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PIPELINE ANALYSIS USING MATLAB'S GRAPHICAL USER INTERFACE (GUI) WINDOW

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Abstract

This project is focused on developing a model and an interface that can help to reduce the complexities and time associated with pipeline calculations as applicable in several industries that depend/involve fluid transportation. Pipelines have varied applications in different types of industries because of the numerous advantages attached to using them. Generally, pipelines are used for the transportation of materials, which can either be the raw materials or finished products, from one point to another during a production process. A combination of equations and parameters used in momentum transfer and general pipeline calculations were written as codes into MATLAB'S script window and linked to its Graphical User Interface (GUI) window. Different pipeline scenarios were solved using the designed system, and the results obtained were compared with the already established trends for its verification. The effect of fluid types, volumetric flow rates, fittings, number of branches and other parameters on head losses was also studied using the designed system. The model developed helps to reduce the complexities in calculating multiple branched systems including other connected parameters with enhanced user-friendly interface for the average user. The developed interface was fast and accurate particularly in calculating the pressure drops across pipeline systems irrespective of the number of branches. The results obtained also followed expected trends.

Keywords: Pressure drop; pipeline, head loss, flowrate, graphical user interface, assumptions.

1 INTRODUCTION

Pipelines are used in industries for the transportation of mostly liquid or gaseous materials from one point to another. Transportation of materials through pipelines can also be between two or more states or even as far as between countries, as seen in the oil and gas industry[1], [2]. In 1883, when Osborne Reynolds injected a dye into a moving stream, he observed that varying the velocity of the flowing fluid resulted to a change in its orderliness, and for a particular rang of values, which he termed as Reynolds number, the characteristics of this flow patterns (which is also an orderliness indicator) was similar. He classified these flow patterns as laminar, transitional and turbulent flows, which is based on the decrease in the orderliness with which the fluid flows[3].As the fluid flows along the pipeline, its velocity decreases. This can be attributed to the pressure drop experienced by the fluid across the pipe. The magnitude of the pressure drop experienced across the pipe depends on the type of fluid, type of piping material, the size of the pipe and the velocity of the fluid flowing through the pipe. The decrease in the fluid's velocity can serve as a hindrance to its efficient transportation, most especially when it is to travel over a long distance. Thus, the placement of pumps at strategically calculated points of the pipeline to increase the velocity of the fluid is very important [4]. Also, selecting the right type of piping material that will best suit the fluid's properties for a given operating condition is very important. Some of the factors to consider when selecting the piping material include the temperature and corrosiveness of the fluid, as well as the cost of the material and the total volume of fluid required to flow through the pipeline over a given period of time. Knowing the maximum allowable pressure that the piping material can sustain as well as the appropriate thickness for the pipeline is also very important [5], [6].These require a lot of calculations which, with the help of MATLAB, will be done in a click of a button.

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MATLAB is a programming language that was developed by Math Works, which allows the user to see how different step-by-step plans work, with continuous iteration until the desired result is obtained. It consists of a command window in which the codes can be typed but cannot be saved in, and the script window where codes can be typed and saved. Besides these, a Graphical User Interface (GUI) window also exists on MATLAB. The GUI window generally makes any designed system user-friendly, ensuing that the users of the designed model must not first be familiar with MATLAB[7], [8].

2 MATERIALS AND METHODOLOGY

2.1 Materials

In the course of this research work, the materials used included an R2015a MATLAB process simulator and a 64-bit operating system with Intel(R) Celeron(R) CPU 847 @ 1.10GHz x64-based processor.

2.2 Methodology

Some of the steps followed during this research project include;

i. Assumptions making
ii. Equations selection
iii. Mathematical modeling

2.2.1 Assumptions

Some of the assumptions made during the modeling of the system include;

i. There was no accumulation in the pipeline, which implies that the system was a steady state system.
ii. Materials that flowed through the pipes were in their liquid state.
iii. There was constant/uniform composition across the pipe
iv. There was uniform temperature across the pipe
v. No chemical reaction took place in the pipe
vi. There was no phase change in the pipe
vii. The system was a single component system

2.2.2 Selection of equations

The system was assumed to be a single component lumped parameter system, with time as the only independent variable. Since it was assumed that no chemical reaction took place in the pipeline and only a single component was involved, nocomponent continuity equation was required. Also, with the assumption that there was little to no heat lost or gained by the fluid in the pipe, since the temperature was assumed to be constant, no energy equation was required. Therefore, only total continuity equation was used.

2.2.2.1 *Total continuity equation*

The total continuity equation of a system is also known as the mass balance equation and it is based on the conservation principle which states that the rate of accumulation of a conserved quantity within a system is the difference between the rate at which this quantity is being added to the system and the rate at which it is being taken out plus the rate of internal production[1]. The conservation principle can further be represented by Equation (1).

$$Massinflow - Massoutflow = Accumulation \quad (1)$$

But since it is a steady state system, Equation (1) becomes;

$$Massinflow - Massoutflow = 0 \quad (2)$$

This implies that;

$$Massinflow = Massoutflow \quad (3)$$

But;

$$Massinflow = (Density * Volume\ )inflow \quad (4)$$

Therefore;

$$(Density * Volume)inflow = \ (Density * Volume)outflow \quad (5)$$

2.2.3 Mathematical modelling

All the symbols and abbreviations that were used in all the equations and their meanings were clearly outlined in the script window before the system's parameters, along with the input variables were stated. The codes for the warning alerts that were required to pop-up when the fluid, piping material, pipe size or schedule number had not yetbeen selected by the user from the dropdown menu in the GUI window were written. Also, warning alerts were written to inform the user when the temperature specified by the user falls outside the range of the temperatures stored in the codes for a givenfluid.

After this, the densities and viscosities of eleven different fluids at a particular range of temperatures were written into the codes. To ensure that for the specific temperature range, the densities and viscosities could be obtained for any desired temperature value inputted by the user for a particular fluid, a code was written to interpolate the density and viscosity values from the stored values in the codes.

Next, based on the industrial pipe size specifications, the standard pipe size values and their corresponding pipe schedules were written for both the primary or main pipeline and the secondary pipe branches. Codes for conversion of values that were not in their SI units were also written along with the codes for the calculationsof the area and volume as well as the relative and absolute roughness for the different piping materials stored in the codes[6], [9].
In addition to these, codes for the calculations of the major and minor head losseswere also written for each of the pipeline section.This is done while taking into consideration the inlet types and piping materials and fittings used, Reynolds number, pressure drop and friction factor.
The Graphical User Interface window on the other hand was divided into two sections. One section was for the input values and the other for the display of the output values. In the input section, the input variables could either be typed into the available textboxes or selected from the dropdown menus. Different types of fittings used in the pipeline network and the number of each type of fittings used in each pipeline section could be specified at the bottom of theinput section. The output section of the window was further divided into various segments where the effect of change in any variable on any of the selected pipelines could easily be studied. To closely study the effects that varying a particular input variable would have on a particular output variable[10]in any of the pipeline sections, tables and graphs were provided at the bottom of the output window.

3 RESULTS AND DISCUSSION

3.1 Input and Output Windows Area

Plates 1 and 2 are the input and output window sectionsrespectively, created using MATLAB'S GUI window.

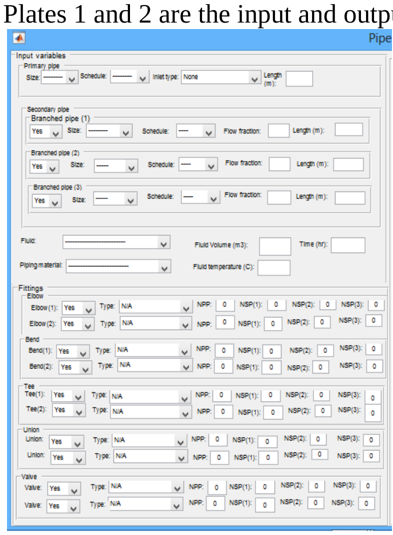


Plate 1: Input window

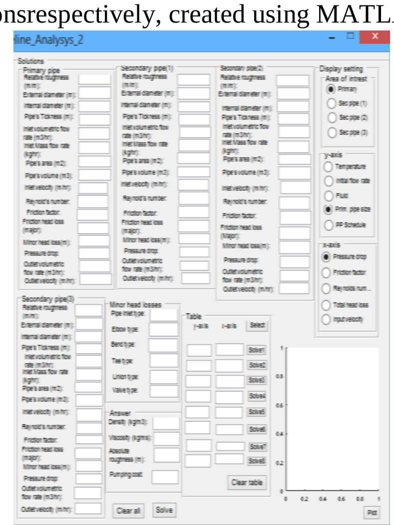


Plate 2: Output window

Where;
NPP - Number (of a particular type of fitting) in the Primary Pipe
NSP(1) - Number (of a particular type of fitting) in the First Branched Secondary Pipe
NSP(2) - Number (of a particular type of fitting) in the Second Branched Secondary Pipe
NSP(3) - Number (of a particular type of fitting) in the Third Branched Secondary Pipe
Plate 1 and 2, provides a point-to-click controlfor the users, eliminating the need to learn the programming language or type the command in MATLAB'S script windowin other to run the model. Plate 1 is the input area where all the input variables can either be selected from a dropdown menu or typed in the provided textbox. Variables such as the size of the pipe, which determines the pipe's external diameter; the pipe's schedule, which determines the pipe's thickness or internal diameter; the type of fluid, the type of fittings, the type of piping material and the number of secondary pipe branches used, can be selected from the dropdown menu list in the input area. Whereas other input variables such as the length of the primary and secondary pipe branches are manually typed into the available textboxes. The fluid's temperature, the fraction of fluid entering each of the secondary pipe branches, the volume of fluid and the approximate time duration for its transportation across the pipeline and the number of a particular type of fitting available in each pipe section, are also manually inputted.
Plate 2 on the other hand shows the output display area, which comprises of sections that displays the results for both the primary and secondary pipes. Values such as the Reynolds number, the major and minor head losses, the pressure drop

experienced by the fluid across the pipe, the pipe's area and volume, and the fluid's velocity and flow rate, which are calculated based on the input variables given by the users, are displayed here.

For better study of the effects that changes in different input variables will have on different output variables of a particular pipe section, radio buttons were placed at the side of the output window. This will enable the selection for both the input and output variables of interest. The result of these variations could then be viewed on the table as well as the graph provided in the output window, if so desired.

Plate 3 shows a typical warning alert that was written into the MATLAB codes.

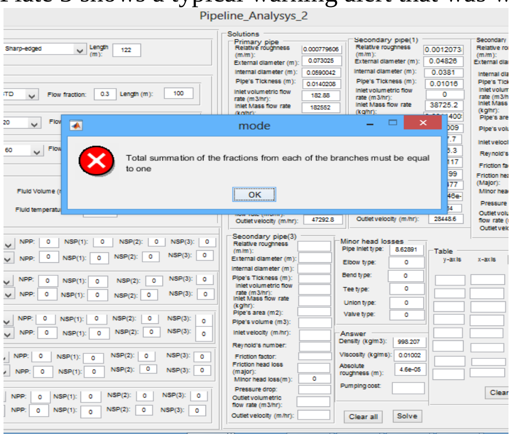


Plate 3: Pop-up warning alert

These warning alerts pop-up only when the system notices an error in the input variables specified by the user. Warning alerts written into the MATLAB codes includes, temperature warning alert, for when the input temperature for a particular fluid is beyond the range specified in the MATLAB codes. pipe size alert, for when no pipe size has been selected from the dropdown menu, the pipe schedule alert, for when the schedule selected does not exist for the selectedpipe size as specified by the pipe sizing standard which was used for the coding. Also, other warning errors exist for when input variables, such as the fluid type and the pipe material used are not specified by the user.

For instance, Plate 3 shows a warning alert which is meant to informthe user that the total volume of fluid entering into the secondary pipelines from the primary pipeline has not yet been considered. This means that if 500 m^3/hr of fluid is leaving the main pipe, 500 m^3/hr of fluid should be entering the branches. If three secondary pipe branches are used, the sum of the fractions, which is the volume of fluid entering each secondary pipeline divided by the total volume of fluid leaving the primary pipeline must be one.The following sections shows some pipeline scenarios which were solved using the designed system.

3.2 Straight Pipeline

Supposing a fluid is flowing through the straight pipeline shown in Figure 1, with the following characteristics listed below in Table 1. What effect will varying the volumetric flow rate of the fluid have on its pressure drop?

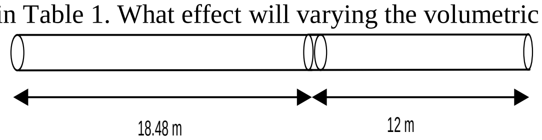


Figure 1: Straight pipeline

Table 1: Characteristics of the pipe and fluid

Property	Primary pipe
Size	4
Schedule	40
Fluid	Ammonia
Temperature (ºC)	-40
Volume (m^3)	90.8
Time (hours)	1
Piping material	Stainless steel
Length (m)	18.48 + 12 = 30.48 m
Fittings	- One threaded union
Inlet type	None

3.2.1 Result

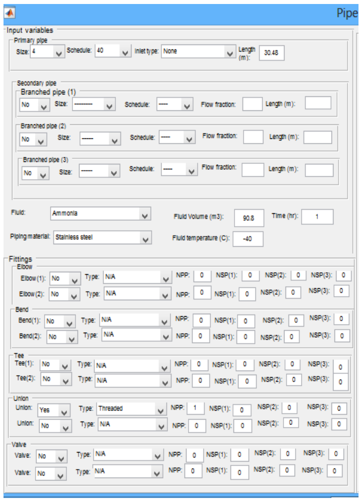


Plate 4: Input

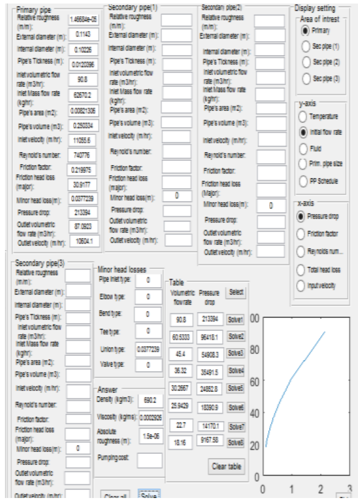


Plate 5: Result

Table 2: Variation of volumetric flow rate with pressure drop

S/N	**Volumetric flow rate (m^3/hr)**	**Pressure drop (Pa)**
1	90.8000	213394.0000
2	60.5333	96418.1000
3	45.4000	54908.3000
4	36.3200	35491.5000
5	30.2667	24852.8000
6	25.9429	18390.9000
7	22.7000	14170.1000
8	18.6000	9167.58000

3.2.2 Discussion of Result

Pressure drop has a direct relationship with volumetric flow rate[1], [11], [12]. This implies that increasing the flow rate (increasing the velocity with which the fluid travels through a constant area pipe) should result to an increase in the pressure drop, and likewise a decrease in the volumetric flow rate should lead to a decrease in the pressure drop. Since pressure drop and velocity are seen to be directly related, increasing the velocity should lead to an increase in the pressure drop, and decreasing the velocity should result to a decrease in the pressure drop. The results obtained when volumetric flow rate was varied using the designed system followed this trend. Also, the phenomenon which says that doubling the volumetric flow rate would result in approximately four times the increase of the initial pressure drop[13] was tested, with references being made to Plates 5 and Table 2.

Assuming V represents the volumetric flow rate and PD represents the Pressure Drop.

$V_1 = 90.8$ m^3/hr, $V_3 = 45.4$ m^3/hr, $PD_1 = 213394$ Pa, $PD_3 = 54908.3$ Pa, $V_1/V_3 = 90.8/45.4 = 2$

$PD_1/ PD_3 = 213394/54908.3 = 3.8864 \approx 4$

As shownSection 3.2, this model obeyed this phenomenon.

3.3 Piping System with One Secondary Branch

Supposing a fluid is flowing through a piping system with one secondary branch and different types of fittings as shown in Figure 2, and with the following characteristics listed below in Table 3. What will be the effect of varying the primary pipe size on the total head loss of the secondary pipe?

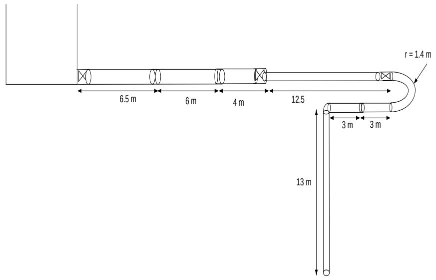
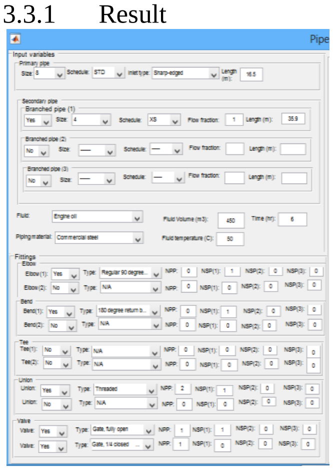


Figure 2: Single-branched pipeline system

Table 3: Characteristics of the pipes and fluid

Property	**Primary pipe**	**Secondary Pipe (1)**
Size	8	4
Schedule	STD	XS
Fluid	Engine oil	-
Temperature (^oC)	50	-
Volume (m^3)	450	-
Time (hours)	6	-
Piping material	Commercial steel	-
Length (m)	16.5 m	12.5 + 22/7*1.4 + 3 + 3 + 13 = 35.9 m
Fittings	- Two threaded union	- One fully opened gate valve - One 180^O return flanged bend - One union and a regular 90^O flanged elbow
Inlet type	Sharp edge	-

3.3.1 Result



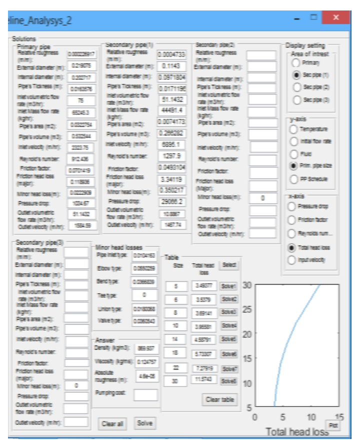


Plate 6: Input **Plate 7: Output**

Table 4: Effect of primary pipe size variation on head loss in the branched pipe

S/N	**Primary pipe size**	**Head loss in the secondary pipe (m)**
1	5	3.4937
2	6	3.5379
3	8	3.6914
4	10	3.9558
5	14	4.5879
6	18	5.7330
7	22	7.2791
8	30	11.5743

Note: The standard pipe size used here has no unit because the diameter number, which is a dimensionless designator, was used to indicate it.

3.3.2 Discussion of Result

Decreasing the pipe's size causes a corresponding increase in the velocity, which is the speed with which the fluid moves in a particular direction, and also, since velocity has a direct relationship with the major loss experienced by the fluid across the pipe[1], [4].It can be implied that increasing the fluid's velocity, by reducing the pipe's size causes an increase in the major head loss experienced across the pipe[14]. This is also applicable to the minor losses experienced across the pipe, because the minor losses also have a direct relationship with the fluid's velocity. Since the total head loss experienced by the fluid across the pipe is the summation of both the major and the minor head losses, both of which vary directly with the velocity, increasing the velocity increases the total losses across the pipes, while decreasing the velocity by increasing the size decreases the total head loss experienced across the pipe. However, it is instructive to note that the changes in the pipe's size are made on the primary pipes, and not the secondary pipe, which is the pipe of interest. From Plate 7 and Table 4, it is observed that increasing the primary pipe's size resulted to an increase in the total head loss experienced by the secondary pipe[15]–[17]. This increment in the total head loss was not caused by an increment in the major head loss, but rather, it was caused by an increment in the minor loss, which in this case was basically the loss caused by sudden contraction[12]. With increase in the size of the primary pipe, there is a corresponding increase in the contraction coefficient, which is directly proportional to the minor head loss caused by contraction. This increase in the minor head loss leads to a corresponding increase in the total minor head loss as well as the total head loss.

4 CONCLUSION

From the results obtained, it can be concluded that the pipeline calculation system gives results that obeys the existing trend. For instance, when, when V was used to represent the volumetric flow rate and PD was used to represent the pressure drop. The corresponding pressure drops, PD_1 and PD_3, obtained when volumetric flow rates, V_1 and V_3, were assigned the values of 90.8 m^3/hr and 45.4 m^3/hr were 213394 Pa and 54908.3 Pa respectively. The results of V_1/V_3 and PD_1/ PD_3 were obtained to be approximately two and four respectively. This tallied with the existing phenomenon that doubling the volumetric flow rate of the fluid flowing through a pipe would result to four times the increase in the initial pressure drop experienced by the fluid across the pipe. Also, comparison of the results obtained from this system was done with an already calculated piping system, and similar results were obtained. Therefore, this system can be conveniently used for pipeline calculations speed, accuracy and user-friendliness.

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