Richard yasin

Mixing concentration in pipe with indentations and oscillating pressure.

Introduction

Femlab is the program used to model the pipe with indentations using oscillating pressure and constant pressure. Standard pipe with oscillating and constant pressure is also modeled for comparison. The flow entering the pipe is divided with concentration equal one to dividing line and concentration equal zero to the end of pipe. The dividing line is found using formula shown below:

$C1*[.5*x-.25*x^4]=C2*[.25-[.5*x^2-.25*x^4]]$ (eq. 1)

Using Navier-stokes and Diffusivity equations, the mixing concentration at the end of the pipe can be found. With assumption that Re= 1, Pe=300 and steady state system, the Average and the variance of concentration at the end of the pipe will be found using boundary integration at the end of pipe in Femlab. The formula of oscillating pressure is shown below

$$P = a*\cos(\omega*t) + Po$$

where,

$$a = 0.1*Po$$

For Average and variance concentration is found using formula shown below

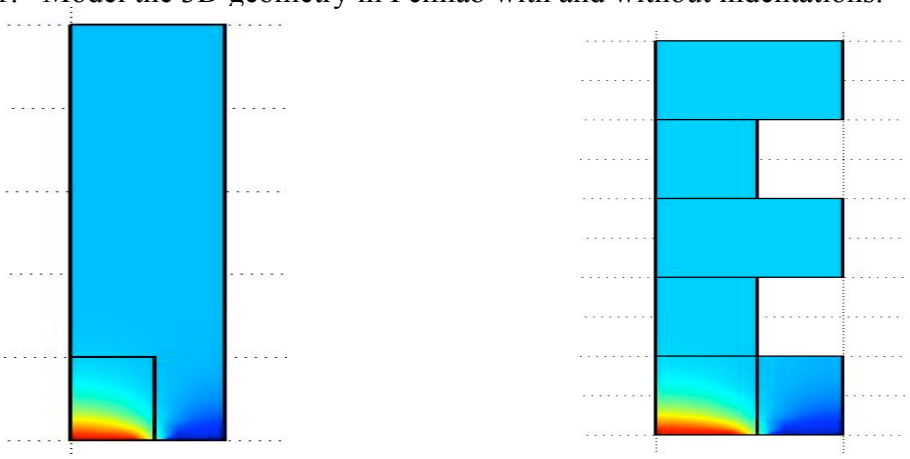
$$Cavg = \frac{\int_0^R cV(r)rdr}{\int_0^R V(r)rdr}$$

$$\sigma^2 = \frac{\int_0^R (c - Cavg)\text{^}2*V(r)rdr}{\int_0^R V(r)rdr}$$

One thing that needs to be remembered is all the calculation is still in dimensionless form.

Procedure

1. Model the 3D geometry in Femlab with and without indentations.



2. Enter the Boundary condition
   No slip at R=1 or R= 0.51149
   Slip/symmetry at R=0
   At end of pipe P=0
   Initial: C=1 until R=0.51149 and C=0 0.51149<x<1

3. Enter the sub domain
   Re=1, Pe=300 for beta add u and v

4. Run the simulation until the time equal one thousand.
5. Find the average and variance of concentration by boundary integration at the end of pipe.

Results and Discussions

Table 1. Standard pipe with steady pressure data

Time	Cavg	σ^2	P	ΔPQ
1000	0.479491	0.022249	10	4.794914
950	0.479491	0.022249	10	4.794914
900	0.479491	0.022249	10	4.794914
850	0.479491	0.022249	10	4.794914
800	0.479491	0.022249	10	4.794914
750	0.479491	0.022249	10	4.794914
700	0.479501	0.022246	10	4.795006
650	0.479501	0.022246	10	4.795006
600	0.479501	0.022246	10	4.795006
550	0.479501	0.022246	10	4.795006
500	0.479501	0.022246	10	4.795006
450	0.479501	0.022246	10	4.795006
400	0.479501	0.022246	10	4.795006
350	0.479501	0.022246	10	4.795006
300	0.479501	0.022246	10	4.795006
250	0.479501	0.022246	10	4.795006
200	0.479473	0.022246	10	4.79473
150	0.479381	0.022281	10	4.793809
100	0.479372	0.022277	10	4.793717
50	0.480376	0.02211	10	4.803759

Table 2. Pipe with Indentations and steady pressure data

Time	Cavg	σ^2	P	ΔPQ
1000	0.508831	1.7757E-06	10	5.088313
950	0.508825	1.7788E-06	10	5.088254
900	0.50882	1.7832E-06	10	5.088196
850	0.508814	1.7882E-06	10	5.088137
800	0.508808	1.7922E-06	10	5.088079
750	0.508814	1.7833E-06	10	5.088137
700	0.508837	1.7598E-06	10	5.088371
650	0.508878	1.7251E-06	10	5.088781
600	0.50896	1.6597E-06	10	5.0896
550	0.508978	1.6528E-06	10	5.089776
500	0.509001	1.653E-06	10	5.09001
450	0.508679	1.9609E-06	10	5.086791
400	0.508111	2.5692E-06	10	5.081114
350	0.506689	4.2607E-06	10	5.066893
300	0.503909	8.975E-06	10	5.039094
250	0.497946	2.6329E-05	10	4.979458
200	0.482185	0.00010826	10	4.821853
150	0.442313	0.00051972	10	4.423129
100	0.348751	0.0023522	10	3.487505
50	0.126277	0.40298941	10	1.262773

From table above, the pipe with indentations is well mixed compare to standard pipe because the variance of indentations pipe is around ~ 0.4 -10^{-6} while the standard pipe is around 0.02. The only problem is that the indentations pipe takes more time to get a well mixed state compare to standard pipe and needs about 7% more work or driving force. The average concentration for the indentation pipe is around 0.508 at t=1000 while Standard pipe give about 0.479. This also proves that indentation will give better well mixed concentration. The indentations pipe will give average concentration of 0.508 with only 10^{-6} deviation.

Table 3. Standard pipe with oscillating Pressure

Time	Cavg	σ^2	P	ΔPQ
1000	0.482026	0.015472	8.757951	4.22156
950	0.477898	0.014468	8.181637	3.909985
900	0.476443	0.017646	8.69556	4.142936
850	0.478563	0.021495	9.682898	4.633879
800	0.481686	0.021264	9.958627	4.796932
750	0.483024	0.017054	9.191812	4.439863
700	0.479581	0.014325	8.3028	3.981864
650	0.476532	0.015929	8.358602	3.983141
600	0.477431	0.020171	9.292243	4.436406
550	0.480362	0.021998	9.983148	4.795522
500	0.483068	0.019039	9.602078	4.638456
450	0.481368	0.01499	8.606402	4.142843
400	0.477706	0.014766	8.19115	3.91296
350	0.476617	0.018387	8.854717	4.220307
300	0.479055	0.021809	9.800676	4.695064
250	0.482155	0.020767	9.893667	4.770282
200	0.482751	0.016368	9.02208	4.35542
150	0.47883	0.014287	8.232012	3.941734
100	0.476464	0.165406	8.471719	4.036467
50	0.478517	0.020618	9.4535	4.523662

When comparing Table 1 (pipe with steady Pressure) and table 3.(pipe with oscillating pressure), the oscillating pipe gives a slightly better results compare to steady

one although the steady pipe use more work (~11%) compare to oscillating pressure. To get better results, more time and data needed to make judgments.

Table 4. Indentations Pipe with oscillating Pressure

Time	Cavg	σ^2	P	ΔPQ
1000	0.502232	6.12391E-08	8.757951	4.398525
950	0.504176	1.94411E-07	8.181637	4.124982
900	0.508157	1.13691E-07	8.69556	4.418711
850	0.510599	2.9364E-06	9.682898	4.944073
800	0.507746	5.82264E-06	9.958627	5.05645
750	0.508633	3.63677E-06	9.191812	4.675259
700	0.502597	2.79994E-07	8.3028	4.172961
650	0.50667	1.85862E-07	8.358602	4.235052
600	0.51069	1.45447E-06	9.292243	4.745452
550	0.509595	6.24817E-06	9.983148	5.087362
500	0.504191	2.50561E-06	9.602078	4.841286
450	0.501753	2.62255E-08	8.606402	4.318284
400	0.504245	2.18205E-07	8.19115	4.130343
350	0.507858	1.46124E-05	8.854717	4.496938
300	0.506773	0.000212454	9.800676	4.966721
250	0.494151	5.16985E-05	9.893667	4.888963
200	0.46557	0.000150738	9.02208	4.200409
150	0.415259	0.000521729	8.232012	3.418416
100	0.323781	0.002076185	8.471719	2.742981
50	0.117264	0.041809347	9.4535	1.108555

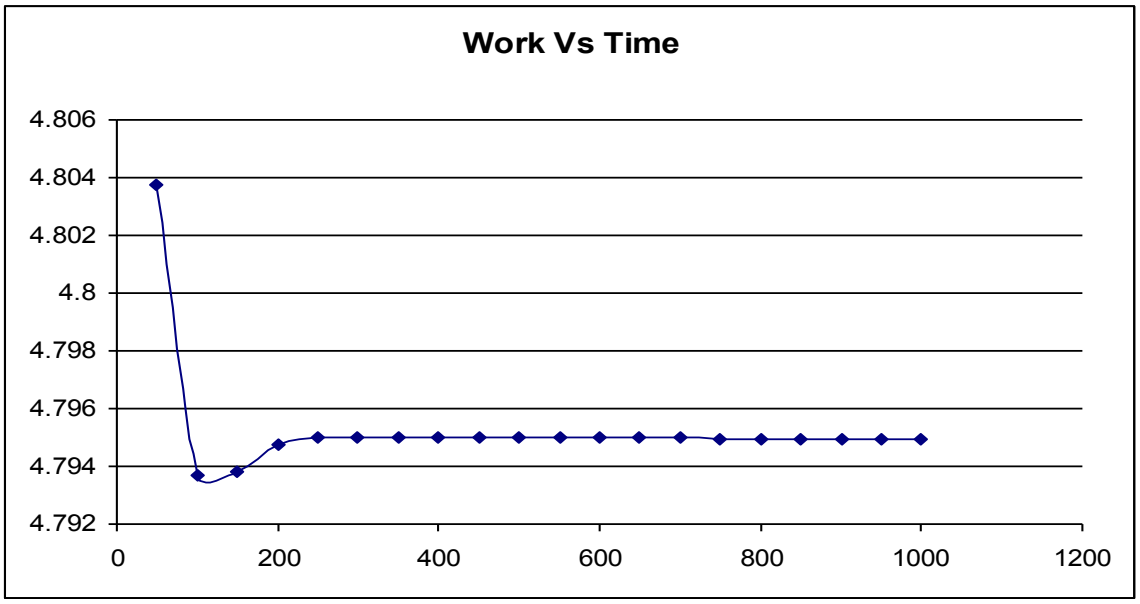
From Table 2. and Table 4. we can see the comparison for steady and oscillating pressure in indentations pipe. The results shows that indentations pipe with oscillating pressure give better well mixed and little variance compare to steady one and it also needs lesser work compare to steady one. The oscillating pressure gives slightly better results in standard pipe but in indentations pipe it increases the mixing.

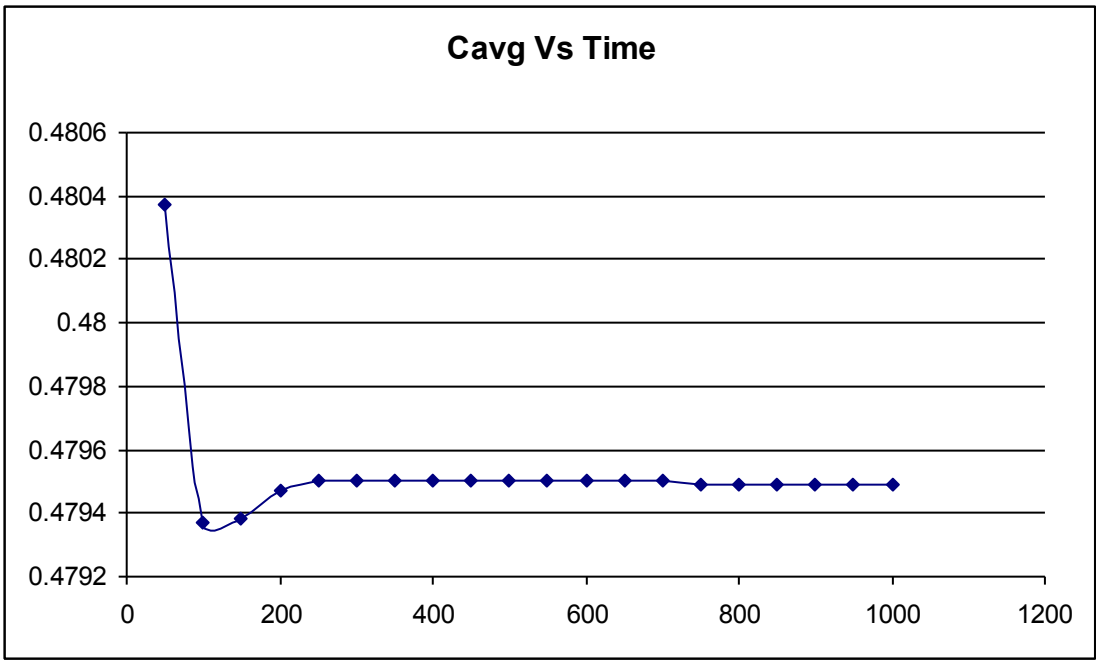
Conclusion

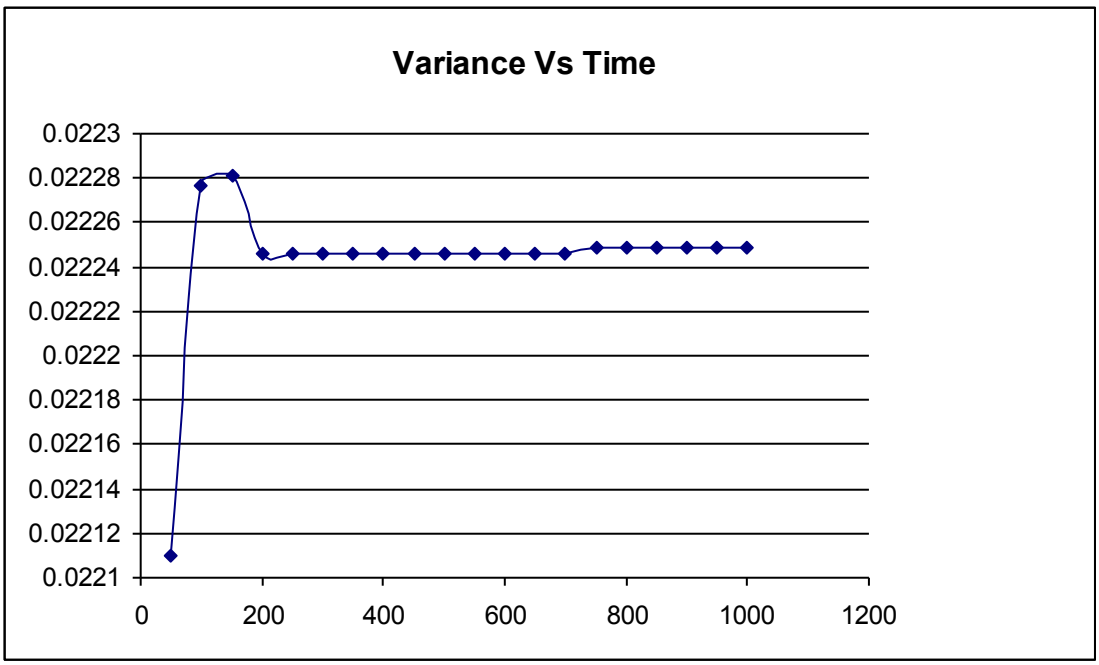
The pipe with indentations and oscillating pressure give better mixing results and less work needed compare to three other pipe condition. Followed by indentations pipe and steady pressure; standard pipe and oscillating pressure; and standard pipe and steady pressure**.** In term of work done and mixing concentration results, the indentations pipe give the best performance compare to the other three. More data at certain points are needed to see clearly what happens also at time equal infinity.

Appendix: Graph

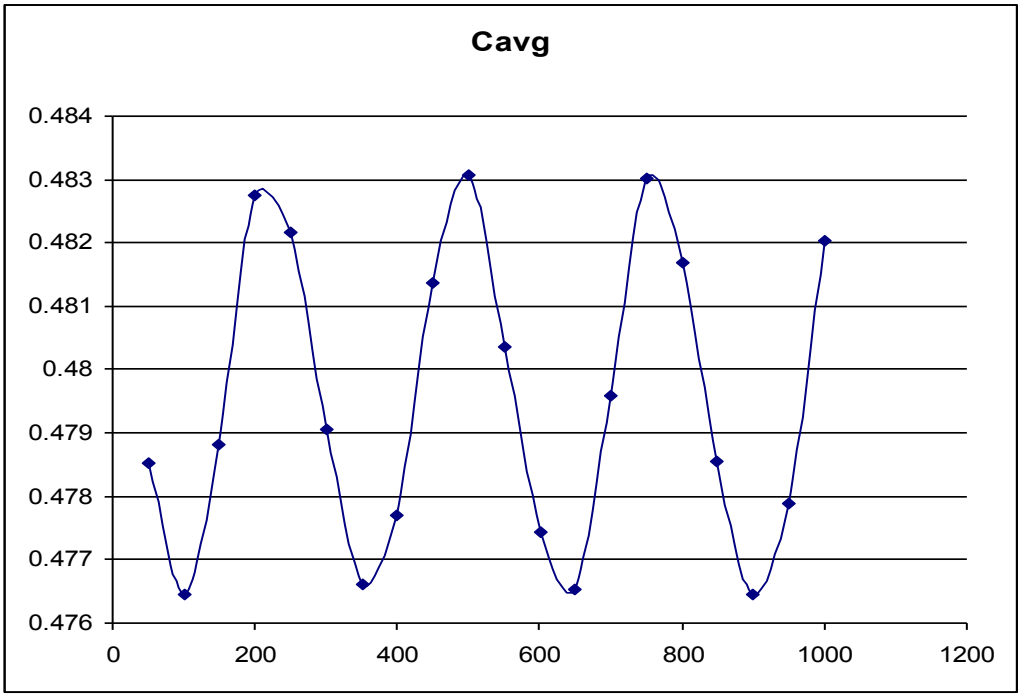
Standard pipe

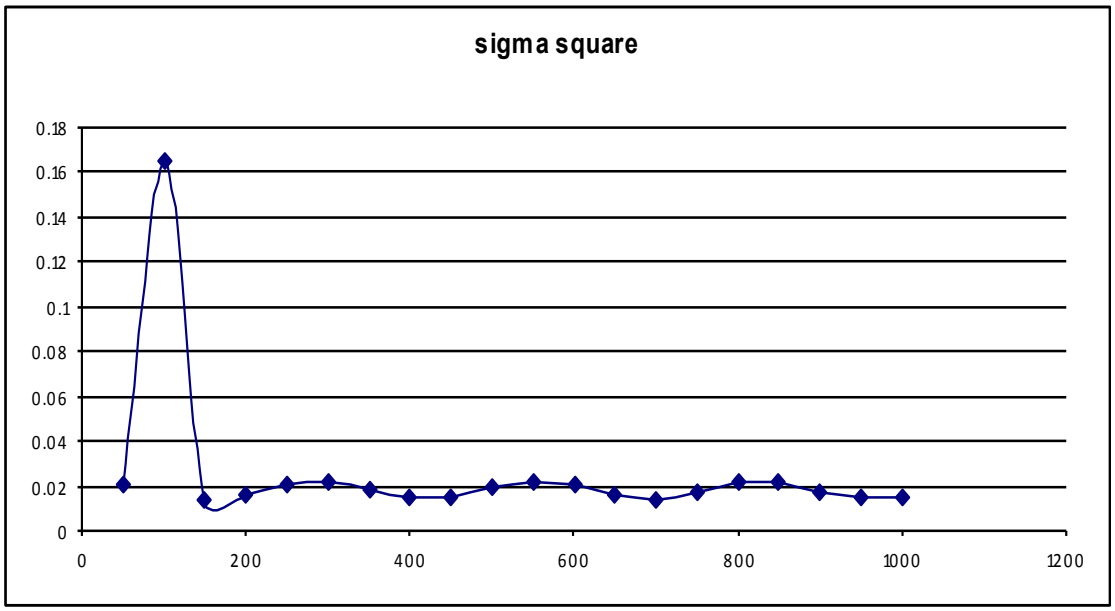


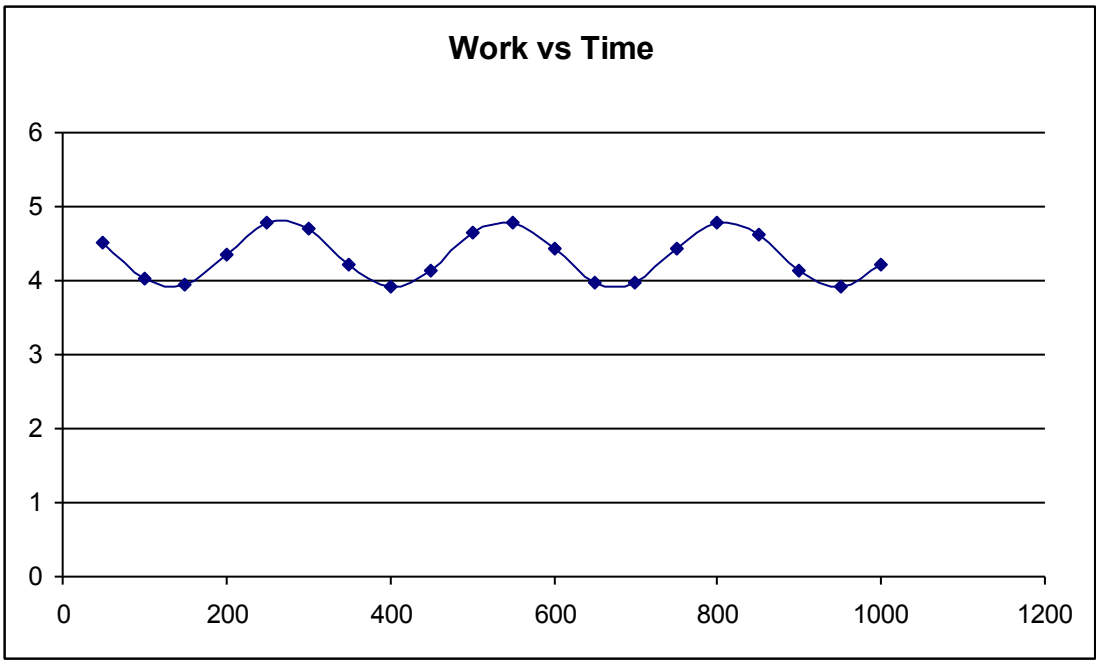




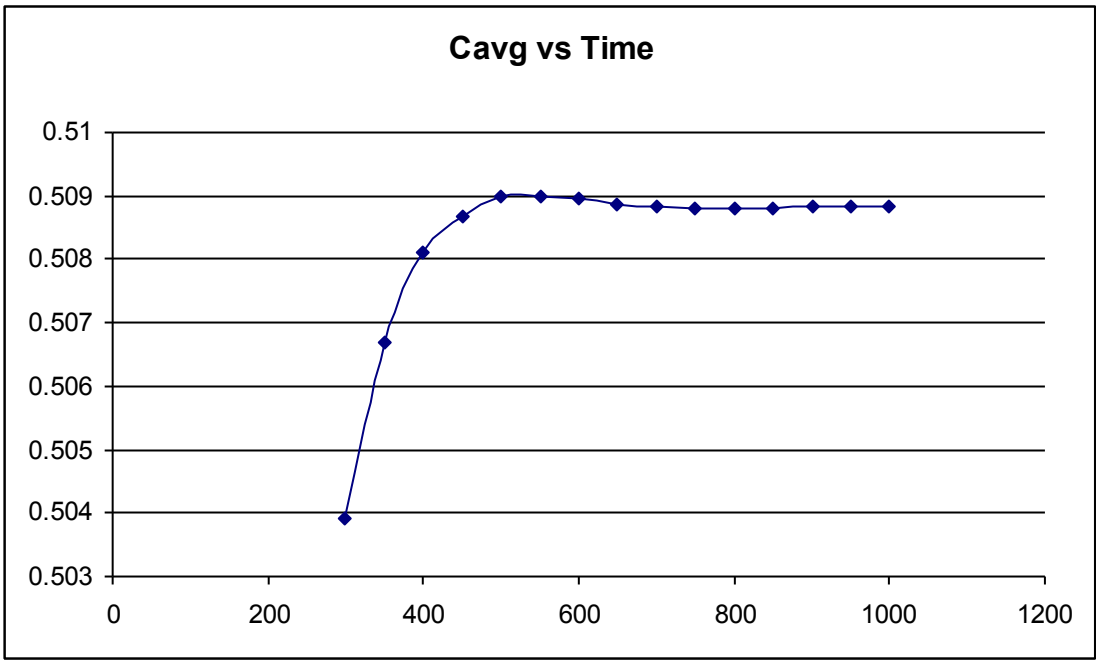
Standard Pipe and Oscillating Pressure

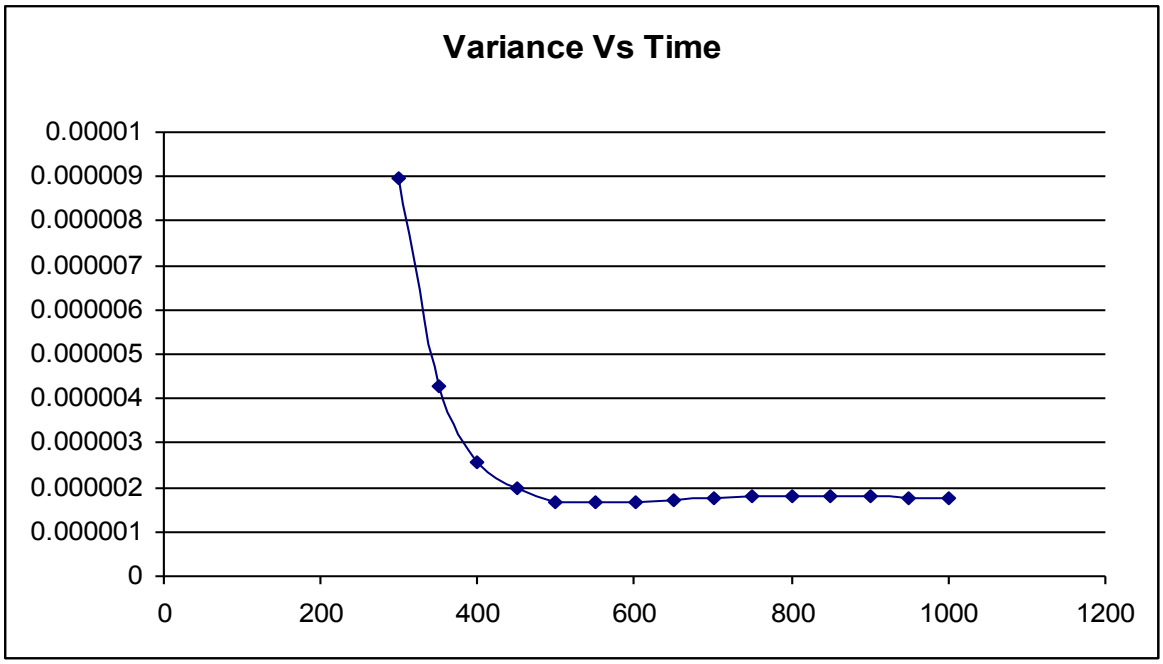

Cavg
0.484
0.483
0.482
0.481
0.48
0.479
0.478
0.477
0.476
0
200
400
600
800
1000
1200

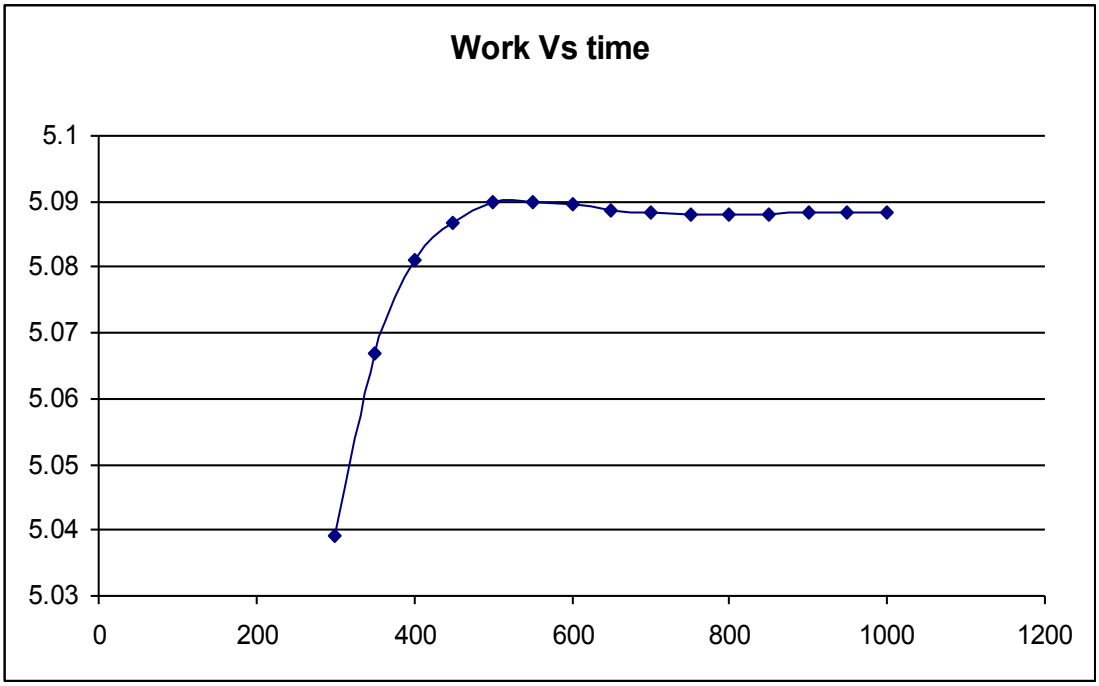

sigma square
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
1200



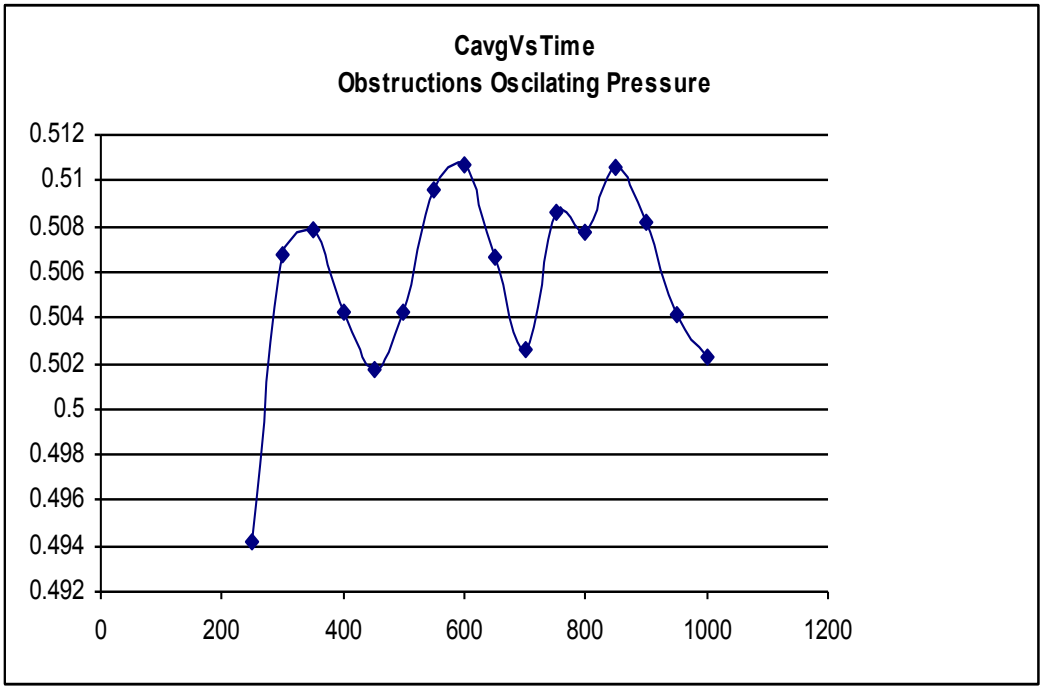
Indentations pipe with Steady Pressure

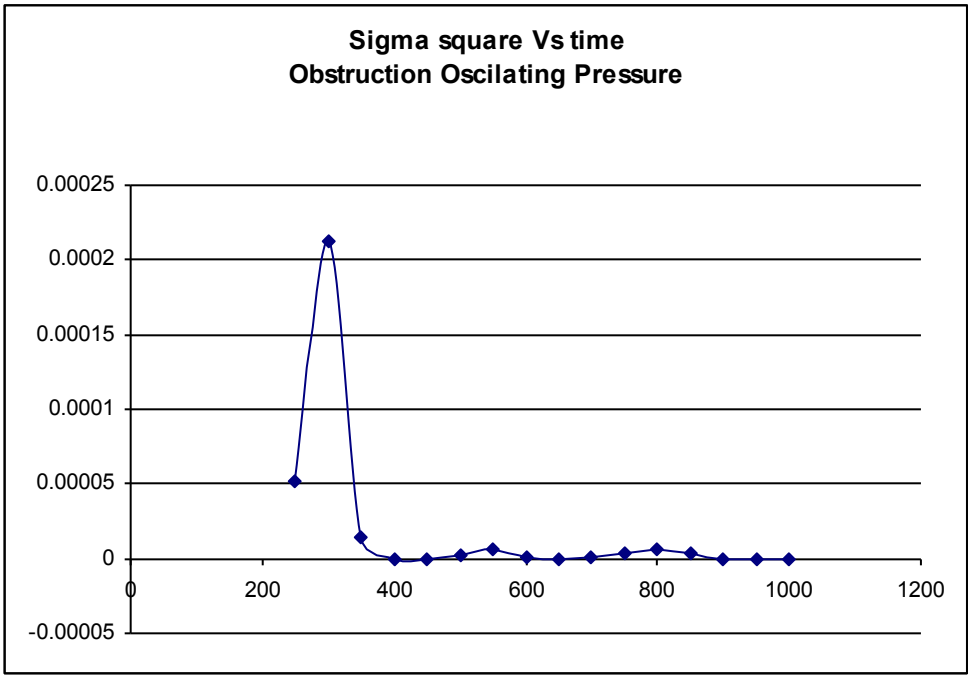


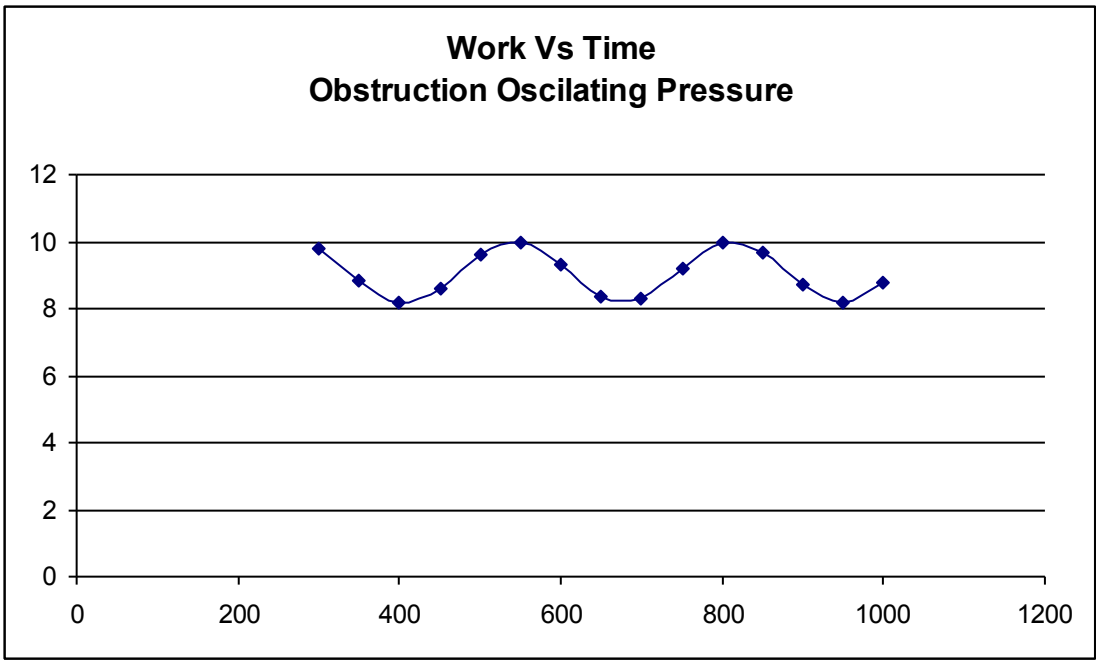




Indentation pipe with oscillating pressure


CavgVsTime
Obstructions Oscilating Pressure
0.512
0.51
0.508
0.506
0.504
0.502
0.5
0.498
0.496
0.494
0.492
0
200
400
600
800
1000
1200


Sigma square Vs time
Obstruction Oscilating Pressure
0.00025
0.0002
0.00015
0.0001
0.00005
0
-0.00005
0
200
400
600
800
1000
1200


Work Vs Time
Obstruction Oscilating Pressure
12
10
8
6
4
2
0
0
200
400
600
800
1000
1200