DHI CASE STORY

NAVIGATING THE CONGO RIVER

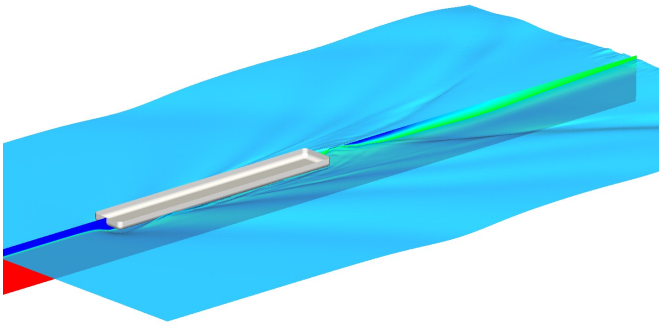
Investigating ship-flow interactions in stratified waters

The new Angola Liquefied Natural Gas (LNG) facility near Soyo sits in highly stratified water, where the top and bottom layers of water do not mix. LNG carriers experience more resistance which may cause them to move slower than in non-stratified water. This impacts manoeuvrability. As such, Angola LNG wanted a clearer understanding of the water stratification in the area and its possible impact on ships. We used our Computational Fluid Dynamics (CFD) modelling expertise to investigate the influence of the stratified water on ships' manoeuvring. In doing so, we gave ship captains a clearer idea of the effect of stratification on the piloting of their ships. This will allow them to improve their navigation, ensuring the safety of themselves and their crew.

ENSURING SHIP SAFETY

When non-saline, lighter water from the Congo River discharges into the colder, heavier saline sea water of the Atlantic Ocean, a strong density stratification forms at the mouth of the river. The upper layer of relatively light water flows at a higher speed than the heavier, often slower moving saline sea water layer underneath.

Angola LNG's new loading facility near Soyo at Pointa de Moita Seca is located near the highly stratified waters of the mouth of the Congo River. In order for captains to steer confidently in these conditions, a detailed understanding of how this stratified flow affects large LNG carriers is crucial. Accurately assessing the impact of stratified flow on ship resistance necessitates a comprehensive knowledge of the flow field.



Iso-surfaces at intermediate density in combination with contour plot in a vertical plane in through midship section. Flow approaching 0° from heading and depth of interface is 9m. U=2.0m/s.

SUMMARY

CLIENT

Angola LNG

CHALLENGE

- Location of new loading facility near density stratified water (water of two densities with one floating on top of the other)
- Lack of knowledge about how the density stratified water changes the manoeuvring properties and resistance of vessels
- Difficulty navigating ships in such stratified waters without proper knowledge of ship-flow interactions

SOLUTION

- Analysis of flow conditions to determine how stratified flow changes the manoeuvring properties of vessels
- Recommendation on how to decrease resistance encountered by ships in stratified waters

VALUE

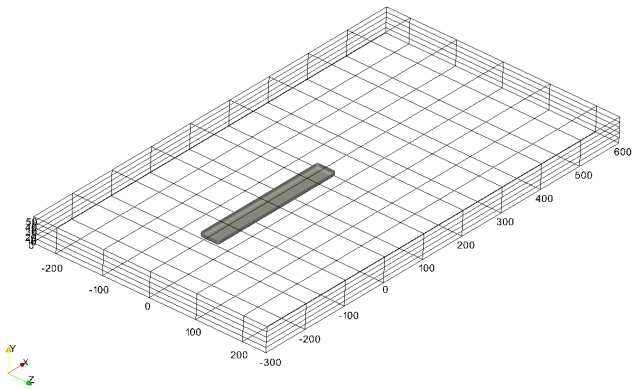
- Increase in knowledge of the effects of flow stratification on navigation
- Aiding ship captains in adjusting and improving manoeuvring of ships to ensure safety to and from the loading facility
- Improvement of navigation training programme using the results of our study

LOCATION / COUNTRY

Soyo, Angola

This includes turbulent mixing and the generation of internal waves at the interface between the two layers of water. The formation of these sub-surface waves can significantly hamper navigation. When a ship's keel (bottom) is travelling just above the interface of the water layers, the vessel sometimes experiences large wave resistance. This resistance occurs particularly if the ship is traveling close to the speed of the fastest internal waves due to the generation of large internal waves. This phenomenon, known as 'dead water', impacts the ability of ships to move through stratified water.

To support the captains and to ensure maximum safety for the LNG carriers calling at their new loading facility, Angola LNG asked us to investigate the influence of the stratified flow on ships.



Overview of model domain in metres. Flow approaching head on.

MODELLING THE CONGO RIVER

We analysed the flow conditions of this area to help determine how stratified flow changes the manoeuvring properties of vessels compared to non-stratified flow. In this case, the flow resembled a two-layer fluid with a 9m thick upper layer.

We used advanced Computational Fluid Dynamics (CFD) methods to investigate ship-flow interaction in the stratified waters of the Congo River. We applied the transient OpenFOAM library for the CFD simulations. The solver used allowed for dynamic simulation of the mixing of two fluids, taking the effects of turbulence into account. We modelled turbulence using the k-ω Shear Stress Transport (SST) turbulence model.

OVERCOMING ENHANCED RESISTANCE

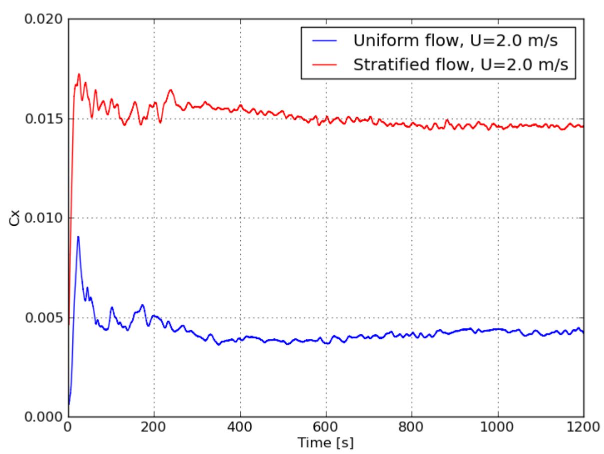
We based the simulation on the common properties of large LNG carriers' midship section: 300m long and 40m wide with a curvature radius of 5m. The draft of the ship was 10m. We also simplified the shape of the hull to a rounded box. We did this because we wanted to analyse only the relative enhancement in resistance in stratified versus non-stratified waters.

During the study, we assessed different combinations of 17 navigation conditions, including:

- the type of fluid (uniform versus two-layer)
- the angle of approach/relative ship flow angle (0° versus 90°)
- flow velocity
- densimetric Froude number
- the depth of the interface
- the ship draft

We found that the resistance experienced by the vessel in stratified water travelling head on (at a 0° angle of approach) was several times stronger than in a homogeneous fluid. In other cases, for example when the vessel turns (at a 90° angle to the flow of the water), there was less resistant. This could pose a problem for ship captains unaccustomed to the drop in resistance as they turn into the Congo River.

We discovered a strong interdependency between ship speed and the resistance. As such, we recommended that ships sailing directly parallel to the flow of the water (0° angle of approach) navigate at supercritical speed. This will help them overcome the enhanced resistance.



Resistance coefficient time series for the ship in uniform density current and in case with stratified density distribution. Flow approaching 0° from heading. Depth of interface is 9m.

Contact: Nicolai F. Heilskov – nfh@dhigroup.com
For more information visit: www.dhigroup.com