Heat transfer through heat exchanger

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1. Aim of the experiment

To determine the overall heat transfer coefficient of a tubular heat exchanger using LMTD and AMTD methods for parallel and counter flow configurations.

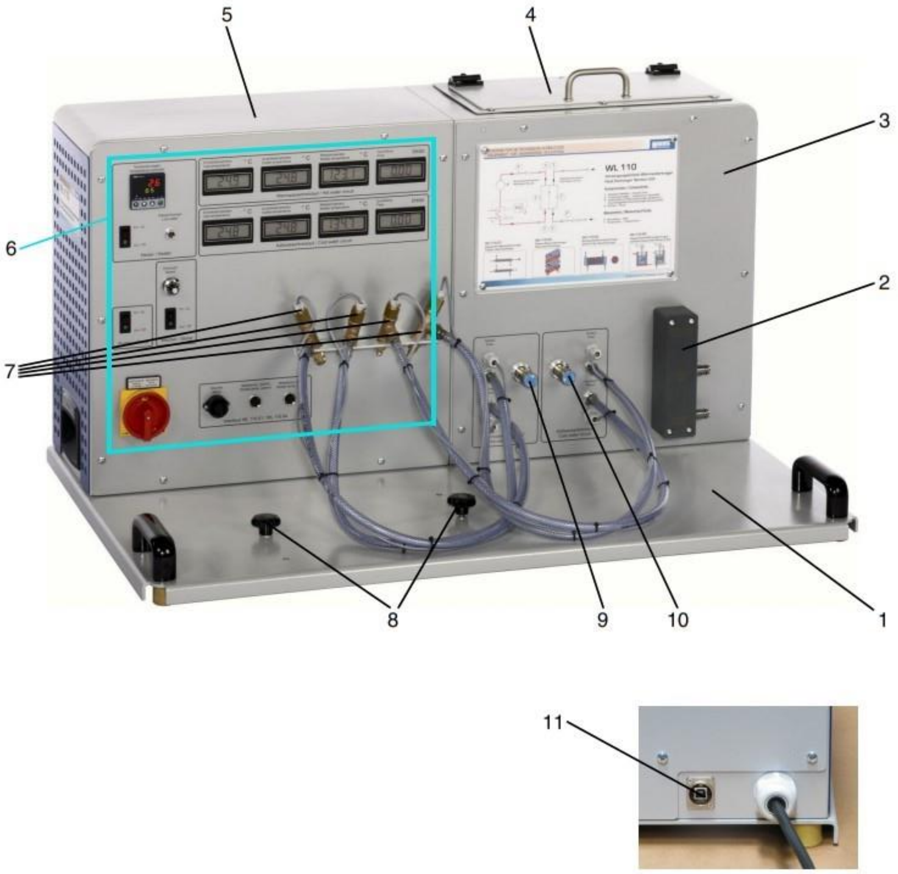
2. Theory

The role of a heat exchanger is to transfer thermal energy between two or more fluids. Depending upon the flow directions of fluid, there are mainly two types flow configuration, i.e., parallel flow and counterflow. In parallel flow the flow of hot and cold fluids occur in same direction while in counter flow the flow direction is opposite. In the determination of the overall heat transfer coefficient (U), the mean temperature difference is essential and can be obtained by either of the two methods, i.e. Arithmetic Mean Temperature Difference (AMTD) and Logarithmic Mean Temperature Difference (LMTD). LMTD method is most useful for the case of determining the overall heat transfer coefficient based on inlet and outlet temperatures when the temperature difference between hot and cold fluid is large.

3. Description of the apparatus

The apparatus consists of a main service unit, a heat exchanger unit and chiller unit. The service unit as shown in figure (1) consists of a base plate, over which heat exchanger is placed. On the left side of the service unit is a control and display panel unit which contains a mains switch, a heater switch, a pump switch, a heater temperature control unit which is used to set temperature of water in heater tank, a temperature display unit which records inlet and outlet temperatures of hot and cold

fluids i.e. $T_{h,in}$, $T_{h,out}$,$T_{c,in}$ and $T_{c,out}$. On the right side of the service unit is a heater tank, a connecting block which connects to the chiller unit and flow control valves, which are used to set flow rates of hot water (V_h)and cold water ($\dot{V_c}$). It also contains couplings to connect the flow pipes to the heat exchanger. The hot water tank contains a thermocouple, a heater coil and a level switch indicator which helps to maintain the correct level of water in the tank.



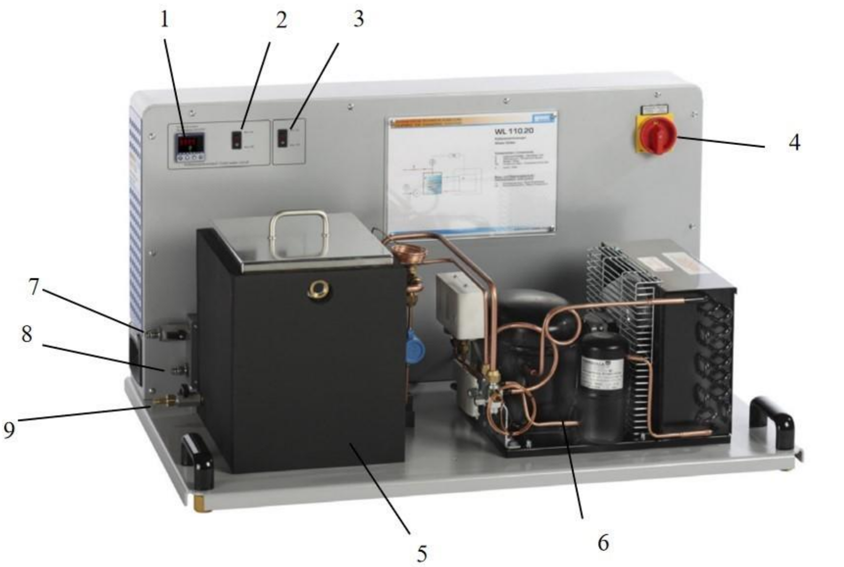
1	Base plate	7	Couplings
2	Connecting block	8	Bolts
3	Right housing half	9	Regulator valve for hot water (V1)
4	Tank cover	10	Regulator valve for cold water (V2)
5	Left housing section	11	USB connecting socket
6	Control and display panel		

Figure 1 : Service unit

In this experiment, two types of heat exchangers can be used, namely tubular heat exchanger and shell and tube heat exchanger. Tubular heat exchanger essentially consists of two concentric tubes as shown in figure(2). The shell and tube heat exchanger consists of tube bundle and an encasing shell as shown in figure(3). In this experiment we will be conducting experiment using tubular heat exchanger.

Figure 2: Tubular heat exchanger

Figure 3: Shell and tube heat exchanger The chiller unit as shown in figure (4) consists of a main switch, a cooling switch, a pump switch, a temperature control unit which is used to set the cold water temperature, a water storage tank, water inlet and outlet valves, a drain valve and a refrigeration system.



1 Temperature control unit
2 Cooling switch
3 Pump switch
4 Main switch
5 Water storage tank
6 Compressor of the chiller
7 Water outlet with flow limiter
8 Water inlet
9 Drain valve

Figure 4 : Chiller unit

4. Experimental procedure

1. Ensure that Mains switch given on the panel is at OFF position .
2. Ensure that the flow and drain valves are in off position.
3. Fill water in chiller unit water tank until water level can be seen from the sight glass.
4. Switch on the chiller unit main switch.
5. Switch on the pump and cooling switch.
6. Set the temperature at a desired set point temperature (say 10°C)
7. Let the water attain the set point temperature.
8. Secure the selected heat exchanger on the base plate of the service unit.

9. Based on the type of flow configuration, parallel or counter flow, ensure the appropriate connection of couplings.

10. Switch on the main switch in the service unit.
11. Check the water level indicator
    a) If the hot water tank is empty: Add water until the low level is reached (level switch trips and the low water warning lamp goes out. Then add 0.5 ltr of water with a beaker.
    b) If the hot water tank is filled but with an unknown volume above the low level: Partially drain the hot water tank until the low level is reached (level switch trips and the low water warning lamp lights up). Then add 0,5ltr of water with a beaker.
12. Start the PC. Start the data acquisition program.
13. Open the cold water feed at the cold water mains.
14. Open the regulator valve for cold water.
15. Open the regulator valve for hot water.
16. Start the pump in the service unit.
17. Ensure that water flow is not obstructed by air bubbles.
18. Set the desired hot water set point temperature (say 40 °C)
19. Set the desired cold and hot water flow rate using the regulator valves.
20. Turn on the heater (H) in the service unit.
21. Wait until steady state has been reached and record the temperature values and flow rates.
22. Same procedure can be used for other flow configuration and heat exchanger.

5. Closing Procedure

1. Turn off the heater .
2. Then stop the pump.
3. Close the regulator valves.
4. Turn off the cooling switch 5. Turn off the pump in the chiller unit.
6. Close the flow valves.
7. Switch off the mains of both units.

6. Observation

1. Steady state temperature readings for Parallel flow configuration

Set Temperatures	$T_{h,in}$ (°C)	$T_{h,out}$ (°C)	$T_{c,in}$ (°C)	$T_{c,out}$ (°C)	$\dot{V}_h$	$\dot{V}_c$
Heater = 40°C Chiller = 10°C	43	38.3	21.2	28	0.73	0.53
Heater = 50°C Chiller = 10°C	52.6	45.8	22.9	32.9	0.74	0.5
Heater = 60°C Chiller = 10°C	61	52.2	24.5	37.4	0.75	0.5

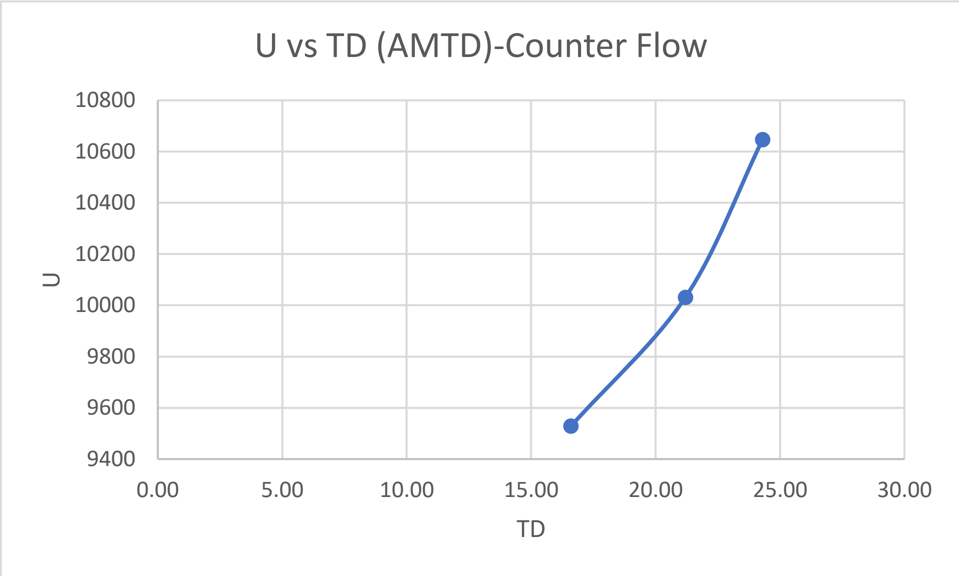
2. Steady state temperature readings for counter flow configuration

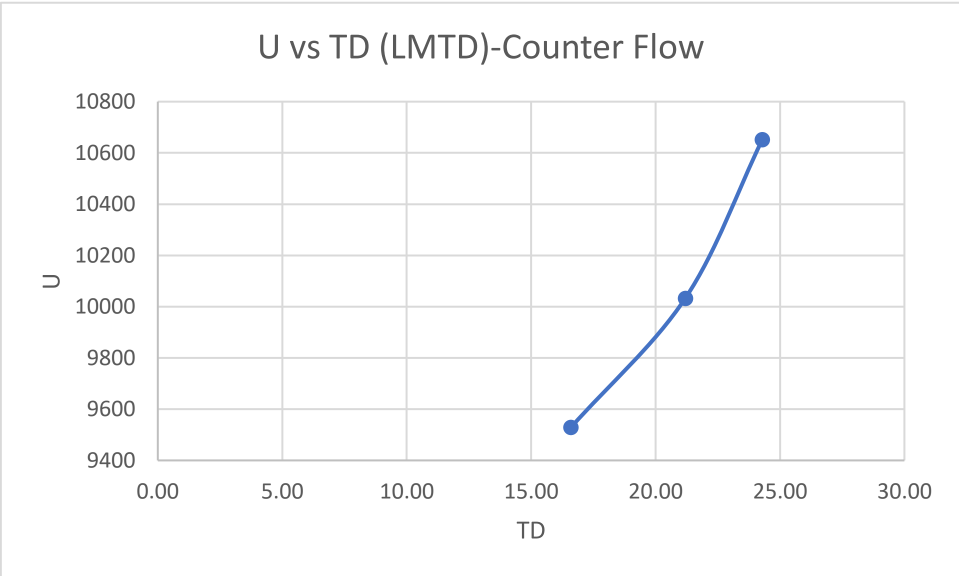
Set Temperatures	$T_{h,in}$ (°C)	$T_{h,out}$ (°C)	$T_{c,in}$ (°C)	$T_{c,out}$ (°C)	$\dot{V}_h$	$\dot{V}_c$
Heater = 40°C Chiller = 10°C	43.3	37.5	21.1	26.5	0.68	0.74
Heater = 50°C Chiller = 10°C	52.4	44.3	23.6	30.7	0.69	0.72
Heater = 60°C Chiller = 10°C	59.9	50	26.6	34.7	0.73	0.72

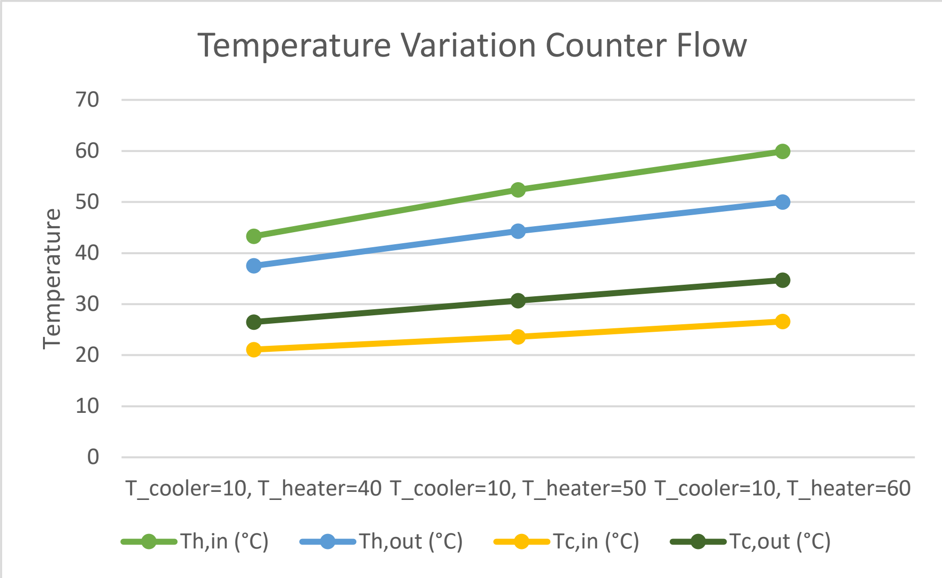
1. Counter Flow:

HOT	COLD	HOT	COLD
ρ	ρ	Q_H	Q_C
992.25	999.77	3913.434	-3995.08092
988.02	999.77	5522.04378	-5110.82424
983.13	999.77	7105.08051	-5830.65864

	TD	HOT	COLD	U
AMTD	16.60	9429.961446	9626.701012	9528.331229
	21.20	10418.95053	9643.064604	10031.00757
	24.30	11695.60578	9597.792	10646.69889
LMTD	16.60	9430.417767	9627.166853	9528.79231
	21.20	10420.88301	9644.853178	10032.8681
	24.29	11700.95797	9602.184181	10651.57107



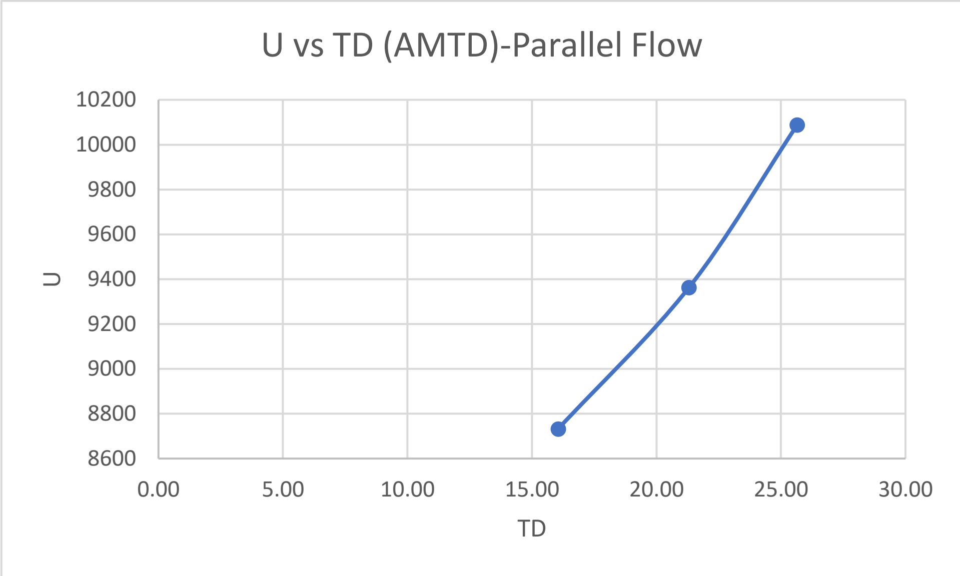


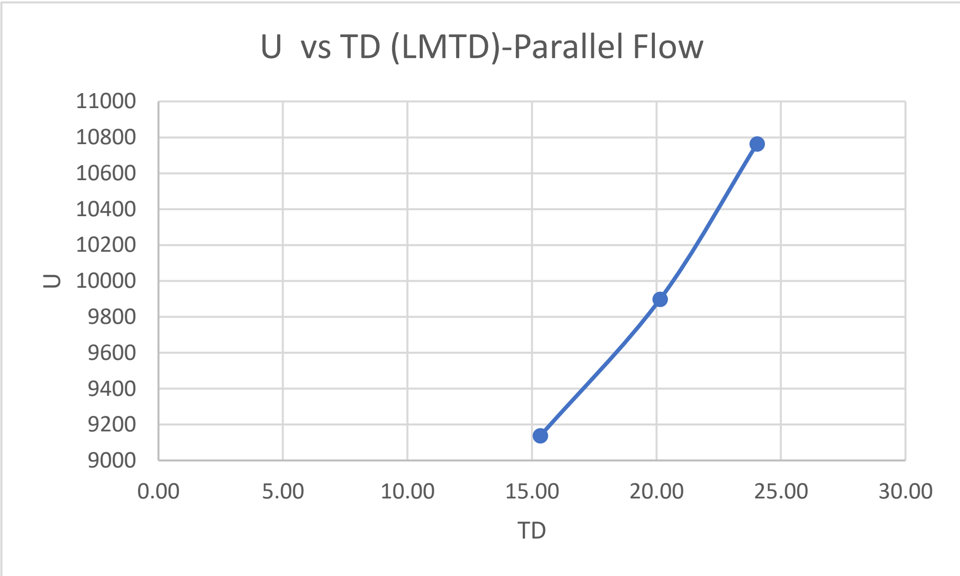


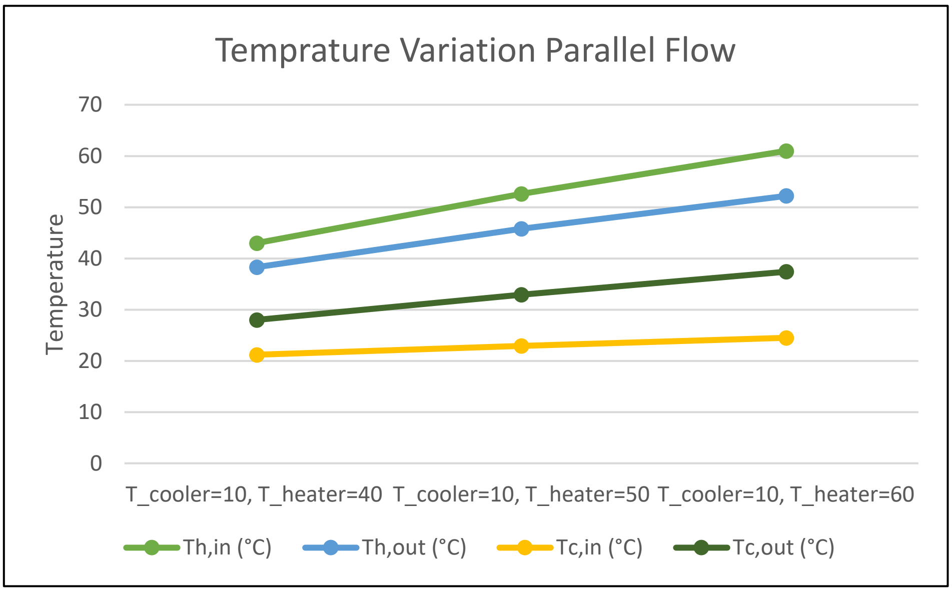
2. Parallel Flow:

	TD	HOT	COLD	U
AMTD	16.05	8484.51028	8979.86562	8732.18795
	21.30	9336.55707	9387.511737	9362.034404
	25.65	10118.76491	10056.16608	10087.4655
LMTD	15.34	8878.298902	9396.644997	9137.47195
	20.15	9871.458619	9925.332535	9898.395577
	24.04	10796.70924	10729.91637	10763.31281

ρ	ρ	Q_H	Q_C
992.25	999.77	3404.40975	-3603.17108
988.02	999.77	4971.71664	-4998.85
983.13	999.77	6488.658	-6448.5165


U vs TD (AMTD)-Parallel Flow
10200
10000
9800
9600
9400
9200
9000
8800
8600
U
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TD


U vs TD (LMTD)-Parallel Flow
11000
10800
10600
10400
10200
10000
9800
9600
9400
9200
9000
U
0.00
5.00
10.00
15.00
20.00
25.00
30.00
TD


Temprature Variation Parallel Flow
70
60
50
40
30
20
10
0
Temperature
T_cooler=10, T_heater=40
T_cooler=10, T_heater=50
T_cooler=10, T_heater=60
Th,in (°C)
Th,out (°C)
Tc,in (°C)
Tc,out (°C)

7. Specifications and data

Mean Area, of tubes, $A_m = 0.025\ m^2$

8. Calculation

$Q_i = \rho V_i\ (T_{i,in} - T_{i,out})$

$Q_i = U_{AMTD,i}\ A_m\ (AMTD)$

$Q_i = U_{LMTD,i}\ A_m\ (LMTD)$

Where,

i = h, for hot fluid

i = c, for cold fluid

Q_i = heat transfer rate for fluid 'i'

ρ = density of water

$U_{AMTD,\ i}$ = heat transfer coefficient based on AMTD for fluid 'i'

$U_{LMTD,\ i}$ = heat transfer coefficient based on LMTD for fluid 'i'

Overall heat transfer coefficient;

a) Based on AMTD, $U_{AMTD,\ i} = \frac{U_{AMTD,h} + U_{AMTD,C}}{2}$

b) Based on LMTD, $U_{LMTD,\ i} = \frac{U_{LMTD,h} + U_{LMTD,C}}{2}$

9. Precautions & maintenance instructions:

1. Ensure the hot water temperature is operated below 70°C.
2. Do not operate pump without water.
3. Ensure the water level in the hot water reservoir is maintained and the warning lamp is switched off.
4. Ensure that the chiller unit has sufficient water.
5. Avoid the use of water with a high-water hardness.

10. Conclusion

1. In both the cases hot in, hot out and cold out temperature is directly proportional to the inlet heater input.

2. AMTD is higher than LMTD in case of parallel flow while they are equal in case of counter flow.

3. U_{AMTD} and U_{LMTD} are directly proportional to heater input temperature.