Quarterly Report

Date of Report:	July 15, 2005
Contract Number:	DTPH56-05-T-0001
Prepared for:	United States Department of Transportation Pipeline and Hazardous Materials Safety Administration Office of Pipeline Safety
Project Title:	"Understanding Magnetic Flux Leakage (MFL) Signals from Mechanical Damage in Pipelines"
Prepared by:	Dr. Lynann Clapham Principal Investigator Queen's University Kingston, Ontario, Canada K7L 3N6 lynann@physics.queensu.ca Mr. Ian Wood Team Project Manager Electricore, Inc. 27943 Smyth Drive, Suite 105 Valencia, CA 91355 ian@electricore.org Ms. Marina Smith Team Technical Coordinator Pipeline Research Council International, Inc. 1401 Wilson Blvd, Suite 1101 Arlington, VA 22209 msmith@prci.org
For quarterly period ending:	June 30, 2005

Public Page

Analyses of pipeline damage incidents have highlighted mechanical damage (e.g., dents and gouges) as one of the most frequent sources of reported pipeline leaks and ruptures. In addition to adversely influencing the operational reliability and deliverability of pipelines, mechanical damage has been responsible for a significant proportion of the injuries and fatalities occurring within the industry. The objective of this project is to understand the origin of Magnetic Flux Leakage (MFL) signals from dents, the ultimate goal being to accurately characterize dents from MFL field inspection data.

Mechanical damage produces magnetic flux leakage (MFL) signals that are unique, and are comprised of a geometry component and a characteristic component related to the residual stress present in the region of the damage. However, current MFL technology limits its reliable application to mechanical damage detection since signals are too weak and are not sufficiently isolated from background influences to allow for adequate damage characterization and interpretation. In this project, experimental and finite element modelling techniques are used to separate and understand both stress and geometry contributions to the MFL signals.

Earlier work by the Queen's University Applied Magnetics Group involved examination of MFL signals from circular dents. The present US DOT PHMSA contract extends this study to include oval or "elongated" dents–specifically dents having a 2:1 length to width aspect ratio.

Research conducted this quarter focused on Task 1 – "Examine the effects of dent ovality on MFL signals." This included Finite Element Analysis (FEA) modeling of MFL signals from dents having shapes and sizes that are more characteristic of those found in mechanically damaged pipelines, namely oval dents of various orientations. Specifically, research was conducted on the following subtasks:

Subtask 1.1 – Design and construct oval tool and die equipment for creating oval dents in experimental plate samples (using existing hydraulic press).

Subtask 1.2 – Model stress distributions around dents using stress FEA software

Subtask 1.1

In this quarter the elongated denting tool was designed and constructed. The design is consistent with that of the circular denting tools used in previous studies conducted by Queen's University. The tool and die (male and female parts, respectively) are shown in Figure 1. Note that in this picture the tool and die are completely separate items and the tool is simply resting on the die.

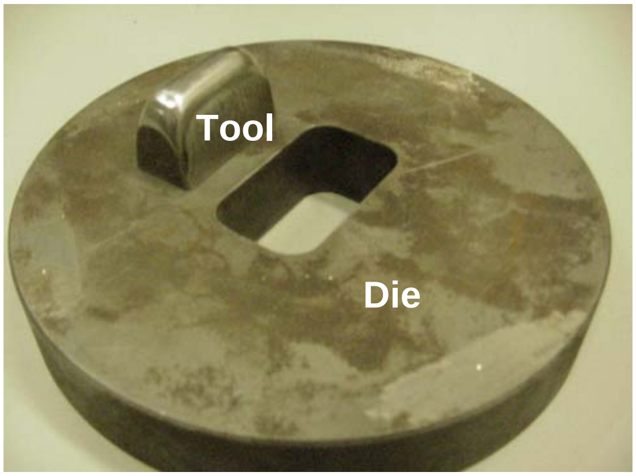


Figure 1: elongated tool and die used for denting in the present study

A 50kN hydraulic press is used to create the dents. The tool is attached to the hydraulic ram using a screw fitting, while the die sits on a support platform below. Samples are plates of mild steel. They are placed on the die and the tool is lowered to create dents of varying sizes.

Test dents were made to evaluate the effectiveness of the denting rig. A typical test dent is shown in Figure 2. Figure 2(a) shows the topside of the dent, while Figure 2(b) shows the underside.

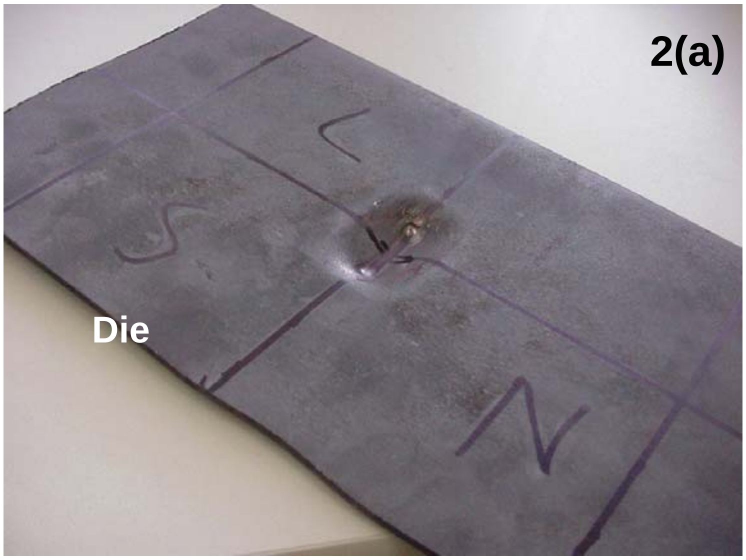
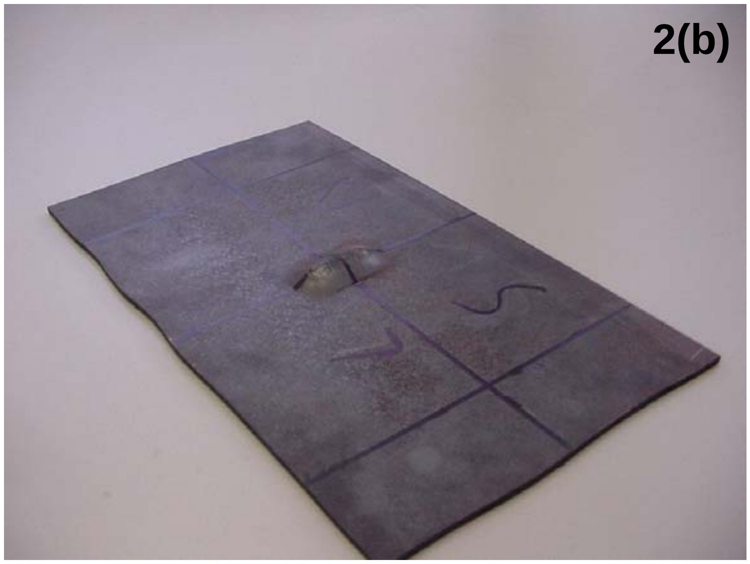


Figure 2. Dent created using the elongated denting tool shown in Figure 1.
a) topside of dent
b) underside of dent



Subtask 1.2

Accurate modelling of the residual stress pattern around the dents is necessary for subsequent magnetic FEA models, since this stress information is used to alter magnetic permeability functions in the magnetic models. A diagram of the modelled denting tool and die, with the plate in place, is shown in Figure 3. The punch stroke dents the metal plate after which the tool is removed and the residual stress analysed.

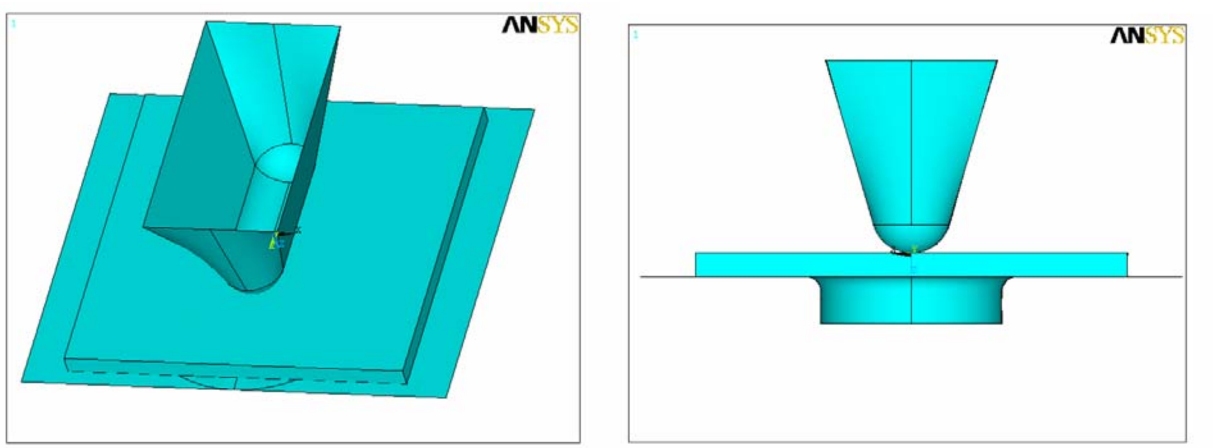


Figure 3: The modelled tool, die and plate used for obtaining the residual stress patterns for elongated dents.

After the tool was "removed" in the model the residual stress distribution was analysed in the plate. Figures 4 and 5 are two examples of typical residual stress patterns; the normal x direction residual stress and the residual shear stress in the xy plane, respectively. These and other residual stress patterns are analysed carefully in order to be able to 'assign' specific stress values to particular regions within the magnetic FEA model.

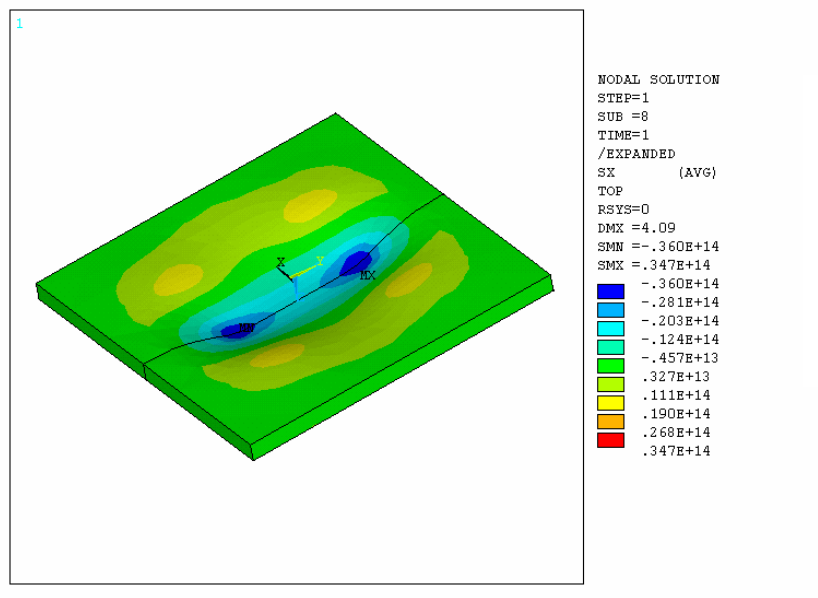


Figure 4. Residual normal stress in the x direction. The scale on the right indicates stress in Pa.

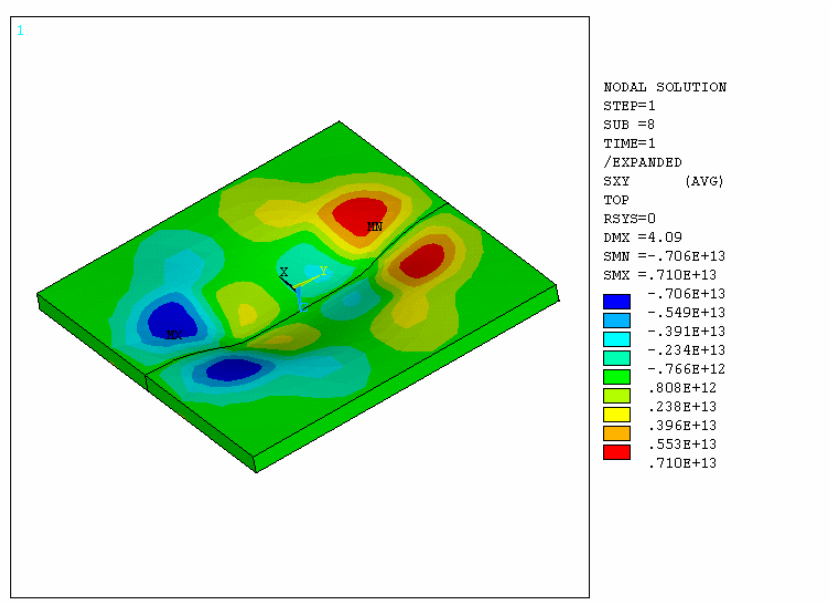


Figure 5. Residual shear stress in the xy plane. The scale on the right indicates stress in Pa.

The magnetic FEA modelling of MFL signals from axially-oriented dents began this quarter and is scheduled to continue into the second quarter of this project. Thus far, the FEA residual stress modelling results have been used to establish regions within the magnetic FEA model which will have different magnetic permeabilities. A magnetic model was constructed for the axially oriented elongated dent (only a quarter model is necessary because of symmetry). The segments in and around the dent region indicate the regions where different permeabilities will be assigned. There are a total of 112 separate segments in this model. The finite element mesh is much smaller than the size of these segments.

In the second quarter of this project magnetic permeability functions will be assigned to the individual segments of the magnetic FEA model. At present, however, all of the segments have an isotropic magnetic permeability that is identical to that of the background plate away from the dent. The "geometry only" MFL result is obtained from this fully isotropic model. Figure 6 shows the 'geometry only' MFL result (radial MFL component B_z) for the model.

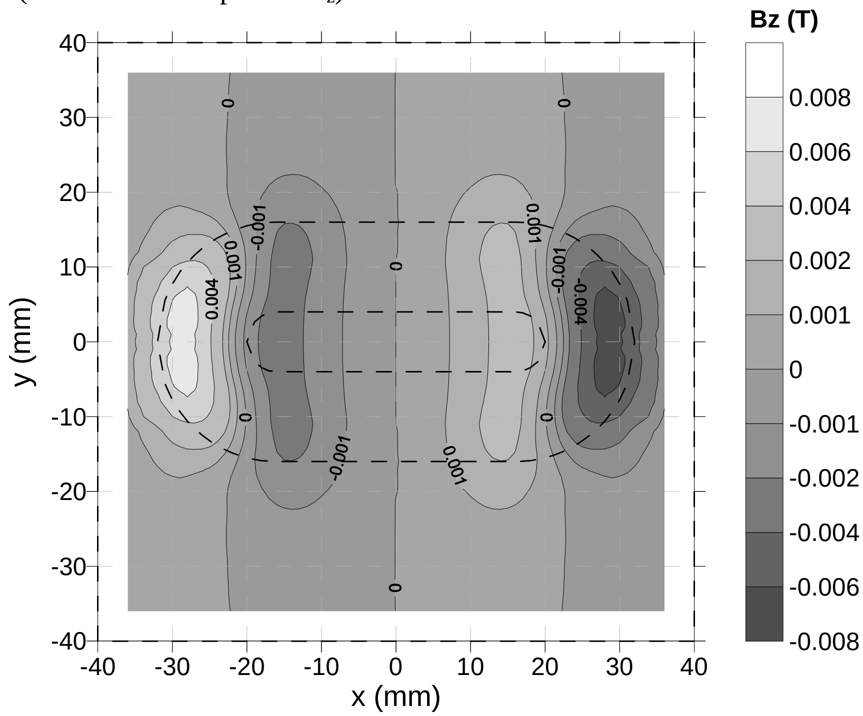


Figure 6: Geometry only MFL contour plot (in the radial (z) direction) for the axially elongated dent model. The dotted lines on the plot indicate the dent bottom and the dent perimeter.