Design of Automatic Heat Exchanger System

Yevale Akshaykumar, Sathe Shubham, Aher Mayur, Naykodi Swati

Abstract— Heat Exchanger is a device which provides a flow of thermal energy between two or more fluids at different temperatures. Heat exchangers are used in the applications like power generation, manufacturing industry, air-conditioning, refrigeration, waste heat recovery, space applications, petrochemical industries etc. They are named according to their application e.g. when heat exchanger used for cooling are called as condensers and heat exchangers used for the boiling are known as boilers. The heat exchanger performance and efficiency can be calculated through the amount of heat transfer using area of heat transfer and pressure drop. According to efficiency and performance capital cost and running cost of the unit are defined For specific processes the temperature of fluid should be maintained at particular temperature this is difficult to handle high temperature fluids manually and maintain the required temperature so we are going to automate the process using PID controller and temperature sensors.

Key Words: Heat Exchanger, PID Controller, Temperature Sensor.

I. INTRODUCTION

A typical interacting process for heating consists of a boiler and for cooling consist of condenser the combination of both system called heat exchanger system. We are using concentric vessel as a jacket heat exchanger. It is circular in cross section having two shells, inner shell contain hot processing fluid and in outer shell contain coolant. Coolant flow around the surface of inner shell (i.e water, brine water etc.). We have considered different assumptions. The first assumption is the rate of inflow and outflow fluid is same to maintain fluid level constant in the heat exchanger. The second assumption is the heat capacity of the wall of inner shell is negligible. The coolant fluid absorb heat from hot processing fluid and release to atmosphere. Process of heat exchange take place by conduction and convection, due to temperature difference between two fluids i.e the hot fluid is at temperature about 100^0C and coolant at room temperature i.e about 30^0C.

The automation is implemented in the heat exchanger for the purpose of accurate process controlling and easy of process handing. Automation is achieved by using temperature sensor and microcontroller in the sense of feedback control system.

In the feed controller system controller is reverse acting. The resistance temperature detector (RTD) is used as temperature sensor. Which is implemented in the feedback path of control architecture. The temperature of hot fluid measured by RTD and the output of the RTD is sent to transmitter unit which convert the output of RTD in standard voltage signal. This signal is processed in controller and respective control action taken. The controller uses actuator to actuate the elements of the heat exchanger system. Actuator is control relay device. Relay operate the elements like fan, pump and stirrer motor. Relay actuates according to the controller decision to obtain set temperature value of the process fluid.

II. DESIGN OF SYSTEM COMPONETS

Design of Jacket Heat Exchanger:

Material used- Aluminium (Al)

1.Dimensions:

a) Inner tank

Area= **0.1414 m²**

Height= **0.15 m**

Volume= **10.60 litre**

b) Outer tank

Area= **0.1696 m²**

Height= **0.15 m**

Volume= **15.26 litre**

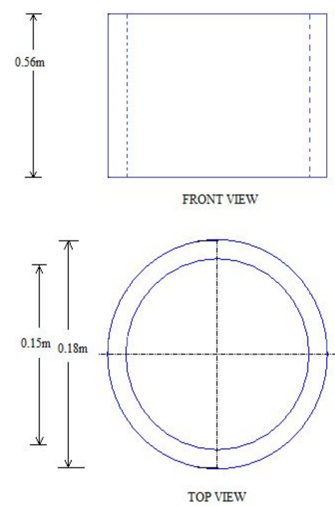

Fig.1 Concentric vessel design

2. Pump and Motor Specification:

Model	HP	Head	Discharge(Q_d)
LE2 (Laxmi)	0.5	6-26 m	0.55×10^{-4} m^3/sec

Table.1 Pump and motor specification

Gauge Pressure (P_g) = $0.0981\times$H

= 0.0981×6

= **0.5886 bar**

Absolute Pressure = Gauge pressure + Atmospheric pressure

= 0.5886+1.01325

P_{atm} = **1.6018 bar**

3. Mass flow rate ($\dot{m}$):

$\dot{m} = \rho \times Q_d$

$=1000 \times 0.55 \times 10^{-4}$

$=$**0. 55kg/sec**

4. Inlet velocity of water (V_1):

$Q_d = A \times V_1$

$0.55\times10^{-4} = \frac{\pi}{4} \times (0.025)^2 \times V_1$

$V_1 = 0.112$ m/sec

$V_1 \cong$ **0.112 m/sec**

5. Outlet velocity of water (V_2):

By using continuity equation,

$A_1 V_1 = A_2 V_2$

$1.6018 \times 0.112 = 1.01325 \times V_2$

$V_2 = 0.778$ m/sec

$V_2 \cong$ **0.77 m/sec**

6. Heat transfer rate:

Fluid	Temperature at inlet	Temperature at outlet
Hot fluid (Milk)	105	40
Cold fluid (Water)	30	40

Table.2 Temperature of fluids

Heat transfer rate for milk

$Q= mc_p(\Delta T)$

$Q= mc_p(Th_1 - Th_2)$

$Q= 0.55 \times 393 \times (105-30)$

Q= 172.71 KJ/sec

7. Convective heat transfer coefficient (h):

A. By Newton's law of cooling

$$T_{mean} = \frac{(Tc_2 + Tc_1)}{2}$$

$T_{mean} = 35^0c$

$Q= hA(\Delta T)$

$Q = hA(T_{h1} - T_{mean})$

$172.72 = h \times 0.1414 \times (105-35)$

h = 17.44 w/m² °c ($h = 17.44\ w/m^2\ ^0c$)

B. By dimensionless number

Water properties at $T_{mean} = 35$ ...... (from table)

$\mu=700\times10^{-6}$ N-sec/m^2

$k = 0.626$ w/mk

$p_r = 4.62$

$$Re = \frac{\rho \times v \times Deq}{\mu}$$

Re = 33342.85

Re > 4000 hence flow is turbulent

Using correlation for turbulent flow,

$Nu = 0.0233\ Re^{0.8}\ Pr^{0.3}$

$Nu = 0.0233 \times (33342.85)^{0.8} \times (4.64)^{0.4}$

Nu = 176.19

But we also have,

$$Nu = \frac{h \times l}{k}$$

$h = 735.29\ w/m^2\ ^0c$

III. CONSTRUCTION

In the construction the basic parts are a concentric vessel, PID controller, shell and tube type heat exchanger, Temperature sensor, Centrifugal pump, Valves, Piping arrangements etc.

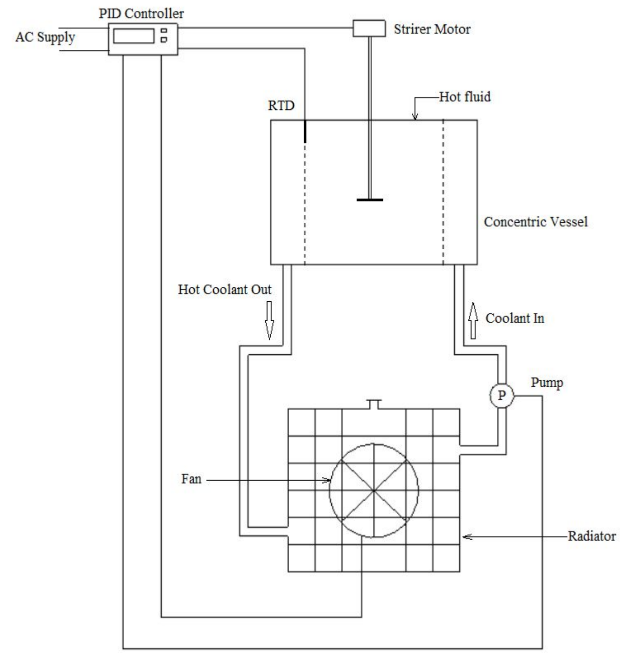

Fig.2 Construction diagram of setup

- Concentric Vessel/Jacket type Heat Exchanger :

It is made of aluminium Sheet metal is used for storing fluid which is to be cooled in inner compartment and on the outside of this coolant flows by means of centrifugal pump. Circulation of coolant may be used as water, glycol water, and brine solution. Jacket heat exchanger apparatus is mounted on the main service unit. Inlet and outlet connections are connected hot and cold streams between the apparatus and the service unit.

- RTD(Resistance temperature detector)

Temperature sensor Resistance temperature detector is placed to sense the temperature of the fluid. The resistance of most metal increases with temperature and their conductivity decreases. RTD commonly employ platinum, nickel or resistance wire elements whose resistance varies with temperature.

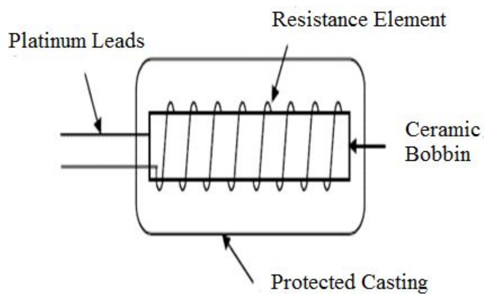

Fig.3 Construction diagram of RTD sensor.

The relationship between the temperature and resistance of conductors in the temperature range near 0°C can be found by equation;

$$Rt = Rref\,[1+ \alpha\, \Delta t]$$

Where;
Rt = Resistance of conductor at temperature t°C
Rref = Resistance at reference temperature, normally 0°C
α = Temperature coefficient
Δt = Difference between operating temperature and reference temperature.

- PID Controller

Proportional integral derivative controller is installed in the setup for the controlling process on the basis of signal from the temperature sensor. A PID controller continuously calculates an error value as the difference between a desired set point and a measured process variable. According to error value PID controller takes control action.

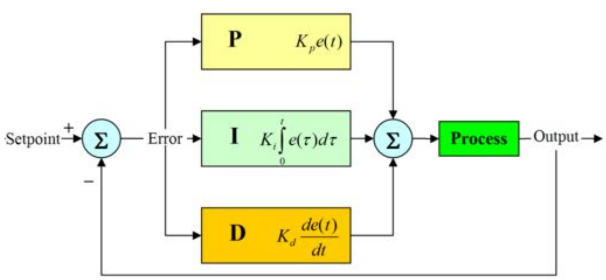

Fig.4 PID Controller block diagram

- Centrifugal Pump

Centrifugal pump is use for circulation of coolant outside of the concentric vessel. Mass flow rate of centrifugal pump is according to design and requirement of mass flow rate of coolant.

- Piping Arrangement

Piping arrangement is use for the circulation of coolant from heat exchanger to concentric vessel. It is provided with insulation to avoid heat dissipation.

IV. WORKING

Fill the fluid which is to be cooled in the inner cavity of concentric vessel and switch on the power.
1) A stirrer motor will stir the fluid in inner compartment.
2) The coolant liquid is circulated around the fluid in vessel via outer cavity of the concentric vessel. Coolant will absorb the heat from hot fluid present in the inner compartment of concentric vessel.
3) This coolant is feed to the shell and tube type heat exchanger in which it is cooled again to the normal temperature and circulated again to the concentric vessel cavity.
4) For the circulation of the coolant through the concentric vessel cavity and shell and tube type heat exchanger centrifugal pump is provided.
5) For the automatic operation of heat exchanger the temperature sensor and PID controller unit is provided.
6) The temperature sensor will sense the temperature of fluid which is to be cooled and give signal to the PID controller. According to the signal from RTD PID controller will take control action.
7) The required temperature of fluid is set as reference value for PID controller. When the temperature of fluid and set value equals the PID controller generate control signal to stop the circulation of coolant.
8) This signal will give to relay which operates the centrifugal pump and pump will stop the circulation of coolant.
9) The fluid which is to be cooled is removed from the inner compartment of concentric vessel by piping and valve arrangement. And the cycle is repeated.

V.CONCLUSION

We can automate the heat exchanger system to obtain the desired set temperature in less time than conventional system with help of PID controller and temperature sensor. (eg. For producing pannier from milk at boiling temperature 105^0c to 80^0c) .

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