# Community Christmas Competition

Simulation of the drag coefficient of a monkey head with OpenFOAM

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# General

**General**

- OpenFOAM v4.1
- Solver: interFoam
- Mesh: blockMesh, snappyHexMesh
- Mesh size: 10m(l) x 6m(w) x 6m(h)
- Boundary conditions: Velocity inlet, total pressure outlet
- Smooth surface is assumed
- Filled holes at monkey eyes by MeshLab

**Specific Parameters**

- Fluid: Air, density = 1.2kg/$m^3$
- Freestream turbulence = 0.1%
- Frontal area of monkey head = 2.55281 $m^2$
- Length for calculating Reynolds Number = 1.6m (length of monkey head along flow dir & diameter of sphere for validation cases)
- Simulated Reynolds Number = 106,667, 213,333, 533,333 & 1,066,667 (for v=1 to 10m/s)

# Validation by Sphere (1 of 2)

**Validation by 1.6m Diameter Sphere**

- To validate applicability of the two approaches for calculating drag coefficients of sphere

**Approach 1:** Resolve boundary layer at sphere surface (y+ ≈ 1) with transition turbulence model (kkLOmega)

**Approach 2:** Wall function approach at sphere surface (y+ ≈ 30) with kOmegaSST turbulence model

**Sphere Drag Coefficients**

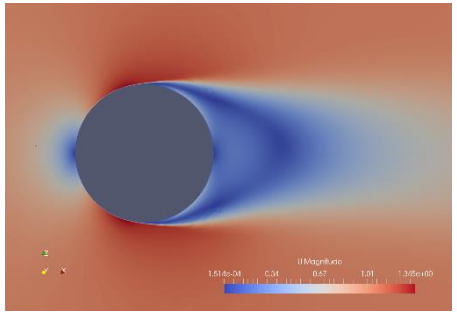
| Reynolds Numbers | 106,667 (v = 1m/s) | 213,333 (v = 2m/s) | 533,333 (v = 5m/s) | 1,066,667 (v = 10m/s) |
|---|---|---|---|---|
| Theoretical | 0.428 | 0.396 | 0.095 | 0.133 |
| Approach 1 | 0.508 | 0.377 | 0.088 | 0.244 |
| Approach 2 | 0.188 | 0.187 | 0.261 | 0.163 |

- Approach 1: Reasonably accurate, point of separation and flow pattern match with literature
- Approach 2: Unable to capture changes in drag coefficients

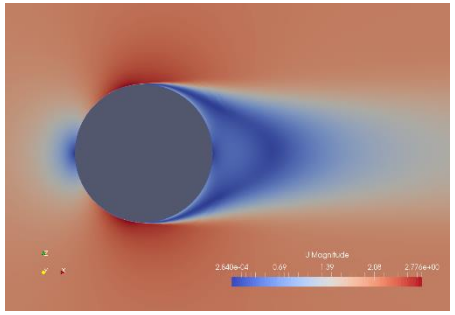
# Validation by Sphere (2 of 2)

## Approach 1

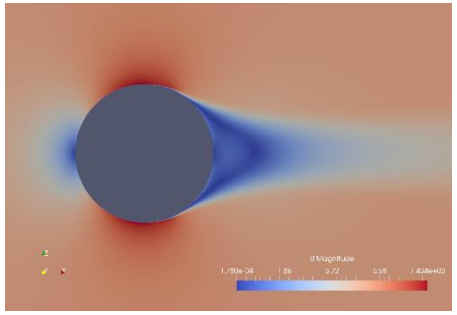
v = 1m/s (Re=106,667)



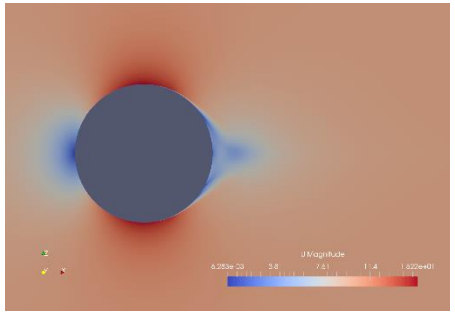
v = 2m/s (Re=213,333)



v = 5m/s (Re=533,333)

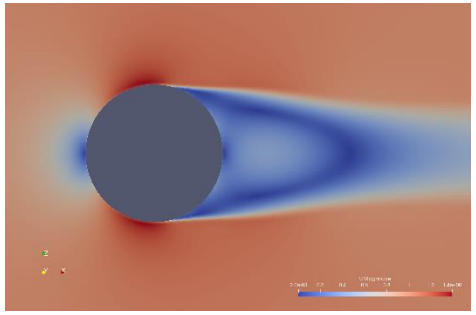


v = 10m/s (Re=1,066,667)

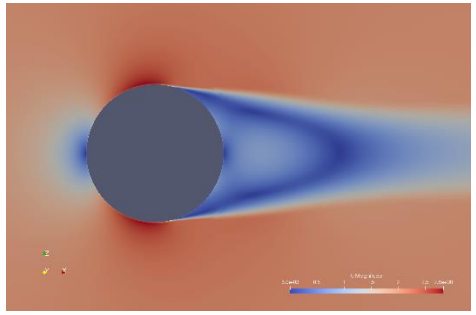


## Approach 2

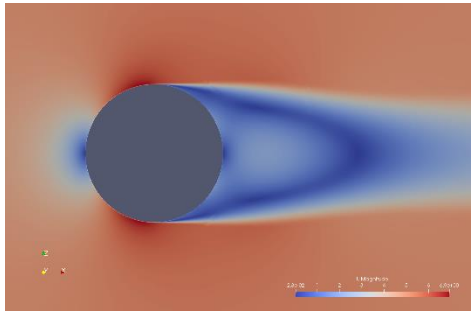
v = 1m/s



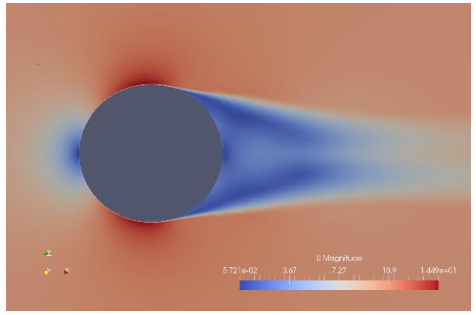
v = 2m/s



v = 5m/s



v = 10m/s



# Methodology Adopted for Monkey Head

**Wall Function Approach**

- Due to time constraint, wall function approach (Approach 2) is still adopted despite its lower accuracy
- 1st cell y+ ≈ 30
- Wall layer ratio = 1.2
- Total cells = 4.0M to 6.1M
- Turbulence model: komegaSST

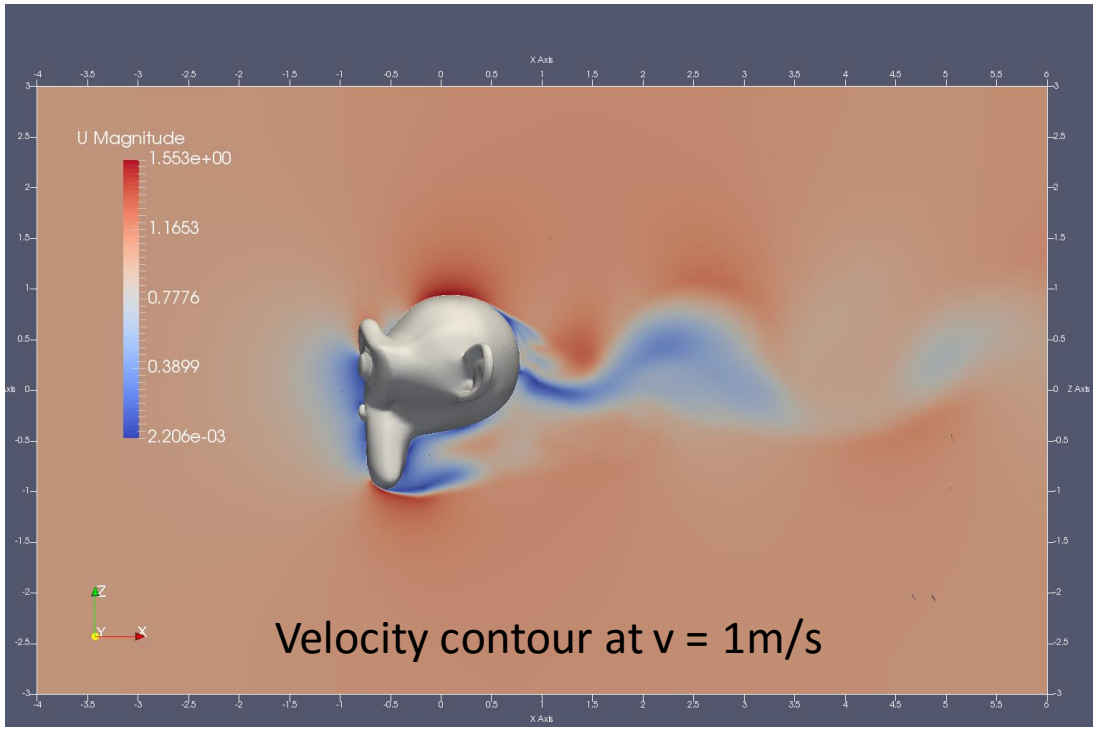
**Limitations**

- Boundary layer is assumed fully turbulent which is not true because:
- (i) At low Re, say below 100,000, boundary layer at monkey head is laminar; and
- (ii) At high Re, there is transition of laminar to turbulent boundary layer. Thus, modeling of flow separation point and pressure behind monkey head are not accurate

# Results

## Drag Coefficients

| Reynolds Numbers | 106,667 (v = 1m/s) | 213,333 (v = 2m/s) | 533,333 (v = 5m/s) | 1,066,667 (v = 10m/s) |
|---|---|---|---|---|
| Drag Coef. | 0.852 | 0.877 | 0.794 | 0.792 |




Velocity contour at v = 1m/s

Streamlines (velocity) and monkey head pressure distribution at v = 1m/s