Axial and Lateral Sliding of Pipe on Simulated Soft Soil Seabed

Mohammad Sarraf. J and C. Vipulanandan, Ph.D., P.E.
Texas Hurricane Center for Innovative Technology (THC-IT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
Email: msarrafj@central.uh.edu, cvipulanandan@uh.edu, Phone: (713) 743-4278

Abstract: Deep-water oil pipelines rest on very soft seabed and are susceptible to axial and lateral movements which are heavily dependent on the pipeline penetration at every stage. Hence, predicting the initial embedment of pipeline after installation or any major changes in the seabed (in our case, severe earthquake) is one of the important design considerations for the bottom stability analysis. Lagrangian Finite element technique with mesh refinement was used to model the pipe soil interaction in the soft soil. The pipe was modeled in Lagrangian and the soil was modeled in Eulerian framework.

1. Introduction.

Offshore pipe embedment is a large deformation problem. Various techniques have been proposed in the past to overcome numerical difficulties in large strain finite element modeling, which include updated Lagrangian, updated Eulerian, pure Eulerian, mesh free and Arbitrary Lagrangian Eulerian, (Wang, 2010). Simulated pipe embedment using remeshing and interpolation technique with small strain (RITSS) and recently implemented Coupled Eulerian Lagrangian (CEL), (Dutta, 2012). In this approach material flow through the fixed mesh and therefore there is no meshing issue at large deformation.

2. Objective

The main focus of this study was to conduct FEM analysis on pipe subjected to vertical loading (self-weight) and lateral loading (earthquake) and investigate the vertical penetration of pipe on a very soft soil. Determine the dynamic force displacement response of a typical PIP subsea pipeline after the laying procedure and after dynamic displacement of soil due to an earthquake in the horizontal direction.

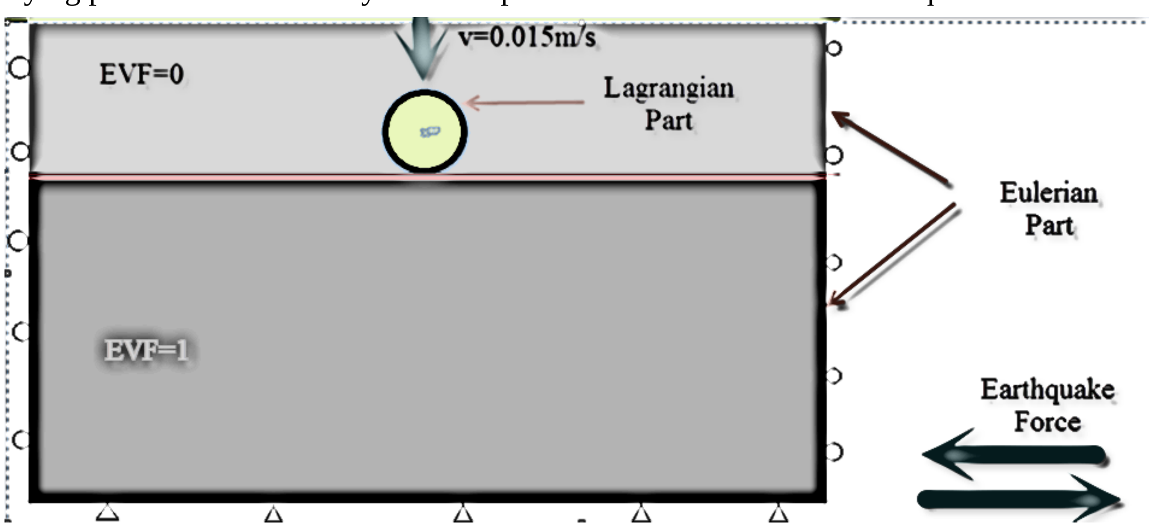

Figure 1.Finite Element model used in this study

3. FEM Formulation and Parameter Selection

A steel pipe of 0.8 m diameter (D) was modeled in this study. To model the soil an Eulerian domain of 8 m × 4.5 m× 0.04 m (width × height × t thickness) was used(Fig.1) the soil was modeled as an elastic perfectly plastic material. Eu=500su0 and poison's ration is taken as 0.49 with a unit weight of 1620 $\frac{\mathrm{kg}}{\mathrm{m}^3}$ for clay. In this study the numerical analyses was divided into four steps. The first step is the geostatic step. During the geostatic step pipe is kept outside the Eulerian part and the gravity and geostatic force applied to pipe. In the second step, the pipe is moved downward in given velocity to the seabed. Since this movement occurs only through the void, no reaction forces observed during this step. In the third step, pipe starts to penetrate into the seabed due to gravity load. And the analyses shifts from displacement control to force control. Simultaneously, a cyclic lateral movement due to the vessel movement during the installation applied to the pipe. In the fourth step earthquake acceleration in the x direction using the amplitude option for the duration of 2 second was applied at the bottom of Eulerian part. In parallel, a fully displacement controlled analyses was conducted to measure force displacement response of pipe over subsea seabed.

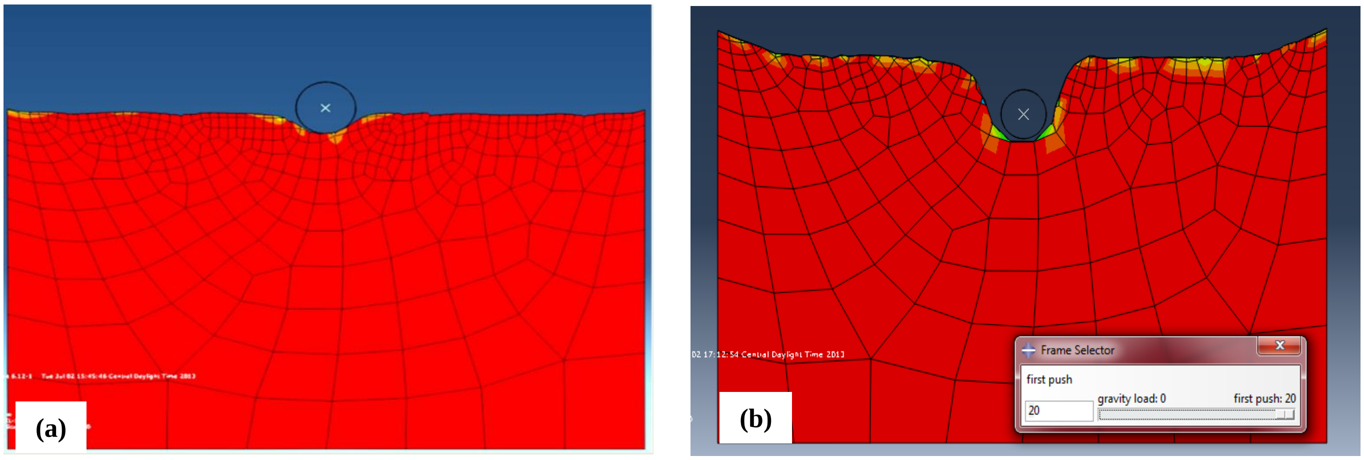

Figure2. Vertical Pipe penetration (Eulerian) a) Subjected to installation force b) After Earthquake Excitation

4. Result and Discussion

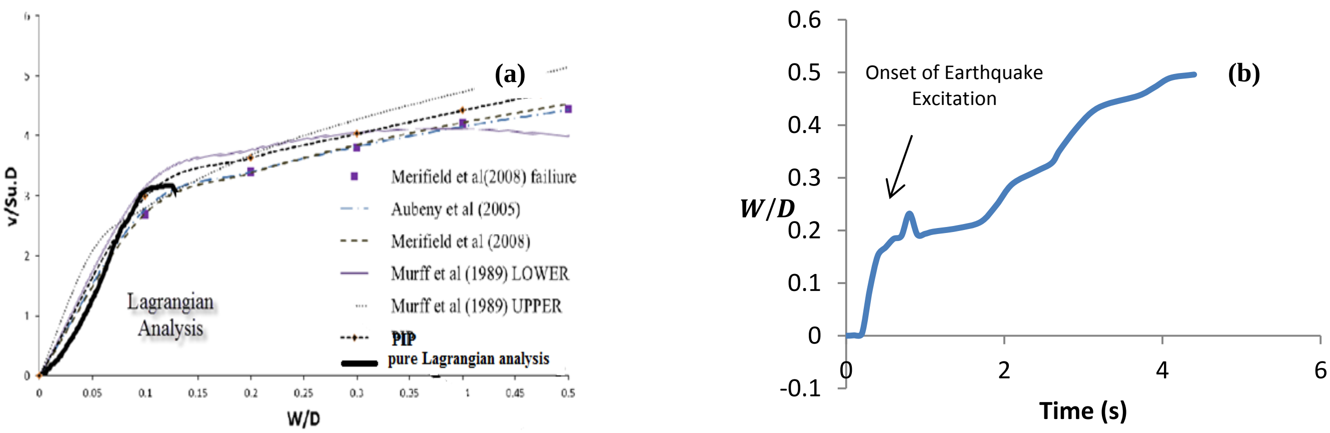

Figure3. a) Normalized Force (V) – Displacement (W) response in Pure Lagrangian Analyses for Displacement control with ALE meshing. b) Penetration Vs. time during installation and Earthquake loading in Coupled Eulerian Lagrangian Analyses (CEL) and at loading control stage.

5. Conclusion

Combined Eulerian –Lagrangian approach can be used to model the pipe behavior in soft soil.

6. Reference

1. D.J. White, U. o. W. A. (. U. o. C. et al., 2011. SAFEBUCK JIP - Observations of Axial Pipe-soil Interaction from Testing on Soft Natural Clays. Offshore Technology Conference,.

2. G.M. Wantland, W.-C. C., M.W. O'Neill, U. o. H., L.C. Reese, U. o. T. a. A. & and E.H. Kalajian, F. I. o. T., 1979. Lateral Stability Of Pipelines In Clay.

3. Harald Brennodden, S. a. A. S. N. N. S., 1992. Time-Dependent Pipe-Soil Resistance for Soft Clay. Offshore Technology Conference,.

4. J.M. Schotman, K. E. L. a. F. S., 1987. Pipe-Soil Interaction: A Model for Laterally Loaded Pipelines in Clay. ffshore Technology Conference, p. 8.