Integrated Development Environment (IDE) Eclipse for OpenFOAM®
Assessing the Performance of bubbleFoam

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1 Introduction

"Eclipse is an open source community whose projects are focused on building an extensible development platform, runtimes and application frameworks for building, deploying and managing software across the entire software lifecycle. Many people know us, and hopefully love us, as a Java IDE but Eclipse is much more than a Java IDE.” - www.eclipse.org

Scope and objective of this tutorial is the introduction of the Integrated Development Environment (IDE) Eclipse for OpenFOAM®. Eclipse is a powerful IDE originally developed for Java programming. But with the C/C++ Development Toolkit (CDT) extension Eclipse becomes a very common IDE for fast and efficient C++ programming.

Due to the amount of advantages of using an IDE only a few of them are listed below.

- Well-arranged graphical user interface offering project explorer, outline, ...
- Fully integrated powerful text editor offering code highlighting, autocompletion, ...
- Integrated compiler offering linked error and warning marks
- Integrated debugger and debugging environment offering breakpoints and variable information
- Project management: bookmarks and tasks
- Extension: version management, multiple language support (Java, Python, ...)

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For further information concerning Eclipse refer to [1, 2, 3].

As OpenFOAM deals with physics we shall do so as well for the introduction of Eclipse: in this tutorial we will deal with bubbly flows (as they occur in bubble columns). In OpenFOAM the bubbleFoam solver enables to simulate the complex flow dynamics of these kind of gas-liquid flows. Currently, there is only the skeleton of a state-of-the-art model available and implemented in bubbleFoam: a two-fluid model framework based upon the Eulerian-Eulerian method. In this model, the flow morphology (i.e., the bubbles’ shape) is not resolved explicitly at all, but is taken into account in an averaged manner presuming a specific shape. I.e., conditional volume-averaging of two-phase conservation equations results in the concept of interpenetrating continua [5], in which all phase interactions have to be modeled in order to physically close the system of governing equations. Thus, closure modeling is of major importance in order to gather reliable results. We will have a look at bubbly forces, which can be categorized further into drag and non-drag forces (→ slides). These forces essentially characterize the fluid dynamics of the two-phase flow system present in a bubble column.

The motivation of this tutorial rests in the fact that the already existing bubbleFoam solver needs to be restructured: i.e., we want to implement runTime-selective models for the calculation of interfacial forces. For this purpose, the existing ‘hard-coded’ models have to be rearranged in C++ libraries. Moreover, new models for both drag and non-drag forces have to be added. The rearrangement to libraries allows runTime-selective access to the interfacial force models during the simulation. The remainder of this tutorial will explain how this can be accomplished using Eclipse.
Figure 2: Bubble Forces – drag and non-drag forces [4]
2 Adding a runTime-selective Model – Drag Force

2.1 Preliminary steps

Start the OpenFOAM-1.6-ext-dbg terminal, as the debugging in the following tutorial will need the debug compiled binaries. Please export the path to the GNU Debugger (GDB) for Eclipse.

- export PATH=/home/ubuntu/gdb4Eclipse/bin:$PATH

Begin creating a personal version of bubbleFoam solver and copy the cylindricBubbleColumn test case in the correct $WM_PROJECT_USER_DIR directories.

- bubbleFoam solver:
  /usr/lib/OpenFOAM-1.6-ext-dbg/applications/solvers/multiphase/bubbleFoam

- cylindricBubbleColumn test case:
  /cdrom/OFW6/Training/case-cyclindricBubbleColumn.tgz

Change the name of the bubbleFoam folder into bubbleFoamMod and run blockMesh on the cylindricBubbleColumn.

2.2 Modifying bubbleFoam

1. Setting up Eclipse for OpenFOAM
   (a) Launch Eclipse using eclipse & and choose your workspace. If you’re developing several projects it’s advisable to create a workspace folders for each project. Herein we use the default workspace.
   (b) Change the developing environment to C++ in the menu bar under Window → Show View → Other.. → C/C++ Projects.
   (c) Make sure that Project → Automatically build in the menu bar is unchecked.
   (d) Import the bubbleFoamMod solver by creating a new C++ project in the menu bar under Files → New → C++ Project. Deactivate Use default location, then select the bubbleFoamMod folder. Set bubbleFoamMod as name for the project and click Finish (see Figure 3).
   (e) For using the OpenFOAM-specific compilation script wmake, change the compiler properties for Eclipse. Right-click on your new project in the project explorer on the left side, select properties. Setting the build command under C/C++ Build, deactivate the default build command and choose OpenFOAM’s wmake. Deactivate Generate Makefiles automatically. Set the build directory - maybe you have to remove the /Release or /Debug. Confirm with OK (see Figure 4).

2. Developing and compiling with Eclipse
   (a) For the actual developing and compiling procedure, open your project folder in the project explorer window and double click a file, so the editor will open the file in the middle of your screen. You can now edit your file comfortably with the Eclipse text editor. Make line number visible by Right-Click → Preferences.. → Editor. Click on Text Editors and check Show line numbers.
(b) For adapting your new solver bubbleFoamMod make the adequate changes in Make/files and rename bubbleFoam.C to bubbleFoamMod.C (see Figure 5). Moreover, place the executable at **EXE = $(FOAM_USER_APPBIN)/bubbleFoamMod**.

(c) Recompile the solver by adding the new make targets **wmake** and **wclean**.

- First select the Make Targets-tab and select the directory where your Make folder is located. Create a new make target, by clicking on the new make target button. For compiling an application give the target a descriptive name – we choose **wmake** - leave the make target plain. The default build command is **wmake**.

- Create the corresponding **wclean** – do not forget to change the build command to **wclean**.

- Execute the **make targets** by double-clicking.

---

**Figure 3:** Import of bubbleFoamMod
Figure 4: Eclipse Compiler Settings

Source Code 1: interfacialModels/Make/files

```plaintext
LIB = $(FOAM_USER_LIBBIN)/libEulerianInterfacialModels

EXE_INC = \
-$(LIB_SRC)/finiteVolume/lnInclude \n-../phaseModel/lnInclude

LIB_LIBS = \
-L$(FOAM_USER_LIBBIN) -lphaseModel
```

Source Code 2: interfacialModels/Make/options

```plaintext
phaseModel/phaseModel.C
LIB = $(FOAM_USER_LIBBIN)/libphaseModel
```

Source Code 3: phaseModel/Make/files
### Figure 5: Eclipse Working Environment - Renaming bubbleFoamMod

### Figure 6: Create make targets
EXE_INC = \\n-$(LIB_SRC)/finiteVolume/lnInclude \\
-$(LIB_SRC)/transportModels/incompressible/lnInclude \\
-InterfacialModels/lnInclude \\
-PhaseModel/lnInclude \\
-Laveraging

EXE_LIBS = \\
-1finiteVolume \\
-1meshTools \\
-1incompressibleTransportModels \\
-L$(FOAM_USER_LIBBIN) 1phaseModel \\
-L$(FOAM_USER_LIBBIN) 1EulerianInterfacialModels

Source Code 4: Make/options
3. Altering bubbleFoam

After the change of the name and recompiling the new solver, we will implement the drag and phase models as their own classes instead of the hard-coded version as currently implemented. Therefore, take some files from the twoPhaseEulerFoam solver, where some physical models for fluidized beds are already implemented dynamically.

- **twoPhaseEulerFoam** solver:
  
  ```
  /usr/lib/OpenFOAM-1.6-ext-dbg/applications/solvers/multiphase/..
  ../twoPhaseEulerFoam with subfolders interfacialModels and phaseModel
  ```

(a) Return to the terminal, copy the folders `interfacialModels`/ and `phaseModel`/ into the main `bubbleFoamMod` directory.

(b) Return to Eclipse and refresh your workspace under *File → Refresh (F5)*.

(c) Delete all subdirectories in `interfacialModels/dragModels` except `dragModel`/ and `SchillerNaumann`/.

(d) In the *Make*-folder of `interfacialModels/` adapt the files `files` (deleting the unused drag models) and `options`. The files should look now as given in the Sources 1 and 2.

(e) Change `phaseModel/Make/files` appropriately. Eventually the file should read as given in Source 3.

(f) Next in the *Make*-directory of `bubbleFoam`, include the new models in the file `options`. The file should look as illustrated in Source 4.

(g) For having access to the new classes, phase model pointers for each phase a and b have to be defined and initialized in `createFields.H` (Source 5). The models will be read in as an entry in the `transportProperties` dictionary of the case. Use the arrow operator `->` in order to call the functions for the phase properties as density, viscosity and diameter.

(h) Next a new dictionary has to be created in order to make runTime-selectivity available for all interfacial force models we are going to add. Therefore define the new dictionary `interfacialProperties` in `createFields.H` (Source 6) and implement one drag model pointer for each phase a and b.

(i) Include the `dragModel.H` file in `bubbleFoamMod.C` as shown in Source 7, so it is available for the compiler and then for our new runTime-selective application.

(j) Finally, alter the `liftDragCoeffs.H` by inserting the correct calculation of the drag coefficient using the new drag models according to Source 8.

(k) For the compilation in Eclipse create new make targets for the phase and interfacial force models, respectively.

- Click onto the `interfacialModels` in the *make targets* tab. In order to compile them as libraries – in OpenFOAM this would be done by typing `wmake libso` – name your target `libso` and don’t change the default builder settings `wmake`.

- In the same way create `wclean` targets for your classes. Finally your make targets should look as illustrated in Figure 8.

- First compile the libraries and then compile the complete solver again. Do not forget to save all the files you have changed before.
At this point you may take advantage of one of Eclipse’ powerful features - the fully linked error and warning marks. Selecting the Problems tab on the bottom lists all errors and warnings. Clicking on them opens the appropriate files where the error or warning is marked on the left margin.

```cpp
Info<< "Reading transportProperties\n" << endl;

I0dictionary transportProperties
{
  IOobject
  {
    "transportProperties",
    runTime.constant(),
    mesh,
    IOobject::MUST_READ,
    IOobject::NO_WRITE
  }
};

autoPtr<phaseModel> phasea = phaseModel::New
{
  mesh,
  transportProperties,
  "a"
};

autoPtr<phaseModel> phaseb = phaseModel::New
{
  mesh,
  transportProperties,
  "b"
};

const dimensionedScalar& rhoa = phasea->rho();
const dimensionedScalar& nua = phasea->nu();
const dimensionedScalar& da = phasea->d();

const dimensionedScalar& rhob = phaseb->rho();
const dimensionedScalar& nub = phaseb->nu();
const dimensionedScalar& db = phaseb->d();

dimensionedScalar Cvm
{
  transportProperties.lookup("Cvm")
};

dimensionedScalar Cl
{
  transportProperties.lookup("Cl")
};

dimensionedScalar Ct
{
  transportProperties.lookup("Ct")
};

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Source Code 5: createFields.H

```cpp
IODictionary interfacialProperties
{
    IObject
    {
        "interfacialProperties",
        runTime.constant(),
        mesh,
        IObject::MUST_READ,
        IObject::NO_WRITE
    }
};

autoPtr<dragModel> draga = dragModel::New
{
    interfacialProperties,
    alpha,
    phasea,
    phaseb
};

autoPtr<dragModel> dragb = dragModel::New
{
    interfacialProperties,
    beta,
    phaseb,
    phasea
};
```

Source Code 6: createFields.H

```cpp
/*
 * −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
 * |========|
 * | Field  |
 * | OpenFOAM: The Open Source CFD Toolbox |
 * | Operation |
 * | Copyright (C) 1991–2008 OpenCFD Ltd. |
 * | And |
 * | Manipulation |
 * −−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−−
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```
Application
  bubbleFoam

Description
  Solver for a system of 2 incompressible fluid phases with one phase
dispersed, e.g. gas bubbles in a liquid.

Source Code 7: bubbleFoamMod.C

```c
volVectorField Ur = Ua - Ub;
volScalarField magUr = mag(Ur);

volScalarField Cda = draga->K(magUr);
volScalarField Cdb = dragb->K(magUr);

// corresponds to dragPhase == "blended" in twoPhaseEulerFoam
volScalarField dragCoef =
  (Cd,
   beta*Cda + alpha*Cdb
  );

volVectorField liftCoeff = alpha*rhob*Cl*(Ur ^ fvc::curl(Ub));
```

Source Code 8: liftDragCoeffs.H
Figure 7: Eclipse make target for C++ libraries

Figure 8: Overview: make targets
2.3 Implementing the models

After giving the solver the adequate C++ class base structure, new interfacial force models can be implemented easily.

1. To start with the implementation of the Tomiyama drag model create the new directory Tomiyama98 in bubbleFoamMod/interfacialModels/dragModels and copy all files from ../dragModels/SchillerNaumann in the new subdirectory.
2. Rename (F2) to Tomiyama98.C and Tomiyama98.H, respectively.
3. Add the new model to the existing solver in the bubbleFoamMod/interfacialModels/Make/files file by adding the following line: dragModels/Tomiyama98/Tomiyama98.C.
4. For the implementation of a new drag force model, change the equations accordingly to the Tomiyama drag force model as given in Source 9 and 10, respectively. For the change of name you can use Edit → Find/Replace.
5. For the calculation of the Eötvös number the surface tension and gravity (as dimensionedScalars) are required. In order to make this properties available, some modifications to the phase model have to be made. Therefore read in the surface tension sigma and gravity g from a dictionary entry (see phaseModel.C – Source 11, lines 57 to 64). Add the lines 68 to 72 and lines 126 to 134 (access functions of sigma and g) in phaseModel.H as shown in Source 12.
6. Create make targets for the phaseModel library as done for the interfacialModels and compile it. Then recompile the interfacialModels library and at last the bubbleFoamMod solver.
#include "addToRunTimeSelectionTable.H"

// * * * * * * * * * * * * * * Static Data Members * * * * * * * * * * * * * //
namespace Foam
{
    defineTypeNameAndDebug(Tomiyama98, 0);
    addToRunTimeSelectionTable
    {
        dragModel,
        Tomiyama98,
        dictionary
    };
}

// * * * * * * * * * * * * * * * * Constructors * * * * * * * * * * * * * * //
Foam::Tomiyama98::Tomiyama98
(const
dictionary& interfaceDict,
const
volScalarField& alpha,
const
phaseModel& phasea,
const
phaseModel& phaseb
)
:
    dragModel(interfaceDict, alpha, phasea, phaseb)
{};

// * * * * * * * * * * * * * * * Destructor * * * * * * * * * * * * * * * //
Foam::Tomiyama98::~Tomiyama98()
{}

// * * * * * * * * * * * * * * * Member Functions * * * * * * * * * * * * * //
Foam::tmp<Foam::volScalarField>
Foam::Tomiyama98::K
(const
volScalarField& Ur)
const
do
{
    volScalarField Re = max(Ur*phasea_.d()/phaseb_.nu(), scalar(1.0e-3));
    volScalarField Eo = (phaseb_.rho()−phasea_.rho())*phasea_.g()*
pow(phasea_.d(), 2)/phaseb_.sigma()•Re/Re;
    // Tomiyama Correlation for contaminated systems
    volScalarField Cds = 24.*(scalar(1) + 0.15*pow(Re, 0.687))/Re;
    volScalarField Cdj = 8./3.*(Eo/(Eo+4.));
    forAll(Cds, celli)
    {
        if(Cds[celli] < Cdj[celli])
        {
            Cds[celli] = Cdj[celli];
        }
    }
    return 0.75*Cds•phaseb_.rho()•Ur/phasea_.d();
}

Source Code 9: Tomiyama98.C

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Class

Tomiyama98

Description

SourceFiles

Tomiyama98.C

#include "dragModel.H"

namespace Foam
{
    Class Tomiyama98 Declaration

    class Tomiyama98
    {
        public dragModel
        {

            // Runtime type information
            TypeName("Tomiyama98");

            // Constructors
// Construct from components
Tomiyama98
{
    const dictionary& interfaceDict,
    const volScalarField& alpha,
    const phaseModel& phasea,
    const phaseModel& phaseb
};

// Destructor
~Tomiyama98();

// Member Functions
tmp<volScalarField> K(const volScalarField& Ur) const;

} // End namespace Foam

Source Code 10: Tomiyama98.H
dict_.lookup("sigma")
},

Source Code 11: phaseModel.C

/--------------------------------------------------
--- Field | OpenFOAM: The Open Source CFD Toolbox
   / Operation | Copyright held by original author
   / And
   / Manipulation
/--------------------------------------------------

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Class

Foam::phaseModel

SourceFiles

phaseModel.C

/--------------------------------------------------
--- Class phaseModel Declaration
/--------------------------------------------------

//-- gravity
dimensionedScalar g;

//-- surface tension
dimensionedScalar sigma;

// Member Functions

const dimensionedScalar& g() const
{
    return g_;
}

const dimensionedScalar& sigma() const
{
    return sigma_;
3 Adjusting the case files

A simulation run can be accomplished within Eclipse, too.

1. Import the provided test case as a C++ project and adapt the project properties for OpenFOAM as mentioned in chapter 2.
2. The new drag force model can be selected via keyword entry in the dictionary interfacialProperties, while the new transport properties have to be added in the transportProperties dictionary.
3. Set up the run configurations in the menu bar under Run → Run Configurations. Double-click on C/C++ Application, choose your test case as project and your solver as C/C++ application. Here, the test case cylindricBubbleColumn is chosen as project and the solver bubbleFoamMod is chosen as application – be aware to select the correct binary file (see Figure 9).
4. Start your simulation by clicking on the Run button and have a look at the console output in Eclipse.

4 Debugging with Eclipse

One capability of Eclipse is efficient debugging. So, in this chapter we would like to check if the new model is implemented correctly and how the runTime-selective access to the models is carried out.
1. Set up the debugging configurations in Run → Debug Configurations. Choose the same settings for project and application as for the run configurations.

2. Make sure, that you are using the GDB (DSF). Create Process Launcher as debugger. If necessary, change it by clicking on Select other... (see Figure 10).

3. Start clicking on Debug. Now, the debug perspective should open – if not, activate it in the menu bar under Window → Open Perspective → Debug. The program should stop at the first breakpoint that is set to entering main{} by default.

In Debug mode Eclipse allows you to set breakpoints by double-clicking on the bar to the left of the line numbers. You can resume debugging by clicking on the green play button (shortcut F8). During debugging the console output on the bottom as well as the variable values and breakpoints on the right hand side are available (see Figure 11). You can walk through the code line-by-line while Eclipse highlights the line of the file you are currently computing. For stepping into function use the step-into-button (shortcut F5) and for stepping over functions use the corresponding step-over-button (shortcut F6).

4. Set the first breakpoint in createFields.H where you implemented the selection of the drag model (autoPtr<dragModel> draga = dragModel::New). Set the second breakpoint in liftDragCoeffs.H where Cds is evaluated using the new drag model (volScalarField Cda = draga->K(magUr)).

5. Now resume to the first breakpoint (F8) and step into the drag model selection process (F5). The debugger now points to the constructor of the new drag model where the drag model to be chosen is read in from the dictionary entry in interfacialProperties.

6. Resume to the next breakpoint (F8) and step into (F5) the evaluation of the drag coefficient. Depending on the model chosen in the interfacialProperties dictionary
Figure 11: Debug Perspective

the debugger now points to either SchillerNaumann.C or Tomiyama98.C – for both cases calling the function \texttt{K(magUr)}. Step into (F5) the evaluation of the Reynolds number 

\[ \text{volScalarField } Re = \max(Ur \cdot \text{phase}_a.d() / \text{phase}_b.nu(), \text{scalar}(1.0e-03)); \]

and make sure that the bubble diameter of phase a (\texttt{phase}_a.d()) is accessed via access function of \texttt{phaseModel}. You can even check the value of the diameter variable in the \texttt{Variables} window on the right side.
A References

References


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