Mathematics-in-Industry Study Group Projects from Australia and New Zealand in the Past Decade

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Abstract Mathematics in Industry Study Groups (MISG) have been an annual event in Australia and New Zealand since 1984. Projects from the last decade are considered. Among the industries involved are those of steel, electricity and agriculture.

1 Introduction

The Mathematics in Industry Study Group (MISG) workshops in Australia and New Zealand were initiated by Australia's national science agency (CSIRO) in 1984. At present, the workshops occur annually as a special interest group meeting of the Australia and New Zealand Industrial and Applied Mathematics (ANZIAM) organisation. During the last decade the workshops have been hosted in turn by Massey University, New Zealand (2004, 2005, 2006), University of Wollongong, Australia (2007, 2008, 2009), Royal Melbourne Institute of Technology (RMIT) University, Australia (2010, 2011, 2012) and Queensland University of Technology (QUT), Australia (2013) [1].

Each workshop lasts for one week (in late January or early February). The week begins with presentations from industry representatives, during which they describe their project. Thereafter, small teams of participants work on each individual project led by two (or sometimes three) moderators. Continuing interaction and discussion with the industry representatives helps to further formulate and make progress with the project. As well as coordinating their group, the moderators are responsible for reporting on progress during presentations mid-week and at the end of the week, and afterwards in written reports published after the conclusion of the workshop.

During the 10-year period (2004–2013), each of the workshops involved between 4 and 7 industry projects. A total of 57 projects were considered in the decade. Several of the industrial partners returned to the workshops on multiple occasions.

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The projects have been varied. Some of the kinds of projects tackled and industrial partners involved are:

- Steel: New Zealand Steel and Bluescope Steel Research
- Electric power: Transpower, Integral Energy
- Whiteware: Fisher and Paykel
- Agriculture: Plant Protection Chemistry New Zealand, Fonterra, NRM/Tegel, Compac Sorting Equipment
- Ecological: Environment Canterbury, Australian Institute of Marine Science
- Medical: Brain Research Institute, Kirby Institute
- Others: Geoscience Australia, Australian Bureau of Statistics, Defence Science and Technology Organisation, Department of Transport and Main Roads

In the following sections, some of the projects are described in more detail. The author was a MISG team member on these ten projects and was also a moderator for them all except for the first (in 2004).

2 New Zealand MISG Projects 2004, 2005, 2006

The MISG 2004–2006 were the first to be based in New Zealand. Six or seven projects were brought in each year.

Modelling of a Poultry Shed: NRM/Tegal Ltd., 2004 This related to the large barns in which chickens are raised for meat over a 6-week period. During this time, water and food is fed to the birds. The chickens themselves produce moisture and heat, which are removed from the shed by ventilation. The project involved modelling this flow of mass and energy. Among diverting considerations were the appropriate surface areas of chickens when standing or seated (spheres or hemispheres) [2].

Implementing Lanier's Patents: Backyard Technology, 2005 Behind this project was the idea that aeroplanes would fly better with appropriate 'holes' in their wings that Lanier expressed in the 1930s. Unfortunately, there was no data to work with, the closest thing being a few patents and photographs from the 1930s. This made things rather challenging. However, the MISG team did assess and summarise what information there was in the patents, and also conducted simple analyses and numerical simulations relating to the conjectures [3].

Process Driven Models for Spray Retention of Plants: Plant Protection Chemistry NZ, 2006 Modelling the deposit of horticultural sprays onto plant leaves can be helpful for designing the implementation to be more effective. A number of processes can be modelled separately such as the transit of the spray from the spray nozzle to the plant, the impact of an individual droplet on a leaf and the flow of droplets across leaves. In the second of these processes, the droplet may leave the leaf through the two different mechanisms of rebound and shatter (possibly to return

to the leaf for additional impacts) or the droplet may remain on the leaf. The group collected these processes together to form a composite model of the process [4]. A continuation of research after the MISG considered the leaf impaction in more detail [5].

Further to the project at MISG 2006, Plant Protection Chemistry NZ were involved in the MISG in 2005 and 2013, these projects involving the passage of spray through porous barriers (hedges) and the uptake of agrichemicals through leaves.

3 Electric Power Projects

During the decade, Transpower Ltd., who manage the New Zealand electricity network, brought seven projects to the workshops. The projects included ones relating to maintaining electricity supply, electricity price structures, and issues relating to wind power. Integral Energy also brought electric power projects.

Operating and Planning an Electricity Transmission Grid to Maximise the Contribution of Wind: Transpower/EECA NZ, 2007 Increasing use of wind power brings new challenges because of its variable nature: at some times there may not be any wind and at other times the wind may be too powerful to be safe to use. In this project the group considered two issues. One related to how to ensure electricity supply with other power sources, when utilising a large amount of intermittent wind power. The other considered the allowances that require to be made to provide sufficient line capacity, when supply is moving between wind power and other power sources. Both studies considered the project in the context of both the financial and electric grid used in New Zealand [6, 7].

How Far can a Simplified Network Rights Auction be Extended?: Transpower, 2012 Financial options are to be introduced to complement the existing pricing structure for electricity at different locations in New Zealand. These are sold by auction and enable the purchaser to buy power at one point in the electricity network and to be supplied with it at another point in the network. The initial scheme will operate on a subset of the nodes already used for spot pricing. The MISG team considered the kind and number of constraints involved in ensuring a workable system and the feasibility of their computation. Further, an approach was suggested for generating the feasible set [8].

4 Steel Projects

Eight projects were brought to the MISGs by New Zealand Steel and Bluescope Steel Research. These considered the steel-making production from initial processes with raw iron through to the final products.

Cold Point Determination in Heat Treated Steel Coils: New Zealand Steel, 2008 Annealling is required following the production of steel sheets by rolling. This reforms the crystalline structure by a period of heating in a furnace. The steel sheets are in the form of cylindrical coils. The team considered the process of heating within these rolls and the location of the point that takes the longest to heat. It is difficult to measure temperatures within a furnace. An initial stage of the modelling was to decide upon appropriate boundary conditions for the coil which is heated by a mixture of conduction, convection and radiation. Also, within a coil, the conduction of heat is not isotropic because of the gaps between layers of the steel sheet. A series solution was found for the partial differential equations that describe the coil temperatures [9–11].

Coating Deformation in the Jet Stripping Process: Bluescope Steel Research, 2009 Steel sheets are galvanised by passing the sheet through a bath of molten coating and then controlling the thickness with air knives. Recent changes in the coating mixture has led to some potential issues to tackle with the quality of the final coating. There is a potential problem with deformations in the coating in the form of pock marks and the like. The process had been mathematically modelled previously [12]. This model was recovered but with the addition of a term due to shear stress. Numerical models indicated how potential deformations may grow [13–15].

Recovery of Vanadium During Steel Manufacturing: New Zealand Steel, 2011 In New Zealand, raw iron is produced from iron sand. The molten iron contains a number of metalloids including vanadium. These must be removed before the steelmaking process and these are also valuable by-products. The removal is done by oxidising the metalloids using oxygen blown into the molten iron and added solid iron oxides. The metalloid oxides rise to the surface of the raw iron from whence they can be scraped into another vessel. The MISG team built up a representative set of differential equations to describe the constituent substances present and the temperature. Special care must be taken of the residual carbon both as this is required later for making steel and because carbon oxidation can be a runaway process leading to carbon boil in which the molten iron is splattered everywhere [16].

5 Further Projects

Two other projects were moderated by the author. Both of the organisations: the Australian Defence Science and Technology Organisation (DSTO) and Fonterra Co-operative Group Ltd. (Fonterra) supported the workshops in multiple years.

Influence Diagrams to Support Decision Making: DSTO, 2010 The 2010 MISG team considered influence diagrams. These can be used in a variety of ways, they indicate links (arrows) between events or actions (boxes) as a support for decision making. The team spent a great deal of time exploring the possibilities for these approaches in their discussion. They visualised the approach being used in a hierarchical fashion where detail in sub-influence diagrams could be hidden until required within

larger networks. A computational simulator was created that used colour shades to show the state of different events and this was helpful for visualising the progress of influence through a system [17].

Can we Predict How Cheese Matures?: Fonterra, 2013 Cheddar cheese is sampled soon after production before storage for ripening. The MISG team produced a differential equations model for key processes involved including ones for the breakdown and consumption of proteins, fats and carbohydrates by bacteria and enzyme-catalysed reactions. Data from the literature was fitted with this simple model. Further to this, data from the Fonterra factory was analysed. The evolution of acidity in the process was also modelled [18].

6 Concluding Remarks

The MISG over the last decade have tackled varied projects. Key points of a selection of these have been presented. The workshops continue to be a productive and instructive venture for participants from both industry and academia.

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