E3.6 Transient Heat Conduction

Engineering Experiments (Me) (Nanyang Technological University)

NANYANG TECHNOLOGICAL UNIVERSITY

School of Mechanical and Aerospace Engineering

E3.6 TRANSIENT HEAT CONDUCTION

THERMAL & FLUID LAB

Venue: N3-B2C-06

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Matric No:______U1922005K________________ Date: _____1/4/2021_________

Name of Supervisor: ____

Grade: ____________________________

NOTE: This title page should be attached to all required material for this experiment before submission.

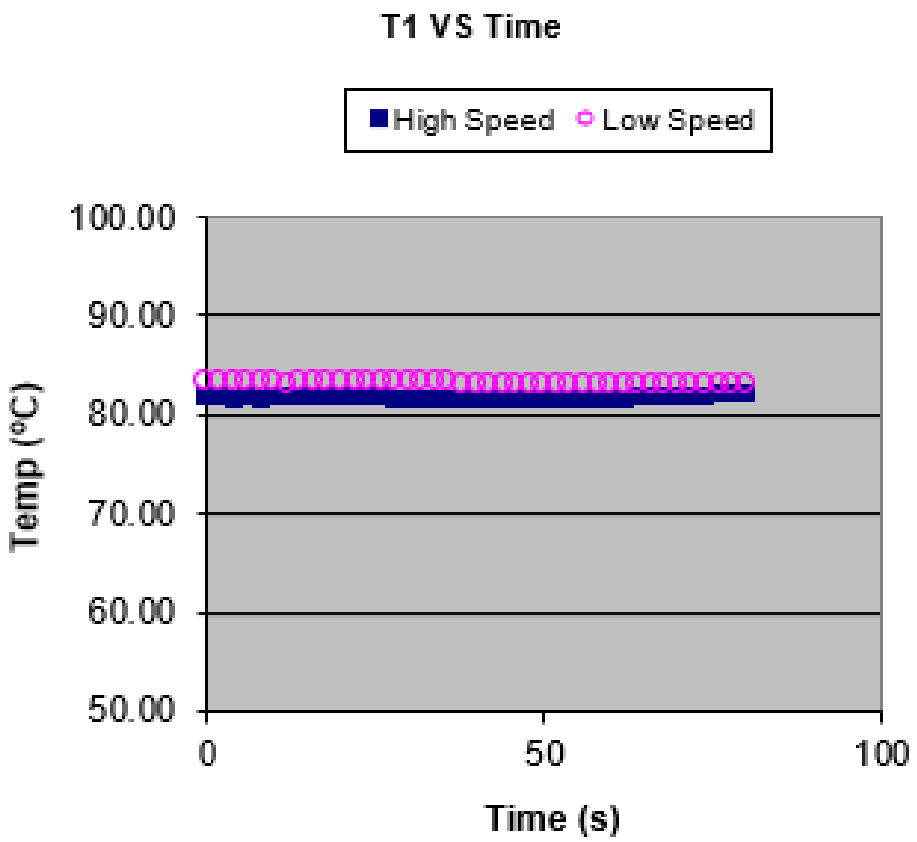
LOG SHEET

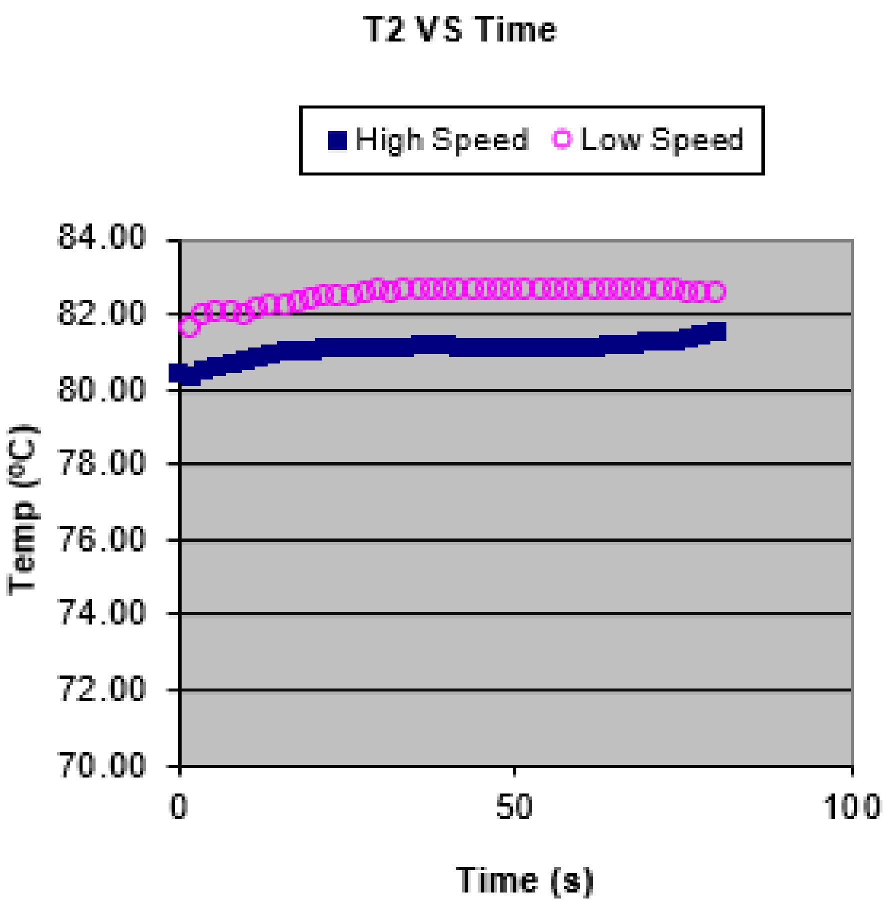
EXPERIMENT E3.6: Transient Heat Conduction

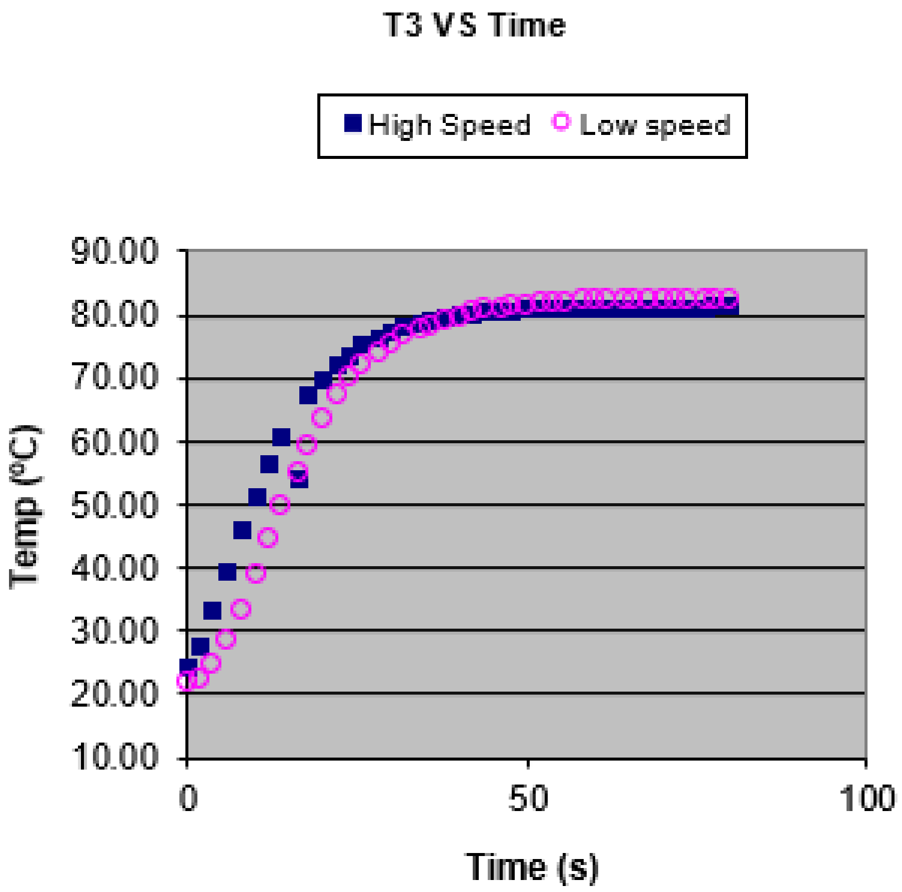
Test Shape: 20mm-in-diameter Stainless Steel Cylinder at different speeds

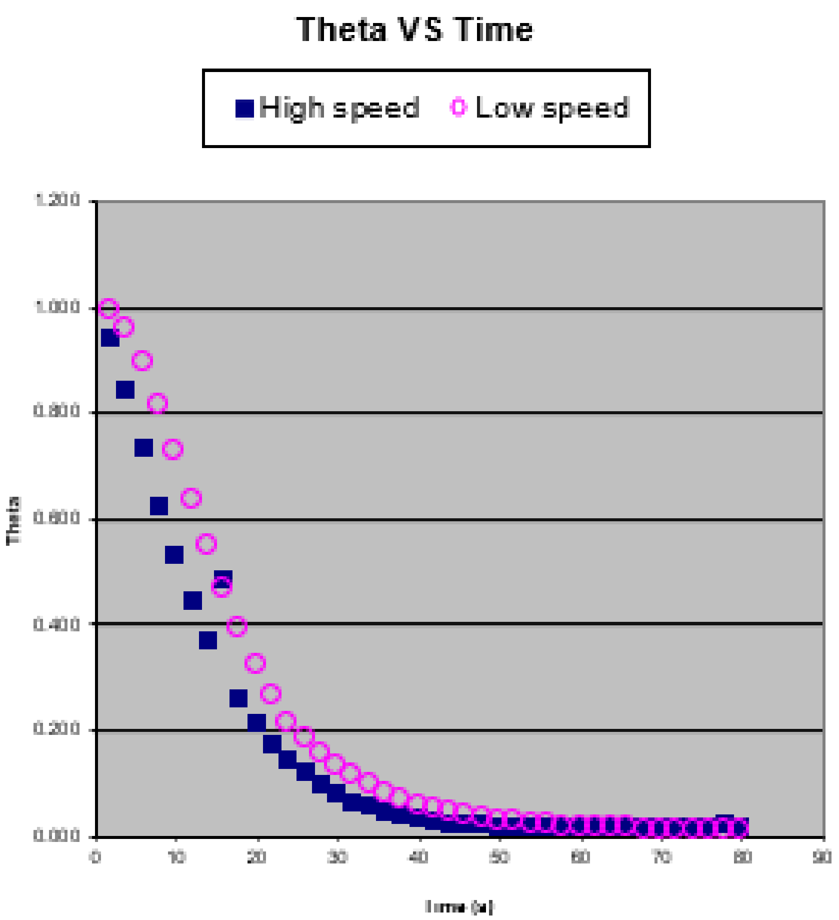
Pump Speed				Stainless Steel			
High				radius = 10 mm			
Time (s)	**T1**	**T2**	**T3**	**theta**	**Fo**	**1/Bi**	**h**
0	81.76	80.44	23.95				#DIV/0!
2	81.66	80.34	27.19	0.944	**0.09**		#DIV/0!
4	81.61	80.49	32.86	0.845	**0.18**		#DIV/0!
6	81.62	80.60	39.36	0.733	**0.27**		#DIV/0!
8	81.61	80.67	45.57	0.625	**0.36**		#DIV/0!
10	81.64	80.74	51.17	0.528	**0.45**		#DIV/0!
12	81.65	80.80	56.00	0.445	**0.54**	0.78	2089.74
14	81.63	80.89	60.22	0.371	**0.63**		#DIV/0!
16	81.63	80.97	53.84	0.482	**0.72**		#DIV/0!
18	81.64	80.99	66.89	0.256	**0.81**		#DIV/0!
20	81.62	81.03	69.44	0.211	**0.9**		#DIV/0!
22	81.63	81.06	71.59	0.174	**0.99**		#DIV/0!
24	81.62	81.07	73.38	0.143	**1.08**	0.74	2202.70
26	81.62	81.11	74.89	0.117	**1.17**		#DIV/0!
28	81.61	81.11	76.12	0.095	**1.26**		#DIV/0!
30	81.61	81.11	77.12	0.078	**1.35**		#DIV/0!
32	81.61	81.12	77.92	0.064	**1.44**		#DIV/0!
34	81.61	81.12	78.54	0.053	**1.53**		#DIV/0!
36	81.59	81.13	79.04	0.044	**1.62**	0.68	2397.06
38	81.59	81.13	79.42	0.038	**1.71**		#DIV/0!
40	81.57	81.13	79.73	0.032	**1.8**		#DIV/0!
42	81.57	81.12	79.98	0.028	**1.89**		#DIV/0!
44	81.55	81.11	80.18	0.024	**1.98**		#DIV/0!
46	81.55	81.10	80.33	0.021	**2.07**		#DIV/0!
48	81.55	81.10	80.46	0.019	**2.16**		#DIV/0!
50	81.54	81.10	80.55	0.017	**2.25**	0.78	2089.7
52	81.53	81.10	80.63	0.016	**2.34**		#DIV/0!
54	81.53	81.09	80.70	0.014	**2.43**		#DIV/0!
56	81.54	81.08	80.74	0.014	**2.52**	0.82	1987.8
58	81.56	81.09	80.78	0.014	**2.61**		#DIV/0!
60	81.58	81.10	80.81	0.013	**2.7**		#DIV/0!
62	81.60	81.12	80.84	0.013	**2.79**		#DIV/0!
64	81.65	81.14	80.86	0.014	**2.88**	0.98	1663.3
66	81.69	81.16	80.88	0.014	**2.97**		#DIV/0!
68	81.77	81.21	80.89	0.015	**3.06**		#DIV/0!
70	81.75	81.24	80.92	0.014	**3.15**		#DIV/0!
72	81.76	81.27	80.94	0.014	**3.24**		#DIV/0!
74	81.81	81.29	80.95	0.015	**3.33**		#DIV/0!
76	81.94	81.33	80.98	0.017	**3.42**		#DIV/0!
78	82.06	81.39	81.00	0.0182	**3.51**	1.37	1189.8
80	82.05	81.48	81.02	0.018	**3.6**		#DIV/0!

Pump Speed				Stainless Steel			
Low				radius = 10 mm			
Time (s)	**T1**	**T2**	**T3**	**theta**	**Fo**	**1/Bi**	**h**
0	83.37	69.07	21.84	**No need to calculate at time=zero**			#DIV/0!
2	83.31	81.63	22.33	0.992	**0.09**		#DIV/0!
4	83.21	81.95	24.50	0.957	**0.18**		#DIV/0!
6	83.12	81.98	28.32	0.894	**0.27**		#DIV/0!
8	83.14	81.99	33.08	0.817	**0.36**		#DIV/0!
10	83.14	81.94	38.48	0.729	**0.45**		#DIV/0!
12	83.10	82.09	44.14	0.636	**0.54**	1.40	1164.29
14	83.15	82.21	49.53	0.548	**0.63**		#DIV/0!
16	83.15	82.19	54.57	0.468	**0.72**		#DIV/0!
18	83.16	82.25	58.98	0.394	**0.81**		#DIV/0!
20	83.16	82.32	63.29	0.324	**0.9**		#DIV/0!
22	83.14	82.45	67.04	0.263	**0.99**		#DIV/0!
24	83.16	82.48	69.99	0.215	**1.08**	0.85	1917.65
26	83.16	82.48	71.98	0.182	**1.17**		#DIV/0!
28	83.14	82.53	73.61	0.155	**1.26**		#DIV/0!
30	83.14	82.59	75.02	0.132	**1.35**		#DIV/0!
32	83.12	82.56	76.30	0.111	**1.44**		#DIV/0!
34	83.12	82.60	77.32	0.095	**1.53**		#DIV/0!
36	83.12	82.63	78.13	0.081	**1.62**	0.90	1811.11
38	83.11	82.61	78.95	0.068	**1.71**		#DIV/0!
40	83.11	82.61	79.57	0.058	**1.8**		#DIV/0!
42	83.10	82.64	80.09	0.049	**1.89**		#DIV/0!
44	83.10	82.65	80.52	0.042	**1.98**		#DIV/0!
46	83.10	82.63	80.84	0.037	**2.07**		#DIV/0!
48	83.09	82.63	81.14	0.032	**2.16**		#DIV/0!
50	83.08	82.61	81.36	0.028	**2.25**	0.88	1852.27
52	83.07	82.62	81.59	0.024	**2.34**		#DIV/0!
54	83.06	82.63	81.75	0.021	**2.43**		#DIV/0!
56	83.05	82.62	81.89	0.019	**2.52**	0.91	1791.21
58	83.04	82.60	81.98	0.017	**2.61**		#DIV/0!
60	83.03	82.60	82.08	0.016	**2.7**		#DIV/0!
62	83.03	82.61	82.14	0.015	**2.79**		#DIV/0!
64	83.03	82.60	82.19	0.014	**2.88**	0.98	1663.27
66	83.02	82.60	82.23	0.013	**2.97**		#DIV/0!
68	83.01	82.60	82.28	0.012	**3.06**		#DIV/0!
70	83.01	82.58	82.30	0.012	**3.15**		#DIV/0!
72	83.00	82.58	82.32	0.011	**3.24**		#DIV/0!
74	83.00	82.58	82.34	0.011	**3.33**		#DIV/0!
76	82.98	82.55	82.35	0.010	**3.42**		#DIV/0!
78	82.97	82.56	82.35	0.010	**3.51**	1.17	1393.16
80	82.96	82.55	82.36	0.010	**3.6**		#DIV/0!


T1 VS Time
High Speed
Low Speed
100.00
90.00
80.00
70.00
60.00
50.00
Temp (ºC)
0
50
100
Time (s)


T2 VS Time
High Speed
Low Speed
84.00
82.00
80.00
78.00
76.00
74.00
72.00
70.00
Temp (ºC)
0
50
100
Time (s)


T3 VS Time
High Speed
Low speed
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
Temp (ºC)
0
50
100
Time (s)


Theta VS Time
High speed
Low speed
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Theta
0
10
20
30
40
50
60
70
80
90

Sample calculations.

① For high speed, when $t = 56s$.

$T_1 = 81.54 \approx \cancel{T_\infty} = T_\infty$, $T_i = 23.95$,

$T_2 = 81.08$

$T_3 = 80.74 = T_c$.

$$\theta = \frac{T_c - T_\infty}{T_i - T_\infty} = \frac{80.74 - 81.54}{\cancel{23.95} - 81.54} = \cancel{0.00951}\ \cancel{0.031}\ 0.013891$$

$$\approx 0.014 \ \#$$

$$F_0 = \frac{\alpha t}{R^2} = \frac{0.45\times10^{-5}(56)}{0.01^2} = 2.52. \ \#$$

$\cancel{Bi = \frac{hx}{k} =}$ From the chart, $\frac{1}{Bi} \approx 0.82$.

$$Bi = \frac{hx}{k}.$$

$$h = \frac{Bi\,k}{x} = \frac{\frac{1}{0.82}(16.3)}{0.01} = 1987.8 \ \#$$

② For low speed, when $t = 56s$.

$T_1 = 83.05 = T_\infty$, $T_i = 21.84$.

$T_2 = 82.62$

$T_3 = 81.89 = T_c$

$$\theta = \frac{T_c - T_\infty}{T_i - T_\infty} = 0.018951 \approx 0.019 \ \#$$

$$F_0 = \frac{\alpha t}{R^2} = \frac{0.45\times10^{-5}(56)}{0.01^2} = 2.52. \ \#$$

From the chart, $\frac{1}{Bi} = 0.91$ #

$$h = \frac{Bi\,k}{x} = \frac{\frac{1}{0.91}(16.3)}{0.01} = 1791.2 \ \#$$

Discussion

1. T_1, T_2, and T_3 versus Time at different pump rates.

For the all the 3 graphs (T1, T2, T3 vs time), the high speed curve has similar trend with the low speed curve. However, for T1 and T2 vs time, the curve appears to be rather constant. This is because the t1 and t2 is the temperature of the fluid, and it was kept constant throughout the duration. As for T3 vs time, the curve shows and increasing trend from approximately 20 degrees to approximately 68 degrees, and decreasing trend from 68 degree onwards, and finally stabilises at approximately 81 degrees. This is because the temperature of the fluid in the steel cylinder was initially at room temperature before it was heated by the fluid to reach its thermal equilibrium temperature.

2. The non-dimensional temperature difference, ϴ versus Time at different pump rates.

The graph of theta vs time shows a downward curve for both high and low speed. However the time taken for theta to reach stability for high speed was much faster than low speed.

3. The effect of pump rates on heat convection coefficient (h).

From the graph h value vs Time, we observe that the h value peaked at approximately 36s for high speed, whereas for low speed it peaked at 2 time interval, approximately 26s and 50s.h value of high speed started off relatively high and dropped after 36s to lowest point at 80s.

4. The heat convective coefficient (h) versus Time.

As t increase, h value increases. However after the peak, h value decrease. This could be due to thermal equilibrium, where the heat transfer is reduced.