Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Experimental testing of the performance of pipeline ploughs

Keith Lauder, Fraser Bransby, Michael Brown
University of Dundee, Scotland.

David Cathie, Neil Morgan
Cathie Associates, SA/NV, Brussels, Belgium.

Jim Pyrah, Julian Steward
CTC Marine Projects Ltd, Darlington, England.

ABSTRACT

The influence of relative density and trenching depth on the pitch a pipeline plough travels at have been investigated by means of 1/50th scale model plough testing. Tests were performed in dry sand at two relative densities with the model plough set up to form trenches of various depths. The relationships between plough pitch and depth are presented and compared between the two sand densities. The results show that relative density and depth can have a significant effect on plough pitch with possible repercussions for plough stability and trenching depth.

KEY WORDS: Plough; pitch; pipeline; trenching.

INTRODUCTION

Small diameter offshore pipelines are frequently buried in the seabed to a depth of several pipeline diameters. Burial is used as protection to prevent external loading from fishing activity/snags or hydrodynamic loading and to prevent movement of the pipeline during thermal expansion on commissioning (Finch et al, 2000).

One method of pipeline burial is ploughing. In this method, a pipeline plough is towed by a vessel to form a trench on the seabed into which the pipeline is placed. A second pass from a backfill plough is used to replace the soil from the spoil heaps above the pipeline to achieve an appropriate cover depth.

The two main areas of commercial operational interest with offshore ploughing are the achievement of an appropriate cover depth (with a flat trench profile) in a single pass of the pipeline plough, and the rate at which the pipeline ploughing can be carried out. Clearly, either the requirement for multi-pass ploughing or slow plough speeds will increase necessary vessel time and therefore cost.

Tow forces are believed to increase with both plough depth and velocity (e.g. Reese & Grinstead, 1986; Cathie & Wintgens, 2001; etc.). In particular, plough tow forces increase with rate at typical ploughing velocities allowing for only partial drainage of material being sheared (e.g. Hata, 1979; Reece and Grinsted, 1986; Os and van Leussen, 1987). Therefore, increasing relative density (which produces more dilation) and reducing permeability (which slows water flow to the dilating zone) also increase tow forces because of the amount of drainage that occurs during ploughing (Cathie & Wintgens, 2001). A pipeline plough vessel pulls with a certain maximum force, and so the maximum ploughing rate that can be achieved depends on the tow force – velocity relationship at the target trench depth for the soil encountered. Thus, accurate prediction of tow forces (both in terms of the forces for slow ploughing and the variation in tow force with velocity) allow for correct estimation of job duration and cost.

In addition, the stability of a pipeline plough during any trenching operation is critical to making steady progress with as few stoppages as possible. It is important for plough stability that the pitch (tilt along the length of the plough, see Palmer et al., 1979) is kept close to zero and constant to ensure the same trenching depth is maintained throughout the length of the trench.

This paper focuses on the effect that trenching depth and sand density have on the kinematics of a pipeline plough and is investigated experimentally by pulling a 1/50th scale model plough at various trenching depths through loose (D_r = 26%) and dense (D_r = 76%) sand beds. The tests were all conducted in dry sand and therefore no investigation of rate effects was undertaken.

Plough kinematics

During operation, trenching depth is controlled by the skid settings and maintained by dynamic equilibrium of moments about the skids due to forces acting on the beam, share and its base. Figure 1 shows the main