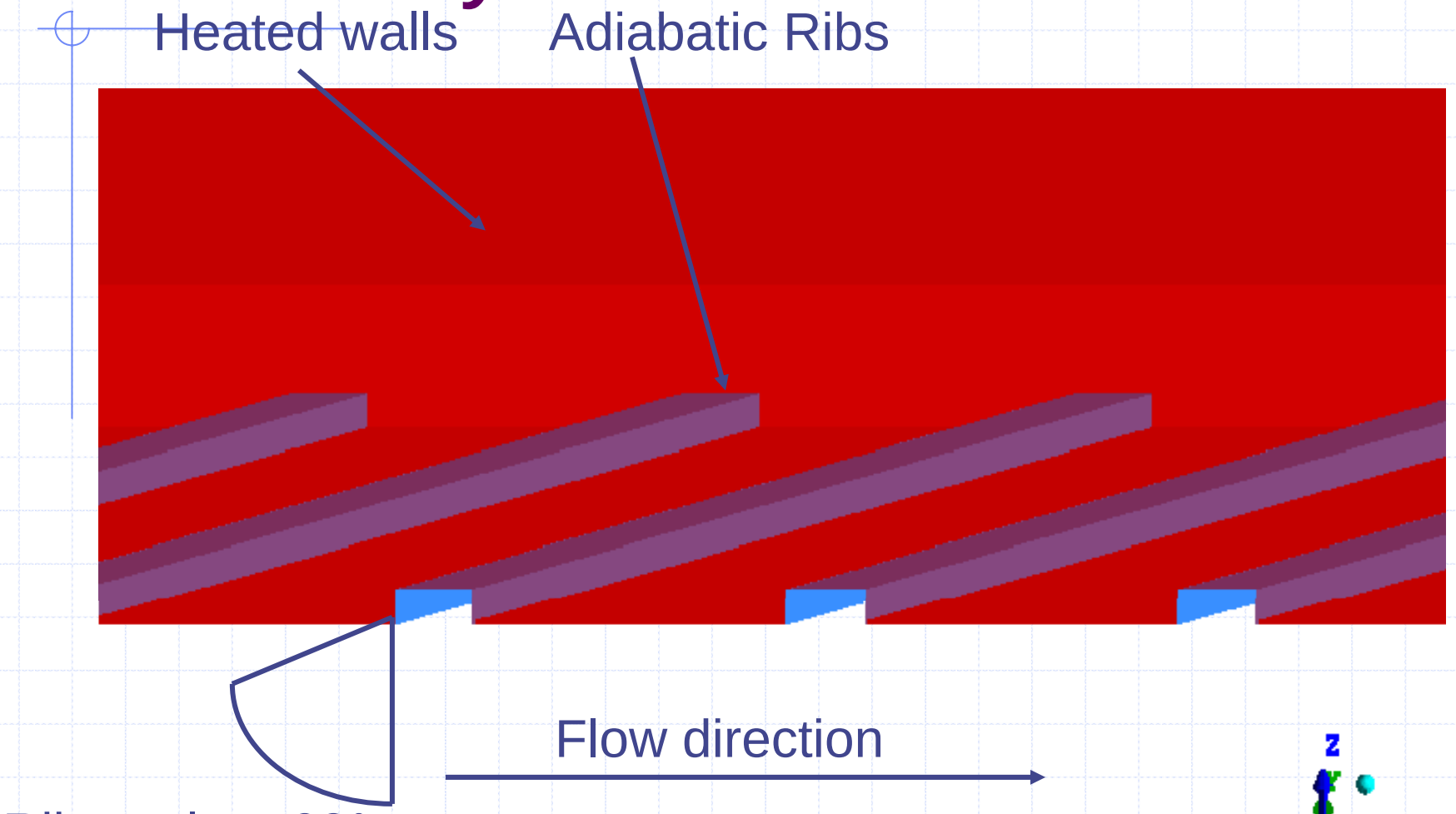
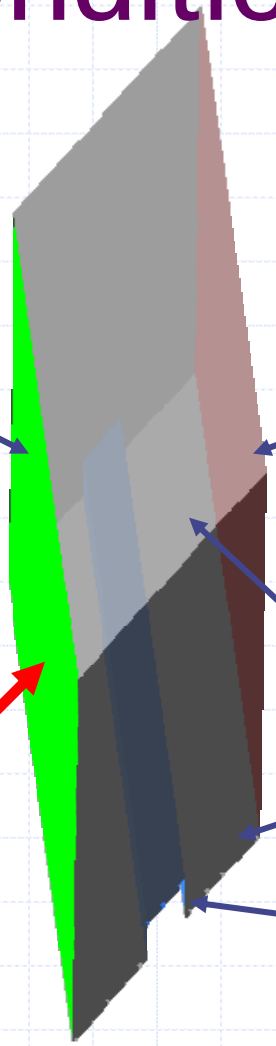
Rib Channel Details

Channel length, L	50 mm
Channel width, W	50 mm
Channel height, H	50 mm
Rib angle, β_{rib}	60°
Heat flux, q	1000 W/m²
Mass flow	0.02747 kg/s

Geometry



Boundary Conditions



Periodic side 1
(Inflow)

Periodic side 2
(Outflow)

Flow direction
(= X-direction)

Side, top, bottom walls
(Heat flux)

Rib wall
(Adiabatic)

Boundary Conditions

- Inlet and Outlet:
  - Periodic
- Pressure loss and wall heat transfer:
  - Compensated by source terms in momentum and energy equation
- Source terms automatically adjusted to meet:
  - Mass flow rate: 0.02747 kg/s
  - Mass-averaged bulk temperature: 320 K

Boundary Conditions

- Walls:
  - Heated walls: q = 1000 W/m²
    - Bottom, top, sides
  - Rib wall: Adiabatic

CEL: Automated Mass Flow
(Red Values must be adjusted)

```
LIBRARY:
  CEL:
    EXPRESSIONS:
      BetaRip = 60 [degree]
      DPDXINI = 40 [Pa / m]
      MGOAL = 0.02747 [kg/s]
      StartTS = 2
      DPDX = step(citern-StartTS)*DPDX2 + step(StartTS-citern)*DPDXINI
      DPDX1 = massFlowAve(AV DPDX )@Domain Interface 1 Side Domain 1 Part 1
      DPDX2 = DPDXRlx*(DPDXNew-DPDX1) + DPDX1
      DPDXNew = (MGOAL/MFLOW1)*DPDX1
      DPDXRlx = 0.2
      MFLOW1 = rho*(cos(BetaRip)*areaInt(Velocity u)@Domain Interface 1 Side Domain 1 Part 1\
                  -sin(BetaRip)*areaInt(Velocity v)@Domain Interface 1 Side Domain 1 Part 1)
      MRATIO1 = MFLOW1 / MGOAL
      rho = areaAve(Density )@Domain Interface 1 Side Domain 1 Part 1
    END
  END
END
```

CEL : Automated Mass Flow

Expression	Meaning
BetaRip	Angle of Inflow plane vs. YZ plane
DPDX	Momentum source term send to CCL
DPDX1	‘Old’ or ‘current’ momentum source term
DPDX2	‘New’ momentum source term after relaxation
DPDXNew	Calculated momentum source term to provide the correct mass flow
DPDXINI	Initial momentum source term for 1st iteration
DPDXRlx	Relaxation factor to change the mom. source term
MGOAL	Target mass flow
MFLOW1	Actual mass flow
StartTS	Iteration number for start of mom. Source term calculation

CEL: Automated Mass Flow

- Additional variable:
  - dp/dx of previous time step
  - defined as algebraic equation

```
LIBRARY:
  ADDITIONAL VARIABLE: AV DPDX
    Option = Definition
    Units = [ Pa / m]
    Variable Type = Specific
  END
END


FLOW:
  DOMAIN: Domain 1
    FLUID MODELS:
      ADDITIONAL VARIABLE: AV DPDX
        Additional Variable Value = DPDX
        Option = Algebraic Equation
      END
  END
END
```

CEL: Automated Bulk Temp.
(Red Values must be adjusted)

- Area-averaged temperature:

```
LIBRARY:
  CEL:
    EXPRESSIONS:
      QSOURCERlx = 1.0
      StartTS = 2
      TbulkGOAL = 320 [K]
      QSOURCE = (-1) * (step(citern-StartTS)*QSOURCE2 + step(StartTS-citern)*QSOURCE1)
      QSOURCE1 = areaInt(Wall Heat Flux)@WallB + areaInt(Wall Heat Flux)@WallT +
                 areaInt(Wall Heat Flux)@WallL + areaInt(Wall Heat Flux)@WallR
      QSOURCE2 = QSOURCERlx*(QSOURCENew-QSOURCE1) + QSOURCE1
      QSOURCENew = (Tbulk/TbulkGOAL)*QSOURCE1
      Tbulk = areaAve(Temperature)@Domain Interface 1 Side Domain 1 Part 1
    END
  END
END
```

CEL: Automated Bulk Temp.
(Red Values must be adjusted)

- Mass-averaged temperature:

```
LIBRARY:
  CEL:
    EXPRESSIONS:
      QSOURCERlx = 1.0
      StartTS = 2
      TbulkGOAL = 320 [K]
      QSOURCE = (-1) * (step(citern-StartTS)*QSOURCE2 + step(StartTS-citern)*QSOURCE1)
      QSOURCE1 = areaInt(Wall Heat Flux)@WallB + areaInt(Wall Heat Flux)@WallT +
                 areaInt(Wall Heat Flux)@WallL + areaInt(Wall Heat Flux)@WallR
      QSOURCE2 = QSOURCERlx*(QSOURCENew-QSOURCE1) + QSOURCE1
      QSOURCENew = (Tbulk/TbulkGOAL)*QSOURCE1
      Tbulk = areaInt(AV TEMPMASS)@Domain Interface 1 Side Domain 1 Part 1 / MFLOW1
      TEMPMASS = Temperature*(cos(BetaRip)*Velocity u - sin(BetaRip)*Velocity v)*rho
    END
  END
END
```

CEL : Automated Bulk Temp

Expression	Meaning
QSOURCE	Energy source term send to CCL
QSOURCE1	‘Old’ or ‘current’ energy source term
QSOURCE2	‘New’ energy source term after relaxation
QSOURCENew	Calculated energy source term to provide the correct bulk temperature
QSOURCERlx	Relaxation factor to change the energy source term
TbulkGOAL	Target bulk temperature at inflow
Tbulk	Actual bulk temperature at inflow
TEMPMASS	Temperature × mass flow density
StartTS	Iteration number for start of mom. Source term calculation

CEL: Automated Bulk Temp.

- Additional variable:
  - (Temperature × mass flow density) of previous time step
  - defined as algebraic equation

```
LIBRARY:
  ADDITIONAL VARIABLE: AV TEMPMASS
    Option = Definition
    Units = [ K * kg / (s * m^2)]
    Variable Type = Specific
  END
END


FLOW:
  DOMAIN: Domain 1
    FLUID MODELS:
      ADDITIONAL VARIABLE: AV TEMPMASS
        Additional Variable Value = TEMPMASS
        Option = Algebraic Equation
      END
  END
END
```

Fluid / Physical Models

- Air with constant properties:
  - Constant density: $\rho = 1.185\ kg/m^3$
  - Specific heat: $c_p = 1004.4\ J(kg\ K)$
  - Conductivity: $\lambda = 0.0261\ W/(m\ K)$
  - Dynamic viscosity: $\mu = 1.831 \times 10^{-5}\ Pa\ s$
- SST turbulence model:
  - Production limiter at stagnation point
  - Automatic wall functions