Helsinki University of Technology
CFD Group / Department of Applied Mechanics

MEMO No CFD/MECHA-4-2008 DATE: 10 November 2008

TITLE

On Initialisation of Properties in Multiphase Finflo

AUTHOR(S)
Heru S.R. Reksoprodjo

ABSTRACT

Initialisation of solution field for the multiphase flow calculation in Finflo is described. Three different cases are considered. Each iterates for a different flow properties, given values of the other two. The properties are the freestream temperature, pressure and cavitation number.

MAIN RESULT

An implementation of a mechanism to differentiate different test parameters have been done on the Finflo code, based on a new user-supplied parameter `MPCASE`.

PAGES
5

KEY WORDS
Initial conditions, water, multiphase, Finflo

APPROVED BY

Timo Siikonen 10 November 2008

Contents

1. Introduction

To initiate multiphase flow computations in Finflo, certain flow parameters must be provided in conjunction with the state equations. The parameters are the freestream velocity, pressure, temperature, and cavitation number. Of these, the freestream velocity can be considered completely independent, while the others are inherently inter-related. Of the other three parameters, two are sufficient do define a complete set, relegating the third one a function of the others. The code must be able to distinguish the different cases, and also to provide the correct value for the third parameter. This step is necessary since Finflo is based on dimensional equations, and thus, a temperature effect is introduced. Note that for a completely incompressible formulation, there is no need for temperature.

2. Motivation

The cavitation number is defined as follows:

$$\sigma = \frac{p - p_{\mathrm{sat}}}{\frac{1}{2}\rho U^2} \tag{1}$$

Furthermore, in its implementation of multiphase calculations, Finflo requires density to be a function of both pressure and temperature, while the saturation pressure is a function of temperature only.

Initially, Finflo chooses the temperature as the iterated value. Since the application has been on the (nearly) incompressible situation, the isothermal condition can guarantee little, or no changes in the temperature field. Unfortunately, this often results in the computation, for a given pressure value and cavitation number, being done with much higher temperature than desired. This can be circumvented by choosing a low enough value for the freestream pressure.

3. Development of the initialisation scheme

The necessity for the iterative process to find suitable value for the freestream pressure opens a possibility for an automatisation. It is recognised that any two of the three parameters (pressure, temperature, σ) are sufficient, resulting in the three different cases:

(1) For a given pressure and σ value, temperature is iterated.
(2) For a given temperature and pressure value, σ is calculated from equation (1), no need for iterations.
(3) For a given σ and temperature value, pressure is iterated.

The process has been implemented within the framework of subroutine `BLOCK_REPORT` in file `outp3.f`, based on the value of user-supplied variable `MPCASE`.

From equation (1), an iterative method can be easily developed for cases 1 and 3. For simplicity, the method of modified *regula falsi* is employed. This method requires two different guess values, in which the results of the function are of opposite signs. The zero intersection is chosen to be the next guess value, depending on the sign of the function. On the end that is kept, the function value is halved, to help with the convergence. Convergence is considered achieved when the changes are less than 10^{-9}.

Case 1: Here the right (negative) initial guess value for the temperature is simply setting it to the saturation value for the given pressure. Since there is a (strongly) linear correlation between the saturation pressure and temperature, this can be easily accomplished from the curve fits procedure in Finflo. The left (positive) value comes from the `INPUT` file. This value should be small enough. This option utilizes subroutine `FTEMPS`.

Case 2: As mentioned earlier, no iteration is needed, since the cavitation number σ is readily computed from equation (1). This option utilizes subroutine `FSIGMA`.

Case 3: Here the left (negative) initial guess value for the pressure is simply setting it to the saturation value, while the right value comes from the `INPUT` file. This value should be large enough. This option utilizes subroutine `FPRESS`.

Note that the computations for all three options are implemented in the file `state.f`. Furthermore, the following subroutines are also employed: `DTSATLOG` and `DPSATLOG`. These subroutines correlate the saturation pressure and temperature.

It is now possible for the user to access this feature by assigning value to the `MPCASE` parameter in the `INPUT` file.

4. Sample calculations

To validate the procedure, the following test case is proposed:

$$\begin{aligned} \text{Temperature} &= 297.15\ \text{K} \\ \text{Pressure} &= 40.00\ \text{kPa} \\ \text{Cavitation number} &= 2.062695 \end{aligned}$$

Note that the cavitation number is obtained by the use of option #2.

For the case #1, the initial temperature is set to 279.15 K; while for the case #3, the initial pressure is set to 100 kPa. The iteration process is illustrated in the following:

Case 1: Temperature iteration:

```
Iterating for suitable temperature value

Given pressure =                    40000.000 Pa
Given cavitation number =               2.062695
Initial temperature =                 279.150 K

Using method of modified regula falsi:
Seed values:
Lower limit =                         279.149993896 K
Upper limit =                         350.212356147 K

Next estimate =                       282.633530766 K
```

```
Next estimate =                      315.108237134 K
Next estimate =                      287.129791435 K
Next estimate =                      305.363713228 K
Next estimate =                      293.085884430 K
Next estimate =                      299.466336280 K
Next estimate =                      295.854810370 K
Next estimate =                      297.800093132 K
Next estimate =                      296.836008097 K
Next estimate =                      297.301261587 K
Next estimate =                      297.067357166 K
Next estimate =                      297.189432684 K
Next estimate =                      297.131020412 K
Next estimate =                      297.159025173 K
Next estimate =                      297.145067135 K
Next estimate =                      297.152337012 K
Next estimate =                      297.148866079 K
Next estimate =                      297.150529494 K
Next estimate =                      297.149700852 K
Next estimate =                      297.150132388 K
Next estimate =                      297.149926382 K
Next estimate =                      297.150025106 K
Next estimate =                      297.149975927 K
Next estimate =                      297.150001538 K
Next estimate =                      297.149989312 K
Next estimate =                      297.149995171 K
Next estimate =                      297.149992253 K
Next estimate =                      297.149993773 K
Next estimate =                      297.149993047 K
Next estimate =                      297.149993395 K
Next estimate =                      297.149993221 K
Next estimate =                      297.149993312 K
Next estimate =                      297.149993269 K
Next estimate =                      297.149993289 K
Next estimate =                      297.149993279 K
Next estimate =                      297.149993284 K
Next estimate =                      297.149993282 K
Next estimate =                      297.149993283 K
Next estimate =                      297.149993282 K
Next estimate =                      297.149993283 K

Final temperature value =            297.150 K
```

Case 2: Cavitation number computation:

```
Calculating the cavitation number value

Given temperature =                  297.150 K
Given pressure =                   40000.000 Pa
Computed cavitation number =           2.062695
```

Case 3: Pressure iteration:

```
Iterating for suitable pressure value

Given temperature =                   297.150 K
Given cavitation number =               2.062695
Initial pressure =                 100000.000 Pa

Using method of modified regula falsi:
Seed values:
Lower limit =                        2985.762635039 Pa
Upper limit =                      100000.000000000 Pa

Next estimate =                     40000.518200141 Pa
Next estimate =                     39999.160333067 Pa
Next estimate =                     40000.000115856 Pa
Next estimate =                     40000.000096850 Pa
Next estimate =                     40000.000104101 Pa
Next estimate =                     40000.000104101 Pa
Next estimate =                     40000.000104101 Pa

Final pressure value =              40000.000 Pa
```

As can be seen, the final values for all cases agree to reasonable precision.

5. Conclusion

In this report, new feature is added for the initialisation of the solution field in the Finflo code. Different multiphase parameters can now be specified in a more coherent manner.

References

[1] Finflo User Guide, Version 7.2, Finflo, Ltd., Espoo, 2005.