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Increasing asset value of LNG storage tank through Tokyo Gas computational fluid dynamics (CFD) simulation model for Mixed LNG Storage Technology

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Background

In recent years, different types of LNG projects are coming on line and diversifying quality characteristics of LNG more widely. For example, LNG from shale gas or coal bed methane is much lighter than conventional LNG mainly from Asia, Oceania and Middle East.

In addition to variety of LNG resources, the style of LNG sales and purchase agreement is also changing from traditional long-term contracts, which promotes delivery of LNG to limited final point of destinations, to more flexible contracts which allow to deliver LNG to free destinations. As the result, various LNGs from various regions will be received within a short time frame and LNG receiving terminals are facing difficulties to keep a good balance between flexibility and safety of the operation and prevent LNG stratification leading to undesirable rollover event in a LNG tank.

Generally, we can reduce the risk of rollover phenomenon by receiving denser LNG through top filling nozzle above lighter LNG layer or receiving lighter LNG into heel LNG through bottom filling nozzle of a tank, as the rudimentary solution of blending.

Tokyo Gas has developed its own CFD simulation models for Mixed LNG Storage Technology since 1990s to assist operator to understand the allowable maximum density difference between the LNG in tank and the LNG unloaded from a new resource without stratification in tank after receiving LNG. However, when the reference data are close to stratification conditions in LNG tank, we had to add safety margin from the calculation results in CFD simulation and, therefore, could not extract the maximum profit from the most valuable assets of LNG tanks.

Aim

Tokyo Gas strives to improve the accuracy of Tokyo Gas CFD simulation models in mixing LNGs under various operational conditions as to expand the flexibility of LNG tank operation and to optimize the asset value of its own LNG receiving terminals.

Methods

Tokyo Gas has created several conditions with potential of stratification in LNG storage tanks at Tokyo Gas's LNG receiving terminals (Japan) targeting the potential of LNG resources.

The major experimental conditions are showing as below:

- Denser LNG onto the top of lighter LNG layer
- Denser LNG into the bottom of lighter LNG layer
- Lighter LNG into the bottom of denser LNG layer
- Wider range in LNG density

The parameters below have been measured and/or observed

- Vertical density profile in the LNG tank (with corresponding elapsed time)
- BOG compressor load
- LNG level
- LNG filling rate
- Composition (heel and receiving LNG)
- Vapour pressure in the LNG tank
- Visual observation of fluid state*

  * "Compact, Lightweight Submergible Observation Device for LNG Tanks" developed by Tokyo Gas

Thereafter we fed above data and conditions back into our own CFD simulation model and optimized this simulation model closer to the actual LNG mixing phenomenon as much as possible. In upgrading this simulation model, we introduced a multi-phase (BOG/LNG/LNG) flow model progressively instead of single-phase (LNG/LNG) flow model which was used previously, and the turbulence model modified to consider these phenomena. For instance, in past we believed that we cannot prevent the stratification when the density of bottom filling LNG is higher than the criteria of heel LNG, but to contrary of our expectation, stratification didn't occur in some cases of the conditions with the above parameters. The latest version of Tokyo Gas CFD model can simulate these phenomena. As the result, we were able to create more accurate criteria chart from this simulation model and reduce unnecessary safety margin caused by inaccuracy.

Results

Findings:

1) It enables us to have more selections to purchase LNG from various sources. This means that we have more options increasing spot LNG cargo at appropriate timing, since we have higher confidence to receive it in economical prices without concern of rollover and damage risk of highly-valuable LNG tanks.
2) We are able to operate the Mixed LNG storage with more accurate criteria chart in old type LNG storage tanks not equipped with jet-mixing nozzles and/or only bottom filling nozzles, for which we have believed that this kind of LNG tanks cannot be operated for mixing LNGs.
3) Terminal operation constraint is reduced. For instance, LNG receiving terminals are free from the requirements of self-circulation and/or emptying operation of LNG to avoid rollover in case of stratification. Therefore, the terminal operators are offered with more operating flexibility in sending out profile.
4) BOG compressors for prevention of rollover damage are not necessary if the terminal owner would manage to mix unloading LNG and heel LNG within the criteria set by Tokyo Gas CFD simulation model analysis.
5) Rollover risk is eliminated, even in case of large-scale blackout of the public power supply system and lack of fuel for the emergency power generator.
6) Utilizing the Tokyo Gas simulation model for LNG tank designing, the position and size of LNG Jet Mixing nozzles, the profile of send-out pump can be optimized in all types and sizes of the LNG tank. Accordingly, Tokyo Gas is able to design LNG tank with minimal rollover risk.

Tokyo Gas's accurate criteria chart calculated from its own simulation model improves turnover ratio of LNG tanks, the most expensive and potentially steadily-profitable units in LNG receiving terminals. It also increases the tank utilization efficiency in inventory management and cargo delivery schedule arrangement.

Conclusions

Tokyo Gas achieves more flexible operation of LNG tank using the analysis results from the latest version of its own CFD simulation model to develop more effective usage of LNG storage tanks. Consequently we are able to improve the asset value of LNG storage tanks and to make contribution to the flexibility of LNG procurement. This solution can be adopted to LNG tanks in almost all LNG receiving terminals.

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