PRODUCTION TECHNOLOGY WEST

ANNUAL REPORT

2015

UNIVERSITY WEST

ABOUT PRODUCTION TECHNOLOGY WEST

The research activities in production technology at University West is fully organised within the department of Engineering Science, where approximately half of the employees are researchers at Production Technology West, PTW. Professor Per Nylén is head of the research activities with assistance of Dr Lennart Malmsköld, responsible for the research and research education at the department. The research personnel reside at Production Technology Centre (PTC) in Trollhättan with access to modern industrial equipment in cooperation with industry. The research activities at PTW are organised in four research arenas:

- Welding
- Machining
- Thermal Spray
- Flexible Industrial Automation

The researchers in both the process- and systems oriented fields have access to modern industrial standard manufacturing equipment and skilled operators. The arenas are described in more detail in the following. There are also joint activities where several arenas are involved, e.g. doctoral courses and other skill enhancement initiatives. These are also described in the following.

University West has associated a scientific advisory board to PTW consisting of external expertise:

Professor BENGT-OLOF ELFSTRÖM,
Chairman, GKN Aerospace

Professor UTA KLEMENT,
Chalmers University of Technology

Professor BENGT LENNARTSON,
Chalmers University of Technology

Associate Professor CHARLOTTA JOHNSSON,
Faculty of Engineering, Lund University

Professor JAN-ERIC STÅHL,
Faculty of Engineering, Lund University

Professor MIHAI NICOLESCU, Royal Institute of Technology

Manager Manufacturing Engineering,
HANS WIKSTRAND, Volvo CE

Research Arenas

PREFACE FROM THE DIRECTOR OF THE RESEARCH ENVIRONMENT

It is a pleasure to present the 2015 Annual Report for the research environment Production Technology West. Our mission has always been to undertake and promote research in the field of production technologies for the benefit of both the industry and the academia. Our goal is that we should play a prominent role in the innovation process of the Swedish manufacturing industry and we have strived to fulfil this objective year after year. I am delighted that, as always, much has happened during 2015 that is worthy of sharing.

Our research environment has, since its move to PTC in 2008, completed more than one hundred research projects in close cooperation with the Swedish industry. We have, during this time, grown significantly. We are proud of the trust that our industrial partners have placed in us, and the incredible support that we have received from the public research agencies, to help us march forward. In my opinion, the year 2015 was once again a successful one, notwithstanding a marginal drop in total income and publication volume, because we have been able to take certain key initiatives that will serve us well in the future. One such initiative has already paved the way for us to position ourselves to play a leading role in the region in the emerging area of additive manufacturing.

The industrial problems often lie in the framework of obtaining a specified quality, enhancing product performance and simultaneously augmenting productivity. One such example from the past year of our efforts to facilitate the above relates to welding research, wherein the close cooperation between our automation and welding groups has led to invaluable understanding of the behaviour of sensors to enable monitoring and control, as well as their integration in an industrial laser welding cell. The thermal spray activities in 2015 have, as during the previous year, mainly been devoted to the two critical areas of ceramic coatings for high temperature applications (gas turbines) and wear/corrosion resistant metallic coatings for automotive and boiler applications. An example of a particularly interesting result emerging from our research is the realization of new types of nano-structured thermal barrier coatings by suspension plasma spraying. 2015 has also been a very productive year for our machining group. Two licentiates graduated from this group and we have chosen to highlight results from one of them in this year's report.

During the past year, we have also made concerted effort to reinforce the competitive strength of the local region. One example is the Maplab project, as a part of which specific focus was placed on the establishment of a laboratory for material property evaluation. I am also pleased that we have further strengthened our joint research activities with Chalmers in 2015. An example is the Prosam project, under which we now have eight PhD students together, spanning four different areas. I am confident that this cooperation will considerably strengthen our research environment in the future.

In summary, I would like to thank our sponsors for the confidence that they have placed in us, all our partner companies for the fruitful cooperation and, not least, I thank my co-workers at PTW for their continued excellent work during 2015. As we look forward to new and challenging research initiatives in 2016, we present to you a flavour of our activities from 2015. Enjoy reading!

Per Nylén
Head of the research environment
Production Technology West

ARENA WELDING

Welding is traditionally divided into Welding Processes and Welding Metallurgy and in several academic institutions one of these branches dominates the research. However, for a producer of welded products, it is the combination of these two areas which is important. Consequently, the research within the welding arena at PTW covers both welding processes and welding metallurgy. The purpose is to do research on issues of interest to a majority of the welding industry. Therefore, we work on the welding processes, which are most common in the industry, like gas metal arc welding, plasma welding, laser welding and friction stir welding. Within welding metallurgy there is extensive activity involving high strength steel, duplex and super duplex steel stainless steels, aluminium and nickel-based super alloys. The studies include weldability, corrosion and mechanical properties, especially fatigue properties. Another area of importance for welding that the research group focuses on is heat treatment. Heat treatment is often a part of the complete welding procedure and there are also many similarities between welding and heat treatment when it comes to effects on the material microstructure and properties.

Research is conducted both by experimental investigations as well as modelling and simulation. Simulation of different phenomena relevant to welding, like the behaviour of the electric arc or the light beam from a laser source and their interference with the material is one of our core areas. In this area, the main activity is CFD (Computational Fluid Dynamics) simulation of the welding arc and the melt in laser welds. The work is carried out in collaboration with many international research groups. Also, simulation of the material structure and stresses in conjunction with welding is an increasingly important activity.

The final goal of a welded joint is to realize a product having good mechanical properties to function in its intended environment. The important properties are typically tensile strength, fracture toughness and fatigue properties. For some materials, the corrosion properties or the high temperature strength are also important. The goal of our work is to build up an increasing knowledge about the relation between the welding conditions, the correspondent heat input to the material and how this, in turn, affects the properties of the welded joint.

Welding is becoming more and more automated and the welding arena is closely cooperating with the automation arena in many topics of industrial relevance. The industrial partners we cooperate with are both suppliers and end users of welding products in Sweden.

FACTS

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Guest Prof Americo Scotti,
Assoc Prof Isabelle Choquet, Dr Joel Andersson
and Dr Asun Valiente

Partners in joint projects
Aga, Elga, Esab, GKN Aerospace, Siemens,
SSAB, Outokumpu, Volvo, Howden and
Uddeholm

SOME HIGHLIGHTS 2015

Discription of the Academic Staff

The Welding Arena has developed further. The permanent academic staff of the welding group comprises Lars-Erik Svensson and Leif Karlsson (both Professors), Isabelle Choquet (Associate Professor), Joel Andersson and Asun Valiente (PhD). We also have had one Guest Professor, Americo Scotti from Brazil, working on welding processes, with support from the KK Foundation. Sten Wessman from Swerea KIMAB was also working 20 percent of his time for us, carrying out computer simulations of welded material structures.

Two welding engineers Kjell Hurtig and Mats Högström complete the group. Mats Högström joined us September 1 this year. He is an experienced welding engineer, who has already made significant contributions in the group.

There are a total of 10 PhD students in the group, six of them in-house and four industrial PhD students. It can be added that we also have two PhD students from Chalmers in our environment, since they work with some of the techniques that we can offer.

Progress of Doctoral Degree Students

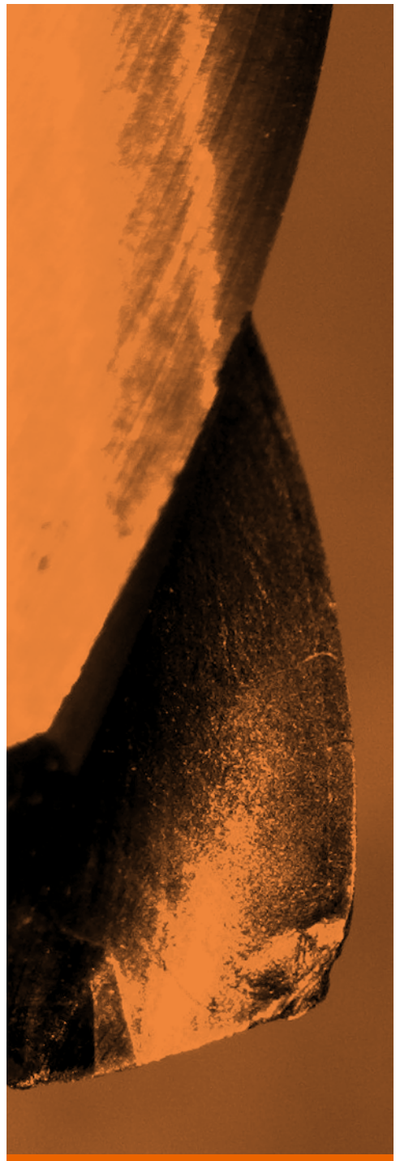
One of our responsibilities is to educate new PhDs in the field. This year we have had one defence of a PhD thesis and four presentations of licentiate theses. They work on different aspects related to welding, illustrating the width of the subject as well as the wide competence of the supervisory group.

The new PhD, Per Lindström, defended his thesis "Improved CWM platform for modelling welding procedures and their effects on structural behaviour" on September 15 2015. Faculty opponent was Professor Hannu Hänninen from Aalto University in Helsinki, Finland.

Four other students defended their licentiate theses. The first of these was Karl Fahlström, who discussed his thesis "Material and Process Solutions for Future Light Weight Vehicles – Laser Welding of Boron Steels" on January 22 with discussion leader Professor Jens Kristensen from Danmarks Tekniska Universitet in Copenhagen, Denmark. Ebrahim Harati presented his licentiate thesis "Fatigue strength of welds in 800 MPa yield strength steels – Effects of weld toe geometry and residual stress", with Professor Heikki Remes from Aalto University as discussion leader on September 1. The third person to present a licentiate thesis was Maria Teresa Coll Ferrari who presented "Effects of austenitising temperature and cooling rate on microstructures of hot-work tool steels" on November 12. The discussion leader in this case was Professor Hans-Olof Andrén from Chalmers. Finally, Andreas Segerstark presented his licentiate thesis "Additive Manufacturing using Alloy 718 Powder – Influence of Laser Metal Deposition Process Parameters on Microstructural Characteristics" on December 18, with Adjunct Professor Robert Pederson from Luleå Technical University as discussion leader.

One special event that took place in November was a Mini-conference on "Fatigue properties of welded components in high strength steels", which attracted around 30 visitors. It was a way to inform interested companies about the project on fatigue properties of welded high strength steels that Ebrahim Harati is running.

Demonstration of High Frequency Mechanical Impact technique on welded sample, during the Mini-conference.



ARENA MACHINING

There is a growing potential in Swedish industry for the area of metal cutting. A large number of Swedish industrial companies, such as manufacturers of mining machinery, heavy vehicles and ball bearings stand strong in the market with new orders and foresee great development in the coming years. New products also require new materials; primarily high-strength steels, lightweight materials and composites. This, in turn, requires better understanding of the relationships between the machine tool characteristics, machining processes parameters, microstructure and component characteristics often including new and challenging hard-to-machine materials. The research within machining arena at University West is, therefore, focused on supporting the industry in meeting these challenges.

The area of Machining Dynamics was initiated by Volvo Aero (now GKN Aerospace) in 2006 to establish a research competence at University West. Today we mainly study the processes of drilling, turning and milling with focus on dynamics in drilling operation and frequency domain identification and optimization of milling systems. Research on drilling processes, has the longest history in the group and was initially focused on design of high-feed drill geometries for difficult to-cut-materials. This area for research was widened later and research on cooling technology, temperature measurement and numerical modeling of cooling and chip formation has been added. These studies create a deeper physical understanding of the machining process including what happens to the workpiece and the tool as a consequence of machining. A central area of interest is data analysis and signal processing to gather information about the vibrations, tool wear and surface quality of the machined part. This information could further be used for selection of high productivity cutting conditions. The knowledge of how vibrations are avoided even at large feeding speed and cutting depth has a significant impact on productivity.

The area of Machining Process and Surface Integrity focuses on the machining parameters that influence the final product characteristics while cutting conditions are selected to manufacture the component in the shortest time possible and at the lowest cost.

The area of Process Planning and Monitoring of Machining Processes focuses on procurement strategies to optimize profitability of machine tools, including product life cycles and maintenance costs. To facilitate this, all gathered knowledge about the processes is applied in a decision support system that provides predictable and reliable results of factors influencing the outcome in a transparent manner. Tool wear models are integrated in CAM systems to facilitate maximizing the life of cutting tools.

Academic collaboration is currently ongoing with University of British Columbia (Canada), the Norwegian University of Science and Technology, Chalmers University of Technology, Swerea IVF, Swerea KIMAB and Örebro University.

During 2015 the research group was extended with researchers from Sandvik and Swerea.

FACTS

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Prof Tomas Beno, Dr Mahdi Eynian, Dr Jari Repo and Guest Researchers Prof Lars Pejryd, Dr Mikael Lundblad and Dr Thomas Björk, Prof Jan-Eric Ståhl is associated to the arena.

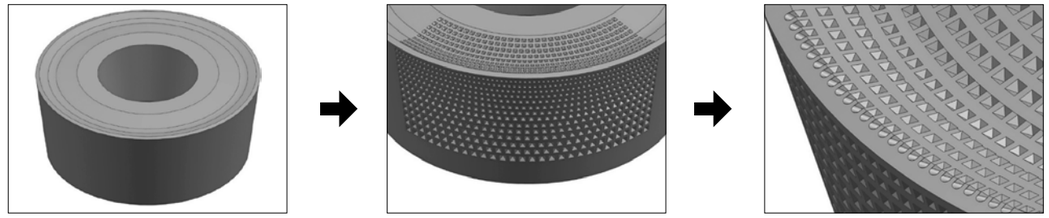
Partners in joint projects:
GKN Aerospace, Sandvik Coromant, Scania AB, SECO Tools, Swerea IVF and Swerea KIMAB

SOME HIGHLIGHTS 2015

Future machining strategies - Breaking the barriers

Heat generated by machining is regarded as one of the most important aspects of modern machining to manage. In particular, when machining heat resistant super alloys. The aim of the project is to enhance the heat dissipation from the cutting zone through the surfaces features on the insert. This by directing several jets of coolant, forced cooling application, towards areas of the surface that exhibits the highest temperatures. Firstly, to further enhance the heat transfer in the boundary layer between the insert and the coolant jets. Some surfaces of the insert has been provided with cooling features to increase the available surface for heat transfer with up 12 pct. Secondly, to design features on the insert that improves the reachability of the coolant towards the cutting zone.

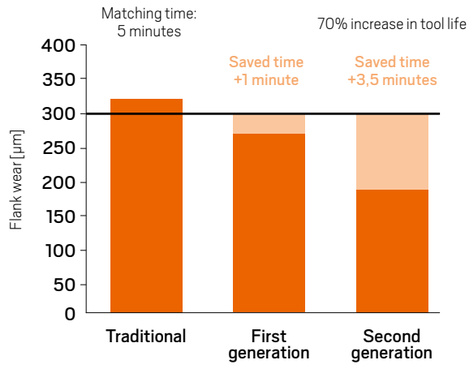
Ongoing research is to generate new cutting tool design and cooling features on the inserts surfaces that can interact with coolant and promote a boundary layer interface towards thermal sustainability of the process. The purpose is to reach the machining capability for carbide inserts as for ceramic insert in the current scenario.



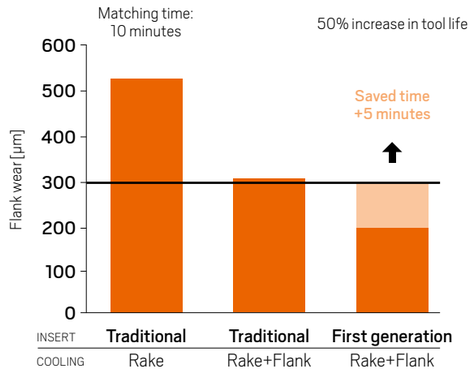
Traditional Insert

First generation insert
(Increased surface area 12%)

Second generation insert
(Channel design to improve coolant reachability)



v_c - 60 m/min; f- 0.2 mm/rev; a_p - 1mm; SCL- 282 m
Rake pressure: 160 bar; Flank pressure: 80 bar



v_c - 60 m/min; f- 0.1 mm/rev; a_p - 1mm; SCL- 565 m
Rake pressure: 160 bar; Flank pressure: 80 bar

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Licentiate degree: Amir Parsian

Title: Reduction of Noise in Drilling with Indexable Inserts

High pitched noises are common in hole-making with indexable drills. An important cause of these noises is a self-induced mechanism, called chatter, which is an important subject for research in metal cutting vibrations. The positions of cutting edges at the current and previous cuts affect the cutting forces and under specific circumstances this can lead to instability in the system which develops chatter vibrations and the mentioned high pitched noises. The purpose of this research is to understand the mechanism and based on that creates a design space for designers who wants to reduce the level of the generated noises.

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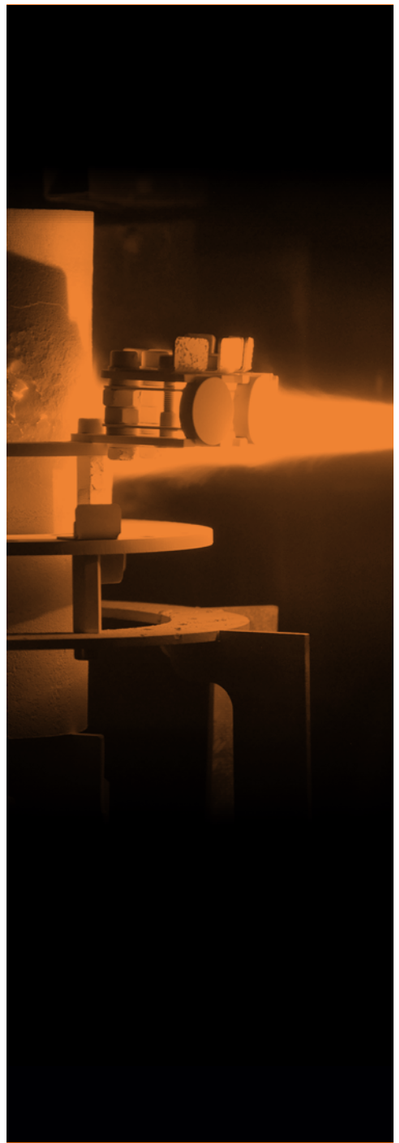

ARENA THERMAL SPRAY

Thermal Barrier Coatings (TBCs)

Research on TBCs was the first research activity ever done at University West and it started in late '80s as a collaboration between Högskolan i Trollhättan/Uddevalla (now University West) and Volvo Aero Corporation (now GKN Aerospace). Since then many pioneering efforts and significant results have been achieved through several PhD studies as well as R&D projects with either national or EU funding. The TBC area is a core research activity of the Thermal Spray Arena, TS Arena, and the main objective is to increase the gas turbine efficiency through better thermal isolation and increase life-time of the TBC systems. Both numerical analysis and experimental work are involved in this area. A good collaboration has been established in this field at both national and international level e.g. Stony Brook Univ., Forschungszentrum Julich, Manchester Univ., Linköping Univ., Chalmers, Jönköping Univ. etc. as well as with industry e.g. GKN, Siemens, Oerlikon etc.

Solid Oxide Fuel Cells (SOFCs)

This research area is newer in the TS Arena and started as an extension of the expertise of the group in ceramic materials for high temperature applications (i.e. the TBC field) and availability of new thermal spray processes, as well as because of the high interest in SOFC from both research and industry perspective. A fuel cell is a very promising energy source that results in low levels of emissions, in combination with very high energy efficiency. Of all types of fuel cells, SOFC's deliver the highest electrical efficiency, but high material and production costs and poor durability are key barriers to their widespread commercialization. The objective here is to develop a new generation of SOFCs that outperform the present ones (in terms of cost and technical performance) and are better suited for large scale production using thermal spraying. Latest achievements in thermal spraying, e.g. axial suspension plasma spraying and nano-sized feedstock material, are to be used here to reach this goal. Good collaborations have been established in the field with both national and international partners e.g. Fraunhofer Inst., Forschungszentrum Julich, Karlsruhe Inst., Höganäs AB, Oerlikon, HC Starck etc.

Wear/corrosion resistant coatings

This research area is being developed in response to increased industrial demand for coating alternatives to electrolytic hard chromium (EHC) which is acknowledged as harmful for operators and environment. Current status of thermal spraying, e.g. availability of high velocity oxy-fuel and air-fuel thermal spraying and cermets as well as other and complex alloyed powders has made thermal spraying a serious competitor to EHC applications The objective in this field is to improve the corrosion and/or wear properties of coatings using cheaper and environmentally friendly coating processes to develop coating alternatives for EHC. Identifying new applications, and explore new materials for related fields, such as high temperature corrosion, is an additional motivation. Collaborations in this area currently involve Tampere Univ., Fraunhofer Inst., Univ. of Modena, SP, Höganäs, Fujimi Corp., Siemens, Oerlikon, HC Starck etc.

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Partners in joint projects
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Höganäs AB, Metalock, MH Engineering,
Oerlikon, Siemens Finspång and Treibacher
Industries AG

SOME HIGHLIGHTS 2015

Mohit Gupta defended his PhD thesis

Thesis Title: Design of Thermal Barrier Coatings – A modelling approach

Atmospheric plasma sprayed (APS) thermal barrier coatings (TBCs) are commonly used for thermal protection of components in modern gas turbine applications such as power generation and aero engines. TBC is a duplex material system consisting of an insulating ceramic topcoat layer and an intermetallic bondcoat layer. TBC microstructures are highly heterogeneous, consisting of defects such as pores and cracks of different sizes which determine the coating's final thermal and mechanical properties, and the service lives of the coatings. Failure in APS TBCs is mainly associated with the thermo-mechanical stresses developing due to the thermally grown oxide (TGO) layer growth at the topcoat-bondcoat interface and thermal expansion mismatch during thermal cycling. The interface roughness has been shown to play a major role in the development of these induced stresses and lifetime of TBCs.

In this work, important microstructural parameters influencing the performance of topcoats were identified and coatings with the feasible identified microstructural parameters were designed, modelled and experimentally verified. It was shown that large globular pores with connected cracks inherited within the topcoat microstructure significantly enhanced TBC performance. Real topcoat-bondcoat interface topographies were used to calculate the induced stresses and a diffusion based TGO growth model was developed to assess the lifetime. The modelling results were compared with existing theories published in previous works and experiments. It was shown that the modelling approach developed in this work could be used as a powerful tool to design new coatings and interfaces as well as to achieve high performance optimised morphologies.

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New Professor with 25 years of experience

Shrikant Joshi joined the research environment Production Technologies West as a Professor on 1 August 2015. Although he has been appointed in the arena of Thermal Spraying, Dr. Joshi has over 25 years of experience in the interdisciplinary fields of Surface Engineering and Laser Materials Processing. His research in Surface Engineering has included studies involving varied coating technologies, namely conventional atmospheric & solution precursor plasma spraying, detonation spraying, cold gas dynamic spraying, electron beam physical vapour deposition (EB-PVD) and cathodic arc PVD. Since joining University West, his specific research focus has been on solution-based plasma spraying and investigation of hybrid coatings involving use of solution and powder feedstock to achieve different coating architectures. The objective of these efforts is to enhance the functional properties of the coatings for thermal barrier, wear & corrosion applications beyond those that can be achieved by conventional powder-based thermal spray routes. Dr. Joshi's prior research activities in the field of laser materials processing have dealt with diverse manufacturing operations like drilling, cutting, welding, heat treatment and alloying/cladding. He has begun to use this experience to also participate in activities related to additive manufacturing at PTW. He has also developed a course on Surface Engineering which is proposed to be offered during Autumn 2016.

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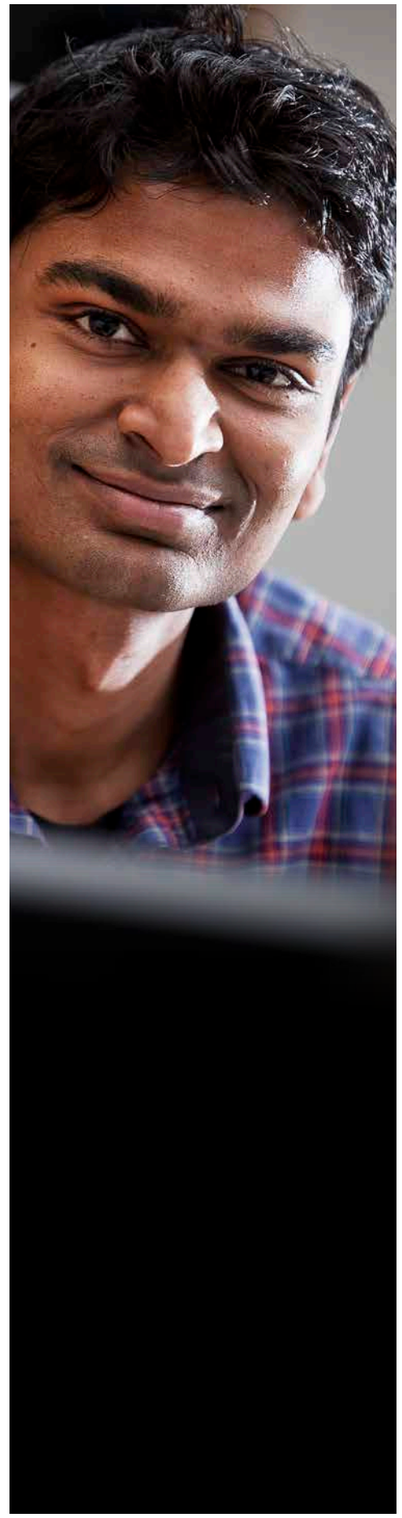

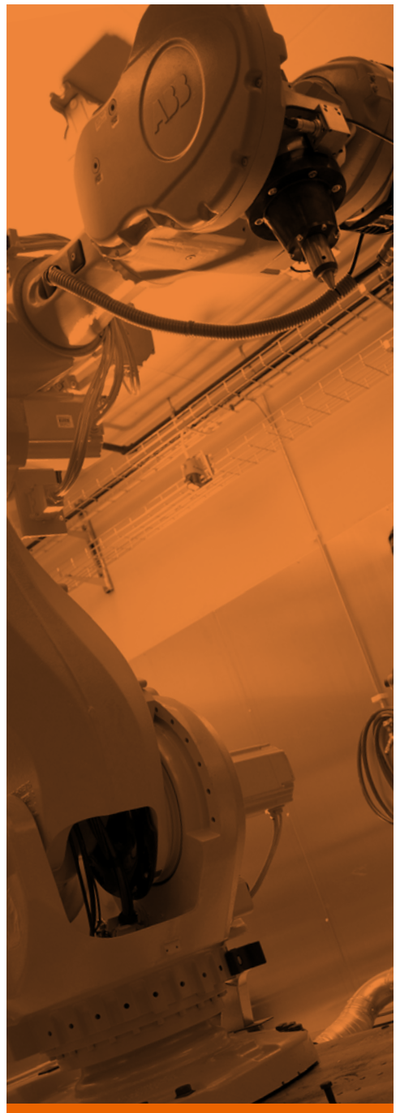

ARENA FLEXIBLE INDUSTRIAL AUTOMATION

Automation research encompasses a wide range of activities, and at PTW this research is concentrated on Flexible Industrial Automation, FIA, as an extension to the traditional automation area. A truly flexible automation cell can evolve with processes and demands, reduce production costs, improve quality, and reduce health and safety issues. By adopting a flexible approach on all levels, it is possible to adapt during production "on the fly", whether for manufacturing small batches or large volumes.

The FIA-group research is focused on three different but adjacent areas: Measurement and Control Systems for Production, Process Planning and Applied Robotics.

Measurement and Control Systems for Production

This research lays focus on different measurement systems for process control and inspection of manufactured parts, with emphasis on welded products. The group has developed methods for quality control and synchronised measurements of properties like temperature, weld pool behaviour, spectral process emissions, etc. during welding.

The research in the field of inspection is focused on non-destructive testing methods, mainly thermography. With this method, a technique for detecting surface cracks has been developed, which is currently used for inspection of welds. This method has advantages compared to conventional methods, since it is fast, non-contact and offers full field information, which makes it suitable for automated inspection.

The research efforts devoted to control focuses on industrially robust solutions for automation. One approach employed is to enhance the performance of sensors by implementing knowledge of the process dynamics in the sensor system and by experimental validation. Another approach employs process models of different approximation levels together with model order reduction for controller design. These approaches require process knowledge as well as knowledge in control engineering, signal and image processing etc.

Process Planning

This research focuses on different types of computer-aided techniques for process planning of manufacturing. Research on more intelligent and flexible automation solutions is conducted by utilising optimisation algorithms together with planning and programming. The area requires knowledge spanning automation, computer science and operations research. Mixing of job shop scheduling and multi-agents plays an important role as well as automatic generation of PLC code.

Applied Robotics

The focus of this research is the automated factory, where a number of flexible automated applications are studied in an industrial setting. By introducing intuitive user interfaces, robotic systems are created where the operator can take an active role and allow for increased human-robot flexibility. Thus, humans can work in close relation to machines combining various capabilities, such as skills, flexibility, strength, speed and quality. Such an automation approach will also enable low volumes down to one-off production.

FACTS

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Partners in joint projects
Binar, Brogrens, GKN Aerospace, Innovatum, Lamera, Lortek, Permanova, Scania, Siemens, Swegon, Swerea Kimab, Teknitesh, Termisk systemteknik, TWI, Volvo Cars, Volvo CE

SOME HIGHLIGHTS 2015

Licentiate degree: Emile Glorieux

In May, Emile Glorieux had his licentiate seminar presenting his thesis "Constructive Cooperative Coevolution for Optimising Interacting Production Stations". Discussion leader was Professor Johan Ölvander, Linköping University. This study was specifically focused on press line optimization, which involves using intelligent computer algorithms to automatically synchronise the operations in a sheet metal press line in order to improve the production rate and reduce wear and energy consumption. The operations in a press line are the closing of the presses and the movement of the robots that transport the plates through the line.

Sheet metal press lines are widely used in the automotive industry to stamp sheet metal plates into the desired shape to make car bodies. In total, there are hundred or more different plates in the body of a car. For each of these, the press line's operations must be synchronised differently, especially the timings and the speed, to get a high production rate. The current practice is to manually adjust the synchronisations, by trial and error, to improve the production rate. The goal of the research is a method to automatically find the best synchronisation, in a virtual environment using computer simulations. In this project, we collaborate closely with Volvo Cars in Sweden to accomplish the above goal.

Contact: Emile Glorieux, emile.glorieux@hv.se

PhD 2015 - Applications for control of an additive manufacturing process

In March Petter Hagqvist defended his PhD thesis "Non-intrusive instrumentation and estimation - Applications for control of an additive manufacturing process". The opponent was Professor Stewart Williams, Cranfield University, UK. Petter Hagqvist awarded his PhD degree from Chalmers and performed his research at PTW with GKN Aerospace as the main cooperating industrial partner.

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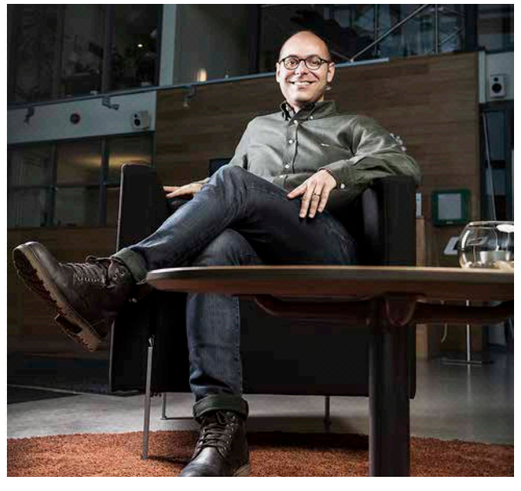

New Guest Professor from Italy

A newly recruited Guest Professor is Antonio Ancona from Bari, Italy. He will work together with the welding automation group in a project "Hybrid sensing for understanding of laser welding technology for process control (Hy-Las)" financed by the Västra Götaland Region MoRE program. He will be engaged at PTW for 50 percent of his time for the next two years with the aim to strengthen the PTW group and to increase the networking between the two research organisations.

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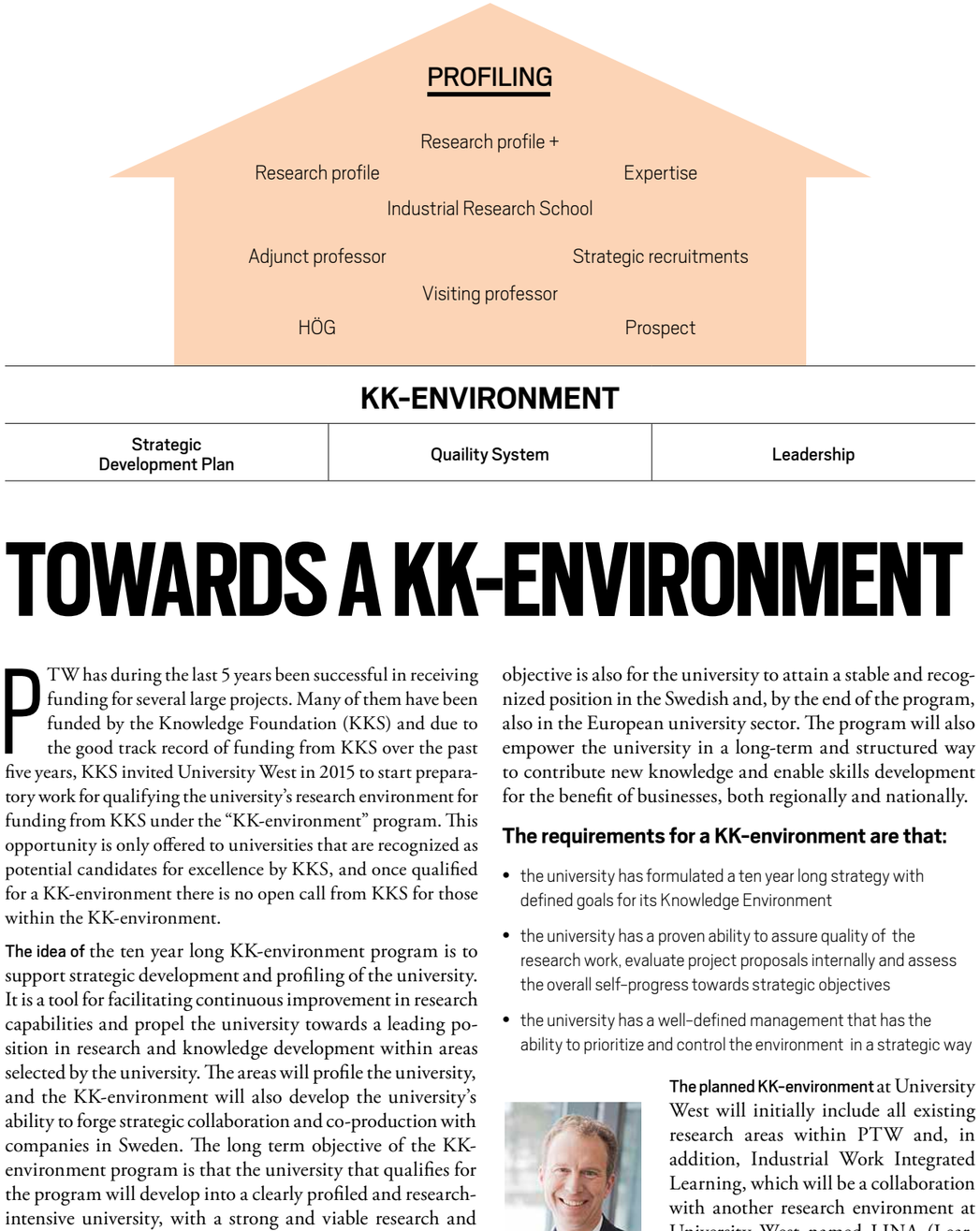

TOWARDS A KK-ENVIRONMENT

PTW has during the last 5 years been successful in receiving funding for several large projects. Many of them have been funded by the Knowledge Foundation (KKS) and due to the good track record of funding from KKS over the past five years, KKS invited University West in 2015 to start preparatory work for qualifying the university's research environment for funding from KKS under the "KK-environment" program. This opportunity is only offered to universities that are recognized as potential candidates for excellence by KKS, and once qualified for a KK-environment there is no open call from KKS for those within the KK-environment.

The idea of the ten year long KK-environment program is to support strategic development and profiling of the university. It is a tool for facilitating continuous improvement in research capabilities and propel the university towards a leading position in research and knowledge development within areas selected by the university. The areas will profile the university, and the KK-environment will also develop the university's ability to forge strategic collaboration and co-production with companies in Sweden. The long term objective of the KK-environment program is that the university that qualifies for the program will develop into a clearly profiled and research-intensive university, with a strong and viable research and training activities based on co-production within clearly defined profile/profiles. A further objective is that the university will be recognized for excellence in its selected areas, and can thereby attract an increasing proportion of external funding, also from other research funding organizations. The university should, through the established KK-environment, also be more successful in recruiting eminent researchers and talented students and to be an attractive partner for companies that the university defines as being strategically crucial. Finally, an objective is also for the university to attain a stable and recognized position in the Swedish and, by the end of the program, also in the European university sector. The program will also empower the university in a long-term and structured way to contribute new knowledge and enable skills development for the benefit of businesses, both regionally and nationally.

The requirements for a KK-environment are that:

- the university has formulated a ten year long strategy with defined goals for its Knowledge Environment
- the university has a proven ability to assure quality of the research work, evaluate project proposals internally and assess the overall self-progress towards strategic objectives
- the university has a well-defined management that has the ability to prioritize and control the environment in a strategic way

Lennart Malmsköld.

The planned KK-environment at University West will initially include all existing research areas within PTW and, in addition, Industrial Work Integrated Learning, which will be a collaboration with another research environment at University West named LINA (Learning in and for the New Working Life). During 2015, a strategic plan, i.e. a first version for the planned KK-environment has been developed, and during 2016, the final steps towards realizing a KK-environment at University West is planned.

Contact: Lennart Malmsköld, lennart.malmskold@hv.se

SUMAN

SUSTAINABLE MANUFACTURING PROCESSES

The KK profile "SUMAN" started 1st of April 2010 and is a 6 year project with a total funding of 72 MSEK. The project engages three areas of research at University West; namely thermal spray, welding, and flexible industrial automation. 15 projects within the three arenas are running in close coproduction with industries. The profile engages 10 professors, 6 senior researchers and 5 experienced engineers, and has led to a vibrant academic environment that includes national and international exchange, participation in research networks, seminars, undergraduate and graduate education.

Summary of on-going projects in SUMAN and their main focus:

Thermal Spray:

- Next generation thermal barrier coatings for gas turbine applications
  - Industrial implementation of past results of the project
  - Advanced SPS TBCs sprayed with 8YSZ
  - New topcoat materials
- Advanced thermal spray coatings for harsh working environments
  - Iron base HVAF coatings to replace Cobalt base coatings used for seat valves in car engines
  - Thick hard-phase coatings for wear applications

Welding and welding automation

- Process investigations
  - Laser welding
  - High frequency tungsten-inert-gas welding
  - Cold metal transfer (CMT)
  - Guaranteed penetration in gas-metal-arc welding
- Materials investigations
  - Cold cracking in high strength steel welds
  - High alloyed materials, like nickel-based super alloys, and weldability
- Modelling and automation of laser welding
  - Modelling of laser welding
  - Sensors for monitoring of laser welding for model validation and for on-line control
  - Multiphysics arc welding simulation

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MAPLABS

SUSTAINABLE PRODUCTION THROUGH LABORATORIES FOR MATERIAL CHARACTERIZATION

The Maplab project aims to strengthen innovation processes, skills and knowledge in sustainable production in manufacturing companies in the region. The project consists of four parts:

- Complete the environment at the PTC with a laboratory in materials and property testing to process control and evaluate material properties and also significantly enhance the environment with experienced researchers.
- Establish a cost-effective, functional interaction structure between PTC, other national research groups and companies in the region.
- Establish long-term, international research collaborations with world-leading research environments in such a way that it significantly strengthens the region's manufacturing industry, including SMEs.
- Utilization of research results is a horizontal, integrated part of the above three sub-projects.

Six research projects have been initiated during 2015:

- Process development in arc welding
- Additive manufacturing using laser metal deposition
- High temperature corrosion coatings for environmentally friendly energy
- High temperature coatings for environmentally friendly gas turbines
- Robotic Friction Stir Welding (FSW)
- Fatigue of welded structures, very high strength steels

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PROSAM – ACADEMIC COLLABORATION

The PROSAM the project has been financed by Västra Götalands Regionen (VGR) during 2014-2015 with a focus on developing strategic collaboration of research efforts within production technology between University West (PTW) and Chalmers aiming for appropriate business oriented research leading to strong international competitiveness. The project is expected to be financed for a second period of two years. The selected areas span Automation, Machining, Thermal Spray and Quality Assured Welded Structures & Additive Manufacturing.

Main activities in the respective areas have been

- Joint research plans for PTW and Chalmers research teams
- Execution of joint research
- Joint applications for funding of collaborative research programs
- Development of academic and industrial research networks

Within the selected research areas, the following results have been achieved as a result of PROSAM:

INDICATOR/TARGET	Goal (after 2+2 years)	Status (after 2 years)
New R&D networks	4	6
Joint scientific publications	20	12
New joint national research applications (most in cooperation with regional industry)	3	7
New joint international research applications	3	1
Companies involved in research projects	8	10
Degrees	14	2
Additional scientific publications	30	15

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Result seminar in PROSAM. Professors, senior researchers, PhD students from Chalmers and University West and participants from the funder, VGR.

PROSAM – STRATEGIC RESEARCH COOPERATION

The research cooperation between University West and Chalmers has an overall aim of establishing new research areas where the combination of expert knowledge at each university provides the foundation to conduct research in areas of mutual interest. The additive manufacturing area has dramatically increased in interest and will be developed further in other collaborations. The corrosion surface treatment area has been initialized as part of the PROSAM project and is intended to be further developed during the subsequent two years of the project.

Chalmers expert research area	Common research area (under construction)	Production Technology West expert area.
Materials technology	Design and Control of properties in SPS surface treatment	Suspension plasma spray (SPS) process for thermal barrier coatings
Materials technology	Design and Control of surface properties and tool wear in machining of NI-based alloys	Machining process with high pressure cooling
Geometry tolerance design in welded structures	Quality assurance in welded structures	Welding processes
Geometry and motion planning	Robot based additive manufacturing based on welding methods	Control and monitoring of welding processes
Automation	Energy optimization in production processes	Automation & optimization in production processes
Non-organic Chemistry	Design and control of properties in thermal spray based high temperature corrosion surface treatment	Thermal Spray metal based processes

The collaboration has also involved and developed several new industrial networks, regional as well as national and international. Companies that are involved in the different research activities in the University West/Chalmers common research areas are:

Machining: GKN, Sandvik, Seco Tools, Brogrens

Automation: Volvo Cars, KUKA Robots, BINAR

Thermal Spray (Cermic and Metal coatings): Treibacher, Innovnano, Mettech, GKN, Siemens, Nasa, Boeing, Turbocoating

Welding structures: GKN, Brogrens, Permanova

Contact: Lennart Malmsköld, lennart.malmskold@hv.se

PROSAM collaboration; Andreas Lindberg, GKN, Nageswaran Tamil Alagan, PTW and Philipp Hoier, Chalmers.

TOWARDS A NATIONAL ARENA IN ADDITIVE MANUFACTURING

Additive Manufacturing (AM) in metal has been of interest for PTW in a series of projects during the last decade. AM is the opposite of machining, since the latter removes material while the former adds material to a component. We foresee a future where AM and machining are combined for flexible manufacturing.

The concept is "hot", and has been so for the last couple of years especially under the umbrella "3D-printing". The PTW efforts in the field have been mainly in cooperation with GKN Aerospace (formerly Volvo Aero) in national and European projects, and the techniques explored have been mainly based on conventional robotized welding with added metal that is melted by a high power laser beam. These technologies reside under the area of "Directed Energy Deposition (DED)", which is among one of today's prominent AM-process types.

During 2015, Petter Hagqvist gained his PhD degree in the field of sensors for control of nickel-based wire DED using an industrial robot for precise laser beam movement. This work was a natural continuation of the study performed by Almir Heralic on titanium-based wire DED, where the efforts were focused on control for obtaining a robust process. A parallel track is to use a powder nozzle instead of a wire feeder to introduce the metal into the laser beam, also known as "blown powder" technique. During 2015, Andreas Segerstark obtained his Licentiate degree on influence of blown-powder process parameters on the microstructure during AM of nickel-based Alloy718. Yet another PhD-student, Tahira Raza, was recruited during 2015 for investigation of metallurgical properties in powder-AM. Since long, the thermal spray group has added various powder materials to surfaces and these can be made thick enough to be classified as AM and be relevant for carefully identified niche applications.

Based on the above results and knowledge in powder metallurgy gained since long in the thermal spray area, University West is one of the founding partners in a recently established national Arena for metal AM in cooperation with Swerea and Chalmers. The Swedish industry has shown great interest in the various AM-technologies, and is expected to gain from the just formed national Arena. Planning of activities to be undertaken by the Arena was initiated during 2015, and we foresee extensive expansions of the Arena during the coming years. An electron beam AM-machine with powder bed will be installed during spring at PTW, and we expect to report on results in subsequent Annual Reports.

The high interest in AM and lack of engineering courses in Sweden has led to development of a national PhD-course in AM. The course is a joint initiative of the universities that already have significant experience in AM within Sweden, namely University West, Örebro University and Mid University. These universities also cover different AM processes. This course is developed under the framework of Produktion2030, and is expected to be followed up by shorter and more specialized courses relevant to the industry.

Industrial partners: GKN Aerospace, VA Automotive, Lidhs Verktyg, SwePart Tools

Academic partners: Chalmers, Swerea, Örebro University, Mid University

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COMPETENCE FOR INDUSTRY

Within the scope of developing methods and tools for transferring knowledge and competence between academia and industry, two projects are currently ongoing. One is focusing on developing IT infrastructure and tools - MERIT - within the program "IT i Högre Utbildning"/"IT in Higher Education", and the other on collaborative support together with industry in competence on advanced level - ProdEx - within the program "Expertkompetens för Innovation"/"Expert competence for Innovation".

Main activities in the projects are to establish collaboration with industry and investigate current and future needs for knowledge. Based on this, short courses will be developed and offered. During 2015 courses have been given in automation, calculations with Matlab, metal cutting and production management. In this work, methods have been developed alongside IT infrastructure and ICT tools in order to facilitate for efficient course classrooms in mixed mode physical and Internet based learning environment. Appropriate format of the courses are 2,5 academic credits per course, given one day a week over a five week period. In addition, methods to convey course content using digital media has been investigated, developed and worked with for the pilot courses. This work is an ongoing activity and will continue during 2016.

The experience is that short courses at advanced level are needed, provide for efficient knowledge transfer and give participating individuals as well as industries benefit in terms of knowledge ahead of competitors. This, in turn, will put them in a better position with more opportunities to manage challenges today and in the near future.

Future challenges relate to scale up with number of courses and students, and develop methods to virtualize advanced lab units and exercises. New short courses will be developed and given and new course content will be introduced based on the needs from industry. These include, but are not limited to, robotics, safety and risk analysis in production systems, and applied solid mechanics using tools like FE simulations among others.

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DOCTORAL DEGREE PROGRAMME

Since 2012 University West offers a doctoral degree programme in Production Technology. A doctoral degree programme comprises 240 university credits, equivalent to four years of full-time studies. The programme consists of a research project and a number of courses determined by the research subject. Research results are reported in journal and conference papers and finally compiled in a doctoral thesis which is to be publicly defended. Normally a licentiate degree is issued half way.

A doctoral study plan in Production Technology at University West includes:

1. Courses – a total of 60–90 credits of which 30 are mandatory and the rest are elective depending on subject

2. Research project and thesis work up to in total 240 credits

The mandatory courses are; Introduction to post graduate studies; Research methodology, design of experiments, and publication; Production technology and Future production.

PTW also runs a KK-funded project "VALUE – Virtualization of Advanced Lab Units and Exercises" for developing doctoral courses at a distance, which will facilitate for increased participation of PhD-students from other universities.

ALIREZA JAVIDI
(CHALMERS)
Modelling of cathode-plasma interaction in short high intensity electric arc – Application to Gas Tungsten Arc Welding

ANA SILVA
Process automation of FSW from both an academic and industrial perspective

ANDREAS SEGERSTARK
Lic 2015
Influence of Laser Metal Deposition Process Parameters on Microstructural Characteristics

ASHISH GANVIR
Microstructure and Thermal Conductivity of Liquid Feedstock Plasma Sprayed Thermal Barrier Coatings

EBRAHIM HARATI
Lic 2015
Fatigue strength of welds in high strength steels- Effects of weld toe geometry and residual stress

EMILE GLORIEUX
Lic 2015
Constructive Cooperative Coevolution for Optimising Interacting Production Stations

ESMAEIL SADEGHIMERESHT
Corrosion performance of HVAF thermal spray coatings

JOSEFINE SVENUNGSSON
Modelling and simulation of laser welding

MORGAN NILSEN
Sensor-based control of laser welding in difficult to access areas

NAGESWARAN TAMMILALAGAN
Investigation of Heat Dissipation in Boundary Layer Interaction of Tool-Fluid in HRSA Machining with Forced Coolant Application

PETTER HAGQVIST PH D
Ph D 2015 (CHALMERS)
Non-intrusive instrumentation and estimation -Applications for control of an additive manufacturing process

TAHIRA RAZA
Influence of process parameters on the laser powder bed fusion additive manufacturing technology of super-alloys

Contact: Associate Professor Anna-Karin Christiansson, anna-karin.christiansson@hv.se,
Director of Doctoral Studies: Associate Professor Maria Skyvell Nilsson, maria.skyvell-nilsson@hv.se

SICOMAP RESEARCH SCHOOL
– SIMULATION AND CONTROL OF MATERIAL AFFECTING PROCESSES

The SiCoMaP research school has been up and running since 2012. It is funded by the KK Foundation and is run in close cooperation with a number of manufacturing industries. The name of the research school is "Simulation and Control of Material affecting Processes" or in short SiCoMaP. The driving forces are reduced manufacturing cost in parallel with increased quality and reduced environmental footprint.

The school emphasizes simulation and control of material affecting processes. This multidisciplinary approach will increase mutual understanding of underlying physics and what is feasible to control. Two major research areas are addressed: production processes and production systems. In both areas simulation technology includes modelling and implementation in realistic situations. Frontline tools for simulation and control are used to enhance product design and increase flexibility in production.

Participating companies: DNV, GKN Aerospace, Innovatum, Swerea IVF, Swerea KIMAB,, Sandvik Coromant, Scania, Seco Tools, Uddeholm and Volvo CE

Contact: Anna-Karin Christiansson, anna-karin.christiansson@hv.se

ADNAN AGIC
SECO TOOLS
Dynamic analysis and optimization of machining

AMIR PARSIAN
SANDVIK, Lic 2015
Dynamics of torsional and axial vibrations in indexable drills

ANA BONILLA
GKN, Lic 2015
Advanced Technology Data and Part Programming

ANDERS JOHANSSON
SCANIA
Development of innovative process for machining system acquisition

ARBAB REHAN
UDDEHOLM
Optimised cold work tool steel for cutting AHSS

ASWIN DEVOTTA
SANDVIK
Influence of cutting insert macro geometry on chip formation

EDVARD SVENMAN
GKN
Improved and novel online measurement techniques for more robust laser welding and detection of flaws

ERIK ÅSTRAND
VOLVO CE
Robust weld procedures for fatigue optimized structures

HENRIK JÄGER
SWEREA KIMAB
Material aspects of high performance stainless steels and Ni-based aerospace alloys and their link to tool wear and surface integrity in component machining

JOACHIM STEFFENBURG-NORDENSTRÖM, GKN
Virtual simulation for robust manufacturing of fabricated aero engine components

JONAS HOLMBERG
SWEREA IVF
Surface integrity of machined advanced alloys

KARL FAHLSTRÖM
SWEREA KIMAB, Lic 2015
Material & Process Solutions for Future Vehicles

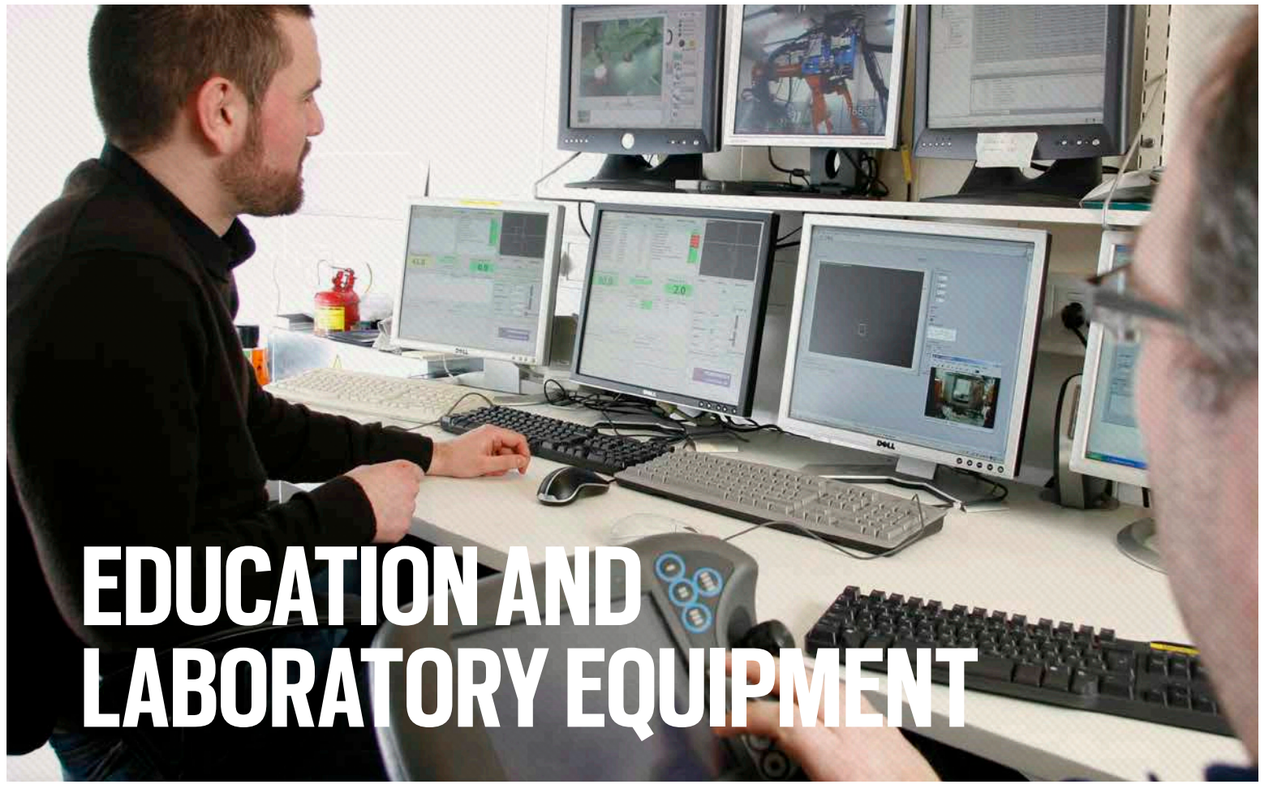
MARIA TERESA COLL FERRARI
UDDEHOLM, Lic 2015
Understanding industrially Relevant Heat Treatments and Resulting Microstructures for Large Die Casting Tools

MOHIT GUPTA
Ph D 2015
Modelling approach to thermal barrier coatings

PER LINDSTRÖM
DNV GL MATERIALS LABORATORY, Ph D 2015
Thermal and Mechanical Assessment of Speciality Welding Procedures

SATYAPAL MAHADE
INNOVATUM
Multi Layered Thermal Barrier Coatings for High Temperature Applications

VAHID HOSSEINI
INNOVATUM
Influence of complex thermal cycles on microstructure and properties of welds in highly alloyed stainless steels



EDUCATION AND LABORATORY EQUIPMENT

The PTW Research Team is involved in engineering education at all levels at the university; basic, advanced and research level. The following programmes are run at basic and advanced level:

Bachelor's Programmes

- Electrical Engineering, Electric Power Technology
- Mechanical Engineering, Industrial Production
- Mechanical Engineering, Product Development
- Industrial Engineering and Management

Master's Programmes

- Robotics
- Manufacturing Engineering

Students often carry out project work and degree projects in the PTW facilities together with partner companies.

Laboratory equipment

The PTW Research Team and its lab equipment are located in Production Technology Centre (PTC) premises, a neutral arena, neither in the University nor in any of the companies. This makes it easy to collaborate and tackle problems that are of high priority for the companies and come up with solutions that often need only small adjustments to be applicable to their production.

The PTC comprises of numerous labs, each of which hosts highly specialised equipment:

- Thermal Spraying Lab
- Welding Lab
- Automation Lab
- Material Lab
- Nondestructive Testing Lab
- Multitasking machine
- Computer cluster for virtual manufacturing

Detailed information about the equipment housed in each lab can be found at:
hv.se/en/production-technology-west/equipment

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INNOVATION AND UTILIZATION

Knowledge becomes utilization

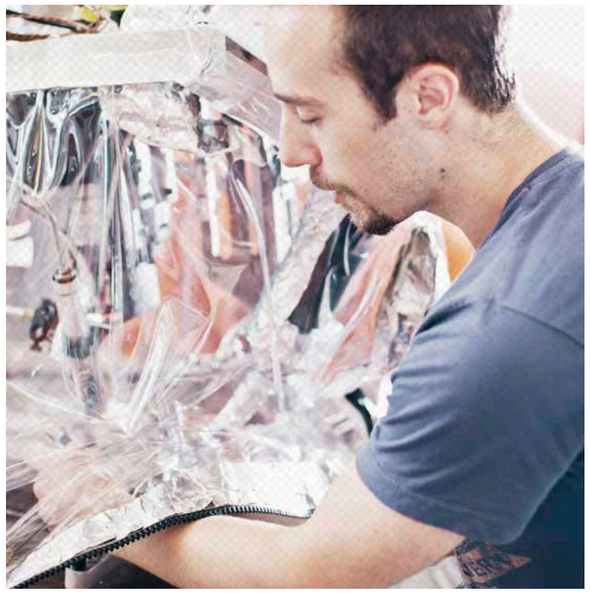
An innovation may be defined as something new that "breaks into" the market or society. The following activities have been performed during the year to increase utilization of research results, and to contribute to the dissemination of results. Intellectual assets resulting from research have been identified by use of the Intellectual Asset Inventory tool from Innovationskontor Väst (IKV). When a potential for utilization could be identified, applications for verification of the results have been drafted.

Two spin-off companies

PTC Innovation AB has performed a number of projects, e.g.

- within RISE for Ragn-Sell for protection of knives from abrasion and corrosion damage: The solution was to coat the knives with a layer of thermally sprayed HVAF coatings, which has prolonged the expected life time 8 times. The solution is based on research in the thermal spray group.
- together with MH-Engineering developed high temperature corrosion protection in heat boilers using HVAF thermal spray technology.
- in cooperation with companies in three European countries developed applications using HVAF thermal spray technology.
- in cooperation with a Swedish company developed wear coatings for a new type of walking sticks for visually impaired.

Contact: Stefan Björklund, stefan.bjorklund@hv.se



Termospect AB – a new company was founded by Anna Runnemalm and Patrik Broberg. The company is part of the Innovatum Incubator and it will make further use of their research results. It has received its first assignment.

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Academic theses in 2015

Licentiate theses:

K. Fahlström, "Laser welding of boron steels for light-weight vehicle applications"

A. E. Bonilla Hernández, "Analysis and direct optimization of cutting tool utilization in CAM"

M. T. Coll Ferrari, "Effect of austenitising temperature and cooling rate on microstructures of hot-work tool steels"

E. Glorieux, "Constructive cooperative coevolution for optimising interacting production stations"

E. Harati, "Fatigue strength of welds in 800 MPa yield strength steels: Effects of weld toe geometry and residual stress"

A. Parsian, "Dynamics of Torsional and Axial Vibrations in Indexable Drills"

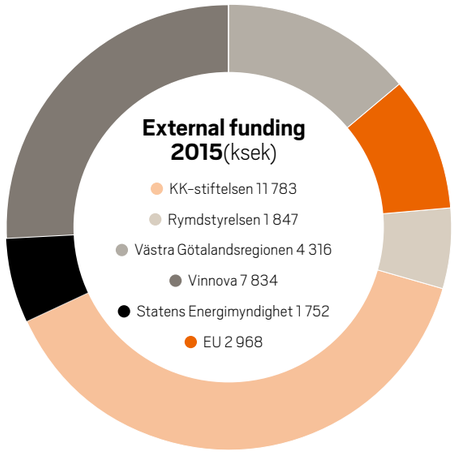
A. Segerstark, "Additive Manufacturing using Alloy 718 Powder: Influence of Laser Metal Deposition Process Parameters on Microstructural Characteristics"

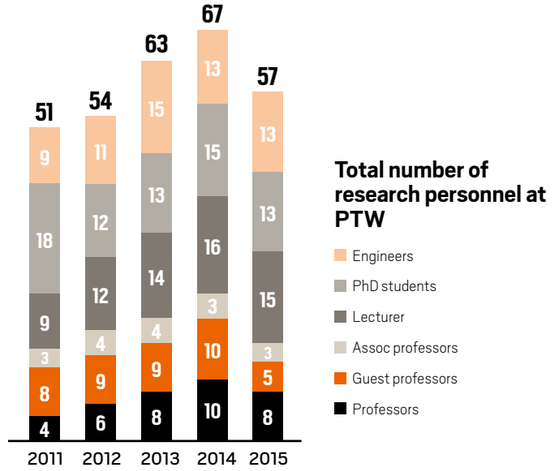
PhD theses:

M. K. Gupta, "Design of Thermal Barrier Coatings: A modelling approach"

P. Hagqvist, "Non-intrusive instrumentation and estimation: Applications for control of an additive manufacturing process"

P. Lindström, "Improved CWM platform for modelling welding procedures and their effects on structural behaviour"

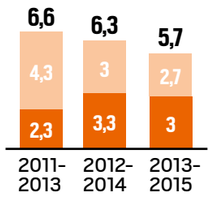




Total number of research personnel at PTW

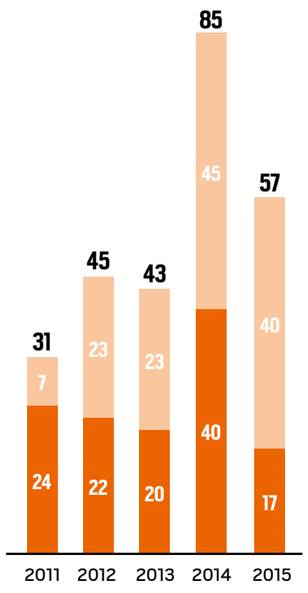
- Engineers
- PhD students
- Lecturer
- Assoc professors
- Guest professors
- Professors

FACTS AND FIGURES



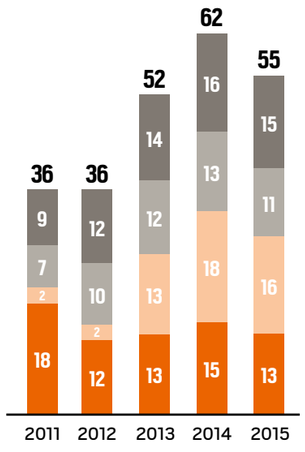
Examina in average over 3 year period

- PHD examina
- Licentiate examina



Publications PTW

- Journals
- Conferences



PhD-students and Supervisors PTW

- Other supervisors
- Main supervisors
- Industrial PhD-students
- PhD students

JOURNAL PUBLICATIONS

A. Devotta, T. Beno, R. Löf, and E. Espes,
"Quantitative Characterization of Chip Morphology Using Computed Tomography in Orthogonal Turning Process," Procedia CIRP, vol. 33, pp. 299–304, 2015.

A. E. Bonilla Hernández, T. Beno, J. Repo, and A. Wretland, "
Analysis of Tool Utilization from Material Removal Rate Perspective," Procedia CIRP, vol. 29, pp. 109–113, 2015.

A. Ganvir, N. Curry, N. Markocsan, P. Nylén, and F.-L. Toma,
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"Time Domain Simulation of Chatter Vibrations in Indexable Drills," 2015.

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"Effect of crystal orientation and texture on fatigue crack evolution in high strength steel welds," International Journal of Fatigue, vol. 77, pp. 95–104, 2015.

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"Evaluation of a temperature measurement method developed for laser metal deposition," Journal of science and technology of welding and joining, 2015.

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"Constructive cooperative coevolutionary optimisation for interacting production stations," The International Journal of Advanced Manufacturing Technology, vol. 78, no. 1–4, pp. 673–688, 2015.

E. Harati, L. Karlsson, L.-E. Svensson, and K. Dalaei,
"The relative effects of residual stresses and weld toe geometry on fatigue life of weldments," International Journal of Fatigue, vol. 77, pp. 160–165, 2015.

E. Åstrand, "A new innovative toolbox for lean welding of fatigue loaded structures," **The International Journal of Advanced Manufacturing Technology, vol. 81, no. 1–4, pp. 635–643, 2015.**

F. Beaubert, H. Pálsson, S. Lalot, I. Choquet, and H. Bauduin,
"Design of a device to induce swirling flow in pipes : A rational approach," Comptes rendus. Mecanique, vol. 343, no. 1, pp. 1–12, 2015.

F. Sikström,
"Operator bias in the estimation of arc efficiency in gas tungsten arc welding," Soldagem & Inspeção, vol. 20, no. 1, pp. 128–133, 2015.

G. Bolelli, L.-M. Berger, T. Börner, H. Koivuluoto, L. Lusvarghi, C. Lyphout, N. Markocsan, V. Matikainen, P. Nylén, P. Sassatelli, R. Trache, and P. Vuoristo,
"Tribology of HVOF- and HVAF-sprayed WC-10Co4Cr hardmetal coatings : A comparative assessment," Surface and Coatings Technology, vol. 265, pp. 125–144, 2015.

G. Bolmsjö,
"Supporting Tools for Operator in Robot Collaborative Mode," Procedia Manufacturing, vol. 3, pp. 409–416, 2015.

J. Medricky, N. Curry, Z. Pala, M. Vilemova, T. Chraska, J. Johansson, and N. Markocsan,
"Optimization of High Porosity Thermal Barrier Coatings Generated with a Porosity Former," Journal of thermal spray technology (Print), vol. 24, no. 4, pp. 622–628, 2015.

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"Laser Welding Process : A Review of Keyhole Welding Modelling," Physics Procedia, vol. 78, pp. 182–191, 2015.

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"Minimization of distortions during laser welding of ultra high strength steel," Journal of laser applications, vol. 27, no. 2, SI, 2015.

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"Improved Quality Output through Computer-Based Training : An Automotive Assembly Field Study," Human Factors and Ergonomics in Manufacturing, vol. 25, no. 3, pp. 304–318, 2015.

L. Mráz, L. Karlsson, and M. Vrána,
"Neutron Diffraction Studies of Residual Stress Distribution in the Vicinity of the Single Pass Fillet Steel Welds," Applied Mechanics and Materials, vol. 732, pp. 13–19, 2015.

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"Welding enabling light weight design of heavy vehicle chassis," Science and technology of welding and joining, vol. 20, no. 6, pp. 473–482, 2015.

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"Cooling Rates and Peak Temperatures during Friction Stir Welding of a High Carbon Steel," Scripta Materialia, vol. 94, pp. 36–39, 2015.

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"Effect of welding position on properties of duplex and superduplex stainless steel circumferential welds," Welding in the World, vol. 59, no. 5, pp. 693–703, 2015.

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