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Pre-Trenching, Pre-Sweeping and Backfilling for the 36" Offshore Pipeline Project in Taiwan

Abstract

The advantages of a trailing suction hopper dredger for a pipeline trenching job is the focus of this paper. This is illustrated by the versatility of this particular kind of equipment on the 36" Offshore Pipeline Project in Taiwan. On three separate occasions during this project, the TSHD proved her capabilities.

First, large water depths were overcome by using the special deep dredging equipment.

Secondly, unexpected soil-problems such as flow-back of soil into the freshly excavated trench and thirdly, freespans caused by scour phenomena were tackled by using the vessel in a jetting-mode.

As such the trailing suction hopper dredger saved the project from having to mobilise expensive specialised equipment and from large delays owing to the unexpected problems.

Introduction

In 1999 Jan De Nul was awarded the trenching and backfilling works for the 36" Offshore Pipeline from Yung-An to Tung-Hsiao in Taiwan (Figure 1). The works were executed under a subcontract from Hyundai Heavy Industries with Chinese Petroleum Company (CPC) as the ultimate Client.

The scope of work involved pre-trenching over a total length of 236 km, pre-sweeping in sand-wave areas and backfilling of the trench with sea-dredged material after pipeline installation. Part of the works had to be executed in dredging depths up to 112 m. In Figure 2 a longitudinal depth profile of the route is shown.

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The 238-km-long pipeline is transporting LNG from Yung-An in the south of Taiwan where the gas arrives in vessels at a LNG-terminal to Tung-Hsiao in the middle of Taiwan. The background for this offshore transport are the structural energy shortages of the north of the island compared to the south and the predictable difficulties in installing an onshore pipeline through one of the most densely populated coastal plains of the world.



Figure 1. Overview of Taiwan with offshore pipeline route from Yung-An to Tung-Hsiao.

A summary of the main characteristics of the project is given in Table I.

The subject of this article will be three occasions on this project where the trailing suction hopper dredger (TSHD) *Gerardus Mercator* demonstrated her versatility.

- The first instance was when pre-trenching had to be executed in water depths of more than 65 m over approximately 100 km and with a maximum water depth up to 112 m.
- The second instance was when during pre-trenching a section in the pipeline route was encountered where the seabed was extremely volatile and it proved impossible to make a trench that would remain open at depth until the lay-barge reached that position. As a solution, post-trenching was executed over a section of 16 km after pipe-lay.
- The third occasion was during the backfilling phase of the project when, during a pre-backfill check survey, it was found that some extreme scouring had occurred since pipe-laying the previous year. With the TSHD *Gerardus Mercator* in jetting mode the resulting freespans were corrected which allowed the backfilling, hydro-testing and further commissioning to be executed.

PRE-TRENCHING IN WATER DEPTHS UP TO 112 M

Over approximately 100 km of the pipeline route, pre-trenching had to be executed in water depths of more than 65 m with a maximum reaching 112 m. Over this

Figure 2. Pipeline depth profile.



Table I. Summary of Project Details

Project name	36" Yung-An to Tung-Hsiao Offshore Pipeline Project
Country	Taiwan
Client	Chinese Petroleum Corporation (CPC) of Taiwan
Main Contractor	Hyundai Heavy Industries (HHI) of Korea
Subcontractor for trenching and backfilling	Jan De Nul Group of Companies
Total length of pipeline	237.8 km
Maximum waterdepth	112 m
Landfall	South: at Yung-An (near Kaohsiung) by means of Horizontal Directional Drilling North: at Tung-Hsiao (near Taichung) by means of Open Cut and Cofferdam
Equipment	Lay-barge "HD-423" TSHD "J.F.J. De Nul" and "Gerardus Mercator" equipped with the deep-dredging installation (1200mm diam suction pipe with 3600kW underwater pump) Cutter Suction Dredger "Vesalius"
Length of pre-trenching and pre-sweeping	218.5 km
Length of post-trenching	16.0 km
Length of landfall dredging (Tung-Hsiao)	1.6 km
Total length trenched	236.1 km
Pre-sweeping sand waves in two sections:	
– height up to 2 m	KP-134 to KP-146, length 12 km
– height up to 12 m	KP-193 to KP-202, length 9 km

section the deep dredging diameter 1200 mm suction pipe with 3600 kW underwater-pump of the TSHD *Gerardus Mercator* was used. New safety procedures in relation to any given sea-state were introduced in order to limit the stresses in the suction pipe and working limits were determined. This was of particular importance as no replacement vessel would have been available in case damage had occurred in areas with water depths over 75 m.

In view of the large water depths and the remoteness of the offshore work site, all survey works were executed by means of a multi-beam echosounding system installed in the moon pool of the TSHD. This provided on-line day-to-day survey information for the project team and Client representatives on board of the vessel. As such, the TSHD *Gerardus Mercator* operated as a fully independent trenching and backfilling unit.

POST-TRENCHING ON A 16-KM-LONG SECTION

Towards the end of the construction season in 1999, the TSHD *J.F.J. De Nul* (Figure 3) was trenching in an area between KP-130 and KP-160 where the soil behaved very liquid-like. The materials dredged consisted of very fine sand with a plate-shape for the individual grains. It proved virtually impossible to obtain reasonable slopes as the sand kept on flowing back to the trench.

Another indication of the very low consistency of the sand was the fact that the sand waves in the same area were moving rapidly. From subsequent multi-beam surveys it could be deduced that the crests of the waves were moving at a speed of 5 to 10 m per day. The water depths were between 26 m and 45 m and currents were relatively high.



Figure 3. Trailing suction hopper dredger J.F.J. De Nul was one of two trailers used for pre-trenching operations.

As a result of these difficulties it was proposed to replace pre-trenching of the section between KP-144 and KP-160 by post-trenching using a trailing suction hopper dredger. As most of the section was trenched up to full design trench depth no unexpected obstacles had to be foreseen during post-trenching. Client and Main Contractor accepted this and at the start of the second construction season in 2000 post-trenching was successfully executed by the TSHD *Gerardus Mercator* on a flooded pipeline (Figure 1).

Equipment

As part of the research and development programme at Jan De Nul, a newly designed jet-head had been tested on the project as a (pre-)trenching device. This device was mounted at the end of the suction pipe of the TSHD in the same way as a regular drag-head.

By re-configuring the valve positions onboard the vessel, the flow which normally runs from the seabed to the surface was reversed. As such, one of the high capacity dredge pumps on board the vessel was being used as a provider of a low-pressure, high-volume jet-stream. At the same time the separate standard jet-pumps on board were also led to the jet-head in order to liquefy the soil.

The jet-head was equipped with two kinds of nozzles:

- The high-pressure nozzles are fed by the vessel's two jet-pumps in series. These jets are used to liquefy the soil in front of the jet-head. In case of the TSHD *Gerardus Mercator*, the jet-pumps can achieve a maximum pressure of 9.5 bar.

- The large low-pressure nozzles are fed by one of the vessel's dredge pumps. The low-pressure, high-volume water-flow created was directed to remove the liquefied soil out of the trench. The working pressure of these jets was approximately 2.7 bar at a flow-rate of more than 5 m³ per second.

As part of the R&D programme the jet-head was conceived so that the nozzles could be closed or re-directed in order to influence direction, exit-pressure and flow.

The multi-beam survey system was also used during the post-lowering operations to monitor the pipeline position by performing regular survey-runs.

Pipeline safety during post-lowering

The jet-head described above was primarily conceived as a pre-trenching device. The concept of post-lowering by jetting is based on the same principles, but an important additional concern is that the product-pipe is already in place. On the other hand it is clear that the closer the jet-stream comes to the soil the more effective it is. This obviously raises issues with respect to the safety of the pipeline.

The first objective is to ensure that the jet-head never touches the pipeline. Therefore, the jet-head was kept a certain distance above the top of the pipeline to provide a safe margin with respect to swell induced movements of the vessel and inaccuracies in the positioning of the jet-head. Whereas the swell could not be controlled, the second factor is tackled by providing an accurate positioning of the jet-head based on

Differential Global Positioning System (DGPS) and Suction Tube Position Monitoring system (STPM).

This measured position is visualised on the dredge monitoring system on the bridge superimposed on the seabed and pipe-position data as obtained from regular multi-beam survey runs. Highly skilled operators in combination with a Dynamic Positioning and tracking system (DP) allowed executing these very secure operations with a safe distance between top of pipeline and jet-head of 2.5 m depending on the swell conditions.

On a second level, protective measures were foreseen to avoid damage to the pipeline in the unlikely event of contact between the jet-head and the pipeline. The jet-head was made virtually weightless under water by adjusting the pressure in the swell compensation devices (DEICO) so that the weight of the jet-head and suction pipe was compensated by the pull-force in the

lifting wires. As a result the jet-head virtually floats through the water. Also, a steel frame padded with softwood on the outside was added around the perimeter of the jet-head.

Next to previous considerations on the part of the operations and equipment of post-trenching, the engineering side of the matter was also carefully studied. Here, the main concern is inducing stresses and strains in the pipeline as a result of too strong or differential results of the jetting. One could imagine that with the power involved the soil could be liquefied too deep. This would have resulted in a situation where the pipeline behind the jet-head could be too deep in comparison with the pipeline before the jet-head. This bending radius induces over-stressing of the pipeline. From acceptable bending radius of the pipe and expected excavation rates during post-lowering it was calculated that the vessel speed should never drop below 0.5 kn along the pipeline.

Figure 4. Trailing suction hopper dredger Gerardus Mercator at work post-trenching the 16 km between KP-144 and KP-160 (an artist's impression).



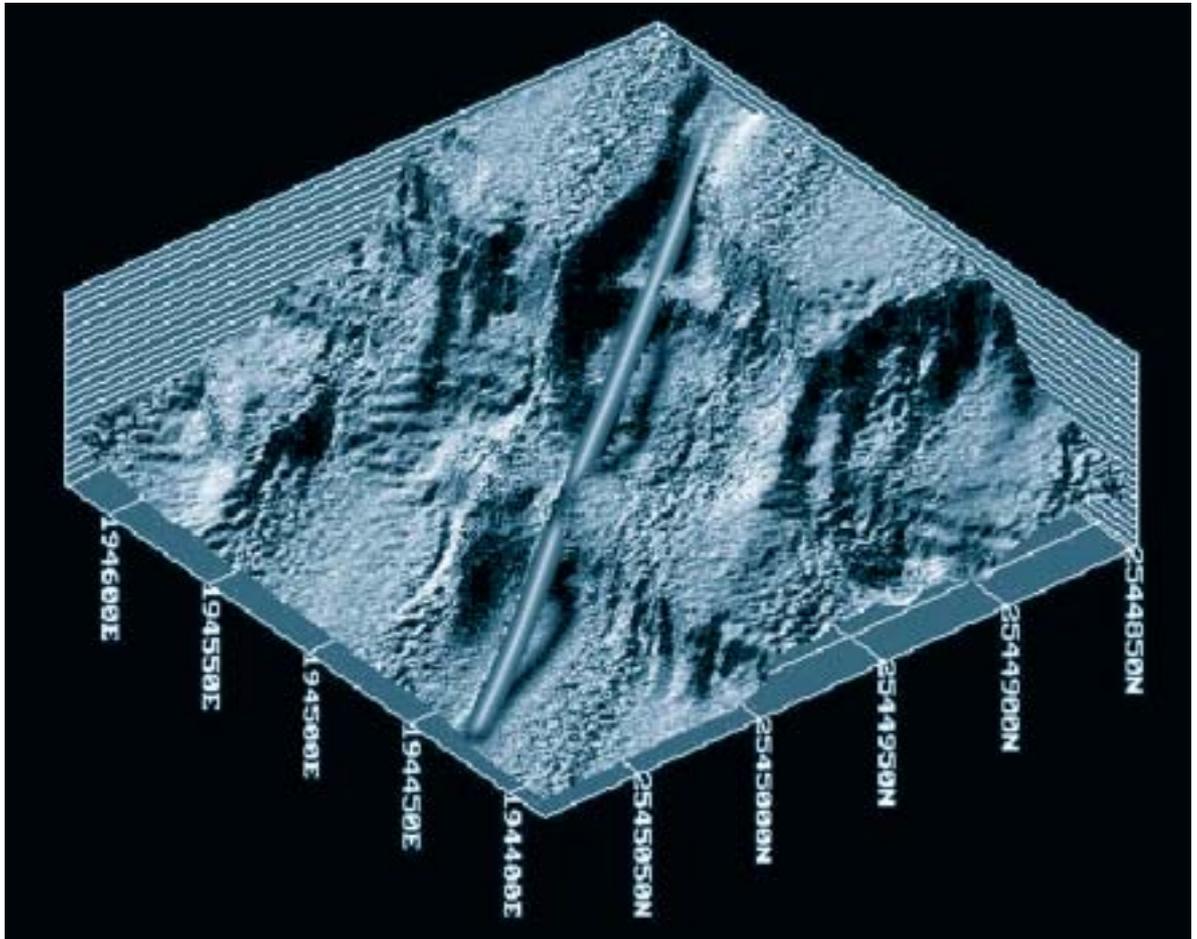


Figure 5. Three-dimensional view of the pipeline freespanning near KP-32.

FREESPAN CORRECTION AT 90 M WATER DEPTH

During the backfilling phase in 2000, standard procedure was to perform a pre-backfill survey in order to determine actual conditions of the trench and the pipe. This was necessary because the southern section of the pipeline had been laid more than one year earlier.

Near KP-32 this pre-backfill survey revealed three major freespans of 40 m, 90 m and 80 m length. In fact the pipe was suspended over a total length of about 300 m only supported by two limited lengths of seabed (Figure 5). Stress and strain analysis indicated that the pipeline in its present position was not over-stressed, but could not survive flooding, testing or operations.

After study and comparison of the as-trenched and as-laid surveys executed in the previous year with the new pre-backfill survey the preliminary conclusion was that the freespans were the result of scour phenomena occurring since the pipe-laying. The location was the site of the south bank of a 3 km wide sub-sea channel perpendicular to the pipeline route. Over a distance of about 300 m the elevation of this bank dropped from -78 m to -95 m of water depth. From the comparison

of above-mentioned surveys, it could be derived that the channel bank had shifted over a distance of more than 100 m to the south since the previous year. Unfortunately, this shift did not occur evenly over the whole bank, but resulted in two "high-spots". Local soil consisted of very fine sandy silt.

The dredging company proposed to engage the TSHD *Gerardus Mercator* in jetting mode to carefully jet away the high spots under the pipe until the pipeline was supported over its full length. In order to avoid re-occurrence in the short term of the same scouring after the corrections, coarse sand was needed to cover the area. Both correction and protection were successfully carried out after approval of Client and Main Contractor.

Owing to the precarious position of the pipe extreme care had to be exercised not to overstress the pipeline during the jetting operations. Therefore, jetting was concentrated on each of the high spots separately for a limited time, typically between 1 and 4 hrs. Then a multi-beam survey of the whole problem area was performed. From the results of this survey in terms of pipeline position and seabed variation the on-board engineering department calculated stresses and strains in the pipeline. Based on these calculations and in

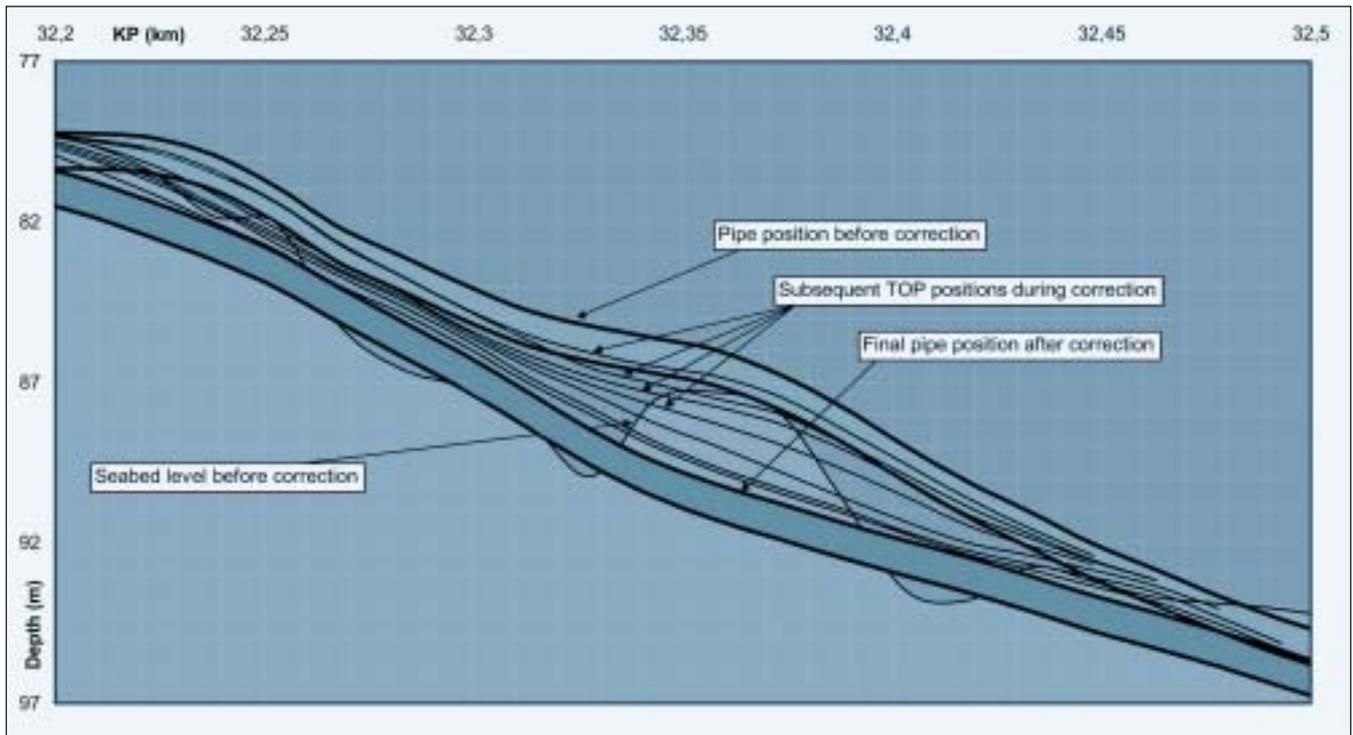


Figure 6. Freespan correction: Pipe positions during subsequent stages of operation.

consultation with the operations department and the representatives of Client and Main Contractor, the location, period and force of the next jetting run were determined (Figure 6). One such cycle took 4 to 7 hrs.

The maximum difference in vertical position of the pipeline before and after operations was about 5 m. Subsequently, the vessel was reconfigured to backfilling mode to install the protective layer of coarse sand. During trenching the only location in the right of way along the pipeline where relatively coarse sand ($D_{50} = 450 \mu\text{m}$) had been found was in the section with the large sand-waves around KP-195. Two loads or a total volume of over $30,000 \text{ m}^3$ of this coarse sand were hauled to the problem area and installed through the special backfill-head mounted at the end of the suction pipe.

Conclusion

As demonstrated on the CPC pipeline project in Taiwan, the use of trailing suction hopper dredgers for trenching offers many advantages.

First, the method of pre-trenching provides the only full-proof assurance available for sufficient pipeline burial. By trenching before pipe-lay it can be ascertained that the pipe is not laid on soils which afterwards prove to be untrenchable.

Secondly, the trailing suction hopper dredger has proven to be a powerful tool to provide solutions to ad-hoc problems encountered during pipeline projects.

The versatility of the TSHD is shown in the fact that it can be deployed successfully in a jetting mode. Equipped with a specially designed jet-head, the TSHD *Gerardus Mercator* was used in Taiwan to post-lower the pipeline in sections where pre-trenching proved cumbersome as a result of adverse soil conditions and to correct freespan resulting from unexpected seabed phenomena.