Slosh mitigation of LNG; New Products

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ABSTRACT

The dynamics of liquids, only partially filling the tank these are transported in, “sloshing”, causes several undesirable aspects. Sloshing of liquids in road tankers reduces the stability of such trucks and increases the risk of such in tankers keeling-over. Furthermore, energy is dissipated by a sloshing liquid, resulting in a higher fuel consumption by these road tankers. Mitigating sloshing by applying “baffle plates” inside the tank aggravates the fuel consumption, which is undesirable for the obvious economic and environmental reasons.

The design and engineering was researched for products to eliminate sloshing of liquids in horizontal cylinder-shaped mobile tanks like such tanks being part of mobile tanks and tank containers. (Eenkhoorn, 2017).

- “Eliminating sloshing”, by liquid load securing, appeared to be far more desirable than “slosh mitigation” (by baffle plates),

When liquid loads are “secured” there are no relative velocity nor acceleration differences between the liquid load and the liquid holding tank or containment system. Liquid dynamics related equations become relatively “easy” to resolve. The (new) challenge becomes thus the design and engineering of products to eliminate liquid sloshing rather than resolving complex liquid dynamic mathematics. Load securing include such of liquid loads is only about “forces”, not about “energy”.

This paper will address the key elements to form a “basis for design” for liquid (LNG) load securing products in rectangular, maritime, LNG containment systems.

Particular targets for LNG containment systems justifying this task, besides improving the ship integrity and stability, are:

- The elimination of the exposure of (“GTT" patented) walls of LNG containment systems to high, LNG wave impact related, forces and thereby allow for new, simpler, cheaper LNG containment wall designs, materials and constructions.
- The elimination of the transfer of (wave) energy of the seas, oceans, onto the LNG and the thereby the reduction of the resulting boil-off of LNG.

As the base design concept principles for slosh mitigation were researched, developed and tested for horizontal, cylinder-shaped tanks, these principles will be the starting point for creating the basis for design of rectangular tank applications, in this paper.

KEY WORDS
Sloshing, Slosh mitigation, Slosh elimination, Stability, Liquid load securing products, Inflatable component, rectangular mobile tanks.

INTRODUCTION

The design of slosh mitigation products, as researched, comprises an “inflatable element”, often comprising more than one compartment, which is placed inside the mobile tank. The scientific and fundamental functional principles have been subject to prior ISOPE papers and presentations, refer Eenkhoorn (2018).

Key functional requirements for slosh mitigating products with a design based on the use of an inflatable element include:

- The membrane material of which the inflatable element is fabricated requires to be of a high Young’s modulus, i.e. in the order of 10⁹ N/m².
- The contact surface of the membrane of the inflated component and the liquid inside the mobile holder requires to be tensioned.
- The obvious compatibility of the membrane material with LNG (i.e. the liquid), especially at the occurring operational conditions. Note: An LNG dedicated “green textile” was developed hereto and was “GTT" approved for LNG and low temperature applications.
- The absence of “free air” (and of liquid originated vapours) in the tank. The only air (nitrogen or vapours) inside the tank is all inside the inflated component(s).

These requirements will not be different for slosh mitigating products for use in rectangular mobile (like LNG carrying) tanks. There are however main differences between the “2-dimensional” (“length” and “diameter”) fundamentals of horizontal cylinder-shaped mobile tanks commonly with a diameter of some 2.5 meters maximum and “3-dimensional” (length, width and height) fundamentals of rectangular mobile tanks especially such with a length and width (much) larger than 2.5 meters. Key differences resulting from this are for example: the reduction of the ratio of the membrane wall thickness over the length and width of the mobile tank, and the larger radii of curvature.

The basis for design of slosh mitigating products for large rectangular tanks using inflatable elements might therefore not only be based on such element transferring forces between the mobile liquid holder and the liquid via the contact surfaces of the inflated element with both tank or liquid. The slosh mitigation functional requirements may also be