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Effect of Relative Surface Roughness of Condenser Material on Friction Factor in a Domestic Refrigerator.

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ABSTRACT: *The performance of a domestic refrigerator is affected by the relative Surface roughness of condenser, evaporator and associated piping. The pressure drop and heat transfer in a refrigerator largely depends on friction factor which is a primary function of relative surface roughness of the involved material of construction. Various equations had been developed in the past by different Researchers to calculate the pressure drop inside tubes for fluid flow. In the present study Cole Brook equation is being used to determine the friction factor in the condenser of a domestic refrigerator using R134a as refrigerant. For this an experimental setup has been developed containing different condensers having different relative roughness values. The theoretical friction factors computed by using the above stated equation under varying Reynolds number conditions would be used to determine the theoretical pressure drop which would then be compared with the experimental results.*

KEYWORDS: *Domestic Refrigerator, Condenser, Pressure Drop, Relative Surface Roughness, Refrigerant, Reynolds Number.*

I. INTRODUCTION

A domestic refrigerator is an essential commodity of modern life. A lot of advancement has been made in this field and research is continuously going on. One important parameter that affects the performance of a refrigerator is the pressure drop in the associated piping mainly in the condenser and evaporator. This pressure drop depends upon the friction factor and researchers have proposed different correlations in the past to predict the friction factor for general fluid flow conditions. In the present paper an attempt has been made to compute the friction factor in a domestic refrigerator by applying Cole Brook equation by varying the Reynolds number of flow and Relative roughness values of condenser piping.

II. THE COLE BROOK EQUATION

This equation is applicable for relative roughness values up to 0.05 and is given as under.

$$\mathbf{1/f^{0.5} = -2 \log_{10} [\{(e/D)/3.7\} + \{2.51/ (Re^* f^{0.5})\}]}$$

where, f = friction factor, Re = Reynolds number and e/D = Relative roughness value of condenser piping material. For the present study this value is taken in the range of 0.001 to 0.005.

III. THE EXPERIMENTAL SET UP

An experimental set up has been developed to determine the effect of relative roughness of condenser piping material on the friction factor and pressure drop in a domestic refrigerator. The set up is equipped with a number of condensers having different relative roughness values mounted in parallel with flow control valves to vary the flow conditions. The friction factor is determined using the Cole Brook equation which is then used to calculate the pressure drop. The actual pressure drop can be compared with the theoretically computed results obtained by using **Cole Brook** equation. The pressure drop per unit length of the pipe corresponding to the friction factor is determined by using the following correlation.

$$\mathbf{\Delta p = 4\, f\, l\, v^2/2\, g\, d}$$

Where

Δp	=	pressure drop,
f	=	friction factor,
v	=	velocity of fluid,
d	=	inside diameter of the tube,
g	=	Acceleration due to gravity and
l	=	length of condenser pipe.

IV. DATA USED

Refrigerant used: R134a
Relative roughness of condenser tube: 0.001 to 0.005
Reynolds number range: 600 to 10^6

By selecting different values of Reynolds number, the friction factor is determined using the **Cole Brook** equation specified above. The friction factor is determined by assigning a specified value to relative roughness, e/D and Reynolds Number, R_e. The solution is not a simple one as the variable, f (friction factor), appears on either side of the equation. So the solution is based on hit and trial method. The solutions obtained are tabulated as under.

Table for Relative roughness (e/D) 0.001

Reynolds Number, R_e	Friction Factor, f	Reynolds Number, R_e	Friction Factor, f
600	0.07168	8000	0.034144
1000	0.06319	9000	0.033191
2000	0.050214	10000	0.032382
3000	0.044411	15000	0.029611
4000	0.04091	20000	0.027946
5000	0.038495	30000	0.02597
6000	0.036696	40000	0.024891
7000	0.035287	50000	0.024021

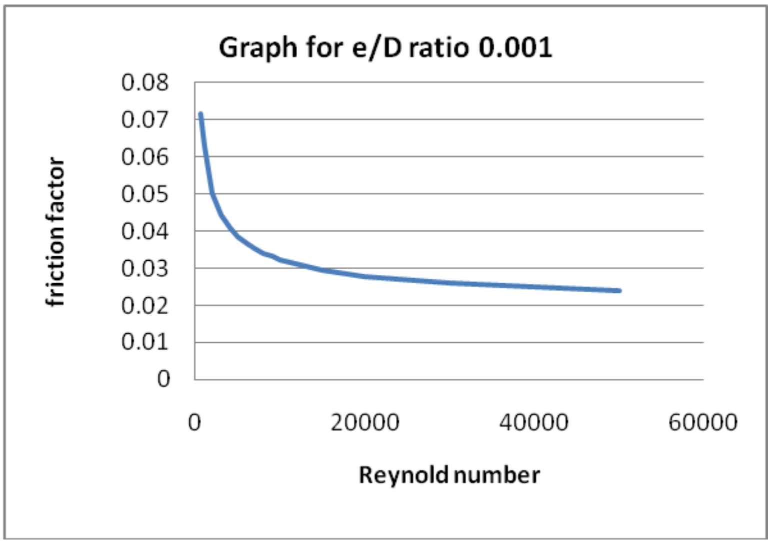

Figure 1

Table for Relative roughness (e/D) 0.002

Reynolds Number, R_e	Friction Factor, f	Reynolds Number, R_e	Friction Factor, f
600	0.076686	8000	0.035435
1000	0.063789	9000	0.034545
2000	0.050969	10000	0.033794
3000	0.045289	15000	0.031266
4000	0.041891	20000	0.029788
5000	0.039566	30000	0.028094
6000	0.037848	40000	0.027604
7000	0.036512	50000	0.026506

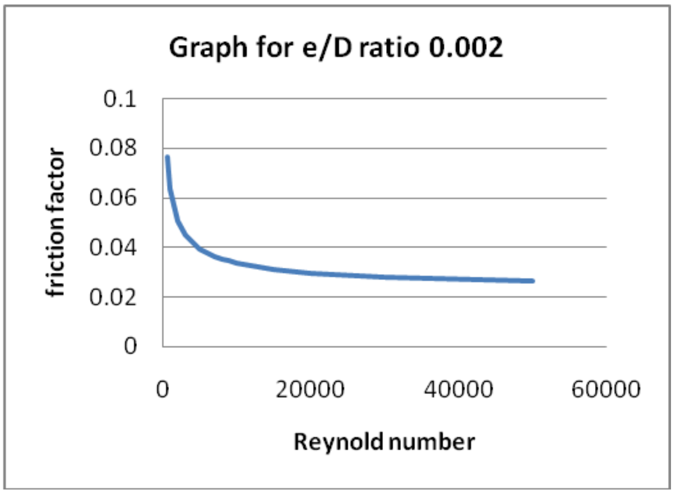

Figure 2

Table for Relative roughness (e/D) 0.003

Reynolds Number, R_e	Friction Factor, f	Reynolds Number, R_e	Friction Factor, f
600	0.077202	8000	0.036672
1000	0.064385	9000	0.035835
2000	0.051717	10000	0.035132
3000	0.046152	15000	0.032801
4000	0.04285	20000	0.031467
5000	0.040608	30000	0.029973
6000	0.038961	40000	0.029084
7000	0.03769	50000	0.028618

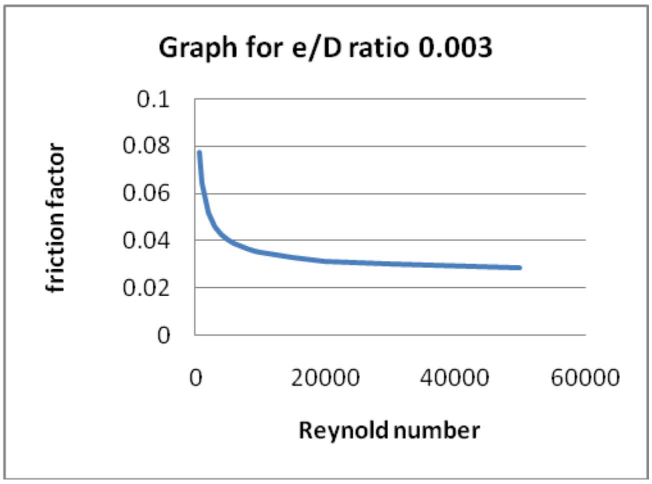

Figure 3

Table for Relative roughness (e/D) 0.004

Reynolds Number, R_e	Friction Factor, f	Reynolds Number, R_e	Friction Factor, f
600	0.077718	8000	0.03786
1000	0.064979	9000	0.037069
2000	0.052458	10000	0.036408
3000	0.047003	15000	0.034239
4000	0.04379	20000	0.033019
5000	0.041622	30000	0.031676
6000	0.040041	40000	0.031053
7000	0.038827	50000	0.030484

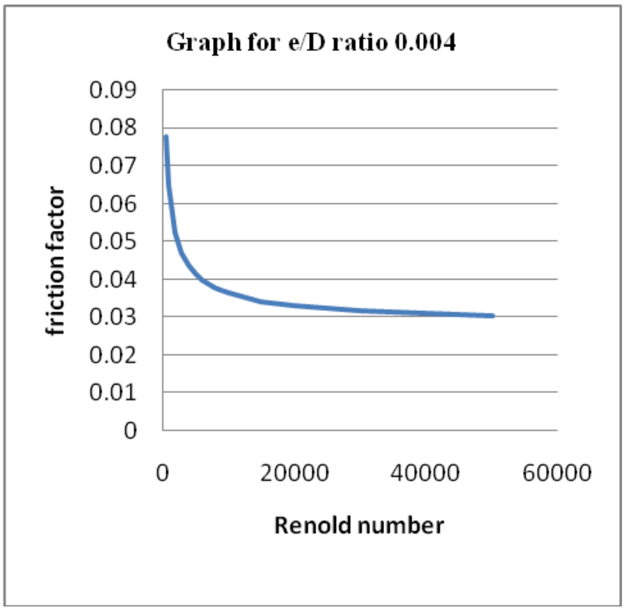

Figure 4

Table for Relative roughness (e/D) 0.005

Reynolds Number, R_e	Friction Factor, f	Reynolds Number, R_e	Friction Factor, f
600	0.078243	8000	0.039006
1000	0.065572	9000	0.038255
2000	0.053192	10000	0.03763
3000	0.047841	15000	0.035597
4000	0.044711	20000	0.03447
5000	0.042613	30000	0.033245
6000	0.041091	40000	0.032886
7000	0.039928	50000	0.032175

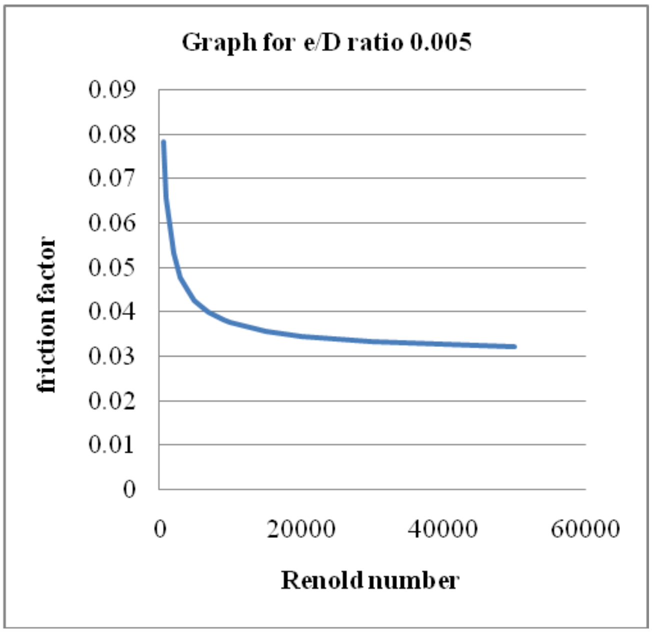

Figure 5

Table for Comparative Results.

ReynoldNo. R_e	Friction Factor f at different e/D ratios				
	e/D=0.001	e/D=0.002	e/D=0.003	e/D=0.004	e/D=0.005
600	0.0716	0.07668	0.07720	0.07771	0.07824
1000	0.0631	0.06378	0.06438	0.06497	0.06557
2000	0.05021	0.05096	0.05171	0.05245	0.05319
3000	0.04441	0.04528	0.04615	0.04700	0.04784
4000	0.0409	0.04189	0.0428	0.0437	0.04471
5000	0.03849	0.03956	0.04060	0.04162	0.04261
6000	0.03669	0.03784	0.03896	0.04004	0.04109
7000	0.03528	0.03651	0.0376	0.03882	0.03992
8000	0.03414	0.03543	0.03667	0.0378	0.03900
9000	0.03319	0.03454	0.03583	0.03706	0.03825
10000	0.03238	0.03379	0.03513	0.03640	0.0376
15000	0.02961	0.03126	0.03280	0.03423	0.03559
20000	0.02794	0.02978	0.03146	0.03301	0.0344
30000	0.0259	0.02809	0.02997	0.03167	0.03324
50000	0.02402	0.02650	0.02861	0.03048	0.03217

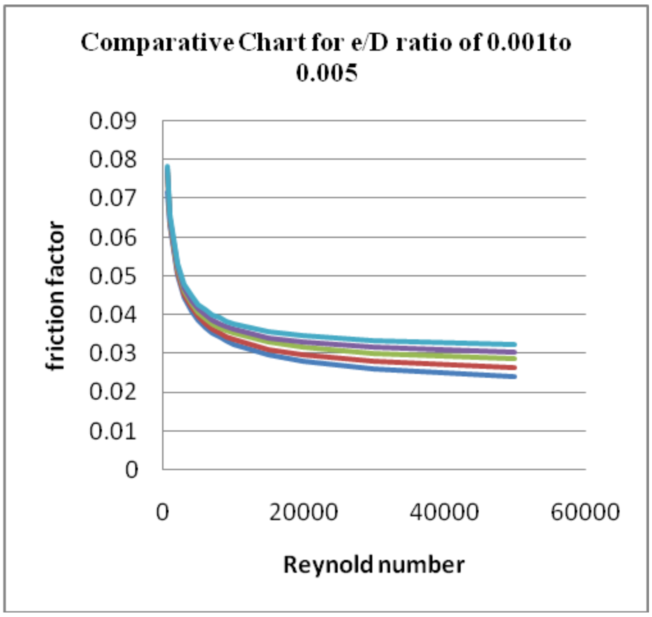

Figure 6

V. RESULTS AND DISCUSSION

From the above tables and graphs it is observed that as the Reynolds number increases the friction factor decreases very rapidly initially but with increase in Reynolds number beyond 50000,there is no significant change in the value of friction factor. Also with increase in relative roughness the friction factor and hence the pressure drop also increases. From all the above graphs, it can be observed that as the value of Reynolds number increases, the value of friction factor decreases. Also as the relative roughness increases, the friction factor also increases for a selected value of Reynolds number.

FUTURE SCOPE

For the present study Cole Brook equation has been used to compute the friction factor values. The above stated results can also be calculated by other equations and the results of various equations can be compared with the experimental values. The same experiments can also be performed on multiple evaporators mounted in parallel in place of multiple condensers as used in the present study.

VI. CONCLUSION

The inside surface roughness of condenser and evaporator of a domestic Refrigerator plays a vital role on its performance. From the above results, it is concluded that:

[1] With increase in Reynolds number, the friction factor decreases.
[2] The friction factor decreases steeply initially with increase in Reynolds number (nearly up to 50000) beyond which the friction factor is almost constant.
[3] With increase in Relative Roughness, the friction factor as well as Pressure drop increases.

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