Postgraduate education for the steel industry

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ABSTRACT

In 1992, the Department of Materials Engineering at the University of Wollongong signed an agreement with PT Krakatau Steel, Indonesia's national steel company, to provide postgraduate coursework education for the company's engineers. Over the next five years, the Department provided an on site program at Krakatau Steel's Cilegon works in Java. Members of the Department staff were flown regularly to Indonesia to deliver lectures and to provide tutoring. The coursework program developed reflected the diverse background of the students entering the program and the desire of the company to improve their engineers' understanding of basic principles of Materials Engineering, and particularly, of the metallurgy of steel. The program was run with cooperation from Tirtayasa University in Cilegon. Over 100 students graduated with Masters degrees from the program. A quite different program was developed for BHP Ltd., Australia's largest steel company, in 1995 to educate their engineers in modern management techniques and specific steelmaking technologies. The program was delivered locally in a variety of modes. This paper discusses the similarities and differences between the respective programs and reflects on the challenges facing universities in providing post graduate education to the steel industry.
INTRODUCTION

Wollongong is a coastal city of approximately 180,000 people located 100 km south of Sydney. The two biggest employers in Wollongong are the BHP's Port Kembla Steelworks, a 5 MT per annum integrated steelworks producing predominately coated flat products and the University of Wollongong, which currently has approximately 10,000 undergraduate students, 3,000 post graduates and 1500 staff. The steelworks date back to the 1920s when a plant was established to take advantage of the significant local coking coal deposits and good port facilities. The University origins date back to the early 1950s with the establishment of a technical college in Wollongong, with full University status being established in 1975 (1).

The history of the University has been strongly connected with providing education to employees of BHP and, in particular, the educating of Metallurgists and Materials Engineers. The first Chair in Metallurgy was sponsored by BHP when Dr Geoffrey Brinson was appointed the Foundation Professor. The Department of Metallurgy was eventually renamed Materials Engineering in 1988, reflecting a more diverse course and the desire of BHP and others for graduates with skills beyond traditional metallurgy. The Department initially focused on teaching ahead of research activities and almost all of the early students were part time employees of BHP. During the last decade, the Department's research activities have risen enormously with members of the Department being successful in winning substantial government and industry grants for research. Some of the areas that have been most successful are welding and joining, surface engineering, HSLA steels, thermomechanical processing, superconductivity, shape memory alloys, microwave processing, steelmaking and refractories. A large proportion of this growth was fueled from cooperation with BHP but new alliances with other industries and government research agencies also allowed the Department to prosper (2). There are currently 19 postdoctoral and 46 postgraduates working in the various research programs associated with the Department.

This rapid growth in research also coincided with changes in emphasis in education. The undergraduate students entering the course were no longer as strongly orientated to the steel industry, reflecting in part, the diverse nature of the new course but also the lower graduate requirements of the Port Kembla steelworks. Of the 1998 intake, only a third of the students were directly associated with BHP. At the same time, demand increased for specialist post graduate courses and during the nineties, the Department has been strongly involved with three significant postgraduate programs in the areas of Materials Welding and Joining, Steel Processing and Products, and Materials Engineering. The final two programs were designed for two steel companies, BHP and PT Krakatau Steel respectively, but were very different in their content and modes of delivery. This paper describes these courses, discusses the important similarities and differences, and considers the larger question of how to provide high quality post graduate education for the steel industry.
PT KRAKATAU STEEL PROGRAM

PT Krakatau Steel (PTKS), Indonesia's national steel company, was formed in 1975 and began soon after producing steel via direct reduced iron/electric arc furnace route at its Cilegon works in Java. Java is one of the most densely populated regions of the world with 115 million people living in area about the size of England. The island is culturally rich with a long and fascinating history, not least, the various wars and rebellions associated with over 300 years of Dutch rule. Approximately 60 per cent of the Javanese workforce is engaged in agriculture, though there was until recently rapid growth in the manufacturing area. One of the most famous incidents in Javanese history involves the eruption of the volcano, Krakatau, in 1883. The volcano's eruption caused the tidal waves up to 30 m high, 16 m$^3$ of ash to blown into the air and the death of 35,000 Javanese. The explosion was heard in Australia, 3,000 km away. (3)

PTKS currently produces 0.4 MT p.a of long products and 2.1 MT p.a. of flat products at its Cilegon works. Iron is produced from both HYL I and HYL III Direct Reduced Iron processes and used to feed electric arc furnaces which in turn provide molten steel feed to continuous casters and rolling mills. They currently have approximately 6,000 employees, with nearly a 1,000 being tertiary qualified engineers. The company has a large commitment to education at all levels and operates its own substantial training facility, as well as providing strong support to Tirtayasa University located in Cilegon. The company is currently state owned but has plans to privatise.

The first contact between the University and PTKS was in 1991 when a delegation from the company visited several universities in Australia to investigate the possibility of providing offshore postgraduate education for their engineers. The University of Wollongong was chosen because of its long association with the steel industry and from discussions a coursework Masters of Engineering Studies program was devised with the objective of giving some knowledge to students of the elements of iron and steelmaking, right from extraction to the finished product; receiving lectures and laboratory work in: primary metallurgy, secondary metallurgy, including mechanical and physical metallurgy, refractories, polymers, and degradation and corrosion. The nine subjects that formed the program are detailed in Appendix I. In addition to the coursework degrees, a research program was also devised that involved metallurgists at PTKS carrying out research masters and PhD's under supervision from University of Wollongong staff.

A contract was signed in March 1992, the first students enrolling in July 1992 and first lectures commenced in August 1992. The contract allowed for four groups of approximately 25 to 30 students each to complete the Masters coursework program and for a number of engineers from PTKS to undertake postgraduate research degrees. The subjects were offered in modular form with two weeks of intensive lecturing, with supplementary laboratory work and exams. Assessment was broken down between continuous assessment held during the lectures, laboratory reports and a final exam. The lectures were provided entirely by University of Wollongong staff who where flown to Jakarta, approximately 6 to 7 hours of flying, and then driven to Cilegon, a further two to three hours traveling. Lectures were given at the PTKS's training center or at the nearby Tirtayasa University campus. Establishing good relations with
personnel from Tirtayasa University was essential to the program's success, especially as laboratory classes were run by employees of Tirtayasa University, after receiving training from University of Wollongong staff. Students were also required to complete a significant Dissertation which typically involved optimizing some aspect of the plant operation and/or selecting appropriate materials for components in the process. This section of the course proved useful for PTKS in terms of increased productivity and performance, as well providing tangible evidence of the courses impact on the skills of their engineering personnel.

Co-ordinating the program fully from Wollongong proved impossible and the logistic problems associated with organizing lectures, accommodation, laboratory classes, exams and gathering of assignments and reports, resulted in Professor Standish being present in Cilegon on a full time basis. Professor Standish's commitment to the course was crucial in ensuring its success and also allowed the growth of a significant research program between the University of Wollongong and PTKS. Equally important to the success of the program was the commitment of PTKS management, notably Mr Djoko Subaygo (Director of Production), in allowing such a large number of their staff to participate in the program. Implementing the program was not without its problems and in the five years that it took to graduate the 100 or so students, the most severe problems encountered were:

1) Language. Most of the students entering the course had limited English skills and though the student's English generally improved substantially during the course many reports had to be re-submitted after correction for grammar and spelling. This made assessment a long and arduous task for all concerned. The improvement of the English skills was viewed by the management of PTKS as a major benefit of the course.

2) Culture. There were many mis-understandings between University staff and students that originated from different cultural perspectives and expectations. For example, the western notion of the need for strict adherence to assessment deadlines seemed at odds with the Javanese concept of "Jam Karet" (translation - rubber time). These difficulties lessened with time as University of Wollongong staff became more knowledgeable of Javanese culture. Professor Standish's full time role at Cilegon was particularly important in overcoming these problems.

3) Educational Resources. The students at PTKS had only limited access to textbooks and general technical literature. This made it somewhat difficult to carry out literature surveys for their dissertations and other assignments. As the course proceeded it became common practice for staff from the University of Wollongong to send copies of papers and sections of books by mail.

These problems aside the course was viewed by all parties as a success. There was observable improvement in the language, technical and inter-personal skills of graduates from the course and this was reflected in many graduates being promoted within PTKS. The Department of Materials Engineering at the University benefited greatly from the experience of delivering an off shore course, and the significant income generated from the course helped fuel the rapid growth of research in the Department that has already been described. The strong relationship established between PTKS and the University continues today with several PTKS employees enrolled in postgraduate programs at the University of Wollongong in the Department of Materials Engineering.
The traditionally strong relationship between the University of Wollongong and BHP was formally recognized and strengthened in 1995 with the formation of the BHP/University of Wollongong Institute for Steel Processing and Products (ISPP). The ISPP was formed to focus educational and research resources on the particular needs of the steel industry with BHP providing $500,000 per annum over an initial period of six years. This funding was used to employ three new professors in 1996: Professor of Steelmaking and Director, Rian Dippenaar, Professor of Surface Coating, Hugh Brown, and, Professor of Management, Richard Badham. Dr Keith Enever was the interim Director of the Institute from March 1995 to July 1996 and it was during this time that two postgraduate courses offered by the ISPP were developed in close consultation with BHP: a Masters of Engineering Practice in Steel Processing and Products and a Graduate Certificate in Steel Processing and Products. The Graduate Certificate was designed to be completed in one year part time, whilst the Masters course required a minimum of two years part time. The program schedule and a brief description of each subject is provided in Appendix 2. The ISPP course differed from the PT Krakatau Steel course in two significant ways, namely:

1. a greater emphasis on steel products, as opposed to steel production. This reflected, in part, BHP's strategic plans for expansion and BHP's traditional technical strength in coated products but also PTKS's development as a steel company.
2. a strong emphasis on the study of management theory and practice. The subjects, Introduction to Quality Concepts, Maintenance Management and Management of Change, introduced students to well established management principles whilst the subjects Management of Process Innovation 1 and 2 examined the social, organizational and political aspects of designing new process technologies. PT Krakatau Steel did support studies in management for its staff but this was not included as a component in the Masters program offered by the University of Wollongong.

The ISPP courses were designed for graduates of engineering or applied science who were working in the steel industry. Students with little knowledge of metallurgy were provided with the appropriate background in the Preliminary Topics in Steel Processing and Products subject. Likewise students with minimal background in mechanical engineering were provided with the necessary background in the same subject. The philosophy of the course was summarized in a promotional brochure:

"The Steel industry is one of the largest and most dynamic industries. Today's steel producer is faced with varied and complex problems involving engineering principles, management structures, labour relations, safety and environmental issues. It has been long recognized that graduates from traditional engineering and science disciplines need specific education orientated towards the special challenges of the steel industry. In particular, there is a need to develop an integrated understanding of steel production. This means understanding of the connection between steel processes and products, as well as the technical and organizational aspects of production. What good is it to know the mechanical details of a rolling mill without an appreciation of how its operation changes the properties of the product? How can improvements
be made in production processes if this is not accepted by the workforce or is not supported by appropriate organizational changes?"

Fifteen students, all employed with BHP, enrolled in course in 1996. Initially, several of these students planned only to do the graduate certificate but most eventually converted to the full masters program. Approximately, half of these students had no metallurgical background. In the first year of the course, most courses were offered in a standard weekly lecture structure at the University campus, each subject consisting of fourteen four hour lectures with assessment by a combination of assignment and examination. Lectures were run at night allowing students from the steelworks do attend after work. The traditional weekly mode of delivery proved to be inconvenient to many students juggling work and family commitments and by the second year of the course most subjects were offered in modular mode, usually run over one week with continuous assessment. Ten new students enrolled in 1997 but a downturn in the local steel industry saw no new students enroll for the course in 1998.

It is still too early to judge the success or otherwise of the course and the future of the course is unclear given BHP’s well publicized managerial and financial difficulties. A recent paper by BHP on educating engineers in metallurgy for the steel industry suggested that there would be a greater emphasis on postgraduate education in the future, as undergraduate courses in metallurgy struggled for support (4). The ISPP has found that the non-accredited short course they have offered over 1 to 2 days, including courses on casting, mould powders, and metallurgical fundamentals, have been very attractive to engineers within the steel industry and suggests that this style of education may meet the needs of the industry better than more traditional University offerings. These courses do suffer from lack of any real assessment and are often short on fundamental knowledge. Of course, there may be ways of satisfying these academic requirements within the 1 to 2 day short course format and this approach is worthy of further consideration.

CONCLUSIONS

There are many differences between the experience gained from the PTKS and BHP programs, even though superficially they should be somewhat similar i.e. postgraduate education for engineers from the steel industry. Both BHP and PTKS recognized the need to provide some metallurgical education for non-materials/metallurgy engineering graduates and the need for steel plant engineers to have a holistic understanding of the steelmaking process. In the case of BHP, this holistic approach extended to formal management studies.

It is also apparent from both these programs that the modular mode of subject delivery is more suited to the work schedules of steel plant engineers. This approach favors continuous assessment techniques which may also be more appropriate for mature age students. The PTKS experience also demonstrated that cultural differences can be significant in the successful running of off shore programs and that a permanent University presence at the off campus site is highly desirable.
REFERENCES

1. J. Castle, University of Wollongong - An illustrated history, University of Wollongong, Wollongong Australia 1991


APPENDIX 1

PT Krakatau Steel Program - Masters of Engineering Studies

MATL987 Metallurgical Processing 1

MATL988 Metallurgical Processing 2
Thermodynamics and kinetics of metallurgical systems: Gibbs free energy, Ellingham diagrams, slag-metal equilibria, reaction order, rate constants, temperature and pressure effects. Transport phenomena: momentum, heat and mass transfer. Metallurgical reaction engineering: batch and flow reactors, design principles.

MATL989 Metallurgical Processing 3

MATL974 Engineering Materials 1
MATL975 Engineering Materials 2

MATL976 Refractories
Chemical composition and properties of oxide and non-oxide ceramics commonly used in refractory applications, bonding of refractories, monolithic refractories and installation technique, refractory cements, degradation examples of applications in the iron and steel industry. Methods for testing refractory properties.

MATL977 Corrosion and Degradation

MATL978 Mechanical Behaviour
Mechanical properties of materials: strength, hardness, strain hardening, creep, rupture, impact, dislocation and grain boundary effects. Mechanical forming operations: rolling, extrusion, forging and wire drawing, flow stress determination. Thermomechanical processing: time and temperature dependent behaviour, die design, high temperature materials problems, defects in mechanical processing. Industrial applications.

MATL985 Dissertation
Extensive literature survey and analysis of some topic relevant to materials engineering and approved by the Head of the Department.
INSTITUTE FOR STEEL PROCESSING AND PRODUCTS COURSE DETAILS

Table I - Graduate Certificate in Steel Processing and Products

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Points</th>
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<tbody>
<tr>
<td>ENGG930</td>
<td>Preliminary Topics in Steel Processing &amp; Products</td>
<td>6</td>
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<tr>
<td>TQM911</td>
<td>Introduction to Quality Concepts</td>
<td>6</td>
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<tr>
<td>ENGG931</td>
<td>Steel Products and their Production</td>
<td>6</td>
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<td>plus one elective</td>
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Table II - Master of Engineering Practice in Steel Processing and Products

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<tr>
<td>MGMT933</td>
<td>Management of Process Innovation 1</td>
<td>6</td>
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<tr>
<td>MECH970</td>
<td>Maintenance Management</td>
<td>6</td>
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<td></td>
<td>plus two electives</td>
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<tr>
<td>Electives:</td>
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<tr>
<td>ENGG932</td>
<td>Rolling Technology</td>
<td>6</td>
</tr>
<tr>
<td>ENGG933</td>
<td>Coating Technology</td>
<td>6</td>
</tr>
<tr>
<td>ENGG934</td>
<td>Steelmaking</td>
<td>6</td>
</tr>
<tr>
<td>ENGG935</td>
<td>Casting</td>
<td>6</td>
</tr>
<tr>
<td>ENGG976</td>
<td>Refractories</td>
<td>6</td>
</tr>
<tr>
<td>ENGG937</td>
<td>Control of Steel Processing</td>
<td>6</td>
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<tr>
<td>ENGG915</td>
<td>Management of Change</td>
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<tr>
<td>MGMT934</td>
<td>Management of Process Innovation 2</td>
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Subject Descriptions

ENGG930 - Preliminary Topics in Steel Processing and Products
A program, approved by the Dean of Engineering, of project work and studies of advanced topics necessary for the understanding of steel processing and the production of steel plate and strip. Topics will be selected from the fields of physical and mechanical behaviour of materials, microstructure, fluid mechanics, heat transfer, manufacturing as a process and observational methods.

ENGG931 - Steel Products and Their Production
An overview of steel products and the processes used to produce them in a modern steelworks. This will include electric arc furnace steelmaking, casting, rolling, annealing, metallic coating and polymer coating.
TQM911 Introduction to Quality Concepts
An overview of the concept of quality in organisational settings. The concept of a "quality audit" and how to undertake it. Issues and problems in implementing and coordinating total quality techniques in an organisational setting. The concepts and issues of design quality, planning quality and implementation quality. Students will be required to undertake an extensive case study of the success factors and challenge issues of implementing total quality into an organisation, and present a detailed, comprehensive analysis from the selected case study.

ENGG932 Rolling Technology
A detailed study of hot and cold rolling and thermal treatment, methods of modelling these processes and the properties and used of steels produced by these processes. A study of batch and continuous annealing of rolled products and the resulting modification to properties.

ENGG933 Coating Technology
A detailed study of the processes of applying metallic and polymer coatings to steel strip, mathematical modelling of the processes, the chemistry of the coatings applied and the properties and uses of the coated products produced by these processes.

MGMG933 Management of Process Innovation 1
A key concern of contemporary technology management is improving the rate and quality of process innovation by adopting new methods to successfully integrate the human, organizational and technological factors. This subject introduces the student to the interdependent human and technological character of production systems and methods for integrating technical and organizational expertise in new production system designs. The nature of production systems and process innovation is introduced through a critique of traditional technological determinist and contingency models, and the use of contemporary configuration theory. The different approaches to production system design are introduced through a critical examination of the changing perspectives within organisations of process engineering, employee management, information systems management, and workers representatives.

MECH970 Introduction to Maintenance Management
Overall perspective for maintenance in business context; Maintenance philosophies; Evolution of the need for maintenance management; Cost & profit drivers in maintenance; Maintenance organisation department structure (resource and administration); Maintenance documentation & computer control; Quality assurance in maintenance; Implementation of maintenance planning; Human factors & motivation skills in maintenance environment; TQM aspects: improvement methodology (Plan-Do-Check-Act).

ENGG934 Steelmaking
An introduction to methods used to produce iron for steelmaking. A survey of methods of steelmaking and a discussion of the factors which might lead to the use of electric arc furnaces. A detailed study of electric arc furnace steelmaking. Types of steel and their uses.
ENGG 935  Casting
A detailed study of the continuous casting of steel including fluid flow, heat transfer, chemical interactions and solidification, modelling of the casting process, mould design and factors influencing the quality of the cast product.

ENGG976  Refractories
Chemical composition and properties of oxide and non-oxide ceramics commonly used in refractory applications, bonding of refractories, monolithic refractories and installation techniques, refractory cements, degradation examples of applications in the iron and steel industry, methods for testing refractory properties.

ENGG936  Control of Steel Processing
Review of measurement and control methods, treating the manufacturing process as a system, specific applications of measurement and control methods to steel processing from steelmaking through to casting.

MGMT915  Management of Change
This subject examines the process of change within an organisation. Issues under discussion will be: change models; characteristics of innovative organisations; acceptance/resistance of change; factors of change; reasons for change; intervention strategies; planning and monitoring change; sustaining change.

MGMT934  Management of Process Innovation 2
Contemporary management literature on process innovation is dominated by universalistic contingency models of 'best practice'. In contrast, this subject develops a more 'contextual' model of innovation, critically reviews alternative explanations of the nature and direction of process innovation, and examines a range of implementation strategies and methods for integrating technical and organisational innovation in the effective realisation of new production systems. This subject introduces students to the following models of process innovation: sequential-engineering models; labour process and socio-technical models; strategic choice and processual models; paradigm, trajectory and configurational models; and inter-organisational and network models of incremental learning and innovation.