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Effect of Reynolds Number on Minor Loss Coefficient of a T-Strainer

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Abstract

Loss coefficient is very important to determine minor loss occur in the piping system. This project is carried out because there is no information for the T-strainer loss coefficient. So, this project is done to determine the value of loss coefficient for T-strainer. To determine T-strainer loss coefficient at different Reynolds number, the apparatus needs to be design and fabricated. The result shows that at low Reynolds number (Re < 25000), minor loss coefficient value is inversely proportional to the value of Reynolds number while at high Reynolds number (Re > 25000), the value of minor loss coefficient almost constant. To determine the optimal link between the Reynolds number and the value of the minor loss coefficient at low Reynolds number, the correlation and regression methods were used. The outcome demonstrates that the best correlation between the Reynolds number and the value of the minor loss coefficient was found is the cubic equation. However, the quadratic relationship graph pattern is more preferable than the cubic relationship graph pattern. The equation is $K_L = 3 \times 10^{-8} R_e^2 - 0.0016 R_e + 35.313$ with the value of R and R^2 are 0.9902, 0.9804 respectively. At high Reynolds number, the loss coefficient for T-strainer is 13.37.

1. Introduction

Fluid flow through pipes is a significant aspect of fluid mechanics studied worldwide, as it integral to daily life, encompassing household water supply, sewage systems, and beyond. The oil and gas industry rely on pipeline systems for transporting petroleum and chemical products. Similarly, fluid flow is evident in underground pipelines in cities, water passing through a fish's scales, and drainage systems [1]. Head loss is the resistance to flow brought into effect by the friction of the piping system, where the potential energy is dissipated into the kinetic energy particularly at such components as the valves, fittings or at the pipe inlets or outlets. Friction head plays a critical role in the computation of systems, since with an increase in the flow rate, the friction head goes up correspondingly causing more energy losses when there is an increment in the flow rate [2]. Reductions in energy of a piping system are classified as major and minor losses. Friction because of fluid viscosity and roughness of the wall of the pipe cause major losses, whereas the minor losses are caused by factors such as fittings, flow direction change and change in velocity of flow [3]. By demonstrating that loss coefficient changes with various Reynolds numbers, this effort addresses there is no standardized value by examining the impact of Reynolds number on the loss coefficient of T-strainers [4]. A strainer is a filter device placed to remove particulates in the fluid to safeguard downstream equipment's. T-strainers are some of the designees intended to entrap and block the debris and not damage the equipment's [5].

The objective of this study is to determine the T-strainers loss coefficient. The findings indicate that the loss coefficient may vary depending on the Reynolds number applied during the experiment. The apparatus needs to be designed and fabricated, conducting experiments at different Reynolds numbers, and collecting 40 sets of data using water as the fluid in the Fluid Mechanics Laboratory at University Tun Hussein Onn Malaysia. The experiment's design had to be able to gather data on the fluid height before (h_1) and after (h_2) the T-strainer in the manometer, as well as the fluid flow rate (Q) through piping system. To determine the value of minor loss coefficient, the equation such as Energy equation, Continuity equation, Reynolds number equation, fluid flow rate equation, and equation related to pressure might be used to calculate this variable. Based on the value of Reynolds number and T-strainer loss coefficient, the graph will be plotted to determine the relationship between these two variables based on the collected data.

2. Methodology

The methodology flowchart in Fig 1 illustrates the step-by-step procedures followed to ensure the project progressed smoothly. Initially, a literature review was conducted to establish a framework for designing the experiment. Subsequently, the experiment was designed, and the apparatus for the pilot test was fabricated. If the pilot test did not yield accurate or satisfactory results, the experiment was refined and redesigned until the desired results were achieved. Once the pilot phase was successful, the process advanced to full data collection, followed by data analysis, discussion, and conclusion for the project.

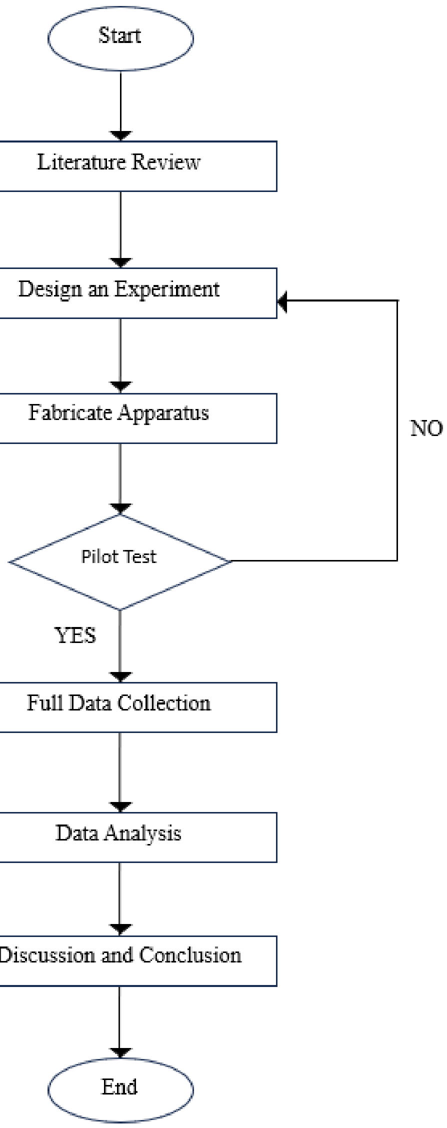


Fig. 1 *Project Methodology Chart of This Project*

The project began with a review of relevant literature, including books, journal articles, theses, and engineering standards, to establish the theoretical basis for the study. Particular attention was given to Reynolds number and minor loss coefficients, which required integration of fundamental fluid mechanics equations such as the energy equation, head loss relationships, continuity, and flow rate expressions. Standards including ASME B31 and saturated water property references were consulted to support equipment selection and ensure the reliability of the experimental framework [4][6].

The experimental design involved developing engineering drawings to confirm the feasibility of fabricating the required components. The apparatus consisted of a support structure and a test section incorporating the T-strainer. Key design considerations included determining the operating flow rates, establishing upstream and downstream pressure measurement points, and ensuring proper system filling. Fabrication was carried out using available tools in UTHM's Fluid Mechanics Laboratory, following established design practices from earlier studies [7].

A pilot test was conducted to verify the functionality and integrity of the fabricated apparatus. The system was connected to a hydraulic bench, and preliminary runs were used to check for leakage and assess measurement stability. The initial results demonstrated good agreement with trends reported in previous studies [8][9], confirming the apparatus was suitable for full-scale testing.

The full data collection process was done in order to obtain all of the raw data required for the T-strainer's performance analysis. The necessary raw data to identify the variables are the water's temperature during the experiment (T), the water height of the manometer before (h_1) and after (h_2) a T-strainer, as well as the time (t) needed for water to fill a 9-liter volumetric tank (∇), and the inner diameter of the pipe before the T-strainer (D_{in}) was measured. As a result, the dataset will be collected from approximately forty experimental runs at different flow rates.

Data analysis involved computing the key parameters and plotting the relationship between Reynolds number and the loss coefficient. This project focuses on identifying the Reynolds number (Equation1) and T-strainer loss coefficient (Equation 2) using various equations. Linear, quadratic, and cubic regression models were evaluated to determine the best-fit representation of the experimental data. To find the best-fit graph, scatter plots, correlation analysis, and regression methods will be used.

$$R_e = \frac{\rho V D}{\mu} \tag{1}$$

$$K_L = \frac{2g}{V^2}(h_1 - h_2) \tag{2}$$

Finally, this section discusses the challenges encountered during the completion of the project, including apparatus fabrication, experimental setup, and data collection. It also presents a plotted graph illustrating the relationship between Reynolds number and loss coefficients. The conclusion summarizes the findings, explores the impact of Reynolds number on the loss coefficient, and suggests future research for improvement.

3. Results and Discussion

3.1 Designed Apparatus

The project successfully designed an apparatus to measure water height in manometers placed before and after a T-strainer, as well as flow rate, in order to fulfill water delivery to the breaker [10][11]. Fig 2 illustrates the picture of the apparatus. Influenced by previous study, the component of the apparatus includes a hydraulic bench, PVC pipes, tape measures, transparent hoses, a T-strainer, adapters, and a wooden board [12].

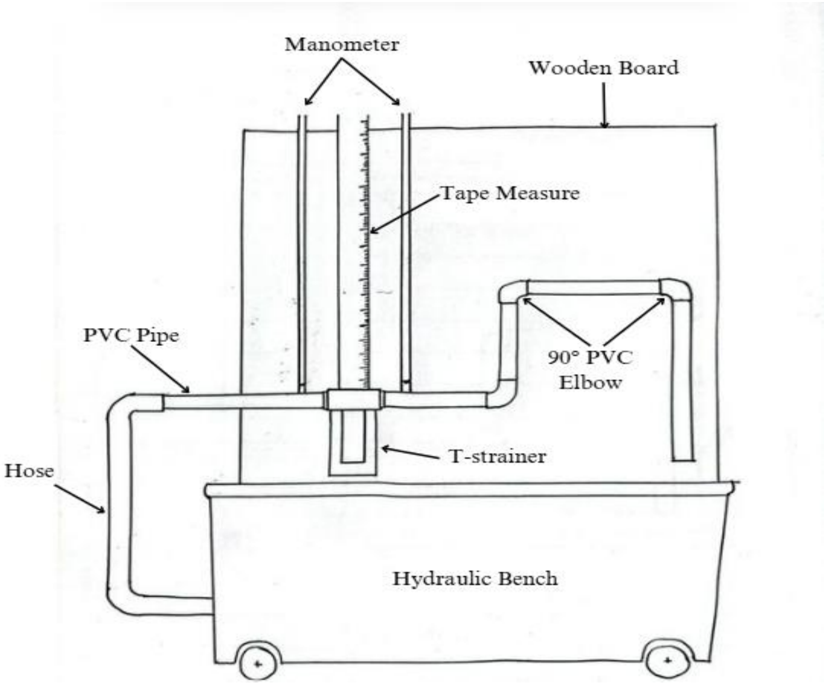


Fig. 2 *Designed apparatus*

3.2 Pilot Test

A pilot test was conducted to verify the accuracy, consistency, and repeatability of the fabricated apparatus in determining the T-strainer loss coefficient. The test was performed twice under identical conditions. The pilot test yielded a dynamic viscosity of 0.891×10^3 kg/m³ and a water density of 997 kg/m³ at a water temperature of 25 °C.

The initial pilot test produced inconsistent pressure readings, which were attributed to air entrainment and minor leakage in the system. After addressing these issues, the second pilot test yielded stable and reliable measurements. The resulting relationship between Reynolds number and the loss coefficient, Fig. 3 showed trends consistent with validated data reported in previous studies [8], demonstrating the correct inverse proportionality.

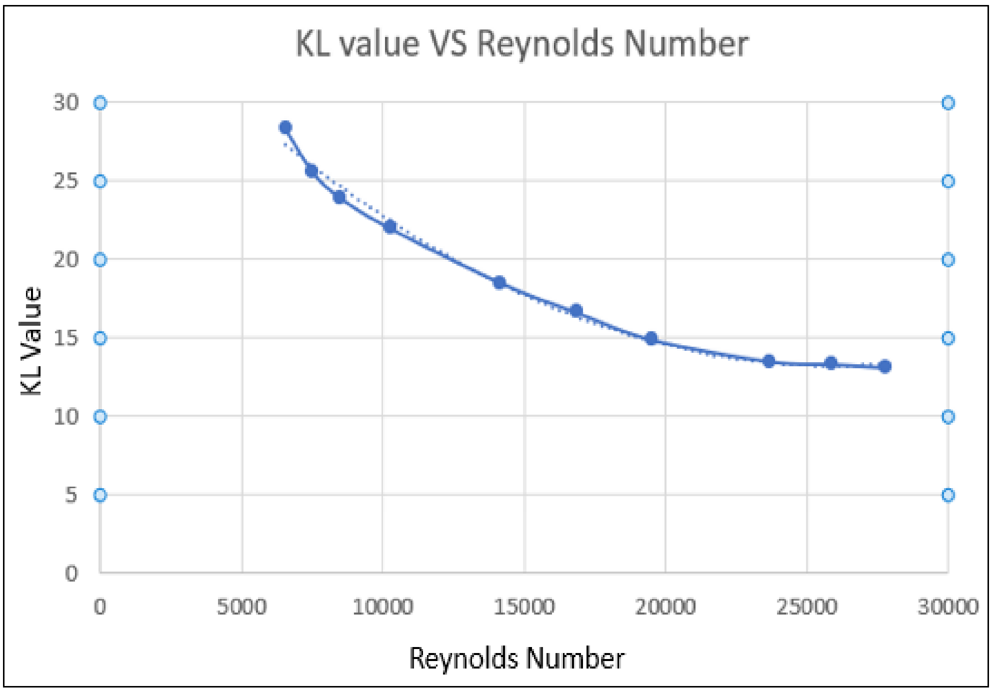


Fig. 3 *Graph K_L value against Reynolds number for the pilot test after improvement*

The improved project's results were compared to previous study [8], which produced validated experimental data. The setup and methodology were validated, showing strong agreement in trends which is inversely proportional.

3.3 Data Analysis

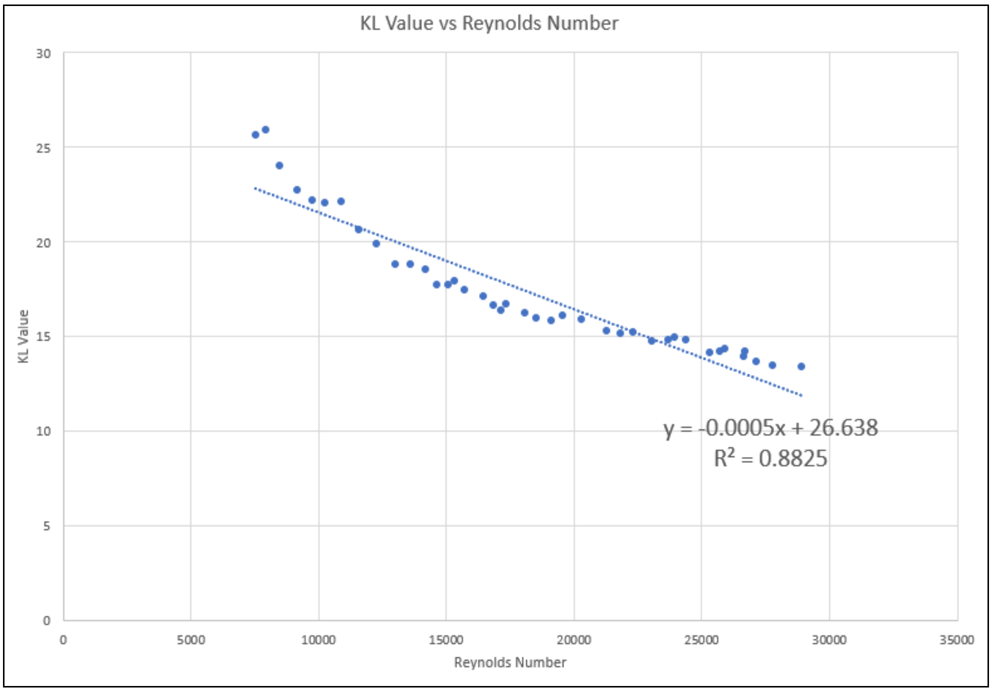
The data collected from the data collection process was processed into engineering parameters to assess the T-strainer's hydraulic behavior. The analysis aimed to determine the value of T-strainer loss coefficient at different Reynolds number. The completed raw data analysis for T-strainer is shown in Table 1. By using fluid mechanics equations such as Continuity equation, Energy equation, Reynolds number equation, fluid flow rate equation, and equation related to pressure was used to calculate the value of T-strainer loss coefficient and Reynolds number. Appendix A shows the sample of calculations for the data analysis. Water temperature was maintained at 25°C throughout the experiment, and physical characteristics like density and dynamic viscosity were derived from reference data. The first raw data set (Test No. 1) from the T-strainer experiment, which served as an example for carrying out in-depth computations.

Table 1 *Completed Raw Data Analysis for T-strainer*

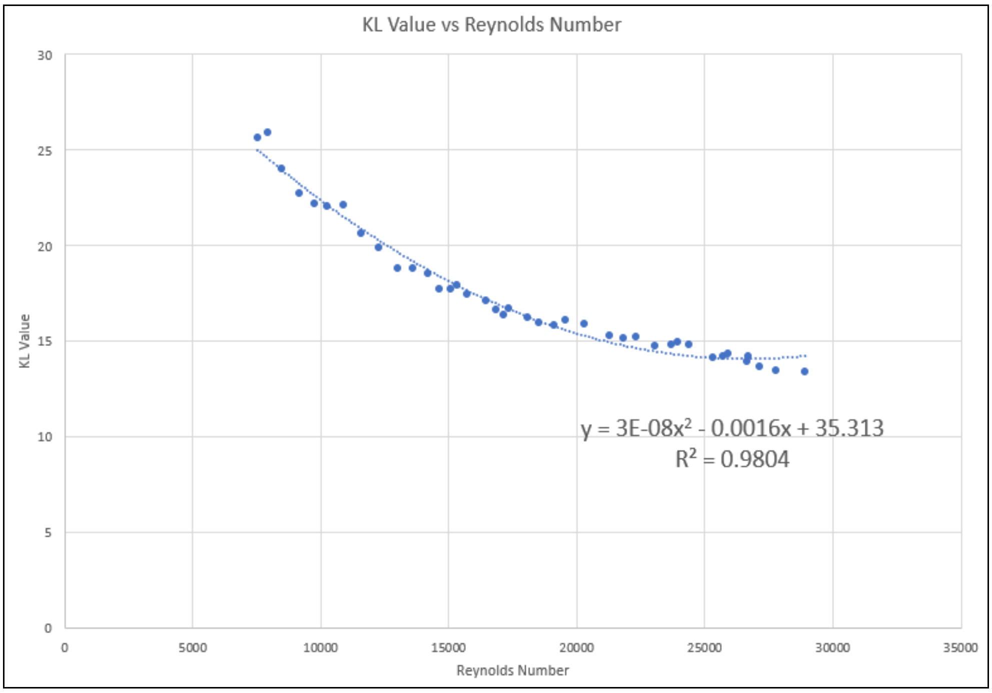
No	Height 1, $h_1(m)$	Height 2, $h_2(m)$	Time Taken, $t(s)$	Volume, $\forall(L)$	Pipe Inner Diameter, $D_i(mm)$	Flow Rate, $Q\left(\frac{m^3}{s}\right)$	Velocity, $V\left(\frac{m}{s}\right)$	Reynolds Number, R_e	Minor Loss Coefficient, K_L
1	1.015	0.867	85.09	9	20	0.00010577	0.33663386	7533.64679	25.62389277
2	1.036	0.869	80.55	9	20	0.00011173	0.35560739	7958.26202	25.91038739
3	1.049	0.873	75.49	9	20	0.00011922	0.37944331	8491.69434	23.98379283
4	1.073	0.878	69.87	9	20	0.00012881	0.40996387	9174.72457	22.76367851
5	1.095	0.881	65.82	9	20	0.00013673	0.43518954	9739.25867	22.16949880
6	1.121	0.885	62.48	9	20	0.00014404	0.45845351	10259.8912	22.03029894
7	1.158	0.890	58.77	9	20	0.00015313	0.48739451	10907.5719	22.13464296
8	1.175	0.894	55.38	9	20	0.00016251	0.51722960	11575.2619	20.60812919
9	1.204	0.900	52.32	9	20	0.00017201	0.54748042	12252.2554	19.89919005
10	1.228	0.904	49.23	9	20	0.00018281	0.58184391	13021.2879	18.77720844
11	1.261	0.908	47.17	9	20	0.00019079	0.60725409	13589.9513	18.78160936
12	1.294	0.915	45.22	9	20	0.00019902	0.63344041	14175.9842	18.53218690
13	1.306	0.918	43.73	9	20	0.00020580	0.65502345	14658.9985	17.74259037
14	1.332	0.922	42.53	9	20	0.00021161	0.67350518	15072.6077	17.73376576
15	1.355	0.926	41.80	9	20	0.00021531	0.68526736	15335.8374	17.92405225
16	1.370	0.930	40.73	9	20	0.00022096	0.70326972	15738.7185	17.45451727
17	1.409	0.935	38.90	9	20	0.00023136	0.73635413	16479.1261	17.15157039
18	1.422	0.941	38.06	9	20	0.00023646	0.75260577	16842.8272	16.66130405
19	1.433	0.943	37.40	9	20	0.00024064	0.76588705	17140.0536	16.38949718
20	1.458	0.947	36.98	9	20	0.00024337	0.77458560	17334.7216	16.71017736
21	1.495	0.955	35.46	9	20	0.00025380	0.80778837	18077.7779	16.23669258
22	1.517	0.959	34.61	9	20	0.00026004	0.82762715	18521.7568	15.98320034
23	1.555	0.968	33.56	9	20	0.00026817	0.85352132	19101.2516	15.80914385
24	1.603	0.976	32.80	9	20	0.00027439	0.87329803	19543.8416	16.13026765
25	1.652	0.983	31.56	9	20	0.00028517	0.90761012	20311.7238	15.93406016
26	1.700	0.995	30.13	9	20	0.00029870	0.95068621	21275.7386	15.30430901
27	1.741	1.004	29.35	9	20	0.00030664	0.97595147	21841.1586	15.18133783
28	1.782	1.012	28.75	9	20	0.00031304	0.99631915	22296.9741	15.21923310
29	1.816	1.018	27.83	9	20	0.00032339	1.02925532	23034.0641	14.77936074
30	1.873	1.028	27.06	9	20	0.00033259	1.05854307	23689.5050	14.79580637
31	1.906	1.035	26.80	9	20	0.00033582	1.06881252	23919.3285	14.95939703
32	1.935	1.038	26.26	9	20	0.00034272	1.09079115	24411.1959	14.79136425
33	1.972	1.048	25.31	9	20	0.00035559	1.13173353	25327.4597	14.15411133
34	2.012	1.058	24.95	9	20	0.00036072	1.14806315	25692.9060	14.20089840
35	2.040	1.062	24.75	9	20	0.00036363	1.15734043	25900.5254	14.32569191
36	2.077	1.072	24.06	9	20	0.00037406	1.19053099	26643.3086	13.91181050
37	2.106	1.079	24.03	9	20	0.00037453	1.19201729	26676.5711	14.18091751
38	2.115	1.086	23.60	9	20	0.00038135	1.21373625	27162.6273	13.70457987

39	2.150	1.088	23.06	9	20	0.00039028	1.24215852	27798.6993	13.50421887
40	2.220	1.080	22.15	9	20	0.00040632	1.29319077	28940.7677	13.37453397

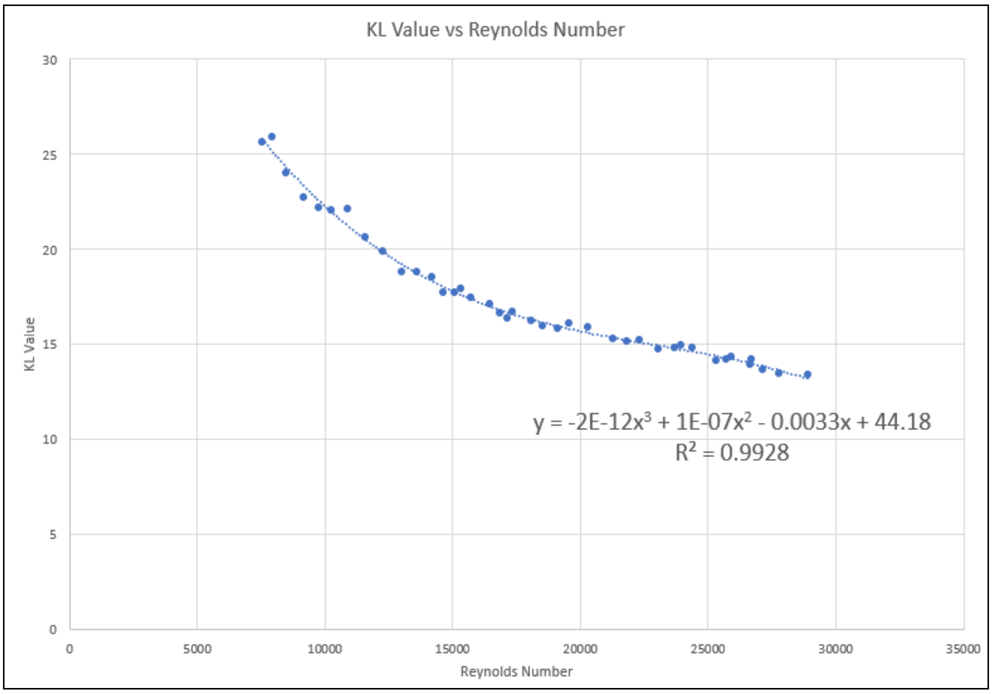
After compiling the data, a graph was plotted to find the relationship between minor loss coefficient (K_L) and Reynolds number (R_e). The result shows inverse proportional at low Reynolds number but at high Reynolds number, the T-strainer loss coefficient is remained constant. For low Reynolds number, use correlation and regression analysis to find the best fit graph. Figure 4 shows the graph of loss coefficient versus Reynolds number for linear, quadratic, and cubic relationship.



(a)



(b)



(c)

Fig. 4 *(a) Linear relationship analysis; (b) Quadratic relationship analysis; (c) Cubic relationship analysis*

3.4 Discussion

The apparatus for measuring the pressure differential in a T-strainer was designed using simple manometers constructed from clear tubing, which provided a cost-effective alternative to commercial pressure gauges. Similarly, the apparatus for measuring flow rate uses a beaker and stopwatch, as flow measurement devices are too expensive to purchase. Flow rate was determined using a volumetric method. The apparatus was designed to ensure fully filled flow, consistent with the assumptions of standard fluid-dynamics equations [4].

During the pilot test, the apparatus was run for 5–10 minutes before data collection to stabilize the readings and remove air bubbles from the system. Unstable data and the presence of bubbles could affect the accuracy of the results. High water pressure leakage also was a concern. To seal the connection between the PVC pipe and the hose adapter, PVC glue was applied to prevent leakage. White PTFE tape was wrapped around the threaded area of the joint between PVC pipe and T-strainer to prevent water or air leakage. This tape fills small gaps between the threads, minimizes friction during assembly, and offers protection against thread seizing or galling [13]. Additionally, pressure loss may influence the accuracy of the results.

The result shows that at low Reynolds number (Re < 25000), minor loss coefficient value is inversely proportional to the value of Reynolds number while at high Reynolds number (Re > 25000), the value of minor loss coefficient almost constant. As R_e increases more, the rate of K_L decline slows vice versa. This trend is consistent with previous studies [7][9][12].

In the data analysis, the correlation between the minor loss coefficient and the Reynolds number of the T-strainer is inverse proportional according to previous research [9]. The value of the correlation coefficient of the T-strainer was obtained in Microsoft Excel. The correlation coefficient of the T-strainer is in negative value and less than -0.9. When r has a range of -1 to 1 and close to either of these values, there is a stronger positive or negative correlation between the two variables [14]. At high Reynolds number, the T-strainer loss coefficient value is 13.37. Regression analysis was performed using linear, quadratic, and cubic models. Although the cubic model yielded the highest statistical fit where the value of R and R-squared are 0.9964 and 0.9928 respectively. However, due to the graph pattern, the quadratic model provided a more practical and physically representative fit to the observed trend with R and R-squared value are 0.9902 and 0.9804 respectively. The resulting quadratic regression equation was used to predict the T-strainer loss coefficient as a function of Reynolds number.

4. Conclusion

In conclusion, the study successfully achieved its objective of understanding the minor loss coefficient (K_L) for a T-strainer, which is crucial for designing efficient piping systems. The results showed that the T-strainer loss coefficient can be determined. At high Reynolds number, the loss coeffieicent for T-strainer is 13.37 while at low Reynolds number K_L values is inversely proportional to Reynolds number. These findings align closely with previous research, indicating consistency and reinforcing the credibility of the experiment despite there is no standardized K_L values for T-strainers in established engineering reference books. Based on correlation and regression analysis, the best fit graph at low Reynolds number is cubic relationship but based on the graph pattern, the quadratic relationship is more preferable. The quadratic relationship represents by the $K_L = 3 \times 10^{-8} R_e^2 - 0.0016 R_e + 35.313$ with R and R-squared value are 0.9902 and 0.9804 respectively.

Several recommendations have been made to improve the project's outcomes, including improving manometer setup for high flow rates, improving sealing and leak prevention in apparatus fabrication, automating data collection and measurement processes, exploring different types and designs of strainers, studying the effect of particle size and concentration on T-strainer performance, and incorporating advanced measurement techniques and computational modeling. These suggestions can help other researchers understand what they should concentrate on and contribute to the development of more effective piping systems.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Hamzah Fansuri Mohamad Din, Ahmad Fu'ad Idris; data collection: Hamzah Fansuri Mohamad Din; analysis and interpretation of results: Hamzah Fansuri Mohamad Din, Ahmad Fu'ad Idris, Mohd Azwir Azlan; draft manuscript preparation: Hamzah Fansuri Mohamad Din, Mohd Azwir Azlan. All authors reviewed the results and approved the final version of the manuscript.

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