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THE EFFECT OF TRANSPORTATION CONDITIONS ON THE LIQUID CARGO SLOSHING INSIDE ROAD TANKS

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ABSTRACT

There were created different models of road tank reservoirs with and without internal baffles using ANSYS CFX. The influence of transported liquid temperature on hydrodynamic pressures inside the reservoir was analyzed. The modes of a single emergency braking of the tank and its movement with interchanging accelerations and decelerations (city traffic mode) were considered to analyze the influence of liquid cargo internal friction on cargo temperature changes and tank shell loading parameters.

Keywords: road tank, liquid cargo sloshing, partially-filled reservoir, liquid temperature.

INTRODUCTION

At various transportation conditions, as well as at various movement modes of the road tank the transported liquid cargo can repeatedly slosh inside the tank reservoir. This fact causes a change in liquid temperature due to the internal friction forces (energy dissipation of the cargo) and can lead to a change in the transported liquid physical properties influencing the parameters of relative movement of liquid cargo in the reservoir and tank shell loading. Also this can have a significant effect on the controllability of the road tank (Cheli, 2013). So, the main purpose of the investigation is to analyze the influence of different movement modes of the tank on the liquid cargo oscillations and properties as well as on the tank shell loading.

Simulations of liquid cargo sloshing in tank reservoirs with different shapes were realized using ANSYS CFX. As hydrodynamic pressures inside the reservoir do not reach significant values, all liquids were considered to be incompressible. All simulations of Newtonian and non-Newtonian liquid cargo sloshing at non-stationary movement modes of tanks were done taking into account the presence of turbulent stresses, depending on the flow rate oscillations.

RESULTS AND CONCLUSIONS

To analyze the transportation temperature effect on the pressure values for the case of a single emergency braking there were performed several simulations of liquid sloshing in a rectangular tank of 4 m length with 1.5x1.5 m^2 cross section. The transportation temperature changed from 10 to 40 °C. The results obtained for water showed that tank shell loading is not significantly (less that 3 %) changed. The similar results were get for concrete mixture and tar. Concrete mixture kinematic viscosity value can change during the transportation of more than 13 times, but it does not lead to a big difference in pressures.

In order to analyze the influence of the liquid internal friction on cargo temperature change there were carried out simulations for liquids with a dynamic viscosity varying in the range of

0,001-300 Pa·s. The transportation of these liquid cargos was analyzed in the rectangular tank, cylindrical tank of 4 m length and 2 m diameter without baffle and with solid baffle of 50 % height ("halfbafflle") and 80 % height of the reservoir. The reservoir was suggested to be half-filled as it is one of the worst conditions for controllability of the car at emergency braking (Kuzniatsova, 2015). The obtained results confirm the obvious fact that the liquid cargo movement inside the reservoir with baffle or without it, is more smoothly with the increase of liquid viscosity. In other words relative velocities of liquid cargo particles decrease when its dynamic viscosity increases. This result can be obtained for almost all tank reservoir configurations. Fig. 1 demonstrated some simulation results for the Newtonian liquid with changing dynamic viscosity sloshing in a rectangular tank and a cylindrical tank with a "halfbaffle". Also it shows some computational results for the non-Newtonian liquid sloshing in the cylindrical tank with a solid baffle of 80% of tank height. The modeled liquid had Bingham features and its density varied in the range of 1000-10000 kg/m^3 at a constant dynamic viscosity.

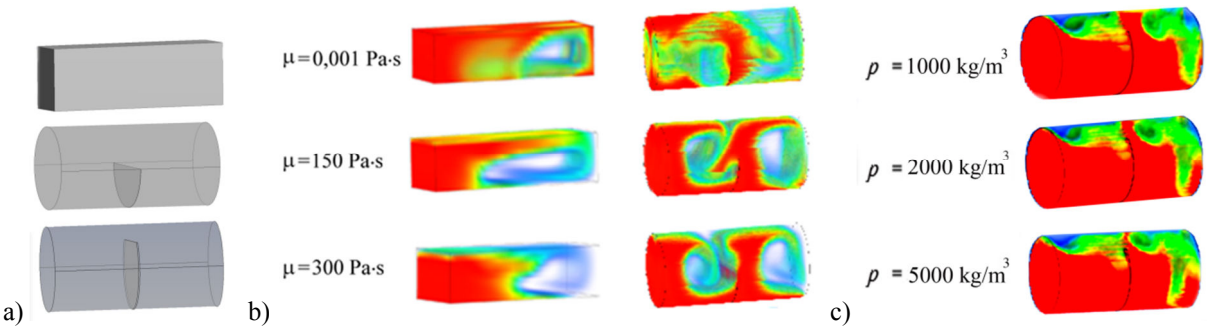

Fig. 1 - Geometry models of tanks (a) and liquid cargo free surface position at t = 0.5 s after the start of tank braking for the Newtonian (b) and at t = 1 s for the non Newtonian (b) liquids

Simulation results showed that the difference in the temperature values of the transported liquids in the case of a single emergency braking takes place within the first second after the start of braking and temperature changes no more than by 2 °C. When the liquid viscosity increases to 1 Pa·s maximal change in its average temperature also increased, and then, the process was adverse with the further increase of liquid cargo dynamic viscosity. So, the process of liquid cargo sloshing in the tank reservoir for the case of its single emergency braking can be considered isothermal. When tank braking and acceleration interchange, for example as in typical city traffic mode, tank shell is under less loading values than in the case of a single emergency braking. This takes place due to lower values of acceleration in city movement mode compared to the sharp acceleration and deceleration modes.

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