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Introduction to open source CFD

Session 4/4

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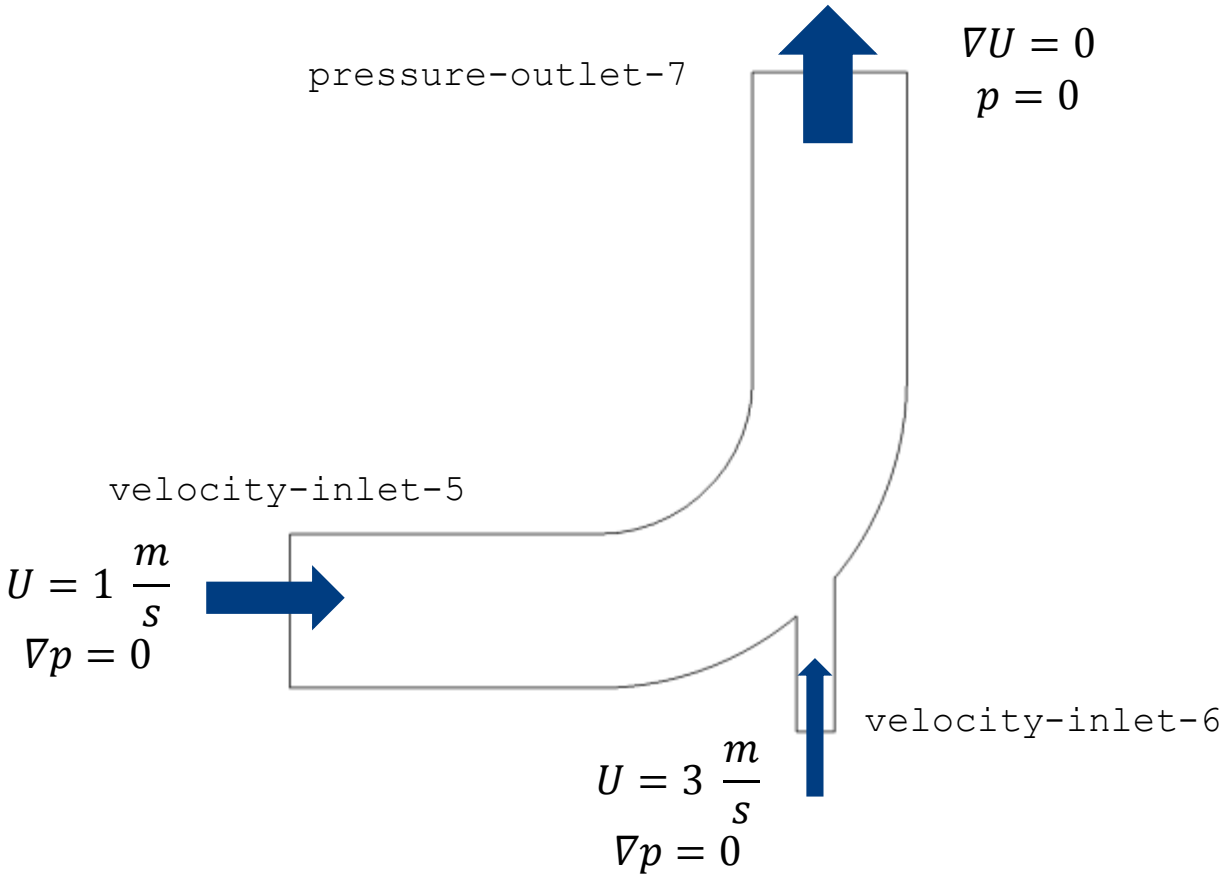
Introduction to open source CFD
Outline

- Creating your own physics library
  - Run a base case
  - Create a modelling library
  - Create a solver
  - Create a test case
  - Online sampling (function object)
- Project work (Wed 18.02.2015 presentation)
- (Miscillaneous)

CREATING A PHYSICS LIBRARY

Creating a physics library
Initial case

- We will use a standard OpenFOAM tutorial: mixing elbow
- Incompressible, transient (`icoFoam`)



Creating a physics library
Initial case

- Go to your run directory

```
> run
```

- Copy the tutorial

```
> cp -r $FOAM_TUTORIALS/incompressible/icoFoam/elbow .
```

- Change directory into the case

```
> cd elbow
```

Creating a physics library
Initial case

- The case contains a Fluent/Ansys mesh

```
> ls -1
0
Allrun
Allclean
constant
elbow.msh
system
```

- Convert the fluent mesh

```
> fluentMeshToFoam elbow.msh
```

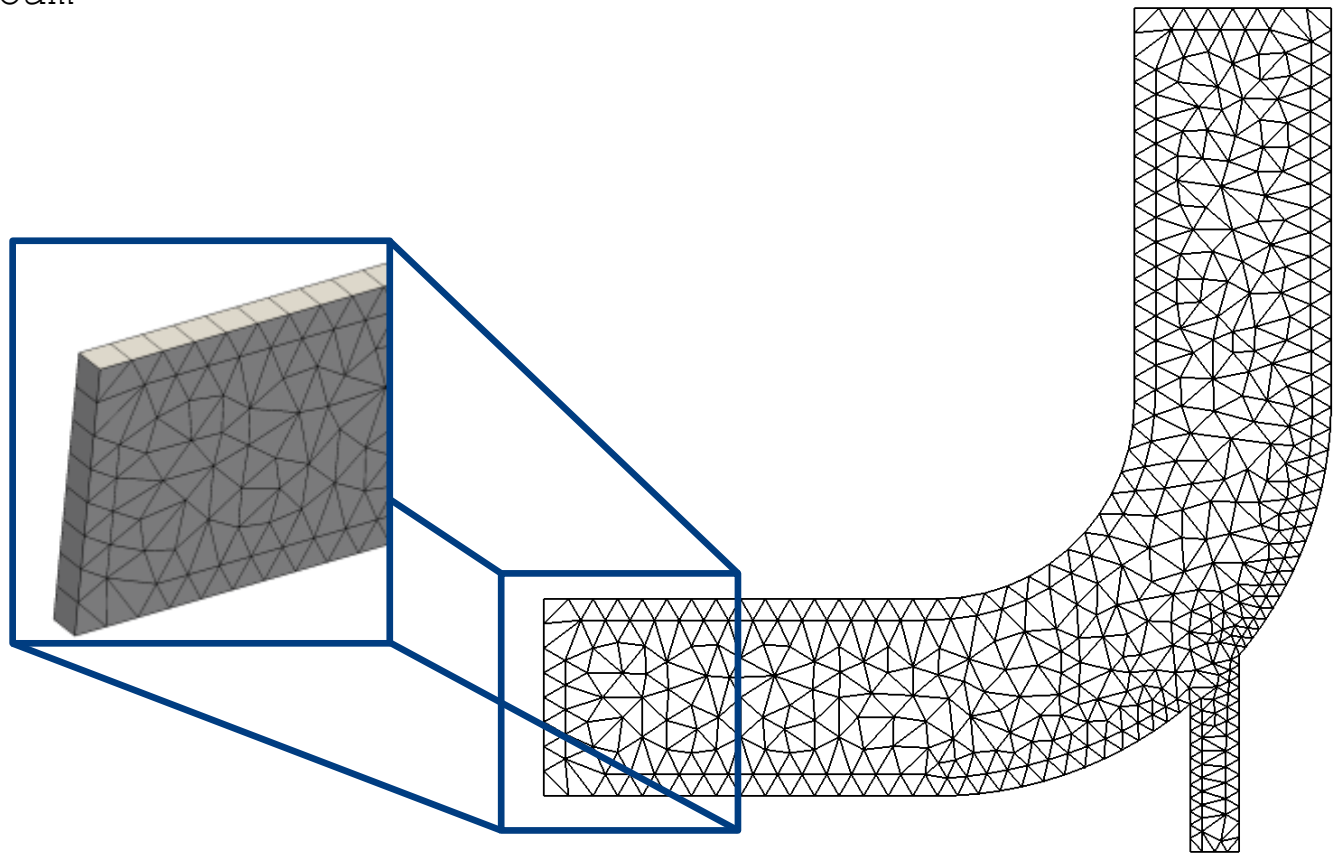
- Other converters can be found in the utilities directory

```
> ls $FOAM_UTILITIES/mesh/conversion
```

Creating a physics library
Initial case

- Now the mesh can be viewed in ParaView

```
> paraFoam
```



Creating a physics library
Initial case

- Run the solver

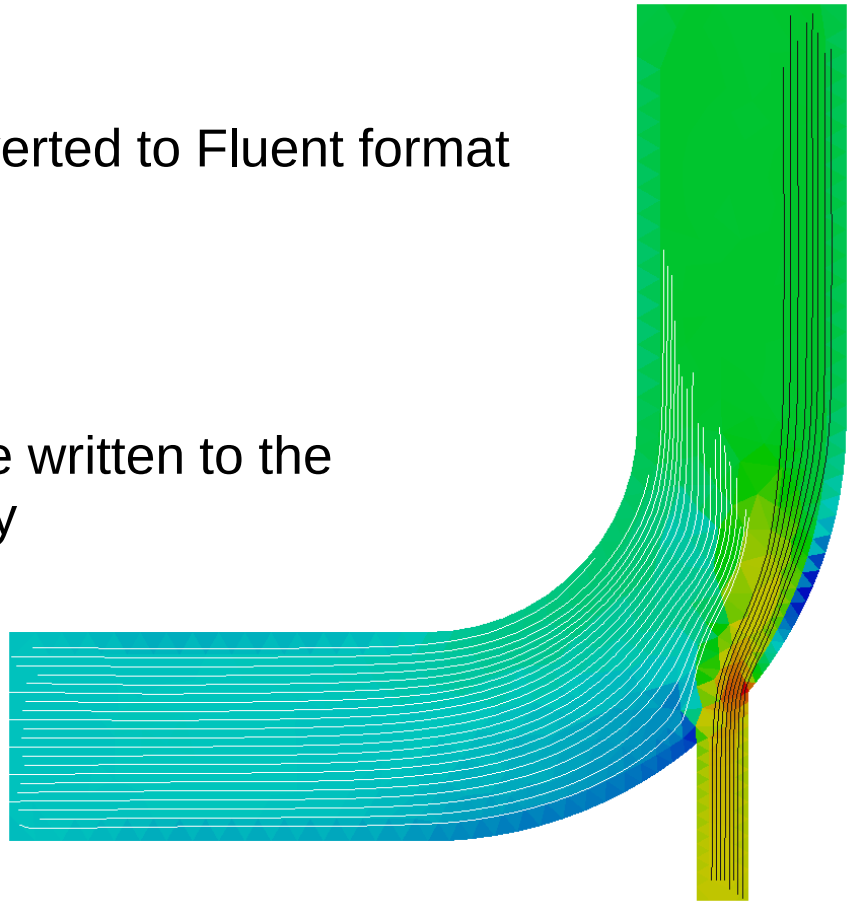
  ```
  > icoFoam
  ```

- Finally, the case can be converted to Fluent format

  ```
  > foamMeshToFluent
  ```

  ```
  > foamDataToFluent
  ```

- The fluent mesh and data are written to the `fluentInterface` directory



Creating a physics library
Modelling library

- Modelling libraries in OpenFOAM® are compiled as shared objects
  - run-time selectable models
  - modular, less duplication
  - shared objects can be linked to multiple executables

- Compiling
  - an executable (e.g. solver): `wmake`
  - a shared library (e.g. physical model): `wmake libso`

- Examples of libraries include
  - turbulence models
  - thermodynamics

Creating a physics library
Modelling library

- Typically three instances of implementation of library object
  - Create

```
autoPtr<incompressible::turbulenceModel> turbulence
(
    incompressible::turbulenceModel::New(U, phi, laminarTransport)
);
```

  - Use

```
fvVectorMatrix UEqn
(
    fvm::ddt(U)
  + fvm::div(phi, U)
  + turbulence->divDevReff(U)
);
```

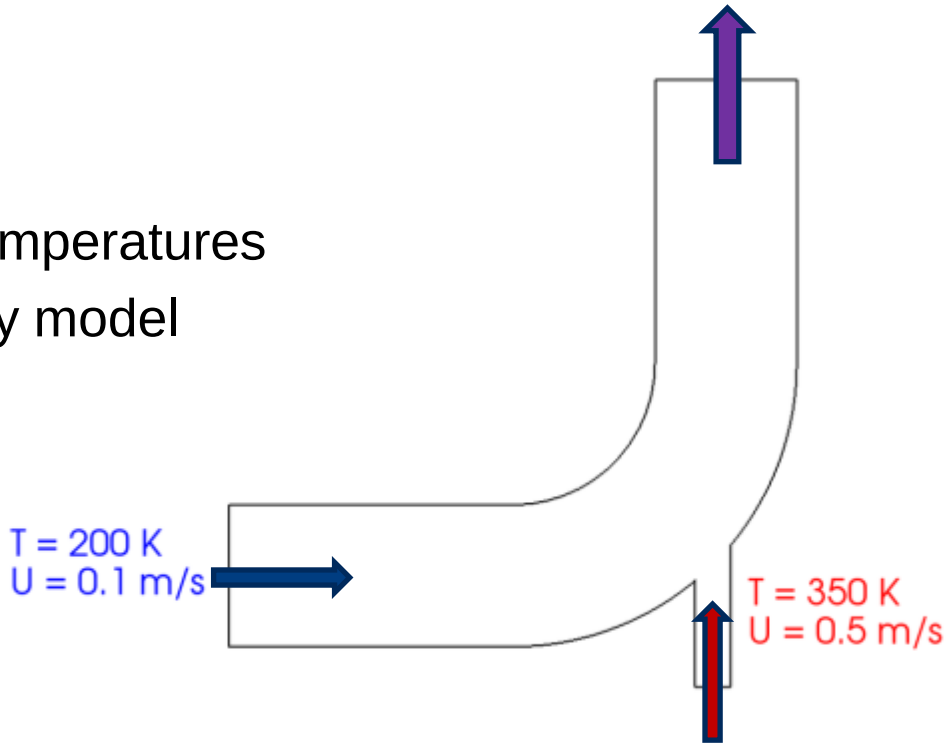
  - Update

```
turbulence->correct();
```

Creating a physics library
Modelling library

- Create a non-Newtonian viscosity model, solver and test case
  - Create a non-Newtonian viscosity **model**
  - Create (modify) a non-Newtonian **solver**
  - Create a **case** to test the solver

- The test case
  - Elbow junction
  - Acetone at different temperatures
  - Vogel thermal viscosity model



Creating a physics library
Creating the modelling library

- Create a non-Newtonian viscosity model, solver and test case
  - **Create a non-Newtonian viscosity model**
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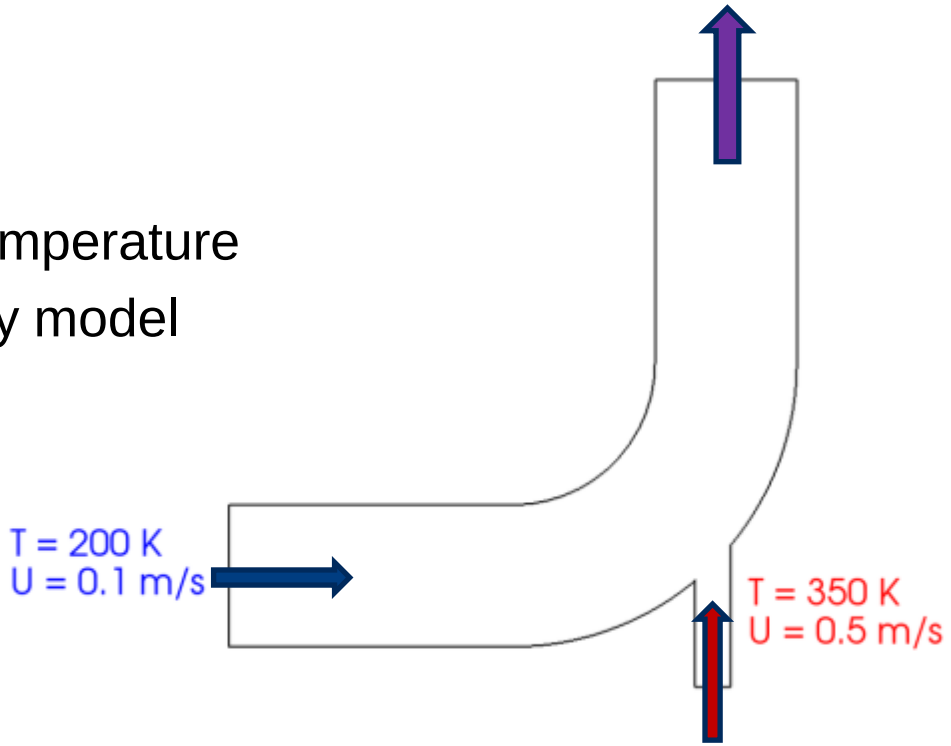
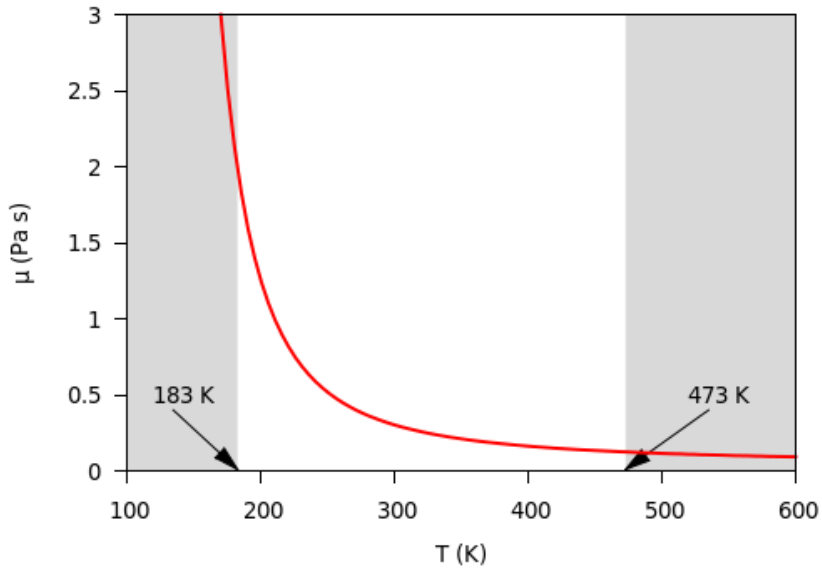


Creating a physics library
Creating the modelling library

- The Vogel non-Newtonian viscosity model[1]:

$$\nu = \frac{1000}{\rho*} \exp\left(a + \frac{b}{c + T}\right)$$



- Create a shared object library to couple the viscosity model to a solver

[1] See DDBST: http://ddbonline.ddbst.de/VogelCalculation/VogelCalculationCGI.exe?component=Acetone

Creating a physics library
Creating the modelling library

- The Vogel non-Newtonian viscosity model:

$$\nu = \frac{1000}{\rho *} \exp\left(a + \frac{b}{c + T}\right)$$

- Create a shared object library to couple the viscosity model to a solver

- Copy an existing model and modify

```
> mkdir -p \
    $WM_PROJECT_USER_DIR/src/transportModels/incompressible/viscosityModels
> cd !$
> export VM=$FOAM_SRC/transportModels/incompressible/viscosityModels
> cp -r $VM/HerschelBulkley Vogel
> cd Vogel
> rename 's/HerschelBulkley/Vogel/g' *.*
> sed -i 's/HerschelBulkley/Vogel/g' *.*
```

Creating a physics library
Creating the modelling library

- Copy a `Make` directory into the Vogel library

```
> cp -r $FOAM_SRC/transportModels/incompressible/Make .
```

- Modify `Make/files` as:

```
1 Vogel.C
2
3 LIB = $(FOAM_USER_LIBBIN)/libvogelViscosityModel
```

- … and `Make/options` as:

```
1 EXE_INC = \
2     -I$(LIB_SRC)/finiteVolume/lnInclude \
3     -I$(LIB_SRC)/transportModels/incompressible/lnInclude
4
5 LIB_LIBS = \
6     -lfiniteVolume \
7     -lincompressibleTransportModels
```

Creating a physics library
Creating the modelling library

- Before making any changes it is a good idea to compile

```
> wmake libso
```

- Modify private member data in `Vogel.H`

```
 1 class Vogel
 2 :
 3 public viscosityModel
 4 {
 5     // Private data
 6
 7     dictionary VogelCoeffs_;
 8
 9     dimensionedScalar a_;
10     dimensionedScalar b_;
11     dimensionedScalar c_;
12     dimensionedScalar rhoStar_;
13
14     volScalarField nu_;
```

Creating a physics library
Creating the modelling library

- Implement the Vogel model as a member function in `Vogel.C`

$$\nu = \frac{1000}{\rho*} \exp\left(a + \frac{b}{c + T}\right)$$

```
50 Foam::tmp<Foam::volScalarField>
51     Foam::viscosityModels::Vogel::calcNu() const
52 {
53     const volScalarField& T =
54         U_.db().lookupObject<volScalarField>("T");
55
56     return
57     (
58         scalar(1000)/rhoStar_*exp(a_ + (b_/(c_ + T)))
59     );
60 }
```

Creating a physics library
Creating the modelling library

- Add the new model variables to the constructor in `Vogel.C`

```
64   Foam::viscosityModels::Vogel::Vogel
65   (
66       const word& name,
67       const dictionary& viscosityProperties,
68       const volVectorField& U,
69       const surfaceScalarField& phi
70   )
71   :
72       viscosityModel(name, viscosityProperties, U, phi),
73       VogelCoeffs_(viscosityProperties.subDict(typeName + "Coeffs")),
74       a_(VogelCoeffs_.lookup("a")),
75       b_(VogelCoeffs_.lookup("b")),
76       c_(VogelCoeffs_.lookup("c")),
77       rhoStar_(VogelCoeffs_.lookup("rhoStar")),
78       nu_
79       (
80           ...
```

Creating a physics library
Creating the modelling library

- Add the new model variables to the read function in `Vogel.C`

```
 95  bool Foam::viscosityModels::Vogel::read
 96  (
 97      const dictionary& viscosityProperties
 98  )
 99  {
100      viscosityModel::read(viscosityProperties);
101
102      VogelCoeffs_ = viscosityProperties.subDict(typeName + "Coeffs");
103
104      VogelCoeffs_.lookup("a") >> a_;
105      VogelCoeffs_.lookup("b") >> b_;
106      VogelCoeffs_.lookup("c") >> c_;
107      VogelCoeffs_.lookup("rhoStar") >> rhoStar_;
108
109      return true;
110  }
```

Creating a physics library
Creating the modelling library

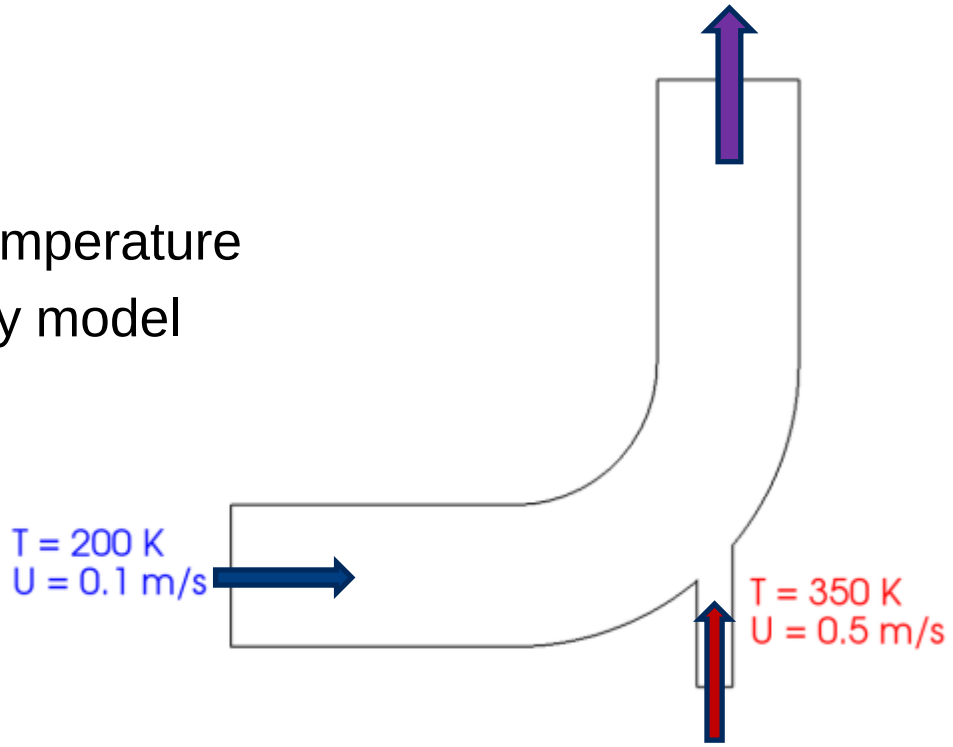
- Finally, compile the library

```
> wmake libso
```

Creating a physics library
Create a thermal non-Newtonian solver

- Create a non-Newtonian viscosity model, solver and test case
  - Create a non-Newtonian viscosity model
  - **Create (modify) a non-Newtonian solver**
  - Create a case to test the solver

- The test case
  - Elbow junction
  - Acetone at different temperature
  - Vogel thermal viscosity model



Creating a physics library
Create a thermal non-Newtonian solver

- Start from `nonNewtonianIcoFoam` solver and implement the thermal tracer

```
> mkdir -p $WM_PROJECT_USER_DIR/applications/solvers/incompressible
> cd $WM_PROJECT_USER_DIR/applications/solvers/incompressible
> cp -r $FOAM_SOLVERS/incompressible/nonNewtonianIcoFoam \
      nonNewtonianIcoThermalFoam
> cd nonNewtonianIcoThermalFoam
> mv nonNewtonianIcoFoam.C nonNewtonianIcoThermalFoam.C
```

- Edit `Make/files`

```
1 nonNewtonianIcoThermalFoam.C
2
3 EXE = $(FOAM_USER_APPBIN)/nonNewtonianIcoThermalFoam.C
```

- Compile the solver

```
> wmake
```

Creating a physics library
Create a thermal non-Newtonian solver

- Add tracer properties to `createFields.H`, first read transportProperties

```
30      // Instantiated the constant/transportProperties dictionary.
31      Info<< "Reading transportProperties\n" << endl;
32
33      IOdictionary transportProperties
34      (
35          IOobject
36          (
37              "transportProperties",
38              runTime.constant(),
39              mesh,
40              IOobject::MUST_READ_IF_MODIFIED,
41              IOobject::NO_WRITE
42          )
43      );
```

Creating a physics library
Create a thermal non-Newtonian solver

- Add tracer properties to `createFields.H`, then instantiate `DT`

```
45      // Instantiated tracer diffusion coefficient DT, read from
46      // constant/transportProperties.
47      dimensionedScalar DT
48      (
49          transportProperties.lookup("DT")
50      );
```

Creating a physics library
Create a thermal non-Newtonian solver

- Add tracer properties to `createFields.H`, and create field `T`

```
52      // Create tracer field T.
53      Info<< "Reading field T\n" << endl;
54      volScalarField T
55      (
56          IOobject
57          (
58              "T",
59              runTime.timeName(),
60              mesh,
61              IOobject::MUST_READ,
62              IOobject::AUTO_WRITE
63          ),
64          mesh
65      );
```

Creating a physics library
Create a thermal non-Newtonian solver

- Solve tracer transport in `nonNewtonianIcoThermalFoam.C`

```
108         // Solve passive scalar transport equation for tracer T.
109         solve
110         (
111             fvm::ddt(T)
112           + fvm::div(phi, T)
113           + fvm::laplacian(DT, T)
114         );
```

Creating a physics library
Create a thermal non-Newtonian solver

- Adjust te header of `nonNewtonianIcoThermalFoam.C`

```
Application
    nonNewtonianIcoThermalFoam

Description
    Transient solver for incompressible, laminar flow of non-Newtonian
    fluids. A transport equation for massless species T is implemented
    and. The Vogel viscosity model adjusts the viscosity according to
    the local value of the T (temperature) field.
```

- Finally, compile the solver

```
> wmake
```

Creating a physics library
Create a test case

- Create a non-Newtonian viscosity model, solver and test case
  - Create a non-Newtonian viscosity model
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  - **Create a case to test the solver**

- The test case
  - Elbow junction
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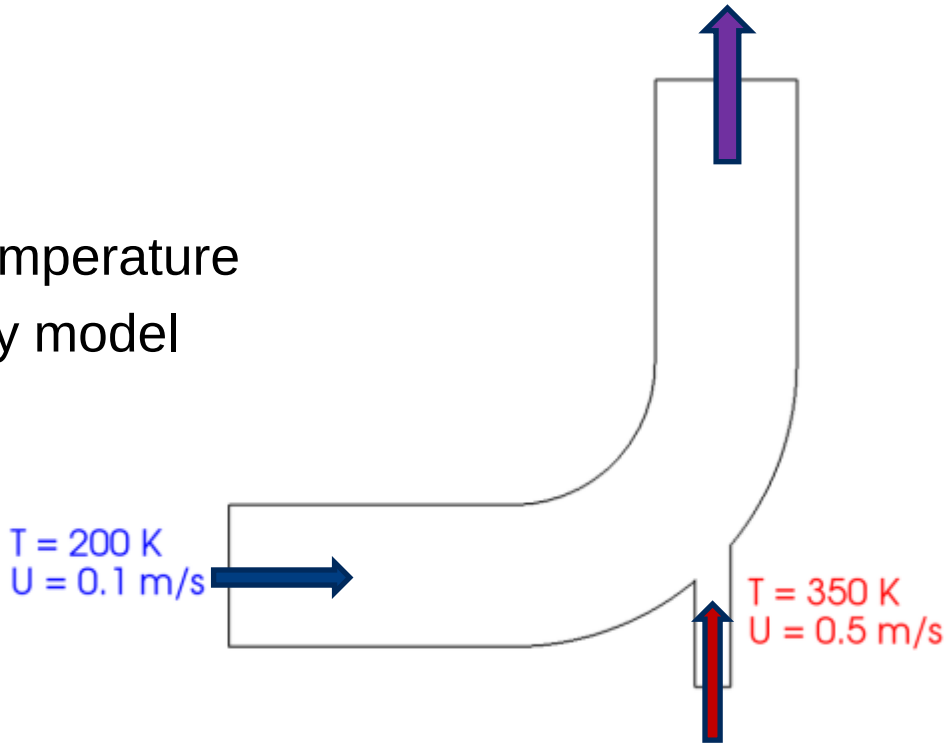


Creating a physics library
Create a test case

- Go to the run directory and copy the elbow case

```
> run
> cp -r $FOAM_TUTORIALS/incompressible/icoFoam/elbow elbowThermal
> cd elbowThermal
```

- Add `T` to `system/fvSolution` and `system/fvSchemes` (e.g. "`div(phi,T) Gauss upwind;`")
- Adjust `0/U` so that patch `velocity-inlet-5` has `(0.1 0 0)` and `velocity-inlet-6` has `(0 0.5 0)` m/s velocity
- Add the `Vogel` library to `system/controlDict`

```
18    libs
19    (
20        "libOpenFOAM.so"
21        "libvogelViscosityModel.so"
22    );
```

Creating a physics library
Create a test case

- Create `0/T` (just copy `0/p`, change name, dimensions, and BCs)

```
17 dimensions      [0 0 0 1 0 0 0];
18
19 internalField   uniform 295;
20
21 boundaryField
22 {
23     wall-4
24     {
25         type            zeroGradient;
26     }
27
28     velocity-inlet-5
29     {
30         type            fixedValue;
31         value           uniform 200;
32     }
33
```

Creating a physics library
Create a test case

- Create `0/T` (just copy `0/p`, change name, dimensions, and BCs)

```
34          velocity-inlet-6
35          {
36              type            fixedValue;
37              value           uniform 350;
38          }
39
40          pressure-outlet-7
41          {
42              type            inletOutlet;
43              inletValue      uniform 295;
44              value           uniform 295;
45          }
```

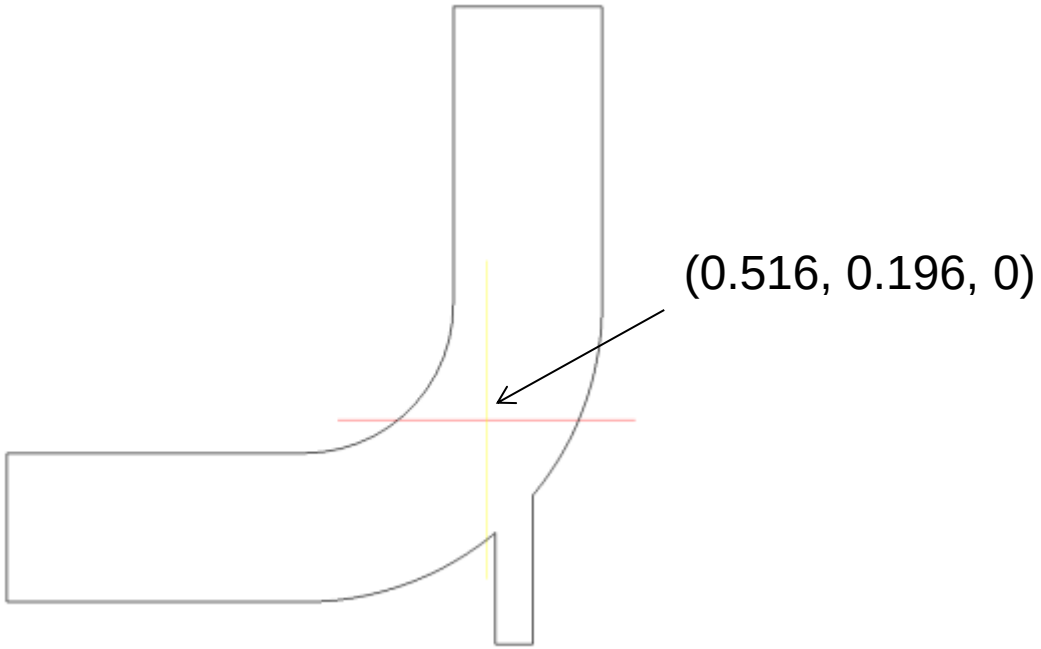
Creating a physics library
Create a test case

- Add the `Vogel` model to `constant/transportProperties`

```
18    transportModel  Vogel;
19
20    nu              nu [ 0 2 -1 0 0 0 0 ] 1;
21
22    DT              DT [ 0 2 -1 0 0 0 0 ] 1e-4;
23
24    VogelCoeffs
25    {
26        a               a [ 0 0 0 0 0 0 0 ] -3.4;
27        b               b [ 0 0 0 1 0 0 0 ] 553;
28        c               c [ 0 0 0 1 0 0 0 ] -47;
29        rhoStar         rhoStar [ 0 -2 1 0 0 0 0 ] 890;
30    }
```

Creating a physics library
Create a test case

- Let’s monitor the mixing zone by sampling viscosity and temperature



Creating a physics library
Create a test case

- Use a function object to sample online. Put the code below in `system/controlDict`:

```
54 functions
55 {
56     probes
57     {
58         type            probes;
59         functionObjectLibs ("libsampling.so");
60         enabled         true;
61         outputControl   timeStep;   // Sample every time step
62         outputInterval  1;          // Write data outputInterval*timeStep
63         fields ( T nu );            // Fields to sample
64         probeLocations
65         (
66             ( 0.516 0.196 0 )       // Sample location ( x y z )
67         );
68     }
69 }
```

Creating a physics library
Create a test case

- Use a function object to sample online. Put the code below in `system/controlDict`:

```
18 application     nonNewtonianIcoThermalFoam;
19
20 startFrom       latestTime;
21
22 startTime       0;
23
24 stopAt          endTime;
25
26 endTime         20;
27
28 deltaT          5e-4;
29
30 writeControl    runTime;
31
32 writeInterval   0.1;
33
34 purgeWrite      0;
```

Creating a physics library
Create a test case

- Before running convert the mesh. The original mesh is huge, so let's create a mesh of more sensible size

```
> fluentMeshToFoam -scale 0.01 elbow.msh
```

- Finally, run the solver

```
> nonNewtonianThermalFoam
```

Creating a physics library
Create a test case

- Before running convert the mesh. The original mesh is huge, so let's create a mesh of more sensible size

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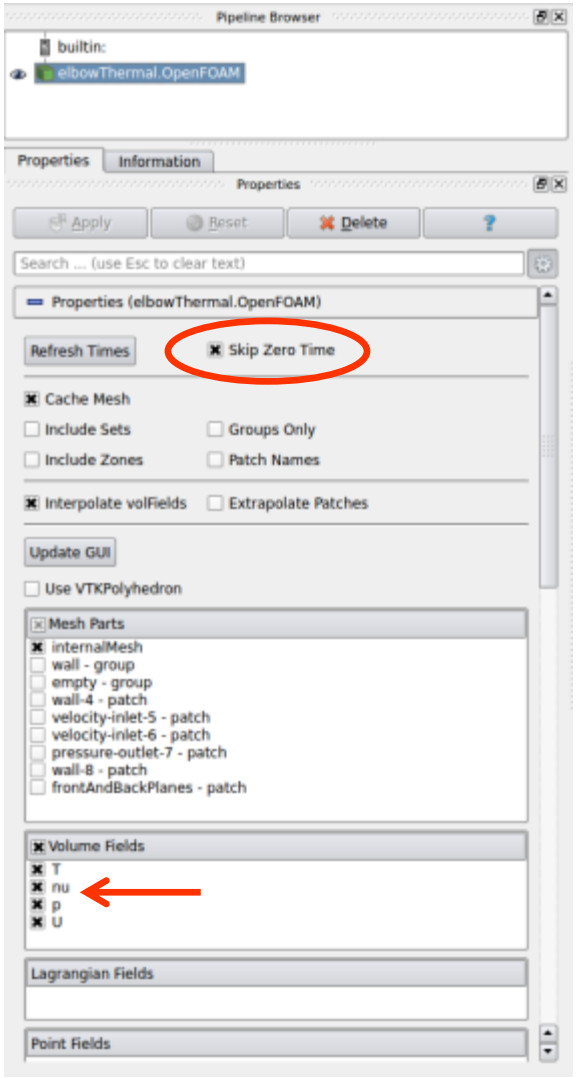
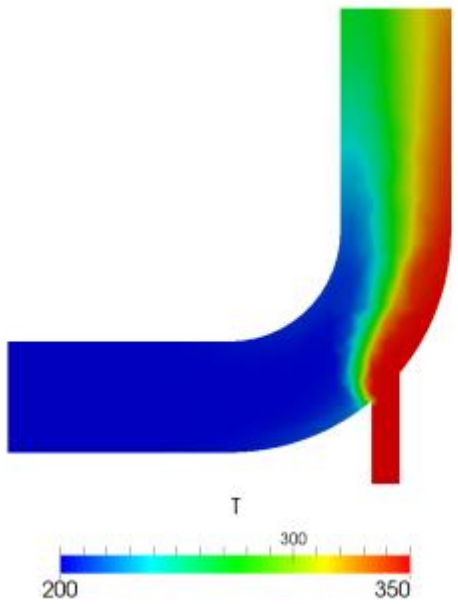
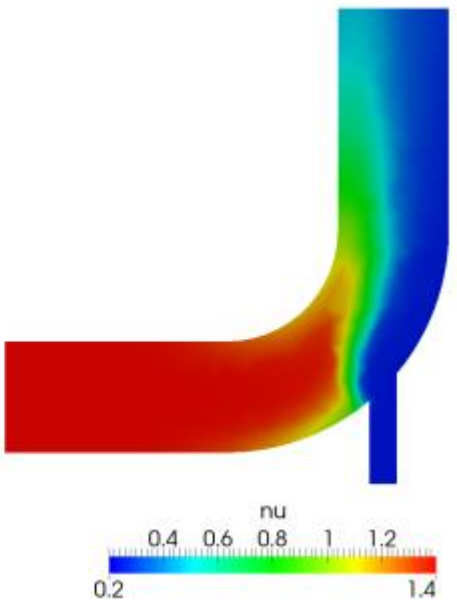
Creating a physics library
Create a test case







Creating a physics library
Create a test case

- View the sampling results, e.g. using `gnuplot`

```
> gnuplot
gnuplot > plot postProcessing/probes/0/nu using 1:2 with lines notitle
```