Flow Past Nine Cylinders In Square Configuration

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Abstract

The main focus of this study is to observe the effect of centre-to-centre spacing ratio, L/D and Reynolds number, Re on the value of drag force on one of 9 different cylinders placed in a square configuration. The centre-to-centre ratio was fixed as 1.5 and Reynolds number was varied in the range 1500 - 2000. It was found that the residuals and the drag forces do not converge to a fixed value but instead keep oscillating about a mean. Moreover the fluctuations are influenced by Reynolds number.

1 Introduction

Flow past vertical cylinders have a lot of practical applications, especially in ocean engineering. There has been a lot of study done on 4-6 cylinders but not a lot on 9 cylinders due to the considerable complexity of the case. Thus in this case study 9 cylinder case is analysed for varied spacing ratios and Reynolds number. Studies are done using two fluids, water and another hypothetical fluid with a kinematic viscosity of $0.001 m^2/s$ and density $1.224 kg/m^3$.

2 Problem Statement

Consider a channel of dimensions **1 m** $\times$**0.6 m** $\times$**0.3 m** with 9 cylinders dipped in it at the centre. Let the diameter of the cylinders be **20 mm** and let the dominant length scale be the diameter of the cylinder. Other dimensions are specified in the figures 1 & 2.
Find the drag force on the first cylinder for the following cases:
Fluid: Water, hypothetical
L/D: 1.5
Re: 1500, 2000

Figure 1: *Top View of the channel*

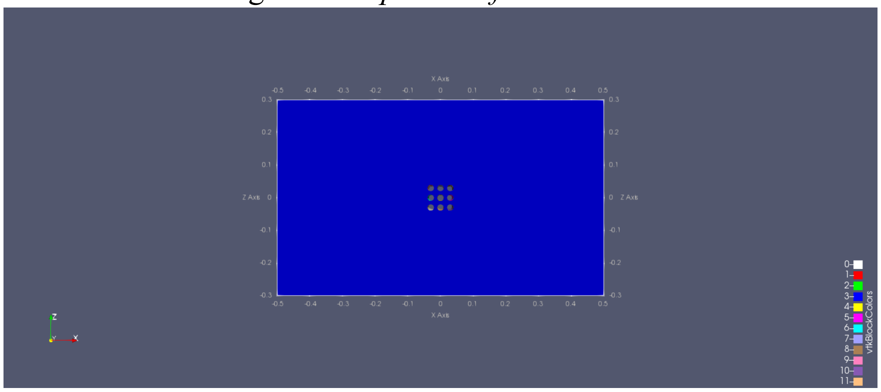
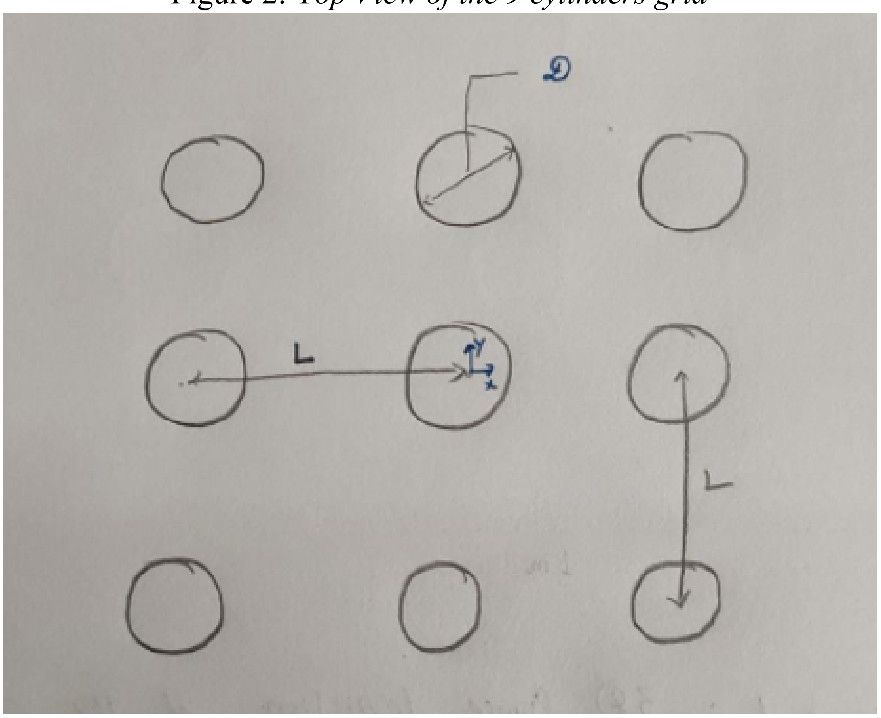


Figure 2: *Top View of the 9 cylinders grid*



3 Governing Equations and Models

3.1 Continuity Equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_i)}{\partial x_i} = 0 \tag{1}$$

This is the universal mass conservation equation.

3.2 Momentum Equation

$$\frac{\partial(\rho u_i)}{\partial t} + \frac{\partial[\rho u_i u_j]}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i \tag{2}$$

This is the momentum equation using RTT.

4 Simulation Procedure

4.1 Geometry and Mesh

The geometry was created modifying the motorbike tutorial of SimpleFOAM. The motor bike parts were removed and 9 cylinders were made using Paraview standard shapes. The resolution of the cylinders was set to 26 units. These were then meshed using BlockMesh and SnappyHexMesh. The parameters are written below: **BlockMesh** Number of cells: 80 40 80 **SnappyHexMesh** maxLocalCells: 100000 maxGlobalCells: 2000000 levels: 4 nSurfaceLayers: 1

4.2 Initial and Boundary Conditions

Pressure: zeroGradient at all boundaries and 0 gauge pressue at outlet
Velocity: refer to the table below

Fluid	Re	nu	Velocity at inlet	Velocity at outlet	Initial velocity condition
Water	1500	0.000001	0.075	zeroGradient	0.0025
Hypothetical fluid	1500	0.001	75	zeroGradient	1
Water	2000	0.000001	0.1	zeroGradient	0.0025
Hypothetical fluid	2000	0.001	100	zeroGradient	1

4.3 Solver

SimpleFoam solver is used for this case. GAMG is uded for solving p and Smooth solver are used for solving U.

Figure 3: *Residual Plot 1*

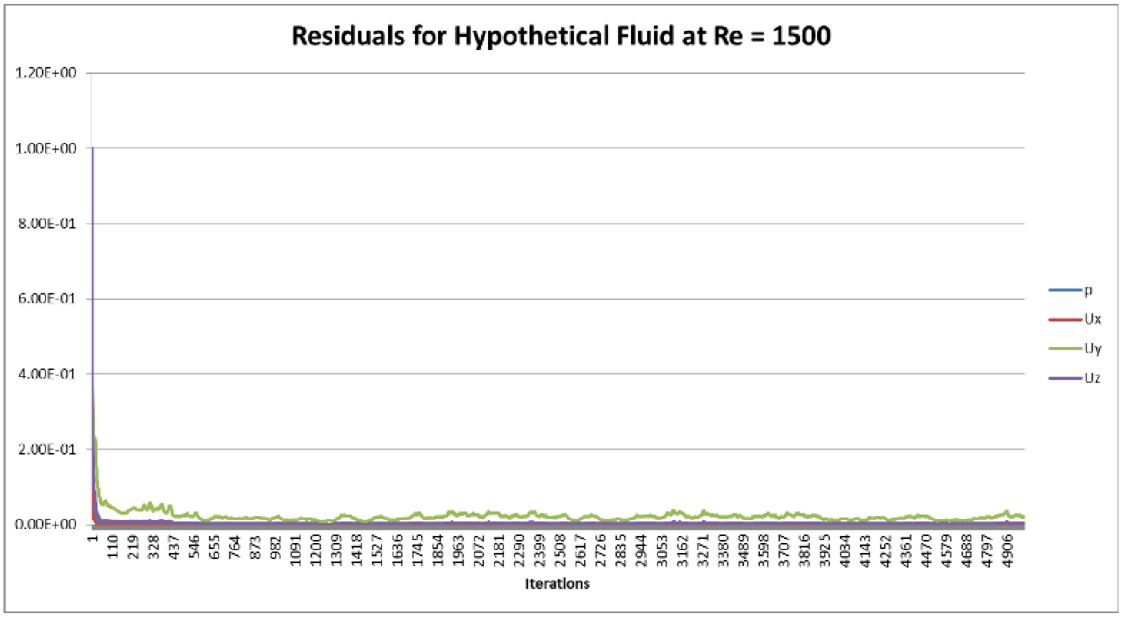


Figure 4: *Residual Plot 2*

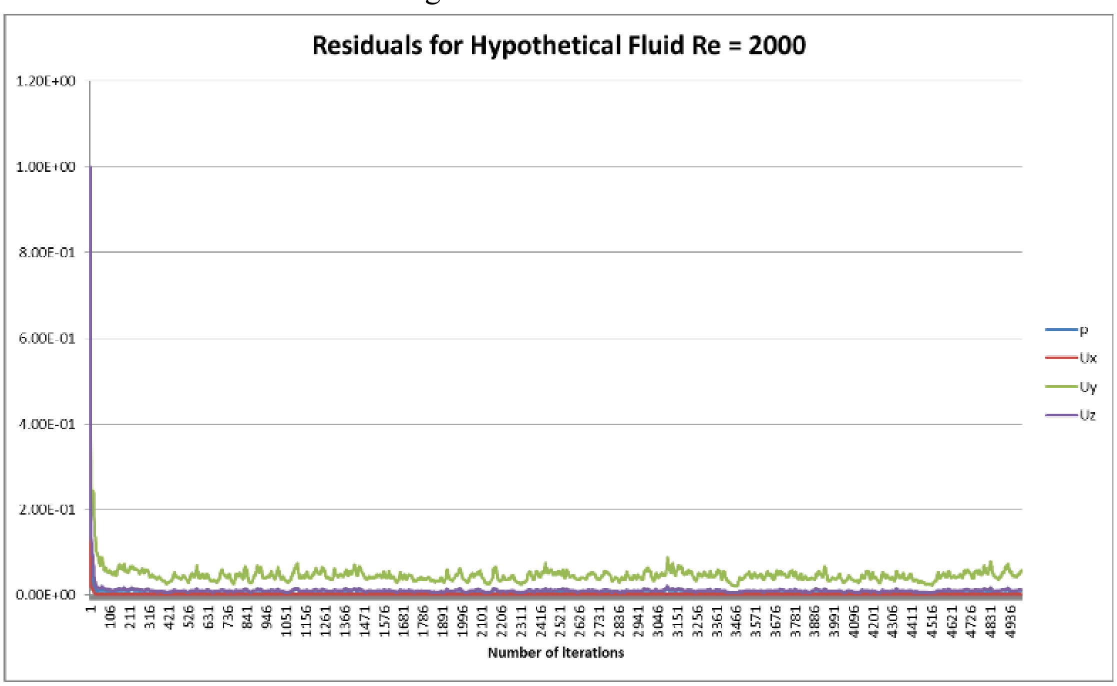


Figure 5: *Residual Plot 3*

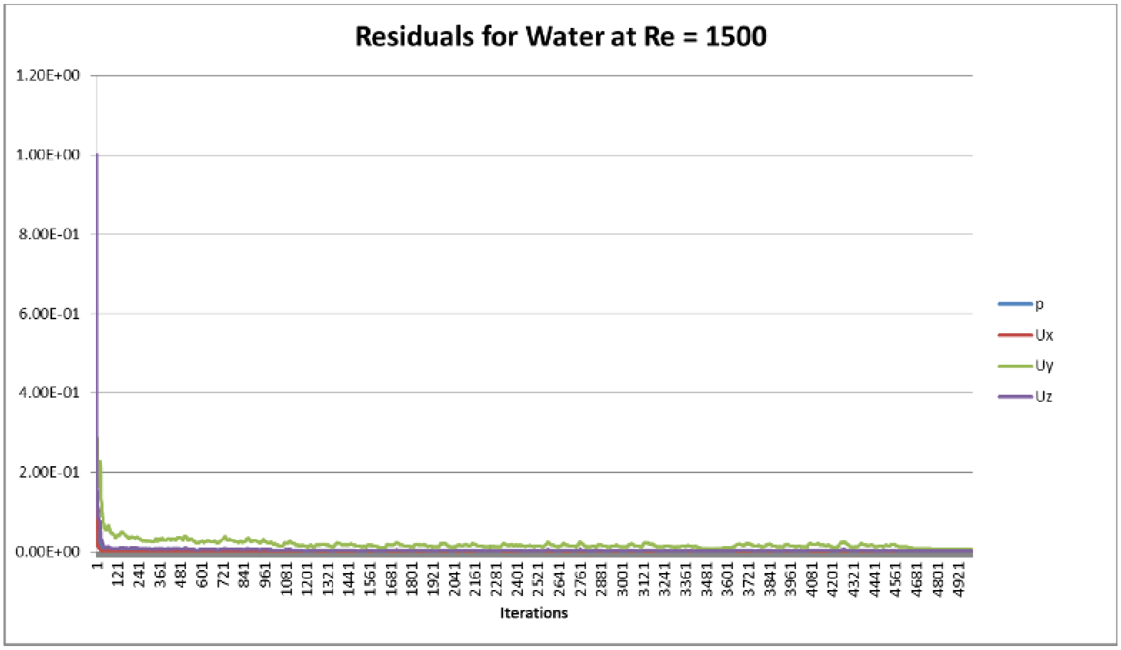


Figure 6: *Residual Plot 4*

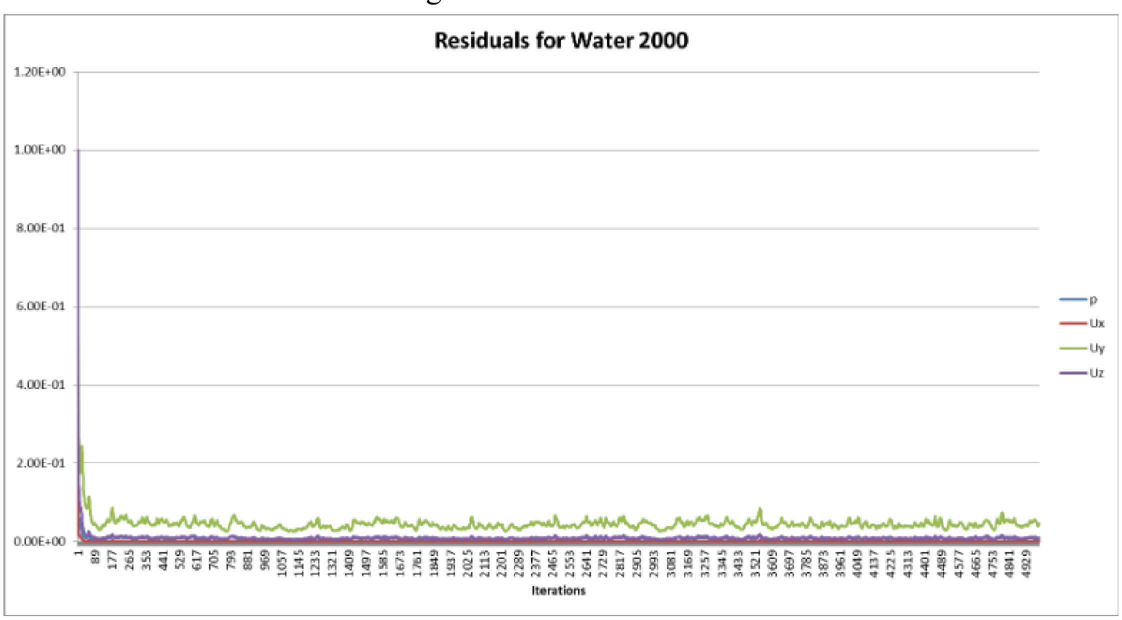


Figure 7: *Drag force plot 1*

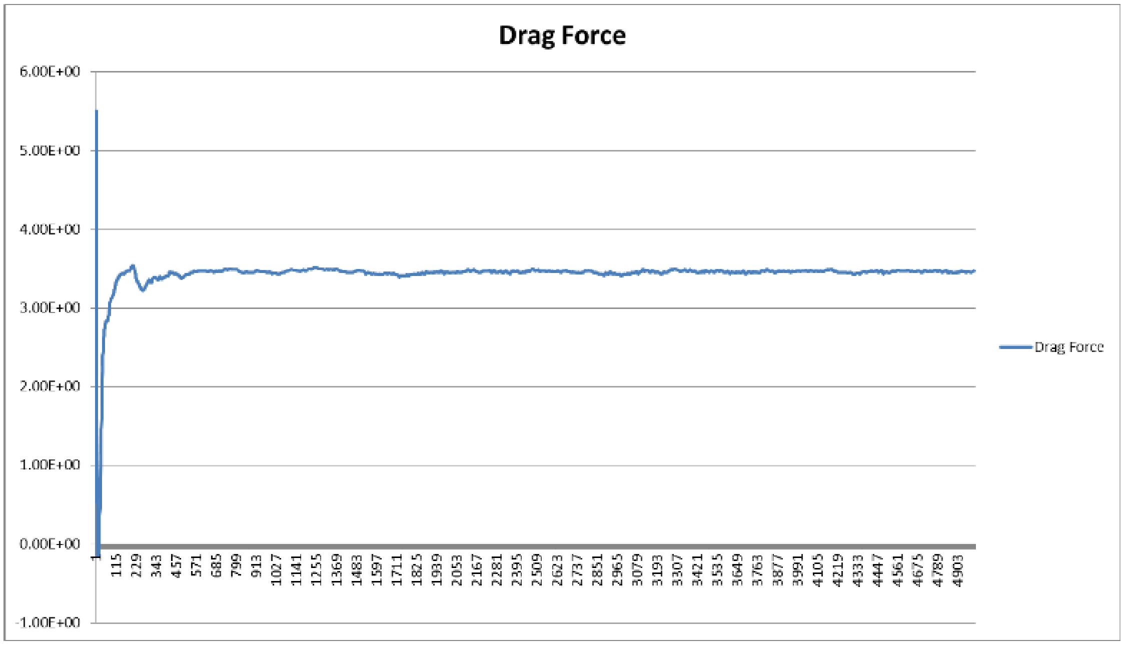


Figure 8: *Drag force plot 2*

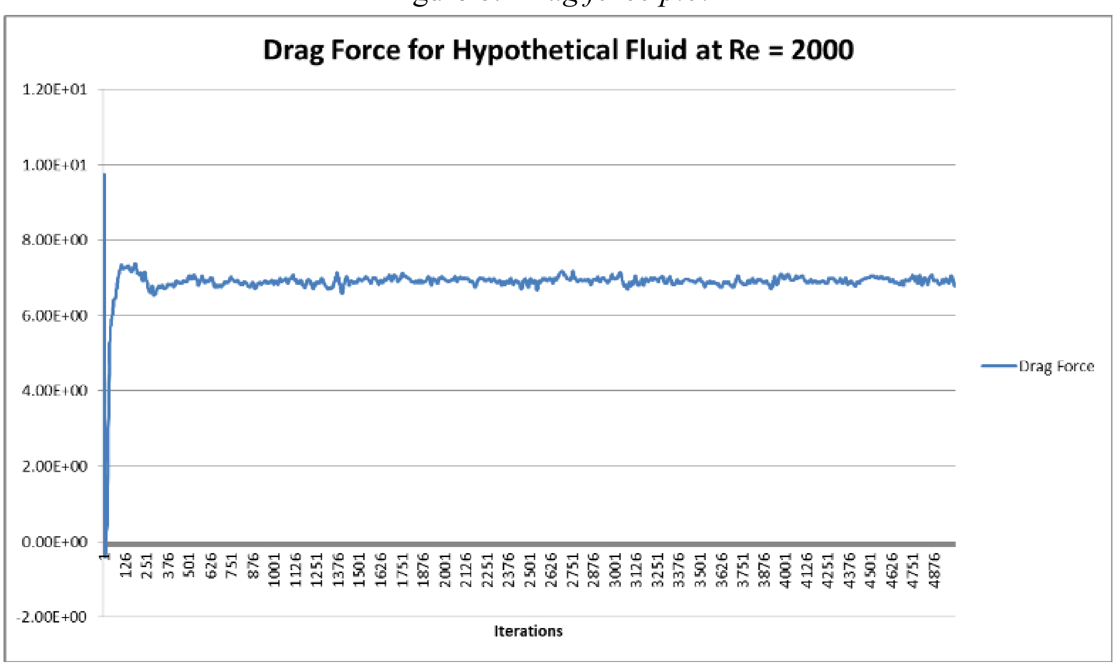


Figure 9: *Drag force plot 3*

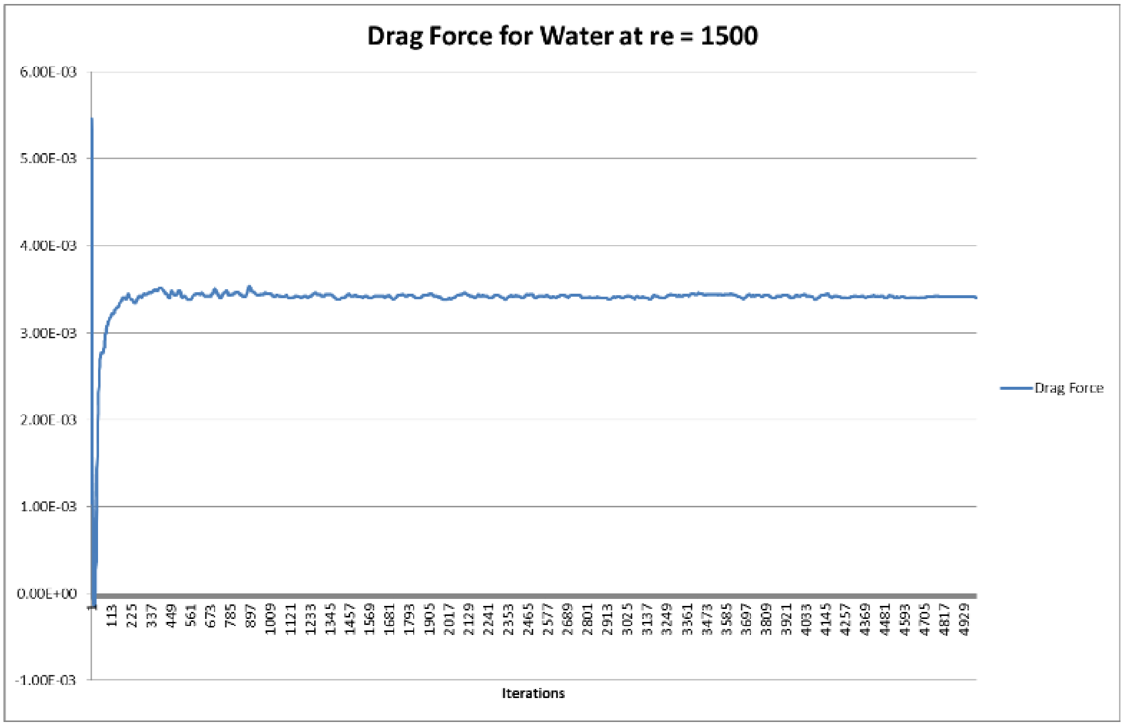
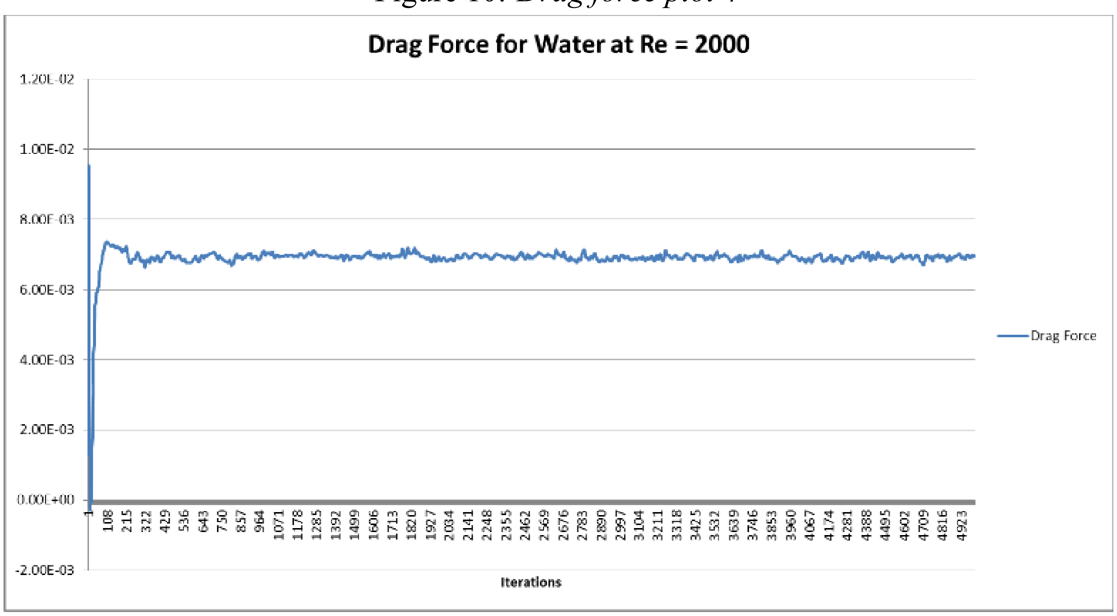


Figure 10: *Drag force plot 4*



5 Results and Discussions

The plots for Residuals and Drag forces are mentioned below:

Inferences:

If we observe the Drag force graphs, the fluctuations in the values are more for Re = 2000 than Re = 1500 both for water and our hypothetical fluid. The same is observed in case of residuals. Thus we can observe that the effect of **vortex shedding** increases with increasing value of Reynolds number.

References

Ma, L., Gao, Y., Guo, Z., Wang, L. (2018). Experimental investigation on flow past nine cylinders in a square configuration. Fluid Dynamics Research, 50(2), 025504. **?**