Experiment Date: 16/10/2018

Date Submitted: 22/10/2018

experiment 1: Constant Pressure Filtration (Short Report)

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**Results**

Using the equation for constant pressure filtration:

Where:

t – Time (s)

A – Area (m2)

V – Volume (m3)

μ – Viscosity (Pas)

r – Specific resistance of the cake (mkg-1)

w – Fractional solid content per unit volume of liquid (m3)

P – Pressure (Pa)

L – Medium resistance (lm-1)

And realising the similarity to , we can plot a graph of inverse volumetric flux against the filtrate height in the measuring cylinder to obtain a slope of and an intercept of

With all other values known, we can calculate values for r and for L. (Heriot-Watt University School of Engineering & Physical Sciences, 2015)

All times in HR:MIN:S format unless otherwise stated.

Experiment 1: ΔP = 6 inHg

Diameter of filter (d) = 14.8cm = 0.148m

Area of filter (A) = 0.01720336m2

Viscosity of water (μ) = 8.90E-04Pas (Perry & Green, 1997)

Pressure differential (ΔP) = 6inHg = 20318.3Pa

Density of water (ρ) = 997.09kgm-3

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| **Repetition** | **1** | | **2** | | **3** | |
| **mL of Filtrate** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** |
| 500 | 00:02:04 | 00:02:44 | 00:04:33 | 00:04:33 | 00:01:49 | 00:01:49 |
| 750 | 00:02:22 | 00:05:06 | 00:03:56 | 00:08:29 | 00:01:33 | 00:03:22 |
| 1000 | 00:02:51 | 00:07:57 | 00:04:06 | 00:12:35 | 00:02:05 | 00:05:27 |
| 1250 | 00:03:04 | 00:11:01 | 00:04:33 | 00:17:08 | 00:02:28 | 00:07:55 |
| 1500 | 00:03:16 | 00:14:17 | 00:04:36 | 00:21:44 | 00:02:45 | 00:10:40 |
| 1750 | 00:03:23 | 00:17:40 | 00:04:58 | 00:26:42 | 00:02:59 | 00:13:39 |
| 2000 | 00:03:14 | 00:21:05 | 00:04:42 | 00:31:24 | 00:02:48 | 00:16:27 |
| **Total** | 00:21:05 |  | 00:31:24 |  | 00:16:27 |  |

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| --- | --- | --- | --- | --- | --- | --- |
| **Average** | | | **Flowrate** | **Flux** | **Y-axis** | **X-axis** |
| **Volume, m3** | **Time, hr:min:s** | **Time, s** | **V/t, m3s-1** | **V/tA, ms-1** | **tA/V, sm-1** | **V/A, m** |
| 0.0005 | 00:03:02 | 182 | 2.74725E-06 | 0.000159693 | 6262.02354 | 0.02906409 |
| 0.00075 | 00:05:39 | 339 | 2.21239E-06 | 0.000128602 | 7775.91934 | 0.04359613 |
| 0.01 | 00:08:40 | 520 | 1.92308E-06 | 0.000111785 | 8945.74791 | 0.05812817 |
| 0.00125 | 00:12:01 | 721 | 1.7337E-06 | 0.000100777 | 9922.89884 | 0.07266022 |
| 0.0015 | 00:15:34 | 934 | 1.606E-06 | 9.33536E-05 | 10711.9597 | 0.08719226 |
| 0.00175 | 00:19:20 | 1160 | 1.50862E-06 | 8.76934E-05 | 11403.371 | 0.10182431 |
| 0.002 | 00:22:59 | 1379 | 1.45033E-06 | 8.43048E-05 | 11861.7177 | 0.11625635 |

Mass of filter = 0.00196kg

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Repetition** | **1** | **2** | **3** | **Average** |
| **Mass of filter and cake (kg)** | 0.02355 | 0.02327 | 0.0245 | 0.023773333 |

w = 0.010938498m3

r = 2.65E+14mkg-1

L = 0.000426124lm-1

|  |  |  |
| --- | --- | --- |
|  | **Time** | **Value** |
| **Standard Deviation** | 00:08:06 | 0.00562035 |

Experiment 2: ΔP = 12 inHg

Diameter of filter (d) = 14.8cm = 0.148m

Area of filter (A) = 0.01720336m2

Viscosity of water (μ) = 8.90E-04Pas

Pressure differential (ΔP) = 12inHg = 40636.7Pa

Density of water (ρ) = 997.09kgm-3

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| **Repetition** | **1** | | **2** | | **3** | |
| **mL of Filtrate** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** |
| 500 | 00:02:15 | 00:02:15 | 00:01:21 | 00:01:21 | 00:02:08 | 00:02:08 |
| 750 | 00:01:52 | 00:04:07 | 00:00:39 | 00:02:00 | 00:01:30 | 00:03:38 |
| 1000 | 00:02:18 | 00:06:25 | 00:01:18 | 00:03:18 | 00:02:06 | 00:05:44 |
| 1250 | 00:02:21 | 00:08:46 | 00:01:45 | 00:05:03 | 00:02:21 | 00:08:05 |
| 1500 | 00:02:36 | 00:11:22 | 00:01:56 | 00:06:59 | 00:02:25 | 00:10:30 |
| 1750 | 00:02:53 | 00:14:15 | 00:02:17 | 00:09:16 | 00:02:39 | 00:13:09 |
| 2000 | 00:02:50 | 00:17:05 | 00:02:09 | 00:11:25 | 00:02:45 | 00:15:54 |
| **Total** | 00:17:05 |  | 00:11:25 |  | 00:15:54 |  |

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| --- | --- | --- | --- | --- | --- | --- |
| **Average** | | | **Flowrate** | **Flux** | **Y-axis** | **X-axis** |
| **Volume, m3** | **Time, hr:min:s** | **Time, s** | **V/t, m3s-1** | **V/tA, ms-1** | **tA/V, sm-1** | **V/A, m** |
| 0.0005 | 00:01:55 | 115 | 4.34783E-06 | 0.00025273 | 3953.77312 | 0.02906409 |
| 0.00075 | 00:03:15 | 195 | 3.84615E-06 | 0.00022357 | 4472.87396 | 0.04359613 |
| 0.01 | 00:05:09 | 309 | 3.23625E-06 | 0.00018812 | 5315.83866 | 0.05812817 |
| 0.00125 | 00:07:18 | 438 | 2.85388E-06 | 0.00016589 | 6028.05782 | 0.07266022 |
| 0.0015 | 00:09:37 | 577 | 2.59965E-06 | 0.00015111 | 6617.55967 | 0.08719226 |
| 0.00175 | 00:12:13 | 733 | 2.38745E-06 | 0.00013878 | 7205.75079 | 0.10172431 |
| 0.002 | 00:14:48 | 888 | 2.25225E-06 | 0.00013092 | 7638.29245 | 0.11625635 |

Mass of filter = 0.00196kg

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Repetition** | **1** | **2** | **3** | **Average** |
| **Mass of filter and cake (kg)** | 0.02483 | 0.02534 | 0.02353 | 0.02456667 |

w = 0.01133632m3

r = 3.53E+14mkg-1

L = 0.0003509lm-1

|  |  |  |
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|  | **Time** | **Value** |
| **Standard Deviation** | 00:04:48 | 0.00333756 |

Experiment 3: ΔP = 16 inHg

Diameter of filter (d) = 14.8cm = 0.148m

Area of filter (A) = 0.01720336m2

Viscosity of water (μ) = 8.90E-04Pas

Pressure differential (ΔP) = 16inHg = 54182.2Pa

Density of water (ρ) = 997.09kgm-3

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| **Repetition** | **1** | | **2** | | **3** | |
| **mL of Filtrate** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** | **Lap Time** | **Total Time** |
| 500 | 00:01:51 | 00:01:51 | 00:01:28 | 00:01:28 | 00:02:09 | 00:02:09 |
| 750 | 00:01:28 | 00:03:19 | 00:00:54 | 00:02:22 | 00:01:10 | 00:03:19 |
| 1000 | 00:01:59 | 00:05:18 | 00:01:29 | 00:03:51 | 00:01:58 | 00:05:17 |
| 1250 | 00:02:08 | 00:07:26 | 00:01:52 | 00:05:43 | 00:02:04 | 00:07:21 |
| 1500 | 00:02:23 | 00:09:49 | 00:02:00 | 00:07:43 | 00:02:18 | 00:09:39 |
| 1750 | 00:02:27 | 00:12:16 | 00:02:08 | 00:09:51 | 00:02:31 | 00:12:10 |
| 2000 | 00:02:21 | 00:14:37 | 00:02:06 | 00:11:57 | 00:02:26 | 00:14:36 |
| **Total** | 00:14:37 |  | 00:11:57 |  | 00:14:36 |  |

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| --- | --- | --- | --- | --- | --- | --- |
| **Average** | | | **Flowrate** | **Flux** | **Y-axis** | **X-axis** |
| **Volume, m3** | **Time, hr:min:s** | **Time, s** | **V/t, m3s-1** | **V/tA, ms-1** | **tA/V, sm-1** | **V/A, m** |
| 0.0005 | 00:01:49 | 109 | 4.5872E-06 | 0.00026664 | 3750.33278 | 0.02906409 |
| 0.00075 | 00:03:00 | 180 | 4.1667E-06 | 0.0002422 | 4128.80673 | 0.04359613 |
| 0.01 | 00:04:49 | 289 | 3.4602E-06 | 0.00020114 | 4971.77144 | 0.05812817 |
| 0.00125 | 00:06:50 | 410 | 3.0488E-06 | 0.00017722 | 5642.70253 | 0.07266022 |
| 0.0015 | 00:09:04 | 544 | 2.7574E-06 | 0.00016028 | 6239.08572 | 0.08719226 |
| 0.00175 | 00:11:26 | 686 | 2.551E-06 | 0.00014829 | 6743.71766 | 0.10172431 |
| 0.002 | 00:13:43 | 823 | 2.4301E-06 | 0.00014126 | 7079.1832 | 0.11625635 |

40510.6902

2564.42725

Mass of filter = 0.00196kg

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| --- | --- | --- | --- | --- |
| **Repetition** | **1** | **2** | **3** | **Average** |
| **Mass of filter and cake (kg)** | 0.02439 | 0.0243 | 0.02375 | 0.02414667 |

w = 0.01112571m3

r = 4.43E+14mkg-1

L = 0.00035214lm-1

|  |  |  |
| --- | --- | --- |
|  | **Time** | **Value** |
| **Standard Deviation** | 00:04:16 | 0.00296291 |

Compressibility Factor

Where:

n – Compressibility factor

ΔP – Pressure drop across the filter (Pa)

r – Specific resistance of the cake under pressure P (mkg-1)

r’ – Specific resistance of the cake under a pressure drop of 1atm (mkg-1)

(Heriot-Watt University School of Engineering & Physical Sciences, 2015)

Viscosity of water = 8.90E-04Pas

r' – 1.03E+15

1atm = 101325Pa

|  |  |  |  |  |
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| **Experiment** | **1** | **2** | **3** | **Average** |
| **Intercept** | 4944.055885 | 2710.01509 | 2564.42725 | 3406.166 |
| **L (lm-1)** | 0.000426124 | 0.0003509 | 0.00035214 | 0.000376 |
| **n** | 0.107983777 | 0.10093083 | 0.09826701 | 0.102394 |

**Discussion of Results**

From each dataset collected from each experiment, the aim was to plot a graph of the inverse flux against the filtrate height in the measuring cylinder. By doing so, it was possible to use the gradients and intercepts of these graphs along with known information to solve for the cake resistance and the medium resistance, and finally the compressibility factor of chalk.

For all three experiments, a strong positive linear correlation between inverse volumetric flux and the filtrate height in the measuring cylinder was observed, shown by the R2 values for all three experiments being over 0.95. This implies that our results are very accurate. The calculated standard deviation for each experiment was also very low, further implying that the results are accurate. The final calculated value, the compressibility factors of chalk for each pressure drop should be constant, and when calculated, whilst not constant, they are within a very reasonable margin of each other, further proving the accuracy of the results. The average value for the compressibility factor of chalk was found to be approximately n≈0.102.

Despite the seemingly accurate results, many possible sources of error were identified in the experiment. Firstly, as the calcium carbonate solution was premade, there was no way of checking the concentration, therefore it was assumed to be between 2-3% w/w. The mixing of the tank was assumed to be perfect, hence when the solution was pumped from the tank, the solution was assumed to be a perfect mixture. The pressure seal on the tank was assumed to be perfect, however due to the need of deconstructing and reconstructing the tank between experiments, it is somewhat likely that this could have been affected somewhat, shown by some of the large variances in time between experiment repetitions. The final potential source of error was human error, as the experiment results relied on a lot of human input. Firstly, controlling the flowrate, liquid level in the filter tank and vacuum pressure had to be very closely monitored. Once water began to flow through the filter, the liquid level had to be read by eye and the stopwatch had to be lapped manually, undoubtedly causing some small errors to occur.

In conclusion, despite the large number of error sources, we achieved a consistent result for the compressibility factor of chalk of approximately n≈0.102.

(Heriot-Watt University School of Engineering & Physical Sciences, 2015)

**Appendix I**

Example Calculations

Area of Filter

Pressure Unit Conversion

Flowrate

Flux

Inverse Flux

Filtrate Height in the Measuring Cylinder

Fractional Solid Content per Unit Volume of Liquid

Specific Cake Resistance

Medium Resistance

r'

Compressibility Factor

# **References**

Heriot-Watt University School of Engineering & Physical Sciences, 2015. *Constant Pressure Filtration.* Edinburgh: Heriot-Watt University.

Perry, R. H. & Green, D. W., 1997. *Perry's Chemical Engineers' Handbook.* 7th ed. New York: McGraw Hill.