DEVELOPMENT OF NEW FUNCTION OBJECT FOR SLOSHING IMPACT ASSESSMENT

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The most important parameter for sloshing impact load assessment is impact pressure on the tank wall. Since analytically predicted tank wall pressures were not acceptable to large amplitude sloshing, scale model experiments are carried out [1]. In model experiment, to measure impact pressure on the tank wall, pressure sensors were mounted along the tank boundary [2][3]. Moreover, CFD simulations were carried out and validated against experimental result [4], [5]. Nevertheless, evaluation of impact pressures by numerical CFD analysis not reliable because of high impact pressure is strictly localized in the space and the time, being very sensitive to the local effect and depends on many physical parameters of liquid, gas and structure involved in the impact e.g. density, viscosity, ullage pressure, surface tension, compressibility, hydroelasticity, viscoelasticity, etc. [4][5][6]. Bureau Veritas guidance note suggested the impact normal velocity with respect to the wall based CFD analysis [7]. The impact normal velocity could evaluate kinetic energy of the liquid and thus quantify the sloshing impact. Therefore, the objectives of this paper are describing new function object called *sloshingDynamicProbe* plugged in *interDyMFoam* and its application. For the development of new function object, OpenFOAM-5.0 was used.
In case of model experiment, it is possible to gather only limited position's data where pressure sensors are mounted on model tank's boundary. On the other hand, the new function object considers all fluid field and wall boundaries. If it stores time series data entire simulation, too much data has stored so huge storage space are required and post-process would be difficult. Therefore, defining a state where normal velocity exceeds threshold velocity (user-defined value) as sloshing event, *sloshingDynamicProbe* store data for a specific time (also user-defined value) before (pre-trigger) and after (post-trigger) the event. Through this, it is possible to reduce the storage and store only impact relevant data.
The *sloshingDynamicProbe*s working in *interDyMFoam* is schematically showed in Figure 1. The function object consists of three parts those are input, process and output. The input part is operated only once when a solver initializing. After the solver has executed, the solver create *sloshingDynamicProbe* object, *sloshingDynamicProbe*'s constructor call *read* member function of *sloshingDynamicProbe* class. It reads the dictionary where the user defined variables are defined. The variables are wall patch names of the sloshing tank, threshold velocity, offset, pre-trigger and post-trigger. Then it initializes member data defined in the header file. The process part is operated at the end of every time loop. It calculates a liquid normal velocity at every probe location, which is offset in the vertical direction from the tank wall. The liquid normal velocity is expressed

$$(\alpha\vec{v})_{p.o.}\cdot\vec{n} \tag{1}$$

where α is the liquid volume fraction (1 for the liquid, 0 for the gas), $\vec{v}$ is the velocity vector, the subscript $p.o.$ means probe offset location from the tank wall, and $\vec{n}$ is the normal vector from the tank wall. It updates buffer to write the relevant sloshing data before the event after calculation. The buffer size is determined by pre-trigger and time step size. When the normal velocity exceeds threshold velocity, the probe is activated. The data for the pre-trigger time are written to the file and then the probe writes the data before the normal velocity is less than the threshold velocity. After the threshold velocity exceeds the normal velocity, the probe is deactivated after the post-trigger time. Figure 2 describes algorithm for activate or deactivate probe as shown is Figure 3. In output part the data of the activated probe are written to the file.

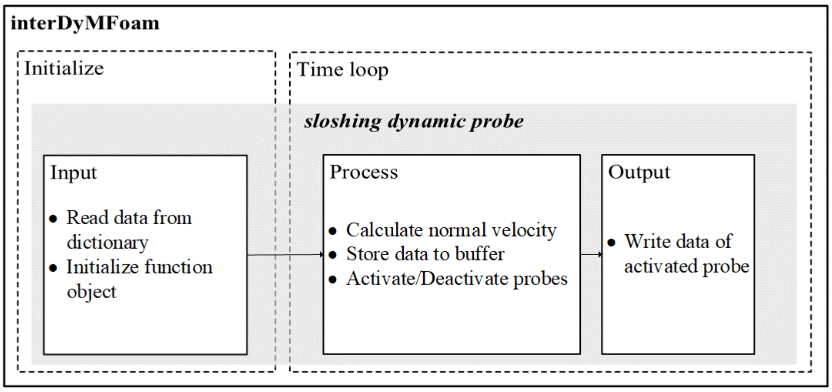

Figure 1: Three parts of *sloshingDynamicProbe* working with *interDyMFoam*.

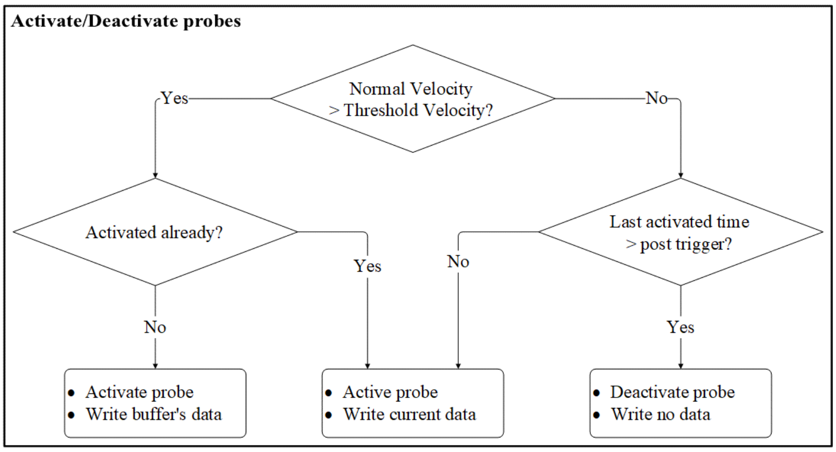

Figure 2: Algorithm for activating/deactivating dynamic probe.

The *sloshingDynamicProbe* has been tested with *sloshingTank3D* tutorial of OpenFOAM-5.0. Figure 3 are example of the output data. It shows the new function object can store relevant data before and after sloshing event without data loss or overlap. When the velocity exceeds the threshold velocity the impact count is increased by one.

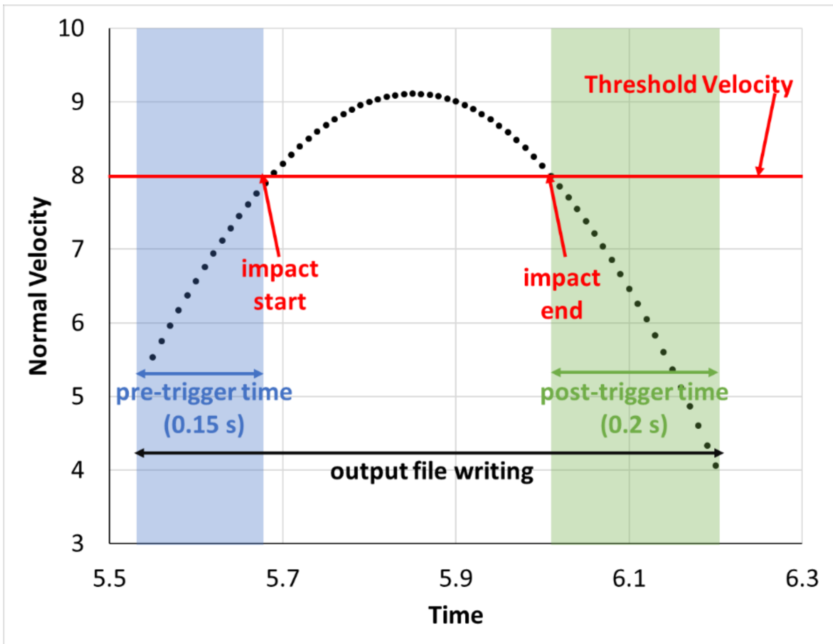

Figure 3: Example of extracted normal velocity at an offset location using the *sloshingDynamicProbe*.

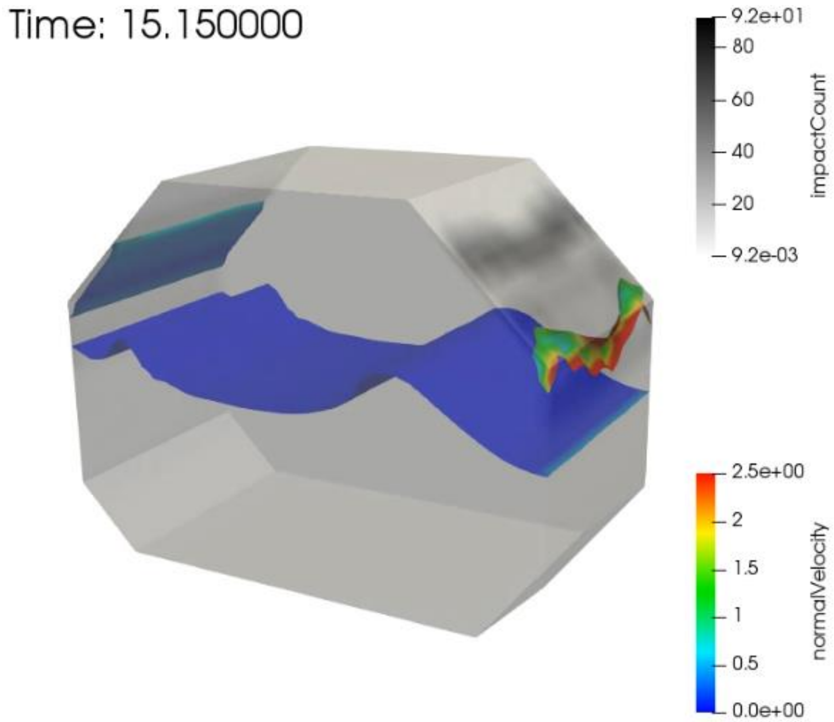

Figure 4: Example of extracted sloshing impact count and normal velocity using the *sloshingDynamicProbe.*

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