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Computational Design and Fabrication of Exhaust Gas Calorimeter with C-Programming Template

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ABSTRACT

In this Paper we presented our work on Design and fabrication of Exhaust gas Calorimeter. Computational design is performed and Fabrication of Exhaust gas Calorimeter is done then Experiment is conducted on Automobile 4-Stroke Diesel Engine. After getting the results we compare the effectiveness of Exhaust gas Calorimeter between the Theoretical and Practical values. We develop a C-Programming Template to get the output values by given Input values.

Keywords: 4-Stroke Diesel Engine, C-Programming Template, Effectiveness, Exhaust gas Calorimeter.

INTRODUCTION

A Heat Exchanger is a device built for efficient Heat transfer from one medium to another. The medium may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in Space heating, Refrigeration, Air Conditioning, Power Plants, Chemical Plants, Petro Chemical Plants, Petroleum Refineries, and Natural Gas Processing.

Design Procedure

Theoretical design is developed in order to find the various parameters of heat exchanger & the device is fabricated according to the values obtained from theoretical design.

Heat Exchanger Analysis

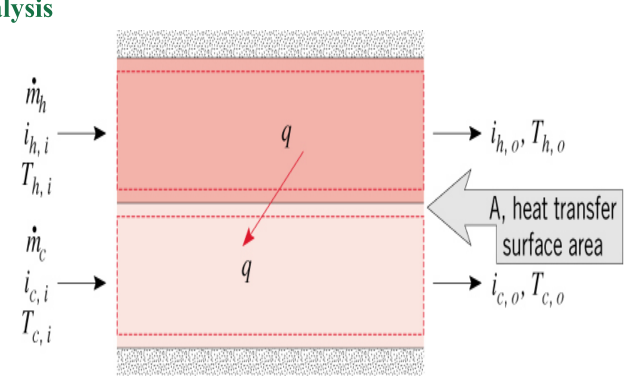

Figure1. *Over all Energy Balance in Calorimeter*

Let,

m = mass flow rate, kg/s,

C_p = specific heat of fluid at constant pressure, J/kg°C

T = Temperature of fluid, °C

Δt = temperature drop or rise of a fluid across the heat exchanger

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LMTD Method

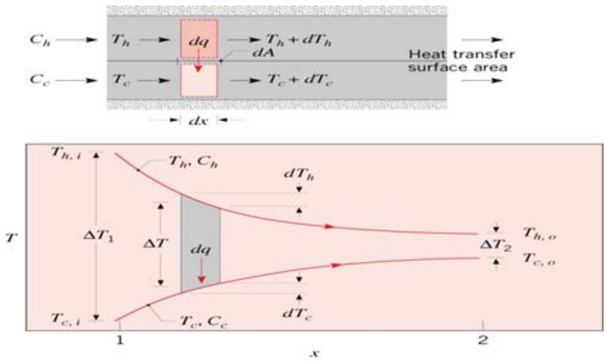


Figure2. *Parallel flow Heattransfer rate in a Calorimeter*

Where ΔT_{lm} is the log mean temperature difference (LMTD).

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2 / \Delta T_1)} = \frac{\Delta T_1 - \Delta T\,2}{\ln(\Delta T_1 / \Delta T_2)}$$

For parallel-flow heat exchanger, $\begin{bmatrix} \Delta T_1 = T_{h,i} - T_{c,i} \\ \Delta T_2 = T_{h,o} - T_{c,o} \end{bmatrix}$

In order to derive expression for LMTD for various types of heat exchangers, the following assumptions are made,

1. The overall heat transfer coefficient U is constant.
2. The flow conditions are steady.
3. The specific heats and mass flow rates of both fluids are Constant.
4. There is no loss of heat to the surroundings, due to the heat Exchanger being perfectly insulated.
5. There is no change of phase either of the fluid during the Heat transfer.
6. The changes in potential and kinetic energies are Negligible.

DESIGN DATA

1. Inlet Temperature of Exhaust gas T1=500°c
2. Outlet Temperature of Exhaust gas T2=247°c
3. Inlet Temperature of water T3=30°c
4. Outlet temperature of water T4=?
5. Mass flow rate of water m_W=2liters/min
   =2kg/min
   =0.033kg/sec
6. Mass flow rate of Exhaust gases Me = Ma + Mf.
   Me = 0.014kg/sec
7. Mass flow rate of water passing through pipe:
   V=0.56m/sec
8. Reynolds Number: Re=5859.29
9. Nusslet Number: NU = 47.61
10. Over All Heat Transfer Coefficient:
   U=1/((1/hi)+(L/k)+(1/ho))

Uo =478.796w/m²k.

11. Over all Heat transfer co-efficient when fouling factor was Consider:

    Uo = 231.82w/m²k.

12. Out let temperature of water: T4=61°c
13. Effectiveness: ε = 0.5389.
14. Number of Transfer Units (NTU): 0.7741
15. Surface Area: 0.4660m².
16. Length of the Copper Pipe: 14.836mts
17. Number of Turns = 27
18. Outer diameter of shell:D_o=0.265mts
19. Inner diameter of shell: di=0.165mts
20. Heat Transfer Rate:

    Q = UA θm.

    θm = 306°c

    Q=33.05kw

21. The amount of heat taken away by cold water:

    Q = mw*Cpw(T4-T3)

    Q = 259.594kj/min.

MATERIAL COLLECTION FOR FABRICATION

Copper Pipe

Figure3. *Copper pipe*

Mild Steel Outer Shell

Figure4. *Outer shell for calorimeter*

Mild Steel Inner Shell

Figure5. *Inner shell for calorimeter*

Flange for Calorimeter

Figure6. *Flange for calorimeter*

Flow Meter Arrangement

Figure7. *Flow meter with gate valve*

Arrangement of Thermocouple

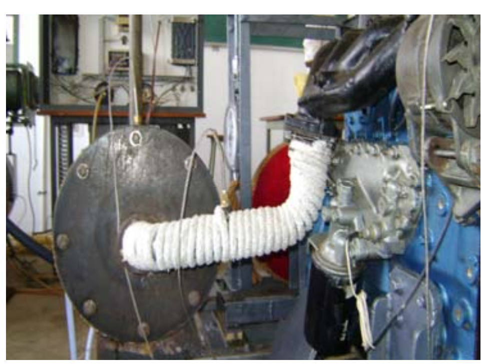


Figure8. *Thermocouple Arrangement*

EXPERIMENTAL SETUP

Figure9. *Experimental setup for Calorimeter*

Table1. *Attributes of Cleveland dataset*

S.No	Specification	Units	T-1	T-2	T-3	T-4	T-5
1	Load	N	0	19.6	39.2	58.8	88.2
2	Speed	Rpm	1000	1000	1000	1000	1000
3	Spring Balance Reading (F1)	Kg	0	0	0	0	0
4	Spring Balance Reading (F2)	Kg	0	2	4	6	9
5	Calorimeter Water Inlet Temperature (T4)	°C	33	33	33	33	33
6	Calorimeter Water outlet Temperature (T5)	°C	40	41	45	50	57
7	Exhaust gas Inlet Temperature (T6)	°C	63	68	71	78	85
8	Exhaust gas Out let Temperature (T7)	°C	53	56	58	62	66
9	Break Drum Diameter	M	0.38	0.38	0.38	0.38	0.38
10	Effectiveness	ε	0.33	0.34	0.34	0.35	0.36
11	Specific heat of exhaust gases,C_p	Kj/kg	0.657	0.70	0.78	0.75	0.74

Model Calculations

Test-1: ε = (T6-T7) / (T6-T4) = 0.33.

Test-2: ε = (T6-T7) / (T6-T4)=0.34.

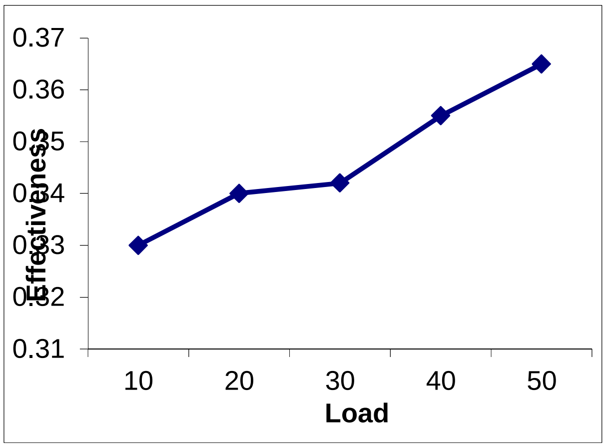
Test-3 : ε = (T6-T7) / (T6-T4)=0.3421.

Test-4: ε = (T6-T7) / (T6-T4)= 0.355.

Test-5: ε = (T6-T7) / (T6-T4) = 0.365.

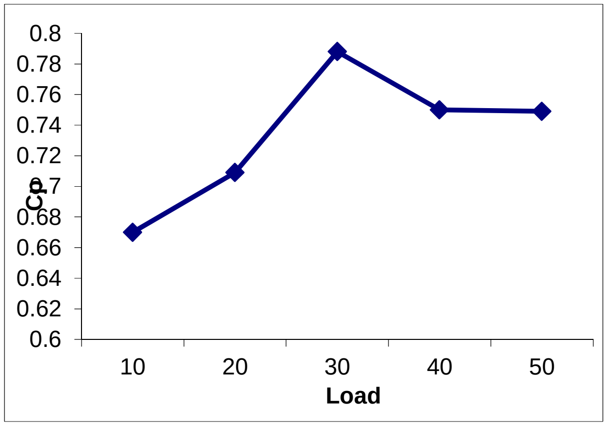
Graphs

Load vs Effectiveness



Graph1. *Load vs Effectiveness*

Load vs Specificheat



Graph2. *Load vs Specific heat*

Computer Programming for Calorimeter

```
#include<stdio.h>
 #include<conio.h>
 #include<math.h>
 void main()
   {
  float a,b,c,d,e,f,g,h;
  float x,y,z;
  printf("Enter the mass flow rate of exhaust
  gases(kg/min):");
  scanf("%f",&a);
  printf("\nEnter the mass flow rate of water(kg/min):");
  scanf("%f",&b);
  printf("\nEnter the inlet temperature of the exhaust gases(o  C):");
  scanf("%f",&c);
  printf("\nEnter the outlet temperature of the exhaust gases(o C):");
  scanf("%f",&d);
  printf("\nEnter the inlet temperature of the water(o C):");
  scanf("%f",&e);
  printf("\nEnter the cp of exhaust gases(kj/Kg K):");
  scanf("%f",&f);
  printf("\nEnter the cp of water(kj/Kg K):");
  scanf("%f",&g);
  x=(a*f*(c-d));
  y=(b*g); h=(x/y);
  z=h+e;
  printf("\n\nThe temperature of the outlet water:%f (o  C)",z);
```

```
double p,NTU;
p=((c-d)/(c-e));
printf("\n\nThe effectiveness is:%lf",p);
NTU=-log(1-p);
printf("\n\nThe ntu value is: ln(%lf)=%lf\n",(1-p),NTU);
double area,ntu,u,cmin,dia,len,cir,cirdia;
int  turns;
printf("\nEnter the ntu value from the above:");
scanf("%lf",&ntu);
printf("\nEnter the over all heat transfer rate(KW):");
scanf("%lf",&u);
cmin=(((b*g)/60)*1000);
printf("\nThe value of cmin is:%lf KJ/sec",cmin);
area=((ntu*cmin)/u);
printf("\n\nThe surface area of the coil is:%lf(sq.mt) ",area);
printf("\n\nEnter the coil dia(m):");
scanf("%lf",&dia);
len=(area/(3.14*dia));
printf("\nThe length of the coil is:%lf mts",len);
printf("\n\nEnter the circumference diameter of the
coil(mts): ");
scanf("%lf",&cirdia);
cir=(3.14*cirdia); turns=(len/cir);
printf("\nNumber of turns is:%d",turns);
float D,Di;
int Qw,Qg,LMTD;
D=(cirdia+0.045);
printf("\n\nThe outer diameter of the shell is:%lf (mts)",D);
Di=(cirdia-0.055);
printf("\n\nThe inner diameter of the shell is:%lf (mts)",Di);
Qw=((b*g)*(z-e));
printf("\n\nThe over all heat carried away by the water:%d
(KW)",Qw);
printf("\n\nEnter the LMTD(parallel flow)( o C):");
scanf("%d",&LMTD);
Qg=(u*area*LMTD)/1000;
printf("\nThe over all heat carried away by the exhaust
gases:%d (KW)",Qg);
getch();
}
```

CONCLUSION

The design & fabrication of Exhaust Gas calorimeter has been successfully completed. Test was conducted and experimental values were noted in order to find out the effectiveness .A comparison between theoretical values & experimental values of effectiveness of Heat Exchanger were made .

The results obtained from theoretical values & experimental values are very near. A C - Program for designing a heat exchanger (exhaust gas calorimeter). By implementing the computerized design, the process of designing of a Exhaust gas calorimeter is same but the time consumption is minimized. The output values from the computerized program are shown. The Results from the C program are quite accurate.

The theoretical effectiveness is 0.53(Refer 3.8.2. Article) if Exhaust gases temperature is 500ºc. The experimental test the effectiveness of the device is 0.36 for a exhaust gas inlet temperature is 85ºc.From the graph the effectiveness is increased linearly so at 500ºc the effectiveness is 0.5 with a a error of 0.17.

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