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Evans, Dorothy (2015) Advanced manufacturing industrial doctorate centre : engineering doctorate students collaborating with industry within an academic and industrial environment. In: 18th International Conference on Engineering & Product Design Education, 2016-09-08 - 2016-09-09. (In Press) ,

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ADVANCED MANUFACTURING INDUSTRIAL DOCTORATE CENTRE: ENGINEERING DOCTORATE STUDENTS COLLABORATING WITH INDUSTRY WITHIN AN ACADEMIC AND INDUSTRIAL ENVIRONMENT

Dorothy EVANS

University of Strathclyde

ABSTRACT

The University of Strathclyde (UoS) acknowledged the importance and need for an Advanced Manufacturing Industrial Doctorate Centre (AMIDC) which is jointly supported by the University's department of Design Manufacture and Engineering Management (DMEM) and their industry-focused research centre, the Advanced Forming Research Centre (AFRC). The Engineering Doctorate (EngD) students work with both Industry and academia during the four year programme giving students an unparalleled opportunity to engage with these companies in an academically accredited manner. This presents the students with a unique learning opportunity and further adds an important element of experience of working in the Design and Engineering industry both at the strategic high level and at the operational day-to-day level. So far, the industrial partner companies have all been large Original Equipment Manufacturers (OEM's), these companies all are engaged in the design and production of highly specified technologically complex products that are sold around the world, these companies are in some cases world leaders in their market place. It could be argued that because of the high value and manufacturing complexity these companies must invest in research and can see the long term benefits in investing in the EngD programmes.

These large companies all have their own well-managed research design and engineering methods and procedures, these methods and procedures are sometimes at variants with the EngD programmes running within the university. It is therefore critical to match the company, the needs of their intended research, the EngD programme as run within the university and importantly the skill set and interest areas of the EngD students.

This paper will describe in principal the organisation and implementation of EngD programmes to suit a variety of OEM's and the particular management differences that have to be considered to ensure a successful outcome for the company, the student and the university. The unique aspect of this approach is to facilitate high-level design activity with industrial partners within a high technology research centre located in a University. The University is offering access to state of the art complex manufacturing technology to industrial partners when they engage in design engineering projects through the EngD programme.

Keywords: Industrial Partners, EngD's, Research Centre, Design and Manufacture.

1 INTRODUCTION

The Engineering Doctorate (EngD) is offered by the Advanced Manufacturing Industrial Doctorate Centre (AMIDC), which commenced in October 2011 and is partly funded by the Engineering and Physical Sciences Research Council (EPSRC), until September 2018. During that time 10 studentships, over 4 academic cohorts will be funded by EPSRC. To date there are 36 students, and an additional 8 students are due to commence in cohort 2016/2017 fully funded without EPSRC contribution.

The Centre focuses on developing new and enhanced manufacturing techniques within the forming sector and is a joint collaboration between Strathclyde's Advanced Forming Research Centre (AFRC) and the Department of Design, Manufacture and Engineering Management (DMEM). The AMIDC is

the only established forging and forming research centre in the UK. EngD research areas vary from Design for Manufacture, Optimising Manufacturing processes, Technology improvements, characterisation of new materials and Supply chain management for manufacturing industry.

1.1 AFRC

The Advanced Forming Research Centre (AFRC) is housed in a bespoke building, sited at Inchinnan, Renfrewshire, near Glasgow. The £80M investment [1] facility contains industrial scale, state of the art forging and forming manufacturing equipment, enabling the research team to develop new knowledge and approaches that are highly relevant to industry. The AFRC is a collaborative venture between the University of Strathclyde, Scottish Enterprise, the Scottish Government, and leading multinational engineering firms including Barnes Aerospace, Boeing, Rolls-Royce, TIMET, Aubert & Duval and Bifrangi UK Ltd.

AFRC is also part of the UK High Value Manufacturing (HVM) Catapult, which was established in 2010, with support from UK and Scottish governments in recognition of the importance of manufacturing to the UK economy. Catapults [2] are bridging the gap between business and academia, helping to turn great ideas into reality, by providing world-class research and development facilities and expertise that would otherwise be out of reach for many businesses in the UK. The AFRC assembles key elements of manufacturing R&D into a framework, which supports the delivery of strategy. A new product or technology goes through several cycles of experimentation, refinement and testing before it can be incorporated into industrial-scale production systems, the AFRC helps developers and adopters of new technologies to measure their product’s stage of development and its readiness for manufacture through readiness levels as highlighted in Figure 1.

Manufacturing Readiness Levels	1	2	3	4	5	6	7	8	9
	Universities			AFRC			Supply Chain/End User		
Milestone/Goal	Basic Principles Observed	Concept Developed	Experimental Proof of Concept	Process Validated in Laboratory	Process Validated on Laboratory Equipment	Process Capability Validated on Production Equipment	Capability Validated on Economic Runs	Capability Validated Over Range of Parts	Capability Validated on Full Range of Parts Over Long Periods

Figure 1. Manufacturing Readiness Levels: similar to NASA’s Technology Readiness Levels (TRL)

The AFRC focuses on developing forming and forging technologies to support the design and manufacture of products, across a range of sectors including Aerospace, Automotive, Energy, Medical Devices and Marine. The AFRC undertakes a programme of core research established in collaboration with Industrial members, as well as contract research and development work commissioned by member and non-member companies from around the globe. The key challenge that the AFRC has is helping industry take low maturity and often disruptive technology and to successfully deploy it in manufacturing facilities. In addition to world-class facilities in the building, AFRC can draw upon the wider capabilities and expertise of the University of Strathclyde.

The AFRC’s vision is to become a world-renowned research facility, supporting fundamental and applied research in advanced forming and forging providing:

- Cross-sectoral collaborative partnership between leading academic institutions and major industrial companies.
- Rapid “technology pipeline” from concept – demonstration – exploitation.
- New standards for the design and forming of high integrity, high value added products.
- Dedicated high quality purpose built facility that reflects the state of the art in forming and forging.

1.2 Industry

The Parnaby [3] report saw the need for a major new scheme to provide Engineering Doctorate (EngD) programmes in the processes and practices of engineering, required by industry. It concluded that such an Engineering Doctorate would be distinct from, and complementary to, the traditional existing PhD, which has been criticised for its lack of industrial relevance

Although the EngD programme is a model, which is known and accepted throughout other Doctorate Centre's across the United Kingdom, some industrial and commercial demands result in different time pressures being applied to the project. The EngD programme has to be flexible, within limits, to accommodate the variety of industrial partner and project particulars.

Funding presents a complex negotiation, the simplest of these being 100% funding from the sponsoring industrial partner. Most funding packages are a 'cocktail' funding package whereby the industrial partner pays a proportion of the overall funding package required and the balance is identified with a range of other funding sources including AFRC itself, University of Strathclyde, Engineering Faculty, a variety of Departmental funding,

Contracts must be negotiated and drawn up in light of funding, Intellectual Property considerations, commercial sensitivity and any appropriate legislation.

The AMIDC programme in the AFRC is directed at technologically complex, high specification, high value and genuinely new areas of research. The upfront negotiations and funding packages have to be commensurate with the demands of the sponsoring company and potential outcomes therefore, while all parties are keen to engage and start progress it is critical that the contractual negotiations are fully understood and agreed before commencing any project.

These companies all have their own well-managed research design and engineering methods and procedures, quite often driven by international standards or legislation, these methods and procedures are sometimes at variants with the EngD programmes running within the university. It is therefore critical to match the company, the needs of their intended research, the EngD programme as run within the university and importantly the skill set and interest areas of the EngD students.

1.3 Engineering Doctorate (EngD)

Similar to the PhD, the EngD is a postgraduate research (PGR) programme. It differs from a traditional academia-based PhD in that it expects PGR students (Research Engineers: REs) to work on projects which are industry-based. This positioning of EngD in industry provides REs with industry relevant skills, as well as industry based research experiences. The Engineering and Physical Sciences Research Council (EPSRC) Review in 2007 [4] found that the EngD programmes were meeting real business needs, many of the REs are having "a major impact on business performance" and that the scheme was making a valuable contribution to UK knowledge generation and transfer into industry, while satisfying its goals in terms of scholarships and publications (EPSRC, 2007). In 2009, 19 Industrial Doctorate Centres (IDCs) were created as a subset of EPSRC's new Centres for Doctoral Training (CDTs). The IDCs are seen as a development of EPSRC's EngD Centres. As of 2011/2012, £19 million [5] was invested in 29 IDCs, the number of EngD students trained at IDCs amounted to about 1400 and the number of company partners under the scheme amounted to some 600 over the previous 20 years.

2 ADVANCED MANUFACTURING INDUSTRIAL DOCTORATE CENTRE

The Advanced Manufacturing Industrial Doctorate Centre (AMIDC) Engineering Doctorate programme is a four year postgraduate research programme in the UK higher education institutions, consisting of a combination of taught and research elements, skills development and training for industry. Successful graduates from the EngD programme are awarded with the EngD degree.

The EngD programme works collaboratively with Industry partners who may fully or part fund an EngD student for the duration of the programme. It provides ambitious and able students with the technical, business and personal development competencies needed to become the senior research managers of the future. A key element of the programme is the close link with the sponsoring company.

2.1 EngD Process

The programme has been structured to meet industry expectations and their continued desire to ensure higher education institutions are at the forefront of research within Design and Advanced Manufacturing. The programme assists graduates to develop their knowledge and understanding of design and manufacturing issues, gain industrial experience and learn how to expertly communicate and implement viable real-world engineering solutions

Industry partners, are vital to the success of the AMIDC as not only do they provide funding that helps support the students but also mentoring and career development through the provision of an industrial mentor and the opportunity to conduct research in an industrial/commercial environment. Throughout the EngD programme the students are supervised and guided by both academic supervisors and their industry sponsors to ensure all parties understand the expectation and deliverables of the project.

Before a student is appointed to commence the EngD programme, a research project and funding package must be in place. The industry partner identifies the area of research, submits a proposal to the EngD Director within the department of DMEM to verify that it meets the requirements for a research based project, identifies that there are skilled academic staff in the area of research to support the project throughout the period of study. The funding comprises of; Fees, tax-free enhanced stipend as well as additional monies to cover any projects costs such as materials, consumables and conferences that the student may attend throughout the time of the EngD. Once this has all been agreed and signed off, this will then go to advert for graduates to apply. Graduates must have a first or second-class Honours degree (minimum 2.1) or an MSc in engineering in the area of the proposed research project.

Students are asked to submit a proposal outlining their understanding of the project (2-3 pages), along with their CV's and Grades. Depending on the funding attained for this project, it will stipulate in the advert whether a Home, EU or International student is required.

The EngD coordinator will sieve through the applications and submit CV's and proposals to both Industry sponsor and academic supervisors for their feedback. Once they have identified several candidates, interviews will take place and an appointment will be made. Recruitment of an EngD can take place at any time of the year, however candidates are required to take up their academic modules at the start of a University year, in the time they are with the programme they will work with their industry partner on the chosen project. The Student may be based at the premises of the Industry sponsor, the AFRC or within the DMEM department of the University.

Each project is different and students are responsible for deciding on how to approach and build their research project. Influenced from an academic and industrial perspective, EngD students have the opportunity to develop research in cutting edge fields and create a positive impact on current manufacturing challenges.

The EngD student will work with their industry sponsor developing a programme of work to build on new knowledge and experiments to test ideas and investigate potential solutions. This is a unique opportunity to work on advanced manufacturing production techniques with the time and flexibility to explore different solutions.

2.2 Academic Modules

Throughout the duration of the EngD study, the student is actively engaged not only with the industry partner research project but also the University research outputs. Figure 2 outlines the steps of the overall EngD programme.

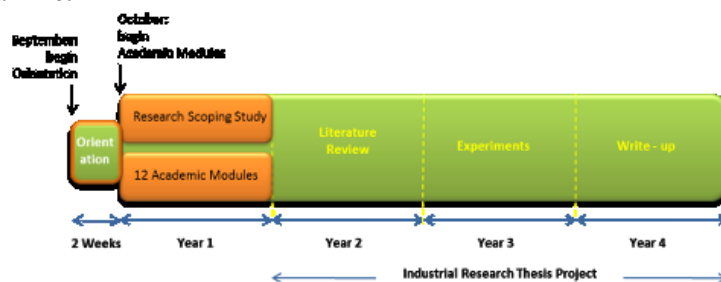


Figure 2. EngD Model

Year 1: Structured into the first semester of the academic year, students undertake compulsory modules; these subjects equip them with general knowledge across a variety of topics:

- Advanced Forming Technology and Systems
- Advanced Material Production Technology
- Manufacturing Automation
- Micro and Nano Manufacturing
- Strategic Technology Management

- Research Methodology

Students are also required to select optional modules from a predefined list;

- Product Design Techniques
- Systems Integration
- Strategic Supply Chain Management
- CAED systems
- Fundamentals of Lean Six Sigma
- Sustainable Product Design and Manufacturing
- Systems thinking and Modelling
- Design of Experiments for Process Optimisation
- Information Management
- Project Management

Students get support from their academic and industrial supervisors on final decisions to complement their research thesis. At the beginning of the first year, students will also be set an initial scoping study to help prepare for their thesis and also allow for industry and academic advisors' input into direction and depth of their research topic.

Years 2, 3 and 4 are dedicated to full-time focused research, which may be based either at the University or with the industry sponsor as appropriate to the needs of the project and the student's career development. Close contact with industry, academic supervision is maintained throughout the programme. Students take modules together with courses in generic skills and technical modules to support their intended research. Providing a solid grounding of knowledge in manufacturing and engineering, equipping EngD student's with the understanding to undertake their industry research thesis project. It is also compulsory that the student attends progress review sessions as well as the university wide research presentation days. They are also tasked with producing academic papers for conferences and journals.

2.3 Conclusion

In conclusion this paper has demonstrated that the EngD programme is a successful academic initiative that in partnership with high-level industries can deliver real deliverables based on innovative practices and can be realised in the long term within the industrial partners operation.

Clearly there are distinct benefits for each of the main participants within the EngD programme, these are the Students, the Academic Institute and the Industrial Partners.

The benefits to the students are at many levels, firstly, they are engaged in a higher degree while also working with industry and receiving an enhanced remuneration package while doing so. The student also has the benefit of a long-term relationship with the industrial partner working in close collaboration with the academic institute. This unique position provides an enhanced environment to develop key skills in the research area, thus improving their long-term employability. Lastly of course they are intending on achieving an Engineering Doctorate qualification.

The benefits to the Academic Institute are that a high level innovation based collaborative agreement is in place with high value industrial partners. In the first instance this is clearly demonstrated through the contractual arrangements and the endeavour on the initial project agreed by the industrial partner and the academic institute. In the longer term and arguably more meaningful the academic institute and industrial partner build a professional relationship that goes on to create new research and knowledge transfer opportunities.

The benefits to industry can be clearly demonstrated as the research identified for the EngD programme is of direct relevance for the industrial partners future. The industrial partner also benefits from access to state of the art advanced manufacturing equipment at an industrial scale within the AFRC. This gives the industry partner the opportunity to measure the impact for the use of the technology and the required knowledge base that has to be associated to it. The industrial partner based on these EngD programmes can then, with added confidence, progress onto specifying these new processes and materials in their future new products, thus providing them with a technological and/or economic benefit.

The longer term benefits of the EngD programme, industrial partners working at a high level with academic institutions on meaningful research are new techniques, materials, processes, components are produced leading to enhanced technological performance and/or enhanced commercial

performance leading to direct positive benefits to the economy. Another direct outcome is the long term development of a pool of highly skilled and talented future leaders again contributing to positive economic development.

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