FOURTH QUARTERLY REPORT

DTPH56-14-H-00008
"Definition of Geotechnical and Operational Load Effects on Pipeline Anomalies"

SUBMITTED BY: **Team Project Manager**
Abdelfettah Fredj
BMT Fleet Technology
311 Legget Drive
Kanata, Ontario K2K 1Z8 Canada
Telephone: (613) 592-2830
E-mail: afredj@fleetech.com

TEAM TECHNICAL COORDINATOR: **Team Technical Coordinator**
Aaron Dinovitzer
BMT Fleet Technology
311 Legget Drive
Kanata, Ontario K2K 1Z8 Canada
Telephone: (613) 592-2830
E-mail: adinovitzer@fleetech.com

TEAM PARTICIPANTS: BMT Fleet Technology Limited
A Fredj, A Dinovitzer and R Gailing

SUBMITTED TO: U. S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Mr. Warren D. Osterberg
Agreement Officer
warren.osterberg@dot.gov

REPORTING PERIOD: November 1, 2014 – January 31, 2015
SUBMITTED ON: January 28, 2015

Table of Contents

List of Figures

2.0 Technical Status

2.1 Technical Progress

<u>Task 1: - Project Kickoff</u>

The meeting discussion and actions were documented in meeting minutes posted to the project website.

<u>Task 2: Documentation of Model Validation</u>

The project team completed preparation of the model validation report from previous work describing the numerical model that will support this project and its capabilities as simulation tool. The report was submitted and posted to the project website.

<u>Task 3: Model Development and Demonstration</u>

<u>Objective</u>: Describe and demonstrate the simulation process to support discussion and confirmation of the project scope of work.

<u>Scope:</u> The scope of this task was to complete three subsidence and three lateral soil movement simulations with differing pipe geometries, soils, materials and operating conditions to illustrate the impact of the problem parameters on the analysis results.

<u>Activities:</u>

The project team completed the preparation of a 3D continuum model to simulate three ground subsidence due to coal-seam mining and three lateral movement simulations. The development was conducted in two steps. In the first step, the soil model considered only the prediction of ground subsidence due to coal-seam mining without considering the effects on pipelines. In the second step, the model considered both the prediction of the ground subsidence and the effects on the pipeline.

- Three subsidence simulations were completed to predict the pipeline response to surface subsidence due to coal-seam mining and illustrate the impact of the width of subsidence area on the analysis results. The analyses were completed for a 30-inch pipeline with 7.92 mm wall thickness, considering the subsidence resulting from a longwall mine face length of 300 m, seam depth of 100m, extraction height of 5m, and three different extraction widths including:
    - Case1: Sub-critical panel extraction width– of W=75 m that has a W/H ratio of 0.75
    - Case2: Critical panel extraction width of 150 m with a W/H ratio of 1.5
    - Case3: Super-critical panel extraction width of 300 m with W/H ratio of 3.
- Three lateral simulations were completed to predict the pipeline response to surface lateral soil movement and illustrate the impact of the width of subsidence area on the analysis results. The analyses were completed for a 30-inch pipeline with 7.92 mm wall thickness, considering ground movement widths of 10m, 20, and 40m.

The report describing the geotechnical simulation process and results in supports in support of an information and technical direction progress meeting was prepared and submitted.

Task 4: Modeling of Subsidence Hazard

Objective: Complete a sensitivity study to define the relationship between problem parameters and the pipe strains developed in soil subsidence events and identify trends.

Scope: The scope of this task is to develop and simulate a range of pipe soil subsidence scenarios considering differing pipe geometries, soils, pipe materials and operating conditions to define the impact of the problem parameters (e.g., depth of subsidence, subsidence length, surcharge) on the analysis results. It is expected that the modeling process will describe pipeline response in terms of axial and bending stresses and strains (or loads), pipe deformation and potential for buckling/wrinkling. These sample modeling results will be used to develop an empirical relationship between the pipe, pipeline, geotechnical and operating parameters affecting peak pipe strains.

Activities:

Analyses were completed for the 30-inch pipe and 40-inch to assess its response subsidence due to coal-seam mining and illustrate the impact of the width of subsidence area on the analysis results.

The strain demand determined from the analysis was compared with the calculated strain limits defined from the guidance provided by BS 7910 for tensile strain, CSA-Z662 and PRCI 2004 for compressive strain. The objective was to develop a simple method to define the effects of operational and geotechnical loads on liquid and gas pipeline systems to support decision making regarding threat severity or repair scheduling. This tool incorporated in strain based design and assessment to facilitate the consideration of complex loading scenarios inducing significant flexural loads, including pipeline subsidence or lowering, and ground movements inducing lateral pipeline movements.

Figure 2 shows an example the axial tensile strains envelope for the 30-inch pipe as a function of the panel width to mining depth ratio (W/H).

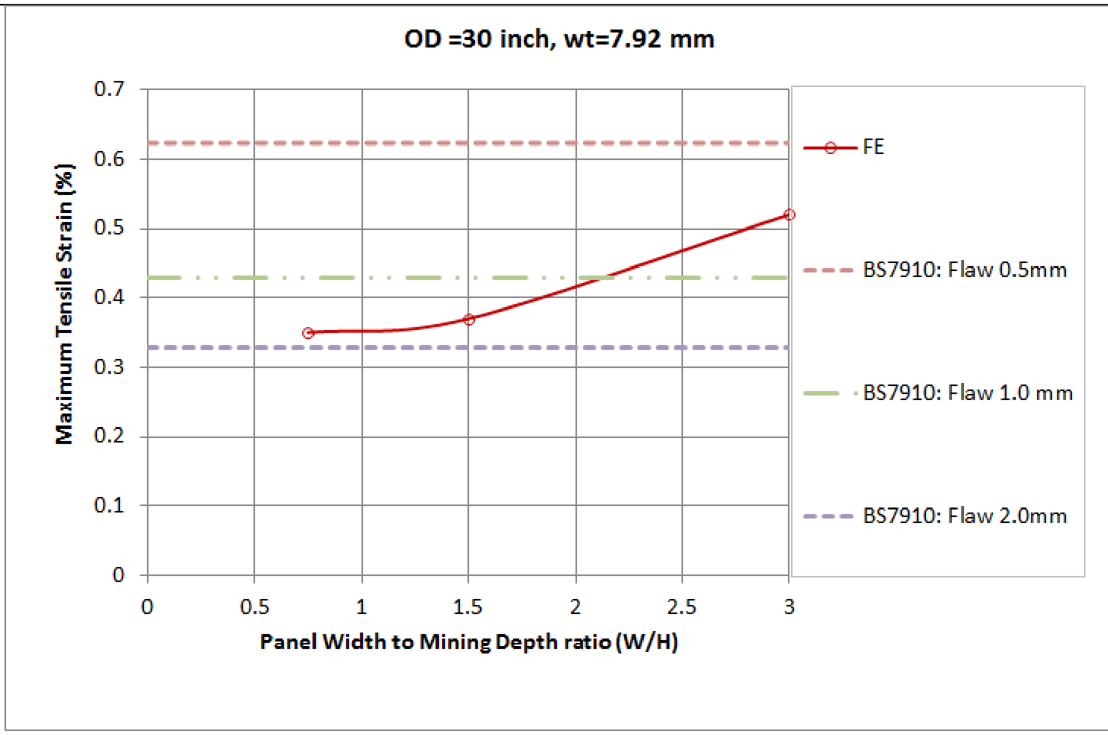

Figure 2: Maximum Tensile Strains in the Pipe in Relation to Panel Width to Mining Depth Ratio (W/H)

Task 5 –Modeling of Lateral Soil Movement

Objective: Complete a sensitivity study to define the relationship between problem parameters and the pipe strains developed in lateral soil movement events and identify trends.

Scope: The scope of this task is to develop and simulate a range of pipe soil lateral movement scenarios considering differing pipe geometries, soils, pipe materials and operating conditions to define the impact of the problem parameters (e.g., soil movement width, surcharge) on the analysis results. It is expected that the modeling process will describe pipeline response in terms of axial and bending stresses and strains (or loads), pipe deformation and potential for buckling/wrinkling. These sample modeling results will be used to develop an empirical relationship between the pipe, geotechnical and operating parameters affecting peak pipe strains.

Activities:

Analyses were completed for the 30-inch pipe and 40-inch to assess its response to lateral ground movement and to determine the structural integrity significance of ground movement induced strain demands. The analyses considered a total of seven (7) potential slope failures with a total estimated width of failure along the pipeline approximately 5 m, 10 m, 15 m, 20 m, 30 m, 40 m and 50 m.

The report describing the geotechnical simulation process and preliminary results in supports in support of an information and technical direction progress meeting is being prepared for submission in the next couple of days

The results of the finite element analyses were interpolated, to produce an envelope defining the combinations of ground displacement and width where the pipe was safe and not safe. Failure or "not safe Pipe" was presumed to occur if the axial strains (tensile and/or compressive strains) at any location exceeded strain limits defined from BS 7910, CSA-Z662 and PRCI 2004.

The objective was to develop a simple method to define the effects of operational and geotechnical loads on liquid and gas pipeline systems to support decision making regarding threat severity or repair scheduling. This tool incorporated in strain based design and assessment to facilitate the consideration of complex loading scenarios inducing significant flexural loads, including pipeline subsidence or lowering, and ground movements inducing lateral pipeline movements.

Figure 3 shows an example of developed 30 inch (D/t=96) set of pipe safety envelopes for BS7910 tensile strain limits, considering a flaw size of 0.5mm, 1mm and 2mm. Figure 4 shows a set of pipe safety envelopes for CSA-Z662 and PRCI compressive strain limits. The results show the importance of ground soil movement width. It shows that the critical soil movement width that maximizes pipe bending moments and strains are about 5m to 10m for the 30 inch pipe.

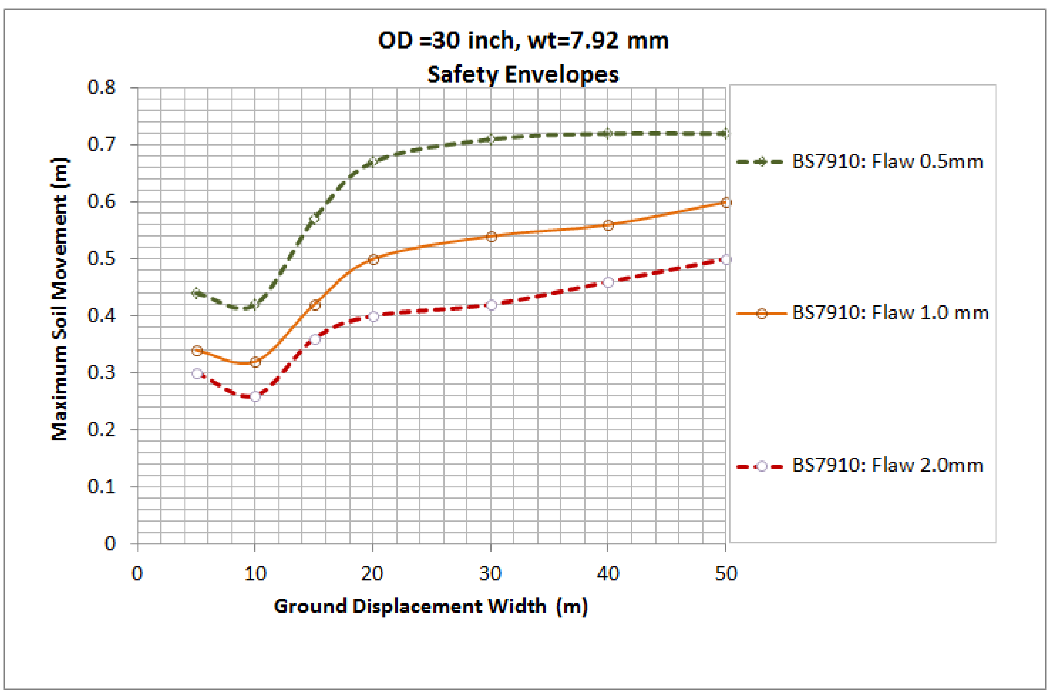

Figure 3: Safety Envelopes: Tensile Strain Limit

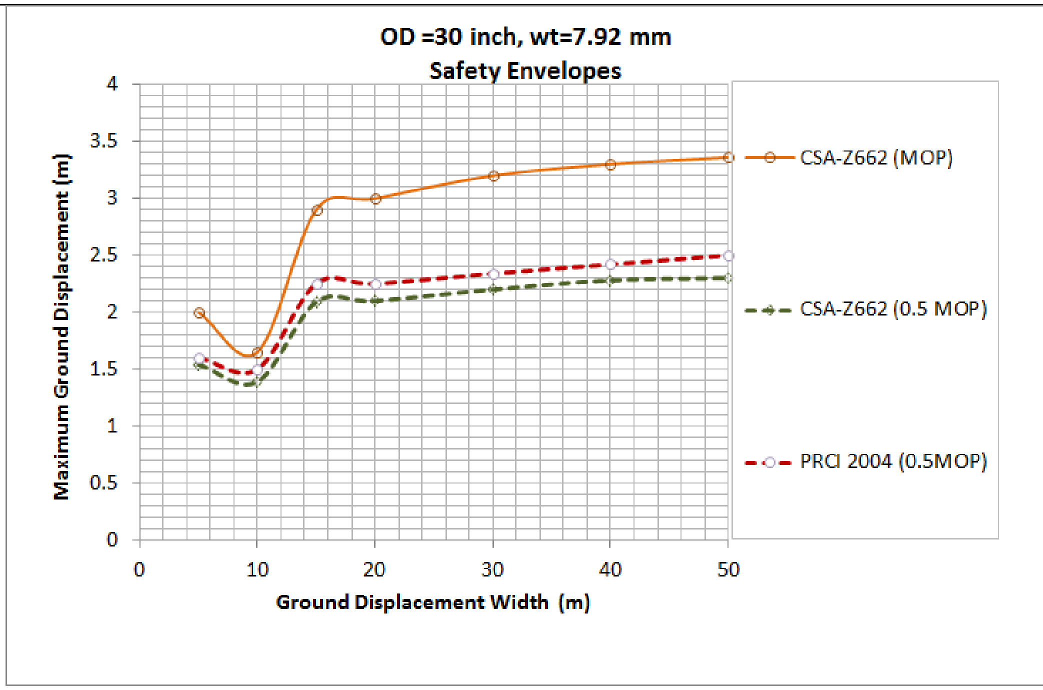

Figure 4: Safety Envelopes: Compressive Strain Limit

<u>Task 6: Project Management and Reporting</u>
The work completed in this task in the last quarter included:

- The project team prepared project status reports
- Peer review meeting and presentation
- Communication with members of the project Advisory Panel to discuss project direction. A formal meeting has not been held or scheduled.

2.3 Plans for Future Activity

Over the next 30-60 days, the following activities will be conducted:

<u>Task 4: Modeling of Ground Subsidence</u>
A sensitivity analysis is being carried to define "safety envelopes" for the case where pipe is loaded by ground subsidence. Safety envelopes were defined with respect to the combination of the panel width to mining depth ratio (W/H) for various soil strengths, pipe geometry (D/t), steel grade and pipe to soil coefficient of friction.

The project team will complete and submit a report describing the geotechnical process and results in support of an information and technical direction progress meeting.

<u>Task 5 –Modeling of Lateral Soil Movement</u>

A sensitivity analysis is being carried to define "safety envelopes" for the case where pipe is loaded by lateral ground movement. Safety envelopes were defined with respect to the combination of ground displacement width for various soil strengths, pipe geometry (D/t), steel grade and pipe to soil coefficient of friction.

The project team will complete and submit a report describing the geotechnical process and results in support of an information and technical direction progress meeting.

Task 7: Project Management and Reporting

The project team will complete and submit the upcoming required monthly and quarterly reports.