WP1: Multiphase modelling with overset mesh

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Outline

1 Background
   - Launch and Recovery Operations
   - OpenFOAM and dynamic mesh
   - Overset mesh method (OGM)

2 Development of overset mesh CFD solver in OpenFOAM
   - The overall strategy
   - ogFoam: a multiphase overset mesh modelling tool

3 Preliminary results
   - Dambreak
   - Wave tank
   - Wedge

4 Conclusions & future work
   - Conclusions
Launch and Recovery Operations

Rescue and recovery

Challenges
- High sea states
- Modelling tool
  - accurate
  - fast
- Risk prediction
  - collision
  - unacceptable motions
- Testing
  - new concept and system
OpenFOAM

**Framework**
- Open source
- Pack: single/multiphase flow modelling
- Language: C++
- Parallelisation: MPI
- In/compressible air and water
- Volume of fluid method

**Meshing**
- Static mesh
- Dynamic mesh
  - dynamic mesh refinement
  - dynamic deforming mesh
  - arbitrary mesh interface (turbomachinery)
- Limitations
  - mesh quality
  - amplitude of motion
The main issues with dynamic deforming mesh are mesh quality as well as limited amplitude of motion.
Overset mesh method

- Start: Late 1970s and 1980s, Joseph Steger, NASA AMES


- Original concepts of OGM
  - To model multi-component systems where an optimum body-fitted grid is used for each component
Zonal approach for L and R

Meshes for larger and small vessels are generated independently then assembled together. The small mesh surrounding the small vessel moves with the vessel (6DoF), the big mesh could move with the large vessel or stay stationary.
Basic steps of OGM

1. **Mesh generation**: component grids are generated in a (virtually) independent manner.

2. **Domain connectivity information (DCI)**:
   - Hole cutting: blank out the mesh cells out of flow domain.
   - Locate the fringe points and seek interpolation stencils (on other meshes).
   - Orphan point: a proper interpolation stencil cannot be established.

3. **Flow information exchange**: the information at a fringe point is interpolated from its supporting stencil.

4. **Solve the flow** on the filed points/cells, update the flow.

5. **Repeat steps 2 to 4** for deforming/moving boundary problems.
A multi-region two-phase flow solver for wave-structure interactions.

- Coupling of incompressible and compressible two-phase Navier-Stokes solvers.
- Coupling of single-phase potential flow and two-phase NS solvers.
- Wave generation:
  - Velocity profile
  - Wave paddle: piston, plunger, flap
- 6DoF:
  - Dynamic deforming mesh
  - Arbitrary mesh interface
ogFoam

On top of wsiFoam and enhanced with overset mesh capability:

- Hole cutting
- DCI information
- Data interpolation

```cpp
int main(int argc, char *argv[]) {
    ...
    //load meshes and initialise flow regions

    //cut hole
    #include "holeCutInterFoam.H"

    //set DCI
    #include "dciInterFoam.H"

    ...
    while (runTime.run())
    {
        ...
        // PIMPLE loop over the regions
        for (int oCorr=0; oCorr<nOuterCorrMultiRegion; oCorr++)
        {
            //Interpolate information for fringe cells
            #include "interFringeInterFoam.H"
        }
    }
    Info<< "End" << endl;
    return 0;
}
```
The red and green lines represent the free surface obtained on overset meshes and a single-block mesh. The white lines illustrate the pressure contour lines on the two overset meshes.
Comparison of the overset mesh solution and the single-block-mesh solution. The red and green lines represent the free surface obtained on overset meshes and a single-block mesh.
Wave tank

Tank size: 320 m \times 55 m; Water depth: 30 m; Wave height: 5 m. Wave Period: 10 s. Comparison of the overset mesh solution and the single-block-mesh solution. Red and blue colours indicate the discrepancy between the two solutions.
Wave tank

Figure 1: Comparison of the overset mesh solutions and the single-block mesh results.
Figure 2: Comparison of the overset mesh solution and the single-block mesh results.
Figure 3: Comparison of the overset mesh solutions and the single-block mesh results.
Figure 4: Discrepancies between the overset mesh solutions and the single-block mesh results.
Figure 5: Discrepancies between the overset mesh solutions and the single-block mesh results.
Figure 6: Discrepancies between the overset mesh solutions and the single-block mesh results.
The wedge oscillates in the vertical direction with a sinusoidal law
\[ y = A \sin(\omega t). \]
Freefall of a wedge

The wedge falls freely under gravity.
Conclusions

- An accurate and fast modelling tool is a necessity to predict risks and to facilitate testing for launch and recovery operations at high sea states.
- Dynamic deforming mesh method has limitations in dealing with the large amplitude of structure motion and mesh quality.
- A multiphase overset mesh modelling tool is being developed within the framework of OpenFOAM. Preliminary results have been produced and presented for several test cases. The tool shows its advantages in dealing with relatively large amplitude of structure motion.
- Next step’s work will focus on the improvement of hole-cutting, information interpolation, parallelisation of the numerical tool and further extension to handle L and R operations.
Thank you