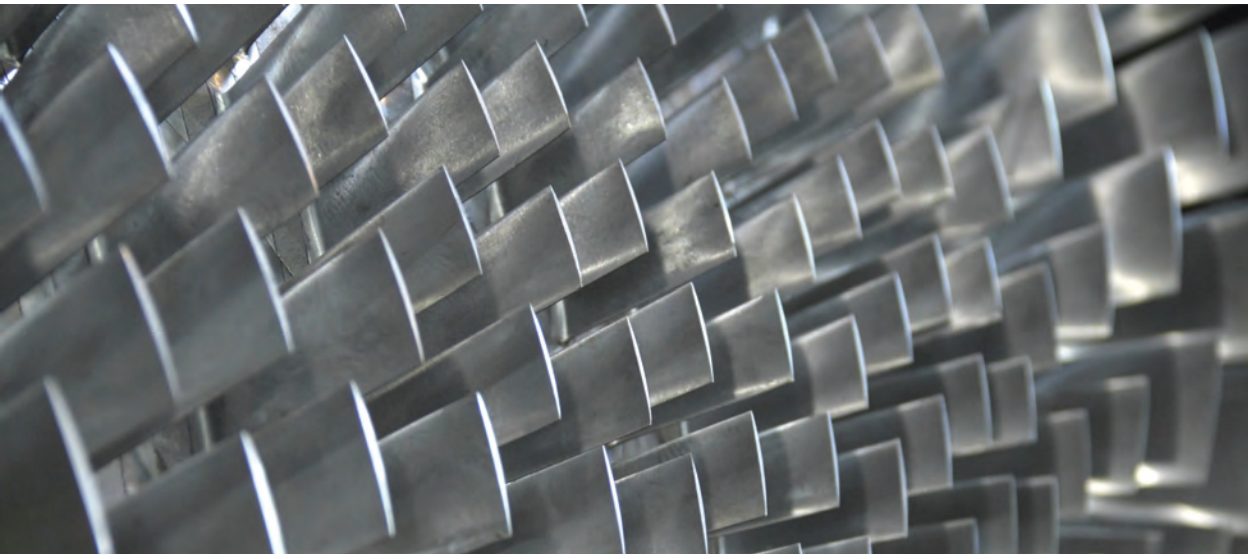
Vetenskapsrådet

# EVALUATION OF SWEDISH RESEARCH IN MECHANICAL ENGINEERING



VETENSKAPSRÅDETS RAPPORTSERIE 1:2013

# EVALUATION OF SWEDISH RESEARCH IN MECHANICAL ENGINEERING

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# PREFACE

In 2012, the Swedish Research Council initiated an evaluation of Swedish research in mechanical engineering. The overall objective of this evaluation is to inform the Swedish Research Council about the scientific quality of the research area in an international context. The evaluation should also identify future needs which can help Swedish researchers as well as stakeholders to develop research in mechanical engineering.

An international Scientific Expert panel was appointed for this evaluation. The evaluation was planned and supported by a secretariat of staff comprised of Andreas Augustsson and Bo Sandberg from the Swedish Research Council. This report contains the findings and recommendations of the Expert panel.

The Swedish Research Council would like to thank the participating researchers for providing the necessary background material and for participating at the hearings in Stockholm with the Expert panel.
The Swedish Research Council would like to express its deepest gratitude to the Expert panel for devoting their time and expertise to the important task. The findings and recommendations are greatly appreciated, and will provide important guidance for future considerations and initiatives.
Stockholm March 2013

Sven Stafström

*Secretary General, Natural and Engineering Sciences*
*Swedish Research Council*

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# EVALUATION REPORT

## To the Swedish Research Council

As requested by the above-mentioned organisation, we have evaluated the Swedish research in Mechanical engineering during the years 2007-2012. We take full responsibility for the judgments and the recommendations given in the report.

Stockholm, January 2013

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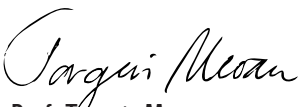

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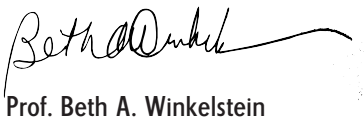

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*University of Pennsylvania*

# EXECUTIVE SUMMARY

The panel has been invited by the Swedish Research Council to evaluate all research in mechanical engineering in Sweden during the years 2007-2012. The results are presented in this report.

The panel finds that Swedish mechanical engineering research is strong in a number of areas. In particular solid mechanics and fluid mechanics have a long historical tradition and these areas already had strong international visibility in the first part of the 20th century. In solid mechanics the work can now be separated into materials mechanics, structural mechanics and dynamics. Closely related to solid mechanics is machine elements, where often tribology is an important research area. In addition to the study of fluid flows, fluid mechanics also includes combustion and heat transfer. Acoustics emerges as a research area with close relations to both fluid mechanics and vibration analysis, and biomechanics is an area that is receiving increasing attention in Sweden, in solid mechanics modelling, and in fluid mechanics modelling.

The panel has observed that funding for fundamental engineering research is difficult to obtain for universities in Sweden. Swedish industry is strong, and although individual companies are willing to put a great deal of money into engineering research, such funding is inevitably rather closely tied to specific engineering applications. It is good that industry is willing to support the technical research, but research in fundamental technical questions is important, in order that Swedish engineering science can maintain a high level. This is necessary both to attract talent to engineering research and education and to lay the foundations for applied research and development to meet future needs of society.

If the engineering researchers find it so difficult to obtain support from the Swedish Research Council that they give up, this will significantly damage the international status of fundamental engineering research in Sweden. The panel was informed that the total amount of funding from the Swedish Research Council has significantly increased over recent years, but it was unclear whether the mechanical engineering area experienced a similar rate of increase. To avoid very negative effects in the mechanical engineering area, the panel recommends that the funding of mechanical engineering research maintain a share corresponding to what it was some years ago. Experience from other countries shows that decisions on what is important engineering research should not be left to researchers from the natural sciences.

Overall the panel concludes that there are very strong research groups in mechanical engineering in Sweden. It is important that the Government

maintains a support structure such that this research is strong and able to respond to future technical imperatives, such as for industrial competiveness, the increased need for sustainable and efficient energy usage and adaptation to climate change.

# 1. INTRODUCTION AND EVALUATION PROCESS

The Swedish Research Council (Vetenskapsrådet, VR) is the largest Swedish funding agency for funding fundamental research, providing support for research of the highest academic quality in all disciplinary domains, at Swedish universities, colleges and institutes. In 2012 the Swedish Research Council allocated some SEK 5 billion to research. The majority of the funding budget is allocated to research projects initiated by researchers, where every research application is reviewed, assessed and prioritised by evaluation panels. The Swedish Research council uses peer review and has about 50 evaluation panels covering well-defined academic fields including one in mechanical engineering. The Swedish Research Council also advises the Swedish Government on research policy issues, and continuously evaluates different research disciplines.

Research in mechanical engineering is financed through direct University funding (34 per cent) and external funding (66 per cent), where the part of the Swedish Research Council constitutes about 10 per cent of the total funding[1]. Thus, most of the external funding comes from other funding bodies, such as the Swedish Agency for Innovation systems (VINNOVA), the Swedish Energy Agency, EU, the Swedish Foundation for Strategic Research, other agencies and foundations and industry.

At the Swedish Research Council, project research applications in mechanical engineering are reviewed and granted through the Scientific Council for Natural and Engineering Sciences. About SEK 43 million (4.2 per cent in 2012) is annually allocated to research project grants within the field of mechanical engineering[2]. In addition to this, there are annual calls for international Postdoc grants, industrial PhD grants and research infrastructure grants, and also occasional calls for Framework grants (within strategic energy research). Within this field there is also one VR supported Linnaeus environment, the Linné FLOW Centre at the Royal Institute of Technology (KTH).

1 From a compilation of data supplied by the participating research units (i.e. reported funding in the Self-evaluation report).

2 Mainly within the panel of Mechanical engineering, but also within the panel of Biomedical engineering where Biomechanics is included.

## Evaluation aims and methods

The overall objective of this evaluation is to inform the Research Council about the scientific quality of the research within the mechanical engineering area in an international context. The evaluation should also identify future needs to support and develop the research area in Sweden.

Specific evaluation objectives are:

- In an international perspective, assess the scientific quality and the possibility of development and renewal.
- Identify areas of research that are well represented by successful Swedish research groups and provide an assessment of the Research Council's support to these areas.
- Identify important but weak or neglected areas of research in Sweden.
- Identify Strengths, Weaknesses, Opportunities and Threats in the research area.
- Identify potential need to support and develop the research area (e.g. forms of support and/or research infrastructure).

In June 2012, the Swedish Research Council surveyed all university departments with relevant research within the field of mechanical engineering to participate in the evaluation. The departments were asked to report short summaries of their research (research areas or groups) including contact persons responsible for each area/group (reporting unit). All surveyed departments and participating reporting units are listed in Appendix 1.

In September, self-evaluation questionnaires were distributed to all contact persons and were due back to the Research Council in mid-November 2012 (Appendix 2). In total eight universities divided into 30 reporting units have participated in this evaluation, including the work of some 300 researchers and about 500 PhD-students.

The self-evaluation reports from the reporting units were distributed to panel members prior the meeting in Stockholm (21-25 January 2013) and initial assessments were made before the meeting. As a complement to the self-evaluation reports, the reporting units were invited to a hearing with the expert panel (Appendix 3.). Each reporting unit was asked to send 1-5 representatives to the hearing, and to make a 10 minute presentation. After the presentation the panel had 30 minutes for questions and discussions with the representatives. Citation records (Source: Thompson Reuter, Web of Science) from all participating professors were also collected from the reporting units and presented to the expert panel.

The rating of quality of the research performed in the relevant period was primarily expressed in terms of international standing. In order to standardise the terminology used in the assessment of research, the following ratings were used.

- **Outstanding**: Outstanding research in an international perspective; of great international interest with broad impact and with publications in internationally leading journals; the research group/unit is among the leading in the evaluated field of research in an international perspective.
- **Excellent**: Research at a very high international level; of international interest with impact within its field and with publications in internationally leading journals; the research group/unit is competitive in the evaluated field of research in an international perspective.
- **Very good**: Research at a very good international level with publications in internationally well-known journals; the research group/unit has a good international reputation within the field.
- **Good**: Research that is of good international standard and partially published in well-known international journals.
- **Insufficient/Weak**: Research of low international standard.

Besides evaluating the individual groups the panel also made an overall assessment of mechanical engineering in Sweden and provided general findings and conclusions with recommendations for the consideration by the Swedish Research Council.

### The expert panel

The chairman and members of the expert panel were selected and appointed by the Swedish Research Council. All surveyed departments were asked to nominate candidates for the expert panel. Further information on the expert panel can be found in Appendix 4.

# 2. GENERAL FINDINGS AND RECOMMENDATIONS

## 2.1 The hearings of reporting units

During the first four days of the panel meeting, hearings were held with 29 reporting units from most of the Swedish universities offering an engineering education. The self-evaluation report from each reporting unit had been carefully studied by the panel members with expertise close to that of the unit, and each of those panel members submitted pre-assessment notes, which were available to all panel members. In the 30 minute question period for each reporting unit, most of the questions were posed by the panel

members with special insight, and thus used to obtain a more detailed understanding of the activities. Other panel members could also ask questions as appropriate. Generally, the hearing gave a very good supplement to the information received in the self-evaluation report.

The focus during the hearing was on research with an international perspective. One of the indicators in this context is the involvement of the European Research Council (ERC) Starting Grants or Advanced Grants. Each reporting unit was therefore asked during the hearing whether members of their group had applied for or obtained such grants. It was explained that these EU Grants are given entirely based on excellence, with much focus on the excellence of the single person applying. Thus, the Grants are a European competition based on research excellence. Some groups had sent in applications, or planned to do so, and a few had even obtained a Grant. However, it appeared that a number of the representatives either had never heard about these Grants or felt that they were not viable competitors.

Another indicator of quality from an international perspective is whether or not members of the group had developed relationships to the extent that they had actually published journal articles together with strong researchers from other countries. Some had, but there were also several groups without such connections. Furthermore, the reported h-index and citation records of the scientists were discussed to assess their international reputation.

The panel asked about the teaching load per senior researcher per year. It was generally found that the teaching load is not high when compared with common teaching loads internationally, so this could not sufficiently explain cases of a lower research output.

The widely varying sizes of individual reporting units made the evaluation more difficult. The size of the units ranged from 4 senior researchers up to 44 senior researchers. For the smaller units the self-evaluation report gave reasonable information on the activities, but for the larger units this was not possible. Then part of the evaluation was based on prior knowledge among the panel members, or on other sources. In future evaluations it is recommended that VR limits the size of reporting units.

## 2.2 SWOT for the research area

### Strengths

Sweden has internationally competitive specialist industries which require and strongly support university research input to their R&D.

There are some strong groups evaluated that have excellent reputations and are carrying out excellent work. The best Fluid Mechanics, Solid Mecha-

nics and Combustion groups are particularly strong which is entirely appropriate given the importance of these areas in maximising energy efficiency.

### Weaknesses

The extent of international collaboration is patchy across disciplines and units.

Most groups assessed as very good or better listed collaborations with research groups in universities outside Sweden. However, relatively few were able to show that this association went beyond mutual convenience to the extent of generating co-authored journal papers, which is seen as a valid measure of quality of such collaborations.

PhD recruitment, particularly of Swedish candidates, was seen to be an issue.

Lack of ambition in terms of application for ERC individual grants is also a weakness in some units.

### Opportunities

Experimental work is an essential component of the research process in mechanical engineering, in combination with fundamental theoretical work, numerical simulation and modelling, and field measurements. Several experimental groups are hampered by the absence of funding opportunities for purchase of key equipment items, which is a consequence of the 'national facility' approach to such investment. National facilities are the most effective way to make large capital facilities investments. However, at a lower expenditure level there is an opportunity to establish a loan pool of equipment to be allocated for agreed periods to allow specified projects to proceed. Such a loan pool would consist of portable equipment items that may be unattainable for individual research groups, but could be shared effectively in this way.

Small groups or areas of research can develop through national and international networks of similar groups. This would avoid duplication of research themes and promote complementary collaborations towards, for example, bids for EU framework projects. This kind of cooperation would only require funding for meetings.

The evaluation panel is strongly supportive of the current provision of VR support for junior researchers and feels that this should be sustained.

### Threats

The lack of growth in VR resources made available to the mechanical engineering sector is a threat to its vibrancy, regeneration, and competitiveness on an international scale. This is exacerbated by the match funding requirements for Linnaeus proposals which direct internal university support to the same areas.

Fundamental engineering research is a real need for Sweden to retain its industrial position. This requires sufficient VR funding to be made available for this purpose, and allocation should be based on the strength of proposal and applicant, irrespective of group size.

Interdisciplinary or multidisciplinary proposals for cross cutting research are hampered by the clear fixed boundaries of the VR Evaluation panels. It is recommended that attention be paid to this aspect in order to ensure that opportunities are not lost, as currently seems to be the case.

# 3. ASSESSMENT OF AREAS

Several self-evaluation reports had been sent to the panel and most of the groups behind these reports came to be interviewed. In writing the assessment it was decided to divide the work presented into four different areas, fluid mechanics, acoustics, solid mechanics and biomechanics. Solid mechanics was such a broad part of the research considered that it was decided to further divide this area into materials mechanics, structural mechanics and tribology.

## 3.1 Fluid Mechanics

The significance of fluid mechanics in the field of mechanical engineering is exemplified by the **outstanding** research which is performed by the Department of Mechanics and the Department of Aeronautics and Vehicle Engineering of the Royal institute of Technology (KTH). Their research has a pronounced international impact with publications in internationally prestigious journals and findings considered milestones in their research field. This group is one of the major drivers in fluid mechanics research internationally. The research in stability and transition, flow control and optimization, turbulence, geophysical flows, computational fluid dynamics etc. is of the highest international level. The group pursues a clear strategy to combine fundamental and applied research, i.e., the models developed in basic research projects are generalized such that they can be applied to engineering technology problems. They have extensive cooperations with the highest ranked academic and non-academic partners in Europe, the US, and Japan. Furthermore, the team is well positioned for the future since the research quality is found in the work of both the experienced and next-generation scientists and the funding situation is stabilized through several well established research centers. The science by individual researchers and also the whole group defines the outstanding position of KTH's fluid mechanics research.

The research in fluid mechanics performed in the Department of Applied Mechanics at Chalmers University of Technology is characterized by an intensive activity in turbulence related simulations and numerical and experimental investigations in multiphase and turbomachinery flows. As far as high-fidelity turbulence modeling, computational jet-acoustics, and gas turbine flow analysis is concerned, the group's performance belongs to the top European level and the results are also well-recognized internationally. This is confirmed by their publication record in internationally leading journals which shows that the research quality is competitive in an international perspective. This means the quality of the scientific output is in the **excellent to outstanding** level. Especially in the field of numerical fluid mechanics, the group has scientifically strong cooperations in Europe and the US. To close the slight gap between numerical and experimental fluid mechanics, it is necessary to improve the experimental equipment such that time resolved spatial measurements can be performed.

The work of the Combustion group at Chalmers, focused on sprays and spray combustion, was assessed as **excellent to outstanding**. The group combines expertise and activity in experimentation, simulation, and modeling to address topics ranging from fundamental flames studies to tests in gasoline and diesel engines. Their funding, which comes from a variety of sources, is on a rising trajectory. They have excellent infrastructure in terms of facilities and diagnostic equipment, including recently purchased systems for ballistic imaging, spectroscopy, stereo PIV, and phase Doppler anemometry. Existing facilities and equipment are ageing, however, and it is difficult to obtain funding for maintenance and upgrade for which costs are significant. They have strong interaction with the automotive industry, excellent international collaborations, and excellent synergy within the group. Their publication record includes many articles in top journals, and recent articles show an excellent citation rate. The work is internationally recognized.

Although the hydrodynamics research group of the Department of Shipping and Marine Technology at Chalmers is still in the development stage, it has already reached a respected international level. The unit is shaping its **very good** research in the numerical analysis of cavitation, hydroacoustics, propulsion systems, fluid-structure interaction and so forth. The current funding situation is stable since the group hosts a Rolls-Royce University Technology Center. However, it is recommended that the marine hydrodynamics group combines with the marine structures group, for increased scientific and financial stability. In doing so, both groups are expected to benefit from each other and to reach the excellence level much faster.

The Department of Energy Sciences at Lund University, which has an excellent to outstanding reputation in the fields of heat transfer and combustion, has plans to address new types of combustors and fuels as well as fundamen-

tal issues related to fuel cells, wind energy, and hydro power. Combustion efforts are organized through several centers: CeCOST, a nationally recognized and supported center focused on combustion modeling and diagnostics, as well as KC-FP and Lund Combustion Center. Overall, they have been funded consistently at a high level from multiple sources, and their level of funding has risen from 2007 to 2013. The breadth of the group, which includes experts in experiments, modeling, and numerical simulation is a strength. They have top quality facilities and diagnostic equipment, and their simulation efforts are well supported through SNIC[3] and PRACE[4] allotments. The articles on heat transfer and combustion are in top quality journals and were judged as high impact. The group's self-assessment document and interview demonstrated clear strategic thinking toward relevant future issues and applications. They are well positioned to continue addressing fundamental questions and to make strong impacts at the international level. The overall rating of the group is **excellent to outstanding**.

At Luleå University of Technology, activities in fluid mechanics and experimental mechanics span a range of areas. Funding levels in both groups have increased compared with 2007. Areas of significant activity include flow through porous media, multiphase flow, convection, and material characterization via microscopic holography and tomography. Both groups, led by relatively young faculty, have significant state-of-the-art equipment available for their experimental needs, including PIV, LDV, infrared imaging, a tunable pulsed laser and ultra-high speed imaging cameras. The publications in fluid mechanics range from fundamental to highly applied, with some appearing in top quality journals. Although both groups appear well engaged on a **good to very good** research level, the panel expressed concern that neither group seemed to have a specific strategy in terms of new research directions or in terms of developing novel synergistic collaborations with leading Swedish or international groups.

In the Division of Applied Thermodynamics and Fluid Mechanics of Linköping University, experimental and numerical research in biofluid dynamics, industrial heat transfer and fluid mechanics, and aerodynamics is performed. The group does have a good publication record and the quality of research is considered in the **very good** range since the unit has already earned an international reputation in the field. However, currently the group is too small. That is, from an international scientific perspective, it is recommended to increase the number of active senior researchers to intensify the international visibility of the scientific outcome.

3 Swedish National Infrastructure for Computing
4 Partnership For Advanced Computing in Europe

The research in the Division of Fluid and Mechatronic Systems of Linköping University is related to fluid power systems and components and aircraft design and aircraft systems. The group is strong in performing applied research in collaboration with industry. Since a link with fundamental research in fluid mechanics is hardly visible, no overall grade will be given in this respect.

In the Division of Electricity at the Department of Engineering Science of Uppsala University, high quality research is performed in the field of renewable energy in the applied sense. Thus, high level experimental and numerical methods are used, e.g., to analyze the flow field of vertical axis wind turbines. In this respect, the fundamental research in fluid mechanics is considered to be in the **good** range.

## 3.2 Acoustics

Acoustics research, in the context of Mechanical Engineering in Sweden, can be characterised in a similar way as in most other European countries. There are few groups of sustainable critical mass, but otherwise, research activity can be found in smaller groupings, with important links with structural dynamics, fluid dynamics and construction science. The subject is too specialist a topic to fully fill an undergraduate programme, although it is included as elective modules in other areas of engineering. However, there are two Master courses, one at KTH and one at Chalmers, which provide the requisite skills and knowledge for graduates, wishing to work or research in acoustics.

The group at KTH is the largest in Sweden and is producing **excellent** research across a broad spectrum of activities. It includes the teams in the Marcus Wallenberg Laboratory (MWL) and in the newer Sound and Music Computing Group (SMCG), with a sustained recruitment and promotion policy. Both sub-groups are internationally recognized and are publishing in the best journals available in the area. MWL is producing internationally recognised research into flow acoustics, and material and structural acoustics, with a commendable balance of fundamental research, linked to numerical and experimental work. The relatively large group size is allowing initiatives and it is well positioned for its future directions: noise control in lightweight vehicles and buildings, thermo-acoustics, non-linear phenomena; smart materials and meta-materials. In addition to its existing excellent experimental facilities, the new centre for experimental mechanics (CEEM) will be used for acoustic and gas dynamic studies. SMCG is producing important work in musical instrument acoustics and in voice characteristics, with new directions in human interaction with vehicles and other products, and performer-instrument interaction.

The group at Chalmers is smaller and also is producing **excellent** research but in a correspondingly narrower field within vibro-acoustics: vehicle acoustics, particularly wheel-road noise, and urban noise propagation. The research is supported by a Master course and a healthy recruitment of PhD students. This group is too small and one of the two research leaders is near to retirement and therefore the group is possibly vulnerable. The future of the present research in room acoustics, musical instruments and product sound quality therefore is dependent on a replacement appointment at senior level.

There is a history of acoustics research at Lund University and this activity now is found, in combination with research in areas of structural mechanics, in the department of construction sciences. Although the scientific quality is **good**, it is possibly suffering from the smallness of the group and a lack of senior staff. Also, although engineering acoustics is described as an inter-disciplinary area, and so it is, more evidence is required that it is actively working with structural mechanics, for example. Existing links with the building industry seem good but quality research into noise transmission in the new generation of lightweight buildings, human perception of impact noise, environmental noise and in classroom acoustics, is promised rather than in evidence.

Elsewhere in Sweden, acoustics research is found in pockets of sometimes good quality activity, often as a product of research by bigger groups in fluids and in structural dynamics.

At Chalmers, it is found within the department of applied mechanics: fluid dynamics, which receives EU and national funding for its research in computational aeroacoustics. Likewise, research in transient flows, within marine hydrodynamics, is expanding into fluid-structure interaction, in response to the recognition of noise and vibration as environmental concerns.

At Umeå University, within the department of computing science, work has been reported on design optimization for wave propagation, as applied to musical instruments and loudspeakers. This is an example of acoustics research activity, often of high quality, found in departments of physics and related disciplines, and it is safe to assume that similar levels of research activity are taking place, elsewhere in Sweden, which has not been reported here.

## 3.3 Solid Mechanics

### 3.3.1 Materials Mechanics

In solid mechanics one of the most active research areas relates to the study of material behavior on the micro level, the meso level, or on the macros-

copic level. This includes detailed descriptions of the deformation mechanisms, both the basic elastic response and the nonlinear behavior where plastic deformations take place, or material creep occurs at elevated temperatures. The area also includes any study of failure, where the material gradually loses its strength due to the evolution of damage. In the studies of failure, fracture mechanics plays an important role, either in describing the relevant micro mechanisms of failure, or in studies where damage evolution around a macroscopic crack affects the crack tip behavior and the resulting crack growth. In recent research multi scale modeling is used more and more, accounting for the interaction of deformation mechanisms on different scales, stretching from macroscopic plasticity or creep models through crystal plasticity and discrete dislocation modeling to the atomic level, e.g. in the form of molecular dynamics.

KTH has a long tradition for work on materials mechanics, with some focus on fracture mechanics. Currently there is **excellent to outstanding** work on ductile fracture at low stress triaxiality with dependence on the third invariant, on paper mechanics and on applications of contact mechanics and contact fatigue. There is also **excellent to outstanding** work on composites, including manufacturing with 3D-weaving of composite fibres, and on improved mechanical properties of batteries when using carbon fibres for both structural material and electrode.

Also at Chalmers there is **excellent to outstanding** work on multiscale modeling of materials and computational homogenization, on atomistic modeling with application to graphene, on multiphysics problems with applications to cellular foams and granular materials, and on applications of fracture mechanics with cohesive zone modeling or damage mechanics modeling.

At Lund University the solid mechanics group does **excellent to outstanding** work on several subjects, such as recrystallization and grain boundary migration, martensitic phase transformation or hydride formation. This includes also work on bridging length-scales between crystal plasticity and discrete dislocation models, and research on smart materials. In the mechanics group there is work on fatigue, on powder metallurgy, and on nano-mechanics, including 3D molecular dynamics simulations of nano-indentation, which will even penetrate into quantum mechanics. Here the panel was impressed with the commitment and quality shown by individuals. The full group activity is considered **very good to excellent**.

The applied mechanics group at Uppsala University is in a fast build up mode following a complete change of direction two years ago. The work is now on experimental micromechanics of fibre-reinforced composites with corresponding development of analytical/numerical techniques, fracture in materials at different length scales, and use of combined optical and me-

chanical techniques to characterize mechanical behavior of wood materials. This work is considered **excellent** and has promising potential.

In Linköping University solid mechanics is a small group, where most work is on high-temperature mechanics, centering around fatigue and creep life of nickel-based superalloys. This includes surface coatings for thermal and oxidation protection. One person works on contact-impact mechanics, such as full car crash simulations, where material modeling is applied as a necessary tool. This group does not show strong international contacts, and is considered **good to very good**.

In Malmö University in the materials science group research activities are found on fatigue crack growth, on stress corrosion cracking in a coated material, and on hydrogen embrittlement, and the group will continue to be an active part in the European Spallation Source (ESS) project. This group is functioning under difficult conditions, being a rather new University without full rights, and the work is considered **very good**.

In Luleå University of Technology there are two solid mechanics groups. One has focus on manufacturing processes, which involves both microstructure models and material modeling tools. The other works on thermo-mechanical forming, failure of ultra-high strength steel components, and full field strain measurements for high strain rates at high temperatures. Both groups are considered **very good**. There is also a materials science group, which looks mainly at polymeric composite materials.

### 3.3.2 Structural Mechanics

Structural mechanics has traditionally been applied in the analysis of load carrying structures in aeronautical, civil, marine and mechanical engineering, but increasingly to "structures" with other functions, including human bodies, and equipment. While the basic principles have existed for a long time, the focus in recent decades has been on computational aspects, using the significant development of enabling computer hardware, constitutive modelling including failure mechanisms of complex materials and structures as well as applications to new areas. At the same time the structural mechanics is extended to deal with multi-bodies in rail, road, vehicles, deployable space structures etc.

In a wider context structural mechanics is combined with loads, especially requiring integrated aero-elastic or hydro-elastic analysis, with the general purpose of incorporating load effects for structural design checks relating to different design criteria – in the context of structural engineering.

The research groups involved in the present assessment reflect the general situation described above. Research on material modelling is primarily described in section 3.3.1. In this section research groups focusing e.g. on concrete structures and computational methods, are discussed.

The Chalmers, Department of Applied Mechanics, Materials & Computational Mechanics group cover a broad area and has done **excellent** work on adaptive finite element (FE) methods in space-time with automatic (built-in) control of the discretization error in a given quantity of interest, commonly known as "goal-oriented adaptivity", metal forming (anisotropic plasticity and elastic springback modelling), optimal control of a mechanical system including assessment of the influence in a quantity of interest from various sources of error, as well as load identification (inverse problem) in dynamically excited mechanical systems, with application to the interaction of wheel and rail.

The Chalmers, Department of Applied Mechanics, Dynamics group does fundamental and applied research with various dynamic, vibration, and wave propagation problems, some with coupling to other physical phenomena such as thermodynamics, piezoelectricity, or wear, often using control and optimization methods, in particular in relation to multibody systems and vehicle dynamics. The applied research is especially performed within the CHARMEC competence center (CHAlmers Railway MEChanics) in close cooperation with industry. The **very good** research performed in this group is for instance signified by development of a method for modelling and optimizing of controlled multibody system and used for different engineering systems, namely magnetostrictive sensors for power harvesting from vibrations, adaptronic engine mounts, suspension systems for commercial vehicles, high speed train bogie and robotic systems. Also the research on system synthesis of components, utilizing data from test for some components and FE modelling results for others, as well as simulation of wheel–rail interaction and comparison with measured contact loads, should be noted.

The Chalmers, Department of Civil and Environmental Engineering, Structural Engineering group focuses on reinforced concrete (RC) structures, but the group also deals with steel and timber structures. Material modelling in a computational mechanics context is an important aspect of the research on RC structures, with particular emphasis on developing materials models for the compression and the structural effects of reinforcement corrosion. The group is also carrying out interesting research on fibre and textile reinforced concrete. In view of the importance of experimental data for this group their laboratory situation needs to be clarified – by renovation of existing facilities or cooperation e.g. with SP Technical Research Institute of Sweden. The research on strengthening of steel structures by FRP composites, carried out by relatively young faculty members, is a noteworthy effort on steel structures. The overall rating of the group is **very good to excellent**.

The Chalmers, Marine Structures group is a small group covering structural mechanics for marine structures, especially ships, but also emerging technologies like wave energy converters.

The group has done excellent work on the assessment of collision and grounding damage, rooted in a solid mechanics approach with the local material behaviour involving plastic deformations, tearing and other failure modes, as well as the possible consequences of such accidents. The group has also engaged in many other very relevant fundamental and applied research tasks. This includes fluid-structure interaction – with a potential of synergy within Chalmers and weather routing of ships to reduce fatigue damage. The overall rating of this group is **very good to excellent**. Under the leadership of a young and dynamic professor with an excellent international research network the group shows a great potential for further development into international prominence.

The KTH Solid Mechanics - Structural Mechanics group is a small part of large consortium from 3 departments at KTH. This group performs interesting research on optimized load-carrying structures, with a particular interest in studies of non-linearities, instability and dynamics. Primary interest has been focused on thin-walled structures in engineering and natural objects, but also membrane as well as different forms of foldable and deployable structures have been extensively studied. Contact and non-smooth mechanical problems are also important study areas. Due to limited information about the activities in this group no overall rating is given.

The Lund University, Department of Construction Sciences, Structural Mechanics group has developed and used new models for large-scale models of soil-rock interaction and soil-structure interaction in cooperation with groups in geophysics. As reported above the group has also developed computational models for fracture simulation and strength analysis of apparently brittle structural components and orthotropic materials such as wood. The Lund University groups of structural mechanics and engineering acoustics have been working in collaboration with other research groups on measurements and signal processing. These activities have been facilitated by closeness to the computer centre (LUNARC) in Lund and the collaboration with a significant provider of high precision measurement systems. The overall rating of the Structural Mechanics group is **very good**.

The Departments of Computing Science, Mathematics and Mathematical Statistics as well as Physics in Umeå University carry out research on design optimization; efficient interactive simulation of multibody dynamic systems with nonsmooth dynamics; as well as adaptive methods for simulating multibody and multiphysics systems and obtaining error estimates for such simulations. Interesting results on shape and topology optimization for acoustic devices and some electromagnetics problems such as metallic antennas, have been obtained. This Mechanical engineering research at Umeå University is rated as **good to very good**.

### 3.3.3 Tribology

This multidisciplinary area is one in which Sweden has a historical tradition that is currently being carried forward by two groups, one based at Luleå University of Technology and one at KTH. There is also an interest in rolling contact fatigue within material groups concerned with the wheel-rail problem, and this work is considered in section 3.3.1.

The largest tribology group is the Division of Machine Elements at Luleå which is at around the average size of the groups included in the assessment. The breadth of coverage within the subject area is high with a clear interest in problems of real practical concern as evidenced by the strong funding obtained from industry which is used to fund PhD studies. The level of VR funding obtained is also strong and this balance has fuelled an expansion in the group during the assessment period. This has introduced new study areas and several of these call on areas of expertise that were not present in the core group. Biotribology has been developed, for example, by acquiring complementary bio compatible materials expertise by an imaginative appointment. In other areas new expertise has been drawn into the group by collaboration within the university and in the broader academic community. New work on tribochemical film formation in the mixed lubrication regime has been built on the group's leading multi-scale simulation work using collaborative input and is a leading contribution to the field. The group is also collaborating with leading international tribology groups and industrial collaboration includes work with the SKF European Research Centre. The group is dynamic with effective leadership that shows clear strategic thinking, and their work is assessed as **excellent**.

The KTH tribology work is that of the Department of Machine Design which is a small group. This research was more difficult to assess as the return was contained within that for a number of departments at KTH so that the self-evaluation report contained relatively little information about the group which forms 10% of the total size. The tribology work is focussed on friction and wear studies with the principal interest being the wheel rail application. This work is well known in the community and is assessed as **very good**. Its recent innovation to include modelling of airborne particle generation is novel and opens up opportunities for further development.

## 3.4 Biomechanics

Although Swedish research activities in the area of biomechanics have been on the rise only in recent years, there are several programs with historical roots dating back more than a decade. Current activity is limited to a few programs, which are generally still quite young or have had a recent influx of

activity and/or personnel. Most of the programs are still small with visions of growth towards doubling the size of their senior personnel in the next 5-10 years.

On balance, most of the activities in biomechanics are focused around finite element and computational modelling applications, building off of the strengths of the resident personnel and relying either on outside collaborators for experimental data or applications from medical colleagues. The reliance on clinical cooperation is similar to the landscape of most biomechanical engineering efforts that exist internationally and is required to remain relevant for that discipline. Also similar to global trends, is a focus on problems in the areas of orthopaedics and injury tolerance, at the tissue and human body levels. In fact, these areas are a primary effort for all but one of the programs in Sweden. The other major initiative is in the application of biomechanics to the cardiopulmonary system. In this latter area, efforts include modelling of tissue properties as well as simulation of the relevant flows.

The funding portfolio of biomechanics activities is on the lower end of the spectrum compared with the other sub-areas of mechanical engineering activities in Sweden. This may reflect the fact that the programs are still relatively young, or that this group of investigators has still to leverage their research towards larger grants and activities relative to the more traditional sub-fields in mechanical engineering.

Several programs have excellent researchers with a great deal of potential to impact diagnostics and medical interventions in the future. Given the growing awareness, interest, and need for biomechanics in today's international backdrop, this is a critical time for the biomechanics programs in Sweden, especially since several are newly formed or have been born out of an apparent coalescence of several investigators with different individual research areas or engineering perspectives. Moving forward, it will be imperative to determine unified areas in which to pursue distinction and to develop strategies, either with personnel or themes, to achieve such goals.

Orthopaedic biomechanics is the best represented sub-area, being a focus of at least one individual's work in each of the 4 programs reviewed. Within that broad context, efforts are placed on human body modelling at Chalmers and KTH with applications in the automotive and neuromuscular physiology environments. The programs at Lund University and Linköping University investigate bone biomechanics using imaging techniques coupled with an effort to model the processes by which bone remodels. Despite sharing this physiological theme, publication outputs vary among the four programs in terms of frequency, target journals, and impact. Those programs aiming to capitalize on their reputation and maximize their impact will need to target the leading engineering and clinical journals in order to be perceived as outstanding in the global arena.

According to the material presented to the panel (both in the reports and the presentations), cellular biomechanics is not well represented in any of the programs in Sweden. This is a rich area of biomechanics, yet requires a very high degree of understanding in cellular biology and may not be well suited to those with strict mechanical engineering backgrounds. Moving forward, however, this may represent an area of opportunity for new initiatives in the future.

The research in the biomechanics group at KTH is rated as **excellent**. The activities in the biomechanics of head and brain injury impressively span from the axonal to the macroscopic levels, integrating multiscale mechanics. The interdisciplinary efforts required for such "neuronic engineering" research are commendable and have led to this group's continued success and promising trajectory for the future. The activities in neuromuscular human body biomechanics are newer but are similarly very good with the potential of becoming excellent. Modelling activities in work related to aneurysms as well as simulations of pulmonary and blood flows are also excellent. It is apparent that there is a common theme of multiscale modelling across biologic tissues in this group, in which there is strength. As such, the panel highly recommends that this group establish a clear thematic vision for their collective work in order to leverage activities towards becoming outstanding.

Biomechanics is a relatively new sub-area within the Construction Sciences Department at Lund University, with only a few individuals working in the area, but a concerted effort to grow biomechanics in the future. This group focuses on bone and osteoarthritis and leverages relationships with clinicians to execute imaging studies. This program is to be commended on its ability and recognition that experimental and computational efforts are needed in cooperation. The research output is similarly admirable given it is still a young group. The publications are in well-regarded journals. On the whole, this program is **excellent** given its relatively small size and recent history, and is expected to grow in recognition and to have a great impact in the future.

Biomechanics at Linköping University is focused largely on structural optimization with applications to biologic growth and vascular mechanics. The research efforts of the unit as a whole are **very good to excellent** with a few excellent individuals. The primary efforts are in modelling and rely on experimental data from respected collaborators, which is a strength. Work in the area of smooth muscle contraction and arterial characterization, growth, and remodelling is very strong.

**Good to very good** work is being done in Chalmers, which has a strong history and very good reputation for computational modelling and human dummy development in the field of impact biomechanics. This group focuses on neck injury and injury mitigation, which is highly applied. Given

the challenges facing the automotive community and the current economic state of that industry, it is highly recommended that this group work towards developing a long-term strategic plan for the future of this type of research. Although there is natural synergy and overlap with sports- and work-related musculoskeletal injury and mitigation, it is not clear that such transitions in research paradigms are as transparent as one would like.

Since the field of biomechanics, whether biosolids or biofluids, is a natural integration of mechanical engineering, applied mechanics, and biology, it is highly interdisciplinary, requiring investigators or teams of cooperation that are equally interdisciplinary in their training, methodologies and analytical approaches. As this sub-field grows and develops in Sweden, it will become requisite to provide appropriate training for individuals working in these fields and also to foster and encourage synergistic relationships among investigators. Although many of the existing programs can proudly claim promising activities and individuals in the area of biomechanics, they still face significant challenges to achieving or maintaining excellence from an international perspective over the longer term.

# APPENDIX 1: LIST OF EVALUATED UNITS

All information about the units is taken from the self-evaluation reports.

## Chalmers University of Technology

### Department of Applied Mechanics

#### Divisions of Dynamics, Fluid Dynamics, Materials and Computational Mechanics, and Vehicle Safety (Biomechanics)

Research area: biomechanics.
Reporting unit (2012): researchers 8; post-docs 2; PhD-students 13.

#### Division of Combustion

Research area: combustion.
Reporting unit (2012): researchers 9; post-docs 3; PhD-students 18.

#### Division of Dynamics and research group of Vehicle Dynamics

Research areas: solid mechanics, mechanical systems, vehicle dynamics.
Reporting unit (2012): researchers 15; post-docs 2; PhD-students 23.

#### Division of Fluid Dynamics

Research areas: fluid mechanics, acoustics, turbomachinery, gas turbine technology.
Reporting unit (2012): researchers 12; post-docs 7; PhD-students 31.

#### Division of Material and Computational Mechanics

Research area: solid mechanics.
Reporting unit (2012): researchers 9; post-docs 1; PhD-students 14.

### Department of Civil and Environmental Engineering

#### Division of Applied Acoustics

Research area: acoustics.
Reporting unit (2012): researchers 5; post-docs 2; PhD-students 13.

### Division of Structural Engineering

Research areas: solid mechanics, structural engineering.
Reporting unit (2012): researchers 11; post-docs 0; PhD-students 12.

## Department of Shipping and Marine Technology, Division of Marine Design

### Research group Hydrodynamics

Research areas: fluid mechanics, acoustics, marine technology, ship hydrodynamics.
Reporting unit (2012): researchers 4; post-docs 2; PhD-students 7.

### Research group Marine Structures

Research areas: fluid mechanics, solid mechanics, marine technology, marine structures, dynamics of floating structures in waves.
Reporting unit (2012): researchers 4; post-docs 0; PhD-students 9.

# KTH Royal Institute of Technology

## Acoustics

### Department of Aeronautical and Vehicle Engineering, The Marcus Wallenberg Laboratory for Sound and Vibration Research, Department of Computer Science and Communication, Sound and Music Computing Group

Research area: acoustics.
Reporting unit (2012): researchers 17; post-docs 6; PhD-students 28.

## Biomechanics

### Department of Computational Biology, Computational Biology, Department of Mechanics, Department of Neuronic Engineering, and Department of Solid Mechanics

Research area: biomechanics.
Reporting unit (2012): researchers 15; post-docs 2; PhD-students 18.

## Fluid mechanics

### Department of Mechanics and Department of Aeronautics and Vehicle Engineering

Research area: fluid mechanics.
Reporting unit (2012): researchers 30; post-docs 14; PhD-students 66.

## Solids

### Department of Aeronautical and Vehicle Engineering, Divisions of Lightweight structures and Road and Rail Vehicles, Department of Machine Design, Division of System and Component Design, Department of Mechanics, Structural Mechanics group, Department of Solid Mechanics, and Department of Transport Science, Division of Highway and Railway Engineering

Research area: solid mechanics.
Reporting unit (2012): researchers 44; post-docs 7; PhD-students 89.

# Linköping University

## Department of Management and Engineering

### Division of Applied Thermodynamics and Fluid Mechanics

Research areas: fluid mechanics, biomechanics.
Reporting unit (2012): researchers 3; post-docs 0; PhD-students 9.

### Division of Mechanics

Research areas: solid mechanics, biomechanics.
Reporting unit (2012): Researchers 9; Post-docs 0; PhD-students 5.

### Division Solid Mechanics

Research area: solid mechanics.
Reporting unit (2012): researchers 5; post-docs 0; PhD-students 9.

### Division of Fluid and Mechatronic Systems

Research area: fluid power systems and components, aircraft design and aircraft systems.
Reporting unit (2012): researchers 3; post-docs 1; PhD-students 7.

# Luleå University of Technology

## Department of Engineering Sciences and Mathematics

### Division of Fluid and Experimental Mechanics, Experimental Mechanics

Research area: experimental mechanics.
Reporting unit (2012): researchers 8; post-docs 1; PhD-students 6.

### Division of Fluid and Experimental Mechanics, Fluid mechanics

Research area: fluid mechanics.
Reporting unit (2012): researchers 13; post-docs 0; PhD-students 15.

### Division of Material Science, Polymeric Composite Materials[1]

Research areas: solid mechanics, material science.
Reporting unit (2012): researchers 7; post-docs -; PhD-students 10.

### Division of Mechanics of Solid Materials, Material Mechanics

Research area: solid mechanics.
Reporting unit (2012): researchers 4; post-docs 0; PhD-students 9.

### Division of Mechanics of Solid Materials, Solid Mechanics

Research area: solid mechanics.
Reporting unit (2012): researchers 8; post-docs 1; PhD-students 10.

### Division of Machine Elements

Research area: tribology.
Reporting unit (2012): researchers 11; post-docs 4; PhD-students 24.

# Lund University

## Department of Construction Sciences

### Biomechanics, Solid Mechanics, Engineering Acoustics, Structural Mechanics

Research areas: acoustics, solid mechanics, biomechanics, structural mechanics.
Reporting unit (2012): researchers 19; post-docs 2; PhD-students 26.

[1] Did not attend the hearing.

## Department of Energy Sciences

### Units of Fluid Mechanics and Heat Transfer

Research areas: fluid mechanics, heat transfer, energy sciences.
Reporting unit (2012): researchers 10; post-docs 6; PhD-students 25.

## Department of Mechanical Engineering

### Division of Mechanics, and Division of Materials Engineering

Research areas: solid mechanics, materials engineering.
Reporting unit (2012): researchers 6; post-docs 1; PhD-students 6.

# Malmö University

## Department of Media Technology and Product Design

### Division of Materials Science and Division of Applied Mathematics

Research areas: solid mechanics, materials engineering/science.
Reporting unit (2012): researchers 14; post-docs 1; PhD-students 5.

# Umeå University

## Department of Computing Science, Department of Mathematics and Mathematical Statistics, Department of Physics and High Performance Computing Center North (HPC2N)

Research areas: fluid mechanics, acoustics, solid mechanics, multibody system dynamics.
Reporting unit (2012): researchers 6; post-docs 2; PhD-students 9.

# Uppsala University

## Department of Engineering Sciences

### Division of Applied Mechanics

Research area: solid mechanics.
Reporting unit (2012): researchers 5; post-docs 1; PhD-students 5.

### Division of Electricity

Research areas: fluid mechanics, acoustics, solid mechanics, hydro- and aerodynamics, electromechanical engineering.
Reporting unit (2012): researchers 24; post-docs 8; PhD-students 47.

# Universities and departments not included

The following universities/departments in Sweden were also invited to participate in this evaluation.

## Blekinge Institute of Technology

### School of Engineering, Department of Mechanical engineering

Declined to participate.

## University of Gävle

### Faculty of Engineering and Sustainable Development, Department of Building, Energy and Environmental Engineering

Did not reply.

## Jönköping University

### School of Engineering, Department of Mechanical engineering

Did not reply.

## University of Skövde

**School of Technology and Society, Mechanical engineering**
Declined to participate.

## University West

**Department of Engineering Sciences**
Declined to participate.

## Linköping University

**Department of Management and Engineering, Division of Machine Design**
Declined to participate – research area outside the scope of this evaluation.

## Mid Sweden University

**Department of Applied Science and Design, Solid Mechanics**
Declined to participate.

## Uppsala University

**Department of Information Technology**
Declined to participate.

**Department of Engineering Science, Division of Microsystems Technology**
Did not reply.

**Department of Engineering Science, Applied Materials Science, Tribomaterials**
Did not reply.

# APPENDIX 2: QUESTIONNAIRE FOR THE SELF-EVALUATION

Dnr: 353-2012-6355

Vetenskapsrådet

**Evaluation of Mechanical Engineering**

*Please fill out the fact sheet and the following self-evaluation in this document and save it as a PDF file. The report must be written in English. The report including the appendix should be sent by e-mail to Andreas Augustsson at the Swedish Research Council, andreas.augustsson@vr.se no later than November 16 2012.*

## Fact sheet

*Please fill out the information in the fact sheet below*

### The reporting unit:

### Name of University and Department(s)

| |
|---|
| |
| |
| |
| |
| |
| Web page(s): www. |

| Contact person: | E-mail: |
|---|---|
| | |

### Research area(s):

*Please check one or more of the following areas:*

☐ **Fluid Mechanics** ☐ **Acoustics** ☐ **Solid Mechanics** ☐ **Biomechanics**

☐ **Other area 1; *Please specify***

☐ **Other area 2; *Please specify***

1

Dnr: 353-2012-6355

Vetenskapsrådet

## Evaluation of Mechanical Engineering

### Researchers:

*Add as many lines in the table below as required to provide the evaluation team with information about your research staff in the reporting unit. List Senior and Junior researchers, but not Post-docs and PhD-students.*

| Researchers/Name | Title | Year of PhD |
|---|---|---|
| | | |

### Post-docs and PhD-students:

*Please enter the number of;*

**Post-docs (2012)**

**PhD-students (2012)**

**PhD-degrees 2007-2012**

*working within the reporting unit.*

2

Dnr: 353-2012-6355

Vetenskapsrådet

## Evaluation of Mechanical Engineering

### Research Funding

**Please approximate the research funding for the reporting unit in kSEK.***

| Source | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Internal funding | | | | | | |
| Funding from Swedish Research Council | | | | | | |
| Other external funding**) | | | | | | |

*) Please note that comments on the research funding overview can be provided in the following self-evaluation (Question #4)

**) Please name the three[1] most important external funders of your research:

### Research output

**Please list, for the reporting unit, the total number of**:

a) Original articles in refereed scientific journals 2007-2012

b) Refereed conference papers 2007-2012

c) Review articles, books 2007-2012

d) Patents and other IPR 2007-2012

*Please note that a selection of publications should be listed in Appendix A.*

3

Dnr: 353-2012-6355

Vetenskapsrådet

## Evaluation of Mechanical Engineering

### Self-Evaluation

***This part of the report (Question 1 – 7) should not exceed more than 8 pages in total. For reporting units with more than 15 senior researchers this part may be extended to maximum 10 pages.***

**1. Short description of research activities and organization (Approx. 1 page)**

| |
|---|
| |

**2. Summarize the unit's most significant scientific achievements for the period 2007-2012. (Approx. 1 page)**

| |
|---|
| |

**3. Which is your reporting units five (5)[1] most significant collaboration partners, academic and non-academic (industrial)?**

| Academic (national and international) | Non-academic |
|---|---|
| | |
| | |
| | |
| | |
| | |

### Research funding

**4. Please comment on the funding situation (based on the funding overview provided in the fact sheet above) for the reporting unit. (Approx. 0.5 page)**

| |
|---|
| |

**5. Please describe any larger infrastructure investments (>2 MSEK) made during 2007-2012 and/or further needed equipment/infrastructure for your research. (Approx. 0.5 page)**

| |
|---|
| |

4

Dnr: 353-2012-6355

Vetenskapsrådet

## Evaluation of Mechanical Engineering

### Future

**6. What are the future plans for the group/unit in terms of**

**a) …direction of the research area? (Approx. 0.5 page)**

**b) …direction of the research group/unit? (Approx. 0.5 page)**

**c) …direction of national and international cooperation? (Approx. 0.5 page)**

### SWOT-analysis

**7. Please discuss what Strengths, Weaknesses, Opportunities and Threats that you see at your reporting unit, e.g. your views on Mechanical engineering in Sweden, research funding etc. (Approx. 2 pages)**

### Appendix A:

**List the reporting unit's most important publications applicable to Mechanical Engineering during 2007-2012. Maximum 20 publications[1].**

[1] For reporting units with more than fifteen senior researchers, maximum six external funders, ten collaboration partners and thirty publications can be listed.

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## Hearing schedule 21 - 25 Januari 2013

| Monday 21 Jan | | Tuesday 22 Jan | | Wednesday 23 Jan | | Thursday 24 Jan | | Friday 25 Jan | |
|---|---|---|---|---|---|---|---|---|---|
| 9.00-11:30 | **Panel meeting** | 9.00-9.40 | **UU - Div. Appl. Mech.** | 9.00-9.40 | **KTH - Fluid Mech.** | 9.00-9.40 | **UU - Div. Elect.** | 9.00-12 | **Panel meeting** |
| | | 9.40-10.20 | **LiU - Div. Mechanics** | 9.40-10.20 | **KTH - Acoustics** | 9.40-10.20 | **UmU - Comp. Sci.** | | |
| | | 10.40-11.20 | **LiU - Div. Solid Mech.** | 10.40-11.20 | **KTH - Solid Mech.** | 10.40-11.20 | **MaH - Mat. Sci. & Appl. Math.** | | |
| | | 11.20-12.00 | **LTU - Div. Mach. Elem.** | 11.20-12.00 | **KTH - Biomech.** | 11.20-12.00 | **Chairman - SNCTAM** | | |
| 11.30 - 12.30 | LUNCH | 12.00 - 13.00 | LUNCH | 12.00 - 13.00 | LUNCH | 12.30 - 13.30 | LUNCH | 12.00 - 13.00 | LUNCH |
| 13.00-13.40 | **CTH - Acoustics & Struct. Eng.** | 13.00-13.40 | **LU - Dep. Energy Sci.** | 13.00-13.40 | **LTU - Div. Fluid and Exp. Mech.** | 13.30-17:30 | **Panel meeting** | 13.15-16.00 | **Panel meeting** |
| 13.40-14.20 | **CTH - Div. of Marine Design** | 13.40-14.20 | **LU - Dep. Mech. Eng.** | 13.40-14.20 | **LTU - Div. Mech. of Solid Mat.** | | | | |
| 14.40-15.20 | **CTH - Fluid Mech. & Combustion** | 14.40-15.20 | **LU - Dep. Constr. Sci.** | 14.40-15.20 | **LiU - Fluid Mech. & Appl. Thermo.** | | | | |
| 15.20-16.00 | **CTH - Dynamics, Mat. Comp. Mech. & Biomech.** | 15.20-17:30 | **Panel meeting** | 15.20-17:30 | **Panel meeting** | | | | |
| 16.00-17.30 | **Panel meeting** | | | | | | | | |

| | | | |
|---|---|---|---|
| **CTH** | CHALMERS University of Technology | **KTH** | KTH Royal Institute of Technology |
| **UU** | Uppsala University | **LTU** | Luleå University of Technology |
| **MaH** | Malmö University | **LiU** | Linköping University |
| **LU** | Lund University | **UmU** | Umeå Univeristy |
| | | **SNCTAM** | Swedish National Committee for Theoretical and Applied Mechanics |

# APPENDIX 4: SHORT CV:s OF THE MEMBERS OF THE EXPERT PANEL

### Professor Viggo Tvergaard (Chairman)

Department of Mechanical Engineering, Technical University of Denmark
**Web**: http://www.fam.web.mek.dtu.dk/vtny.html
**Research interests**: solid mechanics, mechanics of materials, fracture mechanics; instabilities in structures and solids.

### Professor H P Evans

Cardiff School of Engineering, Cardiff University
**Web**: http://www.engin.cf.ac.uk/whoswho/profile.asp?RecordNo=18
**Research interests**: elastohydrodynamic lubrication, tribology.

### Professor Barry Gibbs

School of Architecture, University of Liverpool
**Web**: http://www.cgi.liv.ac.uk/cgi-bin/cgiwrap/archweb/display_pub.cgi?link=staff_pages&author=gibbs_barry.shtml
**Research interests**: vibro-acoustics, building acoustics.

### Professor Ellen Longmire

Aerospace Engineering & Mechanics, University of Minnesota
**Web**: http://www.aem.umn.edu/people/faculty/bio/longmire.shtml
**Research interests**: turbulent flows, multiphase and multi-fluid flows, biomedical flows, velocimetry and image analysis techniques.

### Professor Torgeir Moan

Centre for Ships and Ocean Structures, Norwegian University of Science and Technology
**Web**: http://www.cesos.ntnu.no/~tormo/
**Research interests**: structural mechanics, dynamics of multibody, elastic structures, ocean structures.

### Professor Wolfgang Schröder

Fluid Mechanics and Institute of Aerodynamics, RWTH Aachen University
**Web**: http://www.aia.rwth-aachen.de
**Research interests**: turbulence, computational fluid dynamics and aeroacoustics, measurement techniques, biomedical flows.

### Professor Beth A. Winkelstein

Bioengineering, School of Engineering and Applied Sciences, University of Pennsylvania
**Web**: http://www.seas.upenn.edu/directory/profile.php?ID=105
**Research interests**: orthopaedic biomechanics, soft tissue biomechanics, spine biomechanics, neural injury.

# SAMMANFATTNING

En expertpanel har bjudits in av Vetenskapsrådet för att utvärdera all forskning inom teknisk mekanik i Sverige under åren 2007-2012. Resultaten presenteras i den här rapporten.

Panelen finner att den svenska forskningen inom teknisk mekanik är stark inom en rad områden. I synnerhet hållfasthetslära och strömningsmekanik har långa historiska traditioner och dessa områden hade stark internationell ställning redan under 1900-talets första del. Inom hållfasthetsläran kan arbetet nu delas in i materialmekanik, strukturmekanik och dynamik. Hållfasthetsläran är närbesläktad med maskinelement, där tribologi ofta är ett viktigt forskningsområde. Förutom studiet av vätskeflöden inbegriper strömningsläran också förbränning och värmeöverföring. Teknisk akustik växer fram som ett forskningsområde med nära band till både strömningsmekanik och vibrationsanalys, och biomekanik är ett område som får alltmer uppmärksamhet i Sverige, inom modellering av hållfasthet och strömningsmekanik.

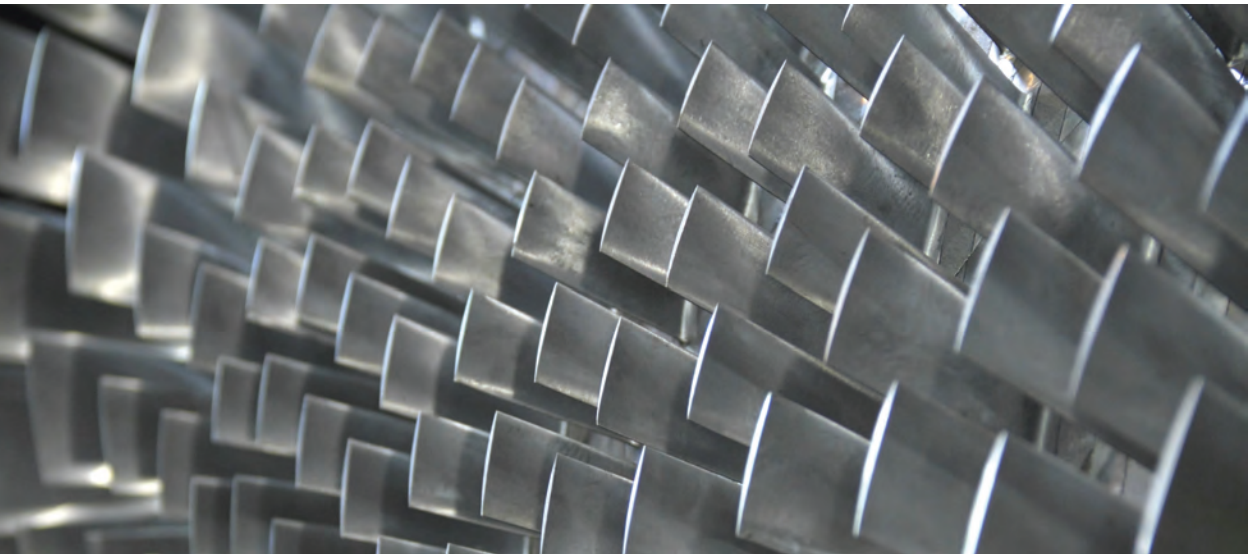
Panelen har observerat att det är svårt för universitet i Sverige att få anslag för grundläggande teknikforskning. Den svenska industrin är stark, och även om enskilda företag är villiga att lägga en hel del pengar på teknikforskning är mycket av den finansieringen relativt tätt knuten till specifika tekniktillämpningar. Det är bra att industrin är villig att stödja den tekniska forskningen, men forskning inom grundläggande tekniska frågor är viktig för att den svenska ingenjörsvetenskapen ska kunna upprätthålla en hög nivå. Det är viktigt både för att locka talang till teknisk forskning och utbildning och för att lägga grunden för att den tillämpade forskningen och utvecklingen ska kunna tillgodose samhällets framtida behov.

Om tekniska forskare upplever det som så svårt att erhålla stöd från Vetenskapsrådet att de ger upp, så kommer detta att skada den svenska tekniska forskningens internationella status avsevärt. Panelen blev underrättad om att Vetenskapsrådets totala summa för anslag har höjts avsevärt på senare år, men det var oklart huruvida man på det tekniska mekanik området har upplevt en liknande ökningsgrad. För att undvika mycket negativa effekter på det tekniska mekanik området rekommenderar panelen att anslagen till forskning inom teknisk mekanik upprätthålls på en andel som överensstämmer med den nivå de låg på för några år sedan. Erfarenheter från andra länder visar att beslut om vad som är viktig teknisk forskning inte bör överlåtas till forskare från naturvetenskaperna.

På det stora hela konstaterar panelen att det finns mycket starka forskargrupper inom teknisk mekanik i Sverige. Det är viktigt att regeringen

upprätthåller en understödsstruktur så att den här forskningen är stark och förmår uppfylla framtida krav inom tekniken, exempelvis vad gäller den industriella konkurrenskraften, det ökade behovet av hållbar och effektiv energianvändning och anpassningen till klimatförändringar.

An expert panel has been invited to evaluate Swedish research in mechanical engineering. This report describes the evaluation process and the expert panel's general findings and conclusions about mechanical engineering in Sweden.



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The Swedish Research Council has a leading role in developing Swedish research of the highest scientific quality, thereby contributing to the development of society. Besides research funding, the agency advises the government on research-related issues and participates actively in the discussions to create understanding of the long-term benefits of research.

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