

# Influence of Viscosity Variation on Coefficient of Friction in Pipe Flow with Different Pipe Materials and Flow Rates using Taguchi Design Method



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**Abstract:** The friction and friction factors are critical factors in flow through pipes, and heat ex-changer etc. The minimal friction is not only beneficial for pumping cost perspective, but also it reduces the loss of energy. All experimental tests were performed in accordance to Taguchi L9 orthogonal array on cast iron, aluminum, and copper pipes to study the effect of variations of viscosity, flow rates, and pipe materials on the friction factor.

**Keywords:** Viscosity, pipe materials, flow rate, friction factor etc.

## I. INTRODUCTION

Liquid flow in pipes is consistently affected by the obstruction to flow posed by the pipe walls roughness based on the law of similarity [1, 2]. Smooth pipes pose slight obstruction to flow while rough pipes pose rising resistance rely upon roughness degree of pipes. These offered obstruction influences the rate of flow (Q) and distribution of fluid velocity in the pipe [3].

The aim of this paper is to put on focus about the frictional losses caused in different pipes materials such as aluminum, stainless steel and galvanized iron. These frictional losses are caused due to resistance to flow by inherent surface roughness due to pipe fabrication, scale built up, losses due to bends and corrosion.

There are various causes for losses due to friction, including: Frictional losses rely upon the flow states and system properties. Motion of fluid particles against one

another. Movement of liquid particles against inner pipe surface. Curves, crimps, and other sharp turns in hose or piping.

The tubing must be chosen so that the production operation can be done viably, the following factors must be consider i.e. tensile forces, inner and outside pressure and corrosive actions in designing of it. An important and integral part of pressure drop in pipes involves the determination of friction factor. The friction factor thus helps us to understand the pressure or energy losses caused due to friction in pipes. This friction factor can be determined by utilizing Darcy-Weisbach (D-W) formula.

The specific solution of Darcy friction-factor in turbulent flow is dictated by utilizing Moody chart or by utilizing Colebrook formula. In this paper we calculate the values of friction facto (f) for aluminum, stainless steel and galvanized iron of the existing setup by using root mean square method for precise calculations. The setup is then modified in order to calculate the exact value of friction factor, as the friction factor obtained on the existing setup is not near to the standard value. Then the estimations of f is obtained for different pipe materials on the modified setup are then compared with the estimations of f on the existing setup and the estimations of f nearer to the standard values are selected as the optimum friction factors for the pipes.

## II. METHODS TO CALCULATE MAJOR LOSSES

In this experimental setup we determine the estimations of f for different pipe materials [4]. The practical investigation for the entrance length for fully developed turbulent flow in a smooth channel was attempted [5]. The various values can be determined by using the following equations-

### A. Reynolds Equation

Reynolds number ( $R_e$ ) in fluid flow problem is utilized to anticipate the flow patterns in various flow conditions. The  $R_e$  is characterized as the proportion of inertia to viscous force and thus measures the general significance of these two sorts of forces for given stream conditions [6].

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The Reynolds equation is given by,

$$R_e = \frac{\rho VD}{\mu}$$

Where,

$R_e$  = Reynolds number.

$\rho$  = Density of mixture of water and glycerin ( $\text{Kg/m}^3$ ).

$V$  = Water Velocity, (m/s).

$D$  = Pipe diameter, (m).

$\mu$  = Dynamic viscosity, ( $\text{N-s/m}^2$ )

The  $R_e$  states about laminar or turbulent flow. For laminar flow,  $R_e$  is lesser than the critical Reynolds number ( $R_{ecr}$ ). For turbulent flow,  $R_e$  is larger than  $R_{ecr}$ . In between the above two conditions, the flow is in transition region. For pipe flow the  $R_{ecr}$  is generally assumed to be 2300 [7].

**B. Darcy-Weisbach Empirical Equation**

The D-W formula is utilized to calculate head loss due to friction in pipe flow. The equation is given by,

$$h_f = \frac{4f l V^2}{2gD}$$

Where,

$h_f$  = Loss of head due to friction in pipe.

$f$  = Friction-factor.

$l$  = Pipe Length.

$V$  = Flow Velocity.

$g$  = Gravitational Acceleration

$D$  = Internal diameter of pipe.

**III. EXPERIMENTAL-PROCEDURE WITH FRICTION SET-UP**

One set of nine experiments were conducted in accordance to L9 orthogonal-array on major losses set-up. Similarly, various types of Taguchi based O-A has been applied by the various researchers for planning and conduction of experiments in their research works [8-13]. The photographic image of this set-up is depicted in Fig. 1.

Tests were performed on cast iron, aluminum, and copper pipes to study the effect of variations of viscosity, flow rate, and pipe material on the friction factor. Modi et al. [14, 15] applied Taguchi method in conventional machining procedure for modeling and analyzing the process factors.

The level and value of factors associated with these experimental tests are shown in Table 1.

**Table 1 Level and value of factors in friction factor determination experiments**

Parameters	Units	Level-1	Level-2	Level-3
Materials of Pipe	-	Cu	Al	GI
Glycerin (%)	<i>Kg/ litre</i>	0 (0%)	1 (50%)	2 (100%)
Flow Rate	<i>litre/sec</i>	0.250	0.375	0.500

The L9 orthogonal array, experimental plan and outputs for friction factor are portrayed in Table 2.

**Table 2 L9 orthogonal array, experimental plan and outputs for friction factor**

S. No.	Material of Pipes	% Mixing of Glycerin	Flow Rate (lit./sec)	Friction Factor
1	Cu	0	0.250	0.002639
2	Cu	50	0.375	0.001120
3	Cu	100	0.500	0.002619
4	Al	0	0.375	0.004836
5	Al	50	0.500	0.002920
6	Al	100	0.250	0.005825
7	GCI	0	0.500	0.005291
8	GCI	50	0.250	0.002716
9	GCI	100	0.375	0.006864



**Fig.1 Experimental Set-Up**

**IV. RESULTS**

The results obtained show that friction factor can be mathematically modeled and can be displayed by the Figs. 2, 3, 4, and 5 by MINITAB 16 software.



**Fig.2 Mean Graph**

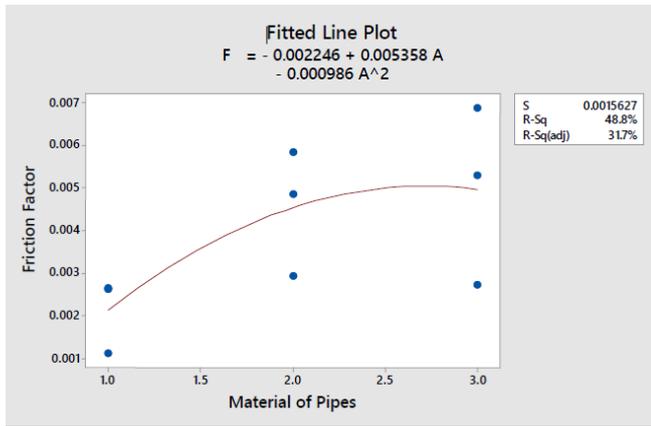


Fig.3 Friction Factor Vs Materials of Pipe

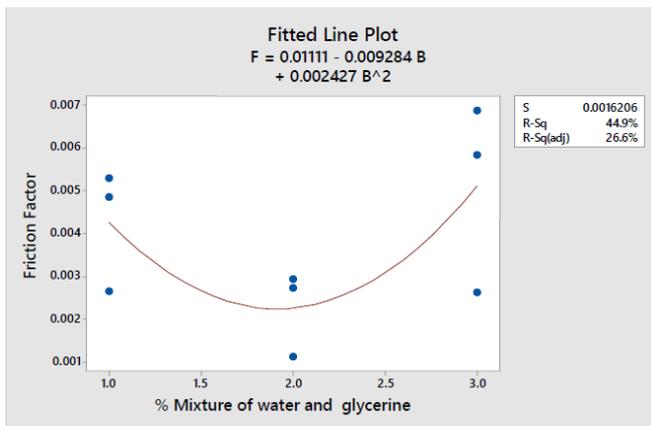


Fig.4 Friction Factor Vs Mixture of water and glycerin

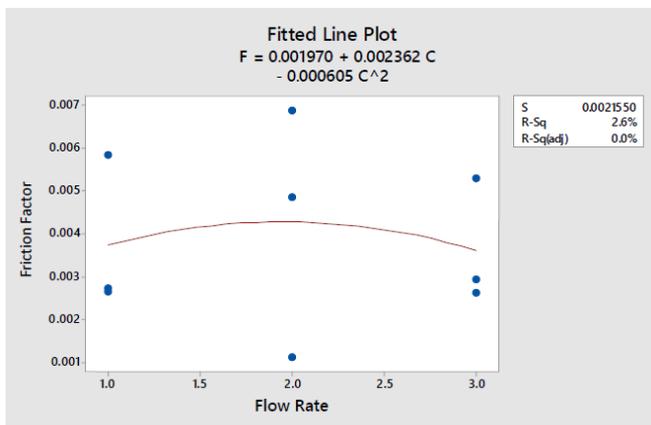


Fig.5 Friction Factor Vs Flow Rate

V. CONCLUSIONS

The below mentioned outcomes could be drawn reliant on the interpretations from the Figures 2, 3, 4, and 5.

1. It is noticed that Cu pipe delivered the minimum friction, followed by Al pipe, and for GI pipe produced the maximum friction.
2. The minimum friction factor is obtained with 1 litre of glycerin mixed with water, followed by pure water, and for 2 liter of glycerin mixed with water produced the maximum friction in this experimental work.

3. The value of friction factor is minimum at maximum flow rate, followed by minimum flow rate, and for medium flow rate produced the maximum friction.

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