Doctoral programme details

Adopted by the faculty council/education committee: 25 Jan 2011 (faculty board)

Revised: 13 Jun 2018

The programme's Swedish name (and English translation)

State also whether the programme has specialisations.

Maskinkonstruktion (Eng. Machine Design)

The subject has the following specialisations:

System and component design.

Internal combustion engines.

Mechatronics and embedded control systems.

Integrated product development.

Product and service design.

Short description of subject area and content

State the third-cycle subjects included in the programme. General syllabuses for included subjects are to be appended to the programme details.

At KTH, *Machine Design* deals with the development and design of machines and technical products from a wide, boundary-crossing perspective. The aim is education oriented towards efficient and innovative product development. This is of strategic importance for Swedish industry. Product development covers many different activities and includes the taking into account of technical issues as well as those of a financial and social nature. The combination of these different aspects is essential for successful product development.

In Machine Design, knowledge and engineering ability are of central importance as regards devising complex mechanical and mechatronic components and systems. To generate financial gain, product development normally takes place in an organisational setting. Thus, the strategy, organisation and methodologies of the associated activities are important. The human role in technical systems (e.g. as commissioner, developer or user) is fundamental in product development. Consequently, it is also an integral part of the subject. Research in Machine Design primarily covers the following areas:

- High-performance mechanical and mechatronic components and systems.
- Physical phenomena that can limit or facilitate new designs.
- Design methodology and development methods for composite physical and cyber-physical products.
- Product development processes taking into account technical, financial, environmental and organisational considerations.
- Method development in innovative design, user-driven design and service design.
- Product innovation processes with a focus on, amongst other things, technical, financial and social aspects.

- Tools and computer support in development and design.
- Design principles that can generate new functions and new products.

To be able to handle the subject’s diversity and complexity, third-cycle education is organised on the basis of a number of distinct specialisations. More specifically, these are: system and component design; internal combustion engines; mechatronics and embedded control systems; integrated product development; and, product and service design. Below, there are brief descriptions of research in these specialisations. Research and education in all the above-mentioned areas are characterised by wide-ranging industrial cooperation and many international collaborations.

System and component design

At the system and component design unit, research is conducted in three interrelated subject areas: machine elements; tribology; and, machine design.

In machine elements, research focuses on sustainable, environment-friendly and energy-efficient components and systems, i.e. roller bearings, slide bearings, gears, couplings, bolted joints, gaskets and various types of lubricants (oils, greases, ionic liquids and water-based lubricants). Energy losses are a considerable element in all generated energy. They stem from frictional losses in moving parts in machines and energy production systems alike. Research in machine elements is directed towards significantly reducing these losses. The mechanical and electronic components now included in ever more machines are increasingly being developed in ways that reduce the electronic-mechanical distinction. Thus, important parts of the research are the development of: machine elements that are more controllable and adaptive; active strategies for machine maintenance; sensor technology for multiparameter measurement; and, tribotronic systems.

Research in tribology is directed towards the modelling and simulation of friction and wear with a holistic perspective of system effects such as emissions, energy efficiency, material hygiene and design.

Research in machine design covers both development and analysis of products. It primarily focuses on problems related to mechanical systems. However, it also takes in connections to/with adjacent systems and environments. In respect of technical systems and components, important elements of the subject are methods and technologies for: behaviour simulation; performance forecasts; dimensioning; and, optimisation. One important research aspect (which takes in various disciplines) is the development of methodologies for more efficient development and analysis of mechanical systems via optimisation of product properties. Statistical, quasi-statistical, kinematic and dynamic models are examples of models that are interesting for behaviour simulation and product-performance forecasting. The applications vary from small to large products and systems, e.g. from small table-based haptic units to winch systems for wave-energy generation. Another important part of the research is building prototypes for: verifying and validating simulation models; and, testing new product concepts.

Internal combustion engines

Internal combustion engine research is largely about combining knowledge in basic subjects with a demanding application that is of great practical importance – the internal combustion engine. The subject deals with piston engines that use internal combustion. In the research, fundamental physics is interfaced with engine technology. The latest research discoveries are covered with the emphasis on global and local environmental issues. Energy supply issues (e.g. biofuel's possibilities and future scenarios) are important starting points for our operations. These latter are pervaded by the conducting of research aimed at making drive systems more efficient. Thermodynamic and combustion technology studies are carried out using experiments and leading simulation programs for both 1D and 3D calculations. The unit has a modern engine laboratory at its disposal. The environmental properties, combustion and thermodynamics of current engines are studied. The regulation and development of control systems is an area that is brought to the fore.

Mechatronics and embedded control systems

Software and electronic developments have brought a dramatic change to machine technology. Computer systems are increasingly being built into mechanical products (said systems then being referred to as "embedded systems" or "*embedded control systems*") and used to create entirely new types of machines and products. This entire area is known as *mechatronics*. Examples of application areas include: active safety systems in vehicles; industrial robots; robot lawn mowers; and, medical equipment such as ventilators or surgical instruments. All these examples include computer-based systems that (using measurement data from sensors, embedded logic, control algorithms and operator/user input) control the machine's behaviour via various types of actuators and mechanisms. An ever greater part of product functionality is being realised in this way through software. Control systems are often designed as embedded, distributed systems linked (both internally and to the surroundings) in a network. Constant improvement of sensors, actuators and calculation technologies is opening the door to new properties and enhanced performance. Besides pure, functional enhancements, mechatronics and embedded control systems also offer new possibilities as regards diagnostics, adaptivity and support for maintenance and any upgrading or downgrading. This development is being driven onwards by improvements in inter-machine communication and communication with data centres. It is becoming possible to achieve: collaboration and coordination on a wider scale (e.g. "intelligent" transport and production systems); and, integration across a machine's life cycle.

To use this technology successfully, developers and researchers are facing great challenges. Widely varying technologies, competencies and traditions need to be integrated. The implementation of mechatronics and embedded systems is bringing an increasing system complexity that imposes requirements in respect of adequate design methods, tools, designers and competent developers. Methods and tools for co-designing mechanical systems, sensors/engines, control systems and computer systems are important elements in the research domain.

Embedded control systems are most often the subject of severe requirements as regards reliability and cost-efficiency. Full exploitation of software flexibility and complexity also requires: efficient handling of a product's configuration; flexibility in operation; and, standardised software platforms. These are areas where constantly increasing system complexity presents major challenges to engineering enterprises and researchers – new methodologies, tools and integrated design methods are needed. Throughout development phases, system designers must take into account: conflicting requirements (reliability, performance, flexibility, new functionalities, existing components/functions, etc.); and, possible realisation (mapping) of functions in software and hardware. They must also deal with the close interdependence of the embedded systems, system functions and surrounding mechanics.

Integrated product development

Product development preferably occurs in complex networks of agents with a large number of activities. The agent network may be a formal organisation with determinable structures. However, even in small organisations, the network is usually complex with many agents in the value chain. The challenges in product development are far more than the purely technical. They are also of a disparate nature, for example: identification of user needs; management of software and hardware requirements; business decisions; and, sustainable development. In this context, purpose-oriented organisation of agents and activities is of critical importance for successful product development.

As a research subject, integrated product development centres on organisation and management of technical development work (with a focus on efficient processes). Touching on organisations' and individuals' ability to work innovatively, innovation is a highly central issue in the discipline. The term "integrated product development" can also relate to a concept where product development methodology champions a holistic approach that takes in a host of aspects in product development (e.g. functionality, production friendliness, marketing possibilities, environmental impact, etc.). This holistic approach requires integration between not only the functions and disciplines in an organisation, but also between individuals and organisations. Integration can also relate to combining business and technical possibilities and/or combining product and service. The research subject is strongly linked to this concept and projects often focus on special aspects of the concept.

Research within the integrated product development unit is carried out in close collaboration with industrial companies. Research issues are most often developed on the basis of a company's actual needs. Consequently, research methods are chosen on the need for results to have an immediate use. With the aim of generating knowledge that can affect product development methodologies, the perspective of the designer or of the product developer are often adopted. Research issues vary and include, amongst other things: support methods in product development; environment-friendly product development; product planning; project work; the marketing of functionalities; organisation and management of development operations; disruptive innovation; business-model innovation; and, idea and knowledge management. The following are of the utmost relevance: projects within interdisciplinary, complex, product development; project portfolio management; procedures for concept development; and, integrated product, service and business development.

Product and service design

The goal of product development is the creation of proposals for products and services that offer market competitiveness and which are popularly perceived as attractive, easy-to-use and worthwhile. This orientation sees products and services as an interaction in which the user's needs, life experience and lifestyle are at the centre of research. The taking into account of technical and marketing considerations complements the user-centred perspective. This is a wide area that distinguishes itself from others by focusing on the interaction between the physical product, services and use.

The product and service design specialisation focuses on methods, matter and end results. This entails, for example: method development (e.g. early phases of product development); the design theme's discourse, context and identity; and, empirical studies of products and services (as models or in use).

Interdisciplinary methods and approaches (e.g. "design thinking" and various types of generative methods that can be used generally in creative and innovative operations) are central in design research. Within the subject, there are strong links between man-computer interaction, architecture, aesthetics, ergonomics and work science. As with all of these, design rests on wide foundations where scientific depth is not the same as disciplinary demarcation. Indeed, it builds rather on a capacity for dynamic interaction between part and whole, experiment and analysis and practice and theory.

Programme organisation

Programme council (state the constituent functions, not the people), programme director, student representation, etc.

The programme is led by a programme director (DA). A DA shall fulfil KTH's requirements to serve as a principal supervisor and should himself/herself be active as a researcher and principal supervisor.

Formally, the programme is administratively under the head of the School of Industrial Engineering and Management (ITM) and the director of third-cycle education (FA). To a great extent, it also shares administrative processes with ITM's other doctoral programmes. Consequently, the DA is a member of ITM's third-cycle education committee (FU).

All principal and assistant supervisors linked to the programme are in the supervisor assembly, which is also the council for the programme. The supervisor assembly is the academic arena for collegial discussion of issues related to supervision, research quality, final seminars, doctoral students' progress, monitoring of study plans, third-cycle courses, etc. The supervisor assembly meets 3 – 4 times per academic year and, if necessary, can also be convened in the interim. A representative chosen by the doctoral students (doctoral student programme representative – PAD) is also called to the assembly. All doctoral students are invited to an assembly meeting at least once each academic year.

Courses

Course offerings

Describe the programme's course offerings, which subject areas are to be covered and how relevant course offerings are ensured.

Third-cycle courses are run regularly in all the programme's specialisations. For all Machine Design specialisations, there are two compulsory course requirements. Each doctoral student shall take the introductory course (FMF3021 – 7.5 higher education credits) and a course/courses offering at total of at least 6 higher education credits (HECs) in the areas theory of science and research methodology.

A course in teaching and learning in higher education is a requirement for doctoral students who are to give first and second-cycle teaching.

The following courses are strongly recommended for all Machine Design doctoral students:

- LH200V "Basic communication and teaching" (GKU), 3 HECs, (compulsory for doctoral students who, during their programmes, assist with KTH's first or second-cycle teaching).
- AK3014 "Theory of science and research methodology" – minor course, 3 HECs.
- AK3015 "The persevering researcher", 2 HECs.
- DS3102 Writing Scientific Articles, 5 HECs.

A course in *product development/design* and/or a course in *systems engineering* is also recommended for all doctoral students in the Machine Design doctoral programme. In addition to these, there are recommendations for the programme's various specialisations as per the descriptions in the programme's general syllabus.

Quality assurance and monitoring of the programme's courses

State how the programme's courses are monitored and how their quality is assured.

There is a course evaluation after each third-cycle course. The course coordinator is responsible for it being carried out. The course evaluation procedure is the same as KTH's procedure for first and second-cycle study courses and programmes.

Support (other than courses) for goal attainment in the subjects

Organised activities other than courses, e.g. seminar series and workshops.

The quality of the individual doctoral student's research is assured through continuous monitoring and through examination by expert reviewers. In addition to the doctoral student's presentations at internal working seminars in the division and/or research group, the doctoral student's work shall be examined on at least three occasions during his/her programme:

1. Thesis plan (after around 1 year of studies).
2. Midway/licentiate seminar (after around half the programme).
3. Final review (when it is assessed there are 6 – 12 months to the public defence).

Usually within the framework of the first year's studies, a thesis plan setting out the doctoral student's research focus and research design shall be drawn up. This is to be approved by a supervisor.

At the midway/licentiate seminar, the manuscript is examined by a special reviewer who has not been involved in the doctoral student's work. The seminar is chaired by someone from the programme's supervisor assembly (but not the doctoral student's principal or assistant supervisor). All doctoral students and researchers linked to the research group are invited to participate in these seminars. At the midway/licentiate seminar, the special reviewer should have docent qualifications.

For quality assurance ahead of the public defence of the doctoral thesis, KTH's and ITM's thesis defence regulations apply.

Before finalisation of the doctoral thesis, the doctoral student's manuscript shall be examined by an independent, special reviewer who has not previously been involved in the doctoral student's thesis work. This is to guarantee that the work is of sufficiently high scientific quality for it to be defended at a public presentation. Special reviewers of doctoral theses should have docent qualifications.

The reviewer's views and improvement proposals are to be presented either as a written report or at a final seminar. The final review uses what is judged to be the next last version of the thesis manuscript. This means that the thesis is entire, if not yet finalised. The review is held when the principal supervisor assesses that there is 6 – 12 months' work before the public defence.

The final seminar shall be announced via communications to all supervisors and doctoral students in the division concerned. The seminar is to be chaired by someone from the programme's supervisor assembly (but not the doctoral student's principal or assistant supervisor).

Besides the collegial quality assurance of individual thesis work, there are also continuous quality enhancement activities at various levels in the programme. There is a course evaluation after each third-cycle course. The course coordinator is responsible for it being carried out.

Description of continuous, systematic quality improvement

Describe the regular evaluation and development activities.

At programme level, the administrative processes are evaluated once a year. The programme director (DA) arranges this. Administrative processes that are shared with other third-cycle courses at ITM are evaluated once a year by ITM's third-cycle education committee. If necessary, the committee can also initiate more wide-ranging overhauls of programme content and programme structure.