most of them able to take part in European Union research projects. They should be prepared to participate in projects in the centres of excellence programme and in the 6th framework via their existing national and international co-operation.

III. Institute of Cybernetics, Tallinn Technical University

The department is led by Prof. Juri Engelbrecht, who also has a Chair in Applied Mechanics at the Department of Mechanics, TTU. There are 4 research groups at the department, each of which will be described and evaluated below.

In the period 1997-2001 3 PhD theses and 7 MSc theses were supervised. At present 5 PhD theses and 2 MSc theses are supervised.

There is a strong collaboration with national and international scientists.

The research funding is mainly from the Estonian Science Foundation and from the Target Funding from Science Competence Council. In addition there are some smaller international grants (primarily mobility grants) as well as application oriented projects.

A. Nonlinear waves

General comments

Besides the head of the Department 4 senior researchers and 1 researcher, all holding a PhD, 2 PhD students and 1 MSc student form this group. Within the group 4 main research interests can be discussed:
a) Acoustodiagnostics of inhomogeneous and prestressed solids (1 PhD,1 PhD student)
b) Phase transition front propagation (1 PhD, 1 MSc student)
c) Solitary waves and solitons (2 PhD, 1 PhD student)
d) Mechanics of the piano hammer-string interaction (1 PhD).

The research under a), b) and c) is of general character and the research under d) is very specialized.

In the research under a) and b) special algorithms for nonlinear wave propagation in complex materials are developed. Collaboration goes on with several groups all over the world and the results are checked experimentally at institutions abroad. In the research under c) fundamental theory (KdV and KP equations with modifications) is studied both in its own right and applied to such different problems as wave propagation in microstructured media and waves in shallow water. The research under a), b) and c) is well documented in many refereed articles in international journals. The research under d) is limited to the piano hammer and its interaction with the string. The hammer is studied using advanced theory from solid mechanics and by use of a testing device. The research is documented internationally and cooperation is going on with the Musical Acoustics Group at KTH, Stockholm and Tallinn Piano Factory. The research is successful and of industrial interest.

Evaluation of research activities

Based on the publication record the research activities are judged *Excellent to good.*

Evaluation of overall capability

The overall capability is judged *Excellent to good.*

Recommendations

1. Nonlinear waves are important for our understanding of a great variety of physical phenomena and young researchers will certainly find a lot of new interesting uses of nonlinear waves. We expect that the very competent senior staff has the capacity of educating at least the double number of research students from all the fields of mathematics, physics and engineering.

2. The successful musical acoustics research deserves a continued tradition in Estonia. We believe that a broadening of the research to other methods and/or instruments may attract students with the not unusual combination of musical interest and scientific brightness. Also the test facility should be developed further with improving its connection to a high-performance computer (real-time sound FFT parallel to the force measurement signals).

B. Fractality and biophysics

General comments

There are 7 researchers working in this field, and 5 research areas to be addressed. The leader is Dr. Kalda, a senior researcher. He is an ambitious and active researcher with

international experience in the field, and his theoretical work gives a good basis and character for the whole research area.

The leader of this group carries out basic research in a new, quickly developing and expanding field. As it is typical in research areas like this, the researchers tend to diverse their activities since the new mathematical tools give many possibilities to apply them in different areas of geometry, physics, engineering, medical sciences, etc.

The specific area of cardiac conduction has achieved a very important, internationally recognisable result. The simple model they proposed a couple of years ago has proved a great success and other researchers in the field may pick up and continue analysing or generalising this model. The extension of a van der Pol like mathematical model provides a relatively simple system that can still describe complicated, even chaotic behaviour with two underlying periodic motions. The more recent results have presented more advanced models related to heart cells (like the cardiac Purkinje cell). The more advanced models provided a much greater variety of dynamic behaviour. The analytical and numerical study of these models contribute to design experiments. The experiments and part of the modelling were carried out in international co-operation. The field is also open for new perspective PhD students and there is an active researcher in the field who may also have an essential role in the future of the institute.

The other successful research area is the cardiac mechanoenergetics. A talented young researcher presented the results in this field. He showed good international background and had good co-operation with more experienced researchers at the institute and in other Estonian institutions. The theoretical predictions based on the modelling and analyses of heart muscle activation are results of international interest. The research was extended in the direction of more practical calculations based on the application of finite element methods. The computer network of the institute and the numerical background provided by the research software are satisfactory for this research work at the present, more applied results may require professional commercial software, though, and also the increase of hardware capacity.

Evaluation of research activities

Each research area is published in peer-reviewed international journals. Also, the first versions of the results are usually published in English in Estonia (see Proceedings of the Estonian Academy of Science). There are plenty of local, regional and international conferences where the results were introduced to the scientific community and discussed in all the corresponding levels.

The research activity of the group is rated *Excellent*.

Evaluation of overall capability

The research work in the field of fractality and biophysics is original and it is connected to the present trends of the international research community. The perspective of the

future research is clear and promising. The interdisciplinary nature of the research makes the results accessible for other disciplines. The integration of postgraduate students in the research project is a positive element. Co-operation CENS and also with medical schools and hospitals in Estonia puts the group into a leading position on national level. Co-operation on international level is also an important characteristic of the group. The national Science Foundation gives them basic support while many international funds provide them mobility.

The overall capability of the group is *Excellent*.

Recommendations

1. The results of the group could have more influence on the Estonian researchers if the group could better convince medical doctors and engineers about the importance of the use of new ideas from nonlinear dynamics. In the given fields, applied researchers should increase their physical sense in this direction. This issue is also related to the possible increased teaching activity at the Tallinn Technical University, to the attraction of more PhD students to the field.

2. We recommend the extension of the experimental work in the Institute. There are inexpensive ways to carry out experiments when the computational facilities are used as measurement devices via analogue-digital converters.

3. We recommend not to diverse the applied fields in fractality much further. However, we still emphasise one important field of applications that can be of great importance in Estonia. This field is the dynamics of the economy. Nonlinear time series analyses, predictions, study of undercurrent mechanisms of economical systems are very important fields, and the mathematical tools are already at hand for the research group members.

C. Nonlinear integrated photoelasticity

General comments

Laboratory of Photoelasticity was founded about 1970 by Prof. Hillar Aben, who is still its leader. At present the group of photoelasticity comprises one senior researcher, two technicians and two students. The research is based on the original idea of integrated photoelasticity. The aim is the determination of three-dimensional stress state in complex shaped transparent articles by means of photoelasticity measurement data. The problem can also be named “the tensor field tomography”. Opposed to the well known scalar field tomography, the inverse problem of tensor field tomography is an extremely complicated, exciting and challenging mathematical and engineering problem. At present it has a solution only in some very particular cases (axisymmetric stress state , weak rotation of principal stress axis etc.). The method has been applied for measuring of residual stresses in glass articles as a quality control of production.

Evaluation of research activities

Publishing of results is quite good. Each year two or three papers are published in prestigious journals and the same amount in good conference proceedings.

The research activities can be marked as *Excellent to good*.

Evaluation of overall capability

Ongoing research activity is original. The strategy of further research is clear, but could be even more wider and challenging.

The group is highly competent and includes one PhD student. Students could be more involved in the research. International cooperation is very good. Activities in organization of International Glass Stress Summer School are highly appreciated. The funds and existing grants are coming from Estonian budget. No information about European grants. Laboratory is well equipped and has no problems with scientific periodicals.

The total grade of capability of group is between *Excellent to good*.

Recommendations

1. The number of students in the group could be enlarged. For this aim the preparation of an optional course "Integrated photoelasticity" for TTU students would be very useful. Having more young bright students, the stategic tasks could be enlarged in the directions of tensor tomography and holographic interferometry.

2. The group has no patents on the original devices and/or measurement methods. The possibilities of patenting should be considered.

D. Wave interactions

General comments

The group is headed by Dr. Tarmo Soomere and contains one additional person with a PhD and two persons with MSc. It has been part of the Department of Marine Physics at the Estonian Marine Institute but is now being moved to Tallinn Technical University. Due to the strong cooperation with the Department of Mechanics at the Institute for Cybernetics, where one of the member of the groups works, this group is evaluated as a part of the Department of Mechanics and Applied Mathematics at IoC.

The group is involved in the theory of nonlinear and interacting waves and the application of these theories to geophysical flows. The theoretical work in mainly

published in the Proc. Estonian Acad. Sci., but a number of publications also exists in the best international journals.

In addition to this research oriented work the group is involved in a number of applied projects which are funded by outside the Estonian Science Foundation and the Target Funding. There are possibilities to increase this type of work having more personnel available.

Evaluation of research activities

The groups could probably publish even more of their work in the best international journals.

The research activities are judged as *Good.*

Evaluation of overall capability

The strategy and perspective of research can be improved. It is not clear how application oriented projects are related to the research projects, for example.

The overall capability is judged as *Excellent to good.*

Recommendations

1. Research should be more focused so that a clear future direction can be identified.

2. The group should be better linked to the Department of Mechanics and Applied Mathematics at IoC.

3. Additional applied work could be done with the use of student projects in a natural manner together with the Department of Mechanics at TTU.

IV. Department of Mechanics, Tallinn Technical University

The Department of Mechanics is led by Prof. Jaan Metsaveer and consists of 4 Chairs, 3 of which will be described and evaluated below. The fourth one, the Chair of Applied Mechanics is held by Juri Engelbrecht and is evaluated in the section dealing with the Institute of Cybernetics.

During the last 5 years, only two MSc students have been supervised by the three chairs evaluated. In addition, 3 PhD theses were co-supervised at Le Havre University, France.

There is a strong collaboration with national and international scientists in the Chair of Solid Mechanics.

The funding is mainly from the Estonian Science Foundation and Target Funding from Science Competence Council. In addition, there are application-oriented projects.

A. Chair of Solid Mechanics

General comments

The group on fluid and thin-walled structure interaction is formed by the Head of the Department, who is the Head of the Chair of Solid Mechanics, one senior researcher holding a PhD and one MSc student. The original aim of the research is to find information on targets that are submerged in fluids or buried in seafloor sediment by means of the sound field radiated or scattered from the targets. Theoretical studies by analytical methods are made on sound scattering from cylindrical shells. For scattering on more complicated structures finite element methods are used. The group has contributed with most originality to the theory of scattering from stiffened cylindrical shells. Collaboration is going on with experimental researchers at the University of Le Havre, France.

The research results of the group have been published in several refereed papers in international journals since 1994 and in a great number of conference contributions. The research group is well established in the international community.

Evaluation of research activities

The research activities of the group are *Excellent to good.*

Evaluation of overall capability:

There is a lack of more MSc and PhD students in the group.

The overall capability is rated *Good.*

Recommendations

1. Wave propagation is a specialty of the Institute of Cybernetics, where mostly nonlinear waves are studied, in contrast with the linear waves studied by this group. We believe that the division between linear and nonlinear wave studies is artificial. Therefore we recommend that the two groups collaborate in teaching and thereby together attract students to the field of wave propagation.

2. We recommend the group to start considering the inverse problem in their research.

3. The work of the group should have important environmental applications that should be persued by the group. EU funding is available in this direction.

B. Chair of Fluid Mechanics

General comments

The group is headed by Professor Tiit Koppel and the staff consists of Prof. Em. Uno Liiv, 1 senior researcher holding a PhD, and 4 MSc students. In addition, there is 1 PhD student working at KTH, Stockholm who is listed as part of the group.

The topic "Unsteady Fluid Flow " has its origin in the Soviet time when some technological aspects of space shuttle "Buran" were studied and financed. At that time the experimental device allowing the generation of highly accelerated fluid flow in pipes was constructed. In 1998-2002 two small Estonian Science Foundation grants were obtained on the basis of this equipment.

The main idea of project is that pulsation of turbulent flow destroys the boundary layer and therefore better mixing of fluid near the pipe wall can be obtained and better heat transfer by cooling liquid is expected. Unfortunately no optimal parameters of the process are found. The problem formulation is narrow and the equipment is somewhat out of date.

A Hydraulic Network Modeling Group was established in the chair 4 years ago. The main task of the group is the creation of network models for drinking water supply and sewerage water networks. The research is applied and results are important for Estonia. Results were used for modeling water network in Tallinn and other Estonian towns.

Several other activities were also described.

Evaluation of research activities

Due to the varied nature of the activities it is difficult to form a unified opinion, but we estimate the research activities as *Satisfactory.*

Evaluation of overall capability.

There exists some international cooperation in the field of temperature measurements. Grants are funded from Estonian Science Foundation but the topic does not seem to have a perspective for wider or international funding.

Overall rating of the group is S*atisfactory*.

Recommendations

1. The hydraulics projects are good application oriented projects and should definitely be continued. It should also be possible to obtain funding from the Innovation Foundation for this research.

2. Unfortunately the research of unsteady pipe flow does not continue in the good tradition in which it started long time ago.

3. The cooperation with KTH should be continued and the corresponding promising research line should be integrated into the group.

C. Chair of Structural Mechanics

The head of the Chair of Structural Mechanics, Ulo Tarno, was not present at the evaluation meeting due to his other obligations. The written report contained little information and only a short description about his activity, so we formed our opinion based on his publication list and also on the more detailed oral presentation of his colleague, Prof. Lahe.

General comments

The detailed presentation on the application of system and transfer matrix methods gave an insight into the research work of the Chair of Structural Mechanics. This field is mainly covered by the somewhat isolated research activity of Prof. Lahe.

The topic of the presented research area clearly shows its education-oriented nature. The international research community has been considering the transfer matrix method as a conventional and not especially competitive field since the appearance of the finite element method, or the boundary element method, or the prospective new method, the meshless method.

The relation of the transfer matrix method and the boundary element method was addressed in a paper published in the Proceedings of the Estonian Academy of Science. This can be considered as a good international level publication – and this is the best the group produced in the recent years.

The group develops its own software, and has no access to commercial finite element software or other professional software widely used in the field in other industrially developed countries. Also, the lack of MSc and PhD students make the position of structural mechanics weak.

On long term, the lack of active international level research in the field will lead to the decrease of the presently good level of undergraduate teaching.

Evaluation of research activities

The publications of the research group contain only one good peer-reviewed journal paper. The overall publication activity is rated *Satisfactory*.

Evaluation of overall capability

In the research group, a single international mobility grant was obtained in the recent years. There have not been graduate or postgraduate students for several years, and the strategy and perspective is not clear. The researchers work in an isolated environment, no lively research contacts with others on national level either in the academic or in the industrial community. There is a serious ageing problem in the field of research.

The overall capability of the group in the given field is rated *Satisfactory to unsatisfactory.*

Recommendations

1. The major profile of this research area should be changed to Finite Element Methods. In case the Chair of Structural Mechanics is not able to turn in this new direction immediately, the experience and knowledge of the colleagues will be lost, and this field, having essential importance for civil engineers, has to be reconstructed with the help of researchers from other institutions.

2. The group needs young researchers urgently. There must be ways to find MSc and PhD students working in the field of structural mechanics. The successful use of the transfer matrix method could be continued in education as before, but it should be used as an introduction mainly in beam theory to the more general finite element method.

V. Laboratory of Energy Processes Diagnostics, Estonian Energy Research Institute, Tallinn Technical University

The institute is headed by Dr. Ulo Rudi, who also has the responsibility for the projects being evaluated, while the laboratory is led by Dr. Alexander Kartushinsky.

No PhD thesis was supervised by the staff in the project and 2 MSc theses were co-supervised by the staff during the last 5 years. There is one co-supervised PhD thesis in progress.

There is some collaboration with national and international scientists.

The funding is mainly from the Estonian science foundation and Target Funding from Science Competence Council.

Mechanics research is carried out in the specific field of two-phase and vortex flows in the Laboratory of Energy Processes Diagnostics of the institute. The chosen name of the laboratory does not express its main activity. This is not a major problem as long as it does not attract funding (for example Target Funding) from the field of diagnostics. At the time, when foreign investors and companies bring factories, production lines, and products with ready-made production technology into a country like Estonia, the area of diagnostics in the maintenance of production and energy processes is a major field for qualified engineers. Therefore, the chosen name of the laboratory should not mislead the funding agencies.

Two-phase and vortex flows

General comments

There are 3 scientists with PhD degrees and 4 with MSc degrees in the project.

The work on two-phase flows deals with both the development of closure models and experimental verification of those models for flows in simple geometry. The theoretical work utilizes the turbulent boundary layer equations and is aimed at refinement of particle collision modeling. In projects with international cooperation, new models have been derived and tested experimentally with good results.

The measurements in the two-phase flow are made with modern laser equipment and the measurements techniques appear to be state of the art.

The vortex flow research deals with theoretical derivation of new vortex flows and a new model of a viscous vortex ring is found. Flows near hemispherical depressions are also studied experimentally and numerically. In the experimental investigation small periodic depressions were found to reduce drag, although no independent confirmation of this result was shown. The numerical modeling of this flow with CFD codes with turbulence models was not done in a satisfactory manner. In addition swirling flows in a cylindrical container was also studied.

Although the research was motivated by practical application, no application was studied in the group. The more practical CFD modeling of the flows was tried but failed because of inexperience with such methods and an out of date computer system.

Evaluation of research activities

The group has some international publications in refereed journals and quite a number of conference proceedings from international conferences.

The research activities are judged as *Good to satisfactory*.

Evaluation of overall capability

The group has no young researchers and it needs to establish more application oriented direction in both two-phase and vortex flow areas.

The overall capability is judged as *Good*.

Recommendations

1. The move to make the Estonian Energy Institute to be a part of Tallinn Technical University should be used by the group to get in closer contact with the other mechanics researchers there. In particular, they should involve students on PhD and MSc level in their group. The experimental equipment and techniques will strengthen the Department of Mechanics.

2. The newly developed closure models for two-phase flow should be tested in general three-dimensional computational fluid dynamics codes. In the long terms such codes should be acquired and used by the group. In the short term this could be done in cooperation with international research groups, e.g. within the ERCOFTAC (European Community on Flow, Turbulence and Combustion) organization.

3. The direction of the research on vortex flows should be reassessed, and concentrated on where the strengths of the group are.

4. The group should be oriented towards prospective applications such as combustion and/or pollution research. EU funding should be available in these fields.

5. The computer resources and software should be strongly upgraded.
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VI. Acknowledgements

We thank the Estonian Higher Education Accreditation Centre and the staff of the visited institutions who were most hospitable to us and went to great lengths to show us all of their facilities and to make our stay a most enjoyable one.

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