QPSF Technology Diffusion Project Proposal

Application of Finite Element Modelling Techniques for Solving Engineering Problems

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Industry Partner and Contact

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1. BACKGROUND AND AIMS

The overall aim of this project is to:

a. apply advances in finite/discrete element techniques to analyze stress distributions in MRI magnets; and,
b. to predict and simulate backfill stope failure risks due to blast loading effects in underground mines.

The project will be in collaboration with Magnetica Ltd, a Brisbane-based company with sophisticated skills and proprietary intellectual property in the design and development of high performance, specialised magnets primarily for use in advanced magnetic resonance imaging (MRI) equipment for human medical imaging.

In recent years the applicant has successfully worked on a number of computational engineering projects applying finite element techniques for solving civil engineering structural problems, such as:

- *"Numerical Modelling of Fibre Reinforced Concrete Beams under Torsion"*

The use of fibre reinforced plymers (FRPs) for strengthening of reinforced concrete structures has received a great deal of attention in the construction industry in recent years. The behaviours of FRP torsionally strengthened reinforced concrete beams, e.g., ultimate torques, cracking and crushing are investigated in the project using the finite element technique, for a number of different configurations of carbon and glass fibres (CFRP & GFRP). Figure 1 shows the stress distribution of a CFRP strengthened beam.

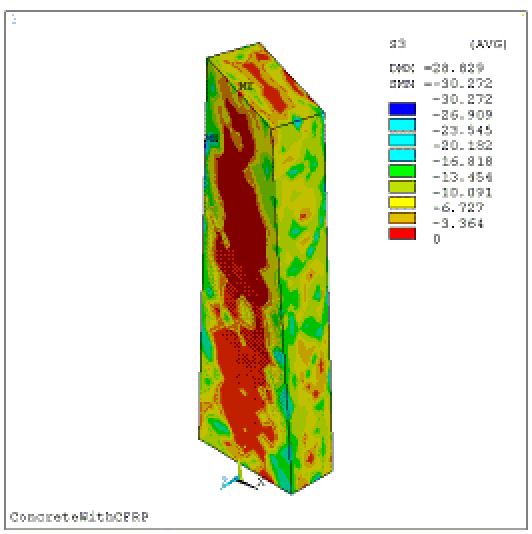

Fig.1 Principal stress distribution of a CFRP beam

- *“Numerical Modelling of Members Curved Spatially in-Plane”*

Members that are curved spatially in their plane are commonplace in structural engineering, yet their general behaviour is little understood owing to complexities that arise in their nonlinear analysis. In the project, the nonlinear finite element method had been applied to model and analyse the behaviour of members curved in space.

This project will extend the previous developed methodology to stress analysis in two problem domains:

(a) Metal alloy superconducting magnets in MRI (Magnetic Resonance Imaging)
MRI magnets produce very large magnetic fields leading to high body forces (Lorentz forces) in the coils. The body forces then create high stresses in the coils, causing motion of the coil windings, inducing fractures in the insulation and binding materials, and also resulting in degraded performance or failure of the magnet.

(b) Prediction of failure risks due to blasting effects in underground mines
Safety is one of the main concerns in underground mining. Blasting within the mines for ore removal is one of the main causes of instability within the mine backfill that leads to accidents.

While these two problems are in separate domains, wires in magnet coils, like rocks in mines, are discrete in nature and are jointed by some kind of materials (resin or wax in magnets, and soil in mines). The problems share common analysis tools and computational methods, i.e., finite element/discrete element modelling tools, and the fracture mechanics method, etc.

2. METHODS

Figure 2 shows a typical coil configuration of a magnet with six coils supported by coil formers. Superconductors in MRI magnets work at 4K temperature and are cooled down by liquid Helium from room temperature. Therefore the analysis of MRI magnets will include (1) finite element modeling of coils and coil formers (support structures), with frictional contacts between coils and coil formers as well as orthotropic material properties to be considered; (3) steady and transient thermal analysis of magnets; (4) static stress analysis of magnets at room and 4K temperatures. For the blast modeling, we plan to (1) numerically model the dynamic response of different types of backfill (hydraulic fill, paste fill etc.) due to blast loading, using finite element/discrete element and finite difference methods; (2) apply state-of-the-art virtual reality techniques in conjunction with the results from the numerical models to visualize the blast damage in an immersive virtual environment.

The modeling and analysis of MRI magnets and rock blasting will be undertaken by using the advanced finite element program ANSYS and the finite element /discrete element program ELFEN.

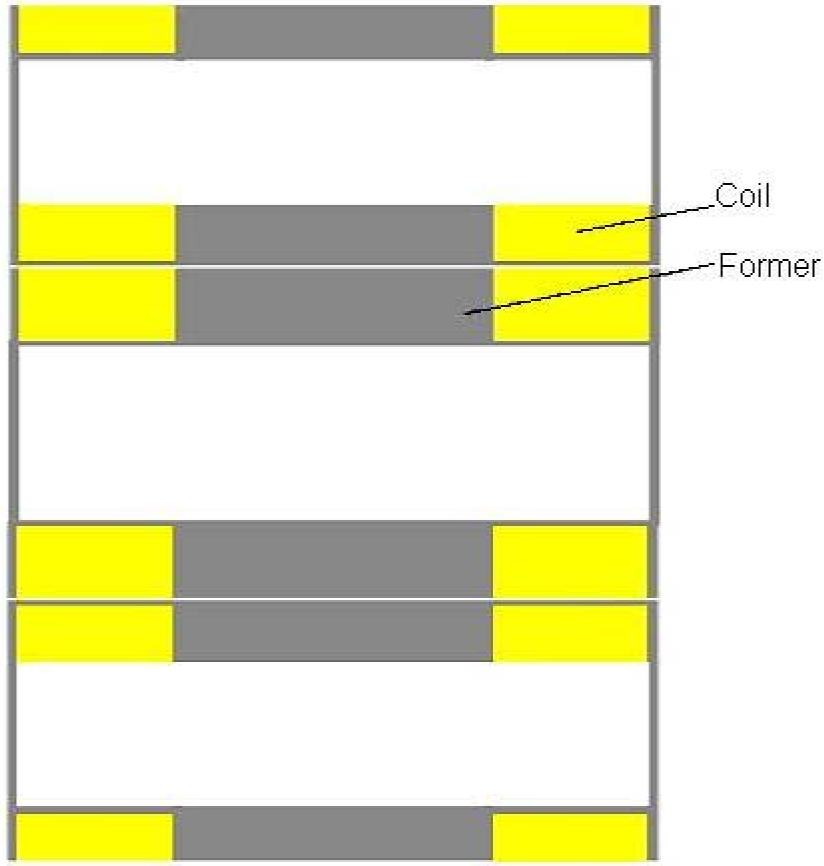

Fig.2 A Typical Coil Configuration, showing the sample (ie patient) space in the middle

3. DELIVERABLES

- Analysis examples of MRI magnets showing stress and strain distributions in coils and coil formers;
- Design optimization examples of magnets to improve the product design based on the analysis results.
- A numerical model capable of predicting blast response for different input parametric conditions in underground mines
- A virtual simulation system for predicting and simulating backfill stope failure risks.

4. REPORTING

It is anticipated that the project will take 1 year from commencement. An interim progress report will be provided by the end of first six months, on the progress of the activities and expected deliverables from the project. A final report will be submitted by the end of twelve months.

5. BUDGET

Item	**Cost**
Salary + on-costs (12 mths)	$38,000
Travel expenses	$3,000
Total	$41,000

6. BUDGET JUSTIFICATION

Magnetica will contribute 60% of the applicant's salary and associated overheads, an in-kind contribution totaling $100,000. Part of the project (blast modeling) is also supported by a DEST grant of $106,300.

This work will also involve a number of trips to factories and mining sites in Australia for which $3,000 is sought to cover travel expenses.