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NUMERICAL AND EXPERIMENTAL INVESTIGATION OF VIOLENT SLOSHING UNDER ROLL EXCITATION

Ronja Hoch[1]*, Matthias Witte[1] and Frank-Hendrik Wurm[1]

[1] Institue of Turbomachines, University of Rostock, Albert-Einstein-Str. 2, 18059 Rostock, Germany
Corresponding Author: ronja.hoch@uni-rostock.de, www.itu.uni-rostock.de

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The motion of liquid with a free surface in partially filled tanks due to external excitation is known as sloshing. It can be observed at a wide range of applications, comprising marine operations as well as automotive or spacecraft tanks [1, 2]. Automotive coolant or fuel tanks are typically exposed to high amplitude excitations due to driving manoeuvres as breaking or going round bends. Sloshing liquid causes high impact pressure on the tank walls as well as air entrainment due to breaking and overturning waves. If the air is carried along into the coolant circuit or fuel supply it will cause severe damage to the engine. In order to prevent this and ensure sufficient liquid flow at the same time, various geometry modifications have been developed in the past. To avoid time consuming experimental test with manifold prototypes, numerical simulation of the sloshing flow is used.

To examine the suitability of commercial numerical solvers, sloshing two-phase flow inside a simplified rectangular tank geometry with interchangeable internal structures was investigated numerically and experimentally. The tank was exposed to a nearly harmonic roll motion around a horizontal axis with a period of 2 s and an amplitude of 45° to model typical excitation forces acting on automotive coolant tanks. Unsteady simulations solving the Reynolds-averaged Navier-Stokes equations (URANS) were performed using a homogeneous multiphase model with k-ε turbulence model. These models were chosen to ensure quick results and numerical stability which is significant if various geometries should be tested.

The tank in the experimental setup was made of transparent acrylic plates to enable optical examination using a camera, a laser sheet and tracer particles. This setup made it possible to determine both the position of the free surface and entrapped air bubbles and the flow field using the optical flow method. Furthermore pressure impacts at tank walls and bottom were measured. The captured data was compared to the numerical results. The simulated results predict the variation of pressures with time adequately but underestimate the experimental pressure peaks up to 50% which was observed in other studies, too [3]. However, they show good agreement in the position of the liquid surface and the prediction of typical flow phenomena like wave breaking, which is the major concern in the development of coolant tanks.

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