<u>Student's Version</u>

HEAT & MASS FLOW PROCESSES

<u>HEAT TRANSFER SERVICE UNIT WITH UNSTEADY STATE HEAT TRANSFER UNIT H111G</u>

<u>EXPERIMENT NO: 17</u>

Using analytical transient temperature/heat flow charts to determine the thermal conductivity of a solid cylinder from measurements takes on a similar cylinder but having a different thermal conductivity.

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EXPERIMENT # 17

OBJECTIVE:

Using analytical transient temperature/heat flow charts to determine the thermal conductivity of a solid cylinder from measurements takes on a similar cylinder but having a different thermal conductivity.

APPARATUS:

Heat Transfer service unit with Unsteady State Heat Transfer Unit H111G.

CAUTION

The water bath may be operated at up to 85-90. This is sufficient to cause severe burns if the operator inadvertently comes in contact with the water or any of the shapes that have been immersed in the bath. Do not attempt to move the units to its heated condition and treat the unit and any of the test shapes after heating in the bath as potentially able to cause burns.

Note: The following procedure describes operation with the 20mm diameter test shapes. However the procedure identical for any of the other available shapes and may be repeated on completion of the test using any other shapes for direct comparison.

PROCEDURE:

1. Ensure that the residual current circuit breaker (RCCB) is open-circuit. Ensure that the drain valve adjacent to the circulating pump is in the closed position and half-fill the water bath with clean water.
2. Pump bleeding- Switch on the RCCB/MCB to cause the pump to run. Incline the pump by lifting the baseboard from the front to allow the air to escape. Noise from the pump is the sign of trapped air. A bleed screw is fitted to the head of the pump.
3. Continue the filling of bath until the water level is at mid height of the holes in the flow duct. If the local water contains of a large amount of dissolved solids that normally result in scale build up then it is recommended that the bath id fitted with de-ionized or mineralized water. Ensue that the thermostat has been turned fully anti-clockwise and is in the off position.
4. Ensure that the H111 unit main switch is in the off position (None of three digital displays should be illustrated). Ensure that the residual current circuit breaker on the H111 rear panel is in the ON position. Ensure that the residual current circuit breaker on the H111G baseboard is in the on position. Not that the residual current circuit breaker on the both units (H111 and H111G) should be tested for normal operation at intervals specified by local regulations.
5. Turn on the power supply to the Unsteady State Heat Transfer unit and turn on the 16A Heater miniature circuit breaker (MCB). Ensure that the red power indicator adjacent to the thermostat is illustrated. Turn the thermostat to position 6 for faster heating. The water will take approximately 30 minutes to heat from cold. At this setting the water will boil, if left unattended. While the water bath is heating the following may be auctioned.

6. Install the 20mm diameter brass cylinder in the shape carrier.
7. Insert the T3 probe to engage fully into the center of the shape.
8. Insert the T2 probe to sense water temperature adjacent to the shape.
9. Avoid touching the shape by hand to reduce thermal effects and place the shape on the bench to reach ambient temperature.
10. The water bath temperature T1 should be stabilized at approximately 80 to 90˚C
11. Set the circulating pump to 3 and therefore the water flow velocity in the flow duct.
12. Turn on the power supply to the Heat Transfer Service Unit H111 and main switch and three digital displays illustrate. Set the temperature selector switch to the T1to indicate the temperature of the bath. Observe the T1 to confirm that it is slowly increasing as the bath is heated.
13. Record the start conditions temperatures and then plunge the shapes in the flow duct. Then record temperatures and time.
14. Observe the T1. If the bath temperature exceeds that is required, reduce the thermostat setting to OFF and wait for the water to cool. The water bath temperature T1 should not be allowed to exceed 85-90 as the pump will cavitate.
15. Once the 20mm diameter brass has reached the water bath temperature, remove it from the tank install the 20mm stainless steel cylinder in the shape carrier.
16. Record the starting condition temperatures and then plunge the shape in the flow duct. Then record temperatures and time.
17. Having achieved the desired temperature, say85, reduces the thermometer setting to position 2. It will cycle ON/OFF to maintain the existing temperature.
18. If time permits the procedures may be repeated for the brass and stainless steel sphere and/or the Brass and Stainless Slab.
19. In addition, by varying the circulating pump speed, the effect of variation of water velocity on local heat transfer coefficient may be investigated.
20. When the experimental procedure is completed, it is good habit to turn off the power to the heater by reducing the AC voltage to zero. And fan leaving the fan running for a short period until the heater has cooled. Then turn off the main switch.

THEORY

(The Students are advised to write the relevant theory yourself)

OBSERVATIONS

Specimen: 20mm diameter Brass Cylinder.

Recorded Time	T1 Bath Temp.	T2 Air/ Water Temp.	T3 Geometric Centre Temp.
Seconds	ºC	ºC	ºC
0			
5			
10			
15			
20			
25			
30			
35			
40			

Specimen: 20mm Stainless steel Cylinder.

Recorded Time	T1 Bath Temp.	T2 Air/ Water Temp.	T3 Geometric Centre Temp.
Seconds	ºC	ºC	ºC
0			
5			
10			
15			
20			
25			
30			
35			
40			

CALCULATED DATA

Specimen: 20mm diameter Brass Cylinder.

Recorded Time	T1 Bath Temperature	T3 Geometric Centre Temperature	θ Non-dimensional Temperature	Fo Fourier Number	1/Bi Inverse Biot Number
Seconds					
0					
5					
10					
15					
20					
25					
30					
35					
40					

CALCULATED DATA

Specimen: 20mm Stainless steel Cylinder.

Recorded Time	T1 Bath Temperature	T3 Geometric Centre Temperature	θ Non-dimensional Temperature	Fo Fourier Number	1/Bi Inverse Biot Number
Seconds					
0					
5					
10					
15					
20					
25					
30					
35					
40					

CALCULATIONS

The calculation procedure for system with finite internal and surface heat transfer resistance is as follows.

For each sample after intermission the non-dimensional temperature θ is calculated.

$$T_c = T3 =$$

$$T\infty = T1 =$$

$$T_i = T3 \; at \; time \; 0 =$$

$$\theta = \frac{T_c - T\infty}{T_i - T\infty}$$

Similarly, the Fourier Number For non dimensional time

$$Fo = \frac{a \; X \; t}{(Length)^2}$$

Where

Thermal diffusivity $=\alpha$

$$\alpha = \frac{k}{\rho c}$$

For brass from USEFUL DATA

$$\boldsymbol{K = 16.3 Wm^{-1}K^{-1}}$$

$$\rho = 7930\ kgm^{-3}$$

$$\boldsymbol{C = 460\ Jkg^{-1}}$$

Hence

$$\boldsymbol{\alpha = k/pc}$$

T =5 second

$$Length = \quad R = 10\ X\ 10^{-3}\ m$$

Hence

$$\text{Fo} = \frac{\text{a X t}}{(\text{Length})^2}$$

From the Heisler chart for a semi infinite cylinder.

The co-ordinates for $\mathbf{F_o} =$ **and** $\boldsymbol{\theta} =$ give

$$\frac{1}{\text{Bi}} =$$

Where $\text{Bi} = \text{h x Length/k}$

Note that from useful data

$$\text{K} = 16.3\text{Wm}^{-1}\text{K}^{-1}$$

$$\rho = 7930\ \text{kgm}^{-3}$$

$$\text{C} = 460\ \text{Jkg}^{-1}\text{k}^{-1}$$

Hence

$$\text{a} = \frac{\text{k}}{\rho\text{c}}$$

Note that both the 20mm diameter brass and stainless steel cylinders after immersion $\boldsymbol{\frac{1}{Bi}}$ becomes near constant.

From $Bi = h\ x\ Length/k$

For cylinder the characteristics length= R the radius = $10 \times 10^{-3} m$

Hence for the brass cylinder where $k = 121 W m^{-1} k^{-1}$

$$h = (Bi\ x\ k\ )/R$$

This is the heat transfer coefficient around the cylinder due to the velocity of the hot water in the flow duct. This velocity depends only upon the pump speed.

As the pump speed and hence velocity was constant for both the brass and stainless steel cylinder then the local heat transfer coefficient h will be the same value for the stainless steel cylinder

Therefore for the stainless steel cylinder

From

$$\mathrm{h} = 3270 \mathrm{Wm}^{-2}\ \mathrm{K}^{-2}$$

$$\frac{1}{\mathrm{Bi}} = 5.5$$

$$\mathrm{R} = 10\mathrm{x}10^{-3}$$

$$\mathrm{k} = \mathrm{hxR/Bi}$$

GRAPH:

<u>COMMENTS:</u>