Trends in

Applied Sciences Research

ISSN 1819-3579

Academic
Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 2 (1): 15-22, 2007
ISSN 1819-3579

Computer Aided Plumbing Design

[1]O.O. Ajayi and [2]O.A. Koya
[1]Department of Mechanical Engineering,
Covenant University, P.O. Box 1023, Ota, Ogun State, Nigeria
[2]Department of Mechanical Engineering,
Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

Abstract: This study has been used to eliminate the rigorous activities and time consuming mathematical analysis involved in plumbing design. The various mathematical steps employed in the design of plumbing systems has been converted into easily interpreted hand user computer program that can be used to generate automatically all the various parameters needed for full design work, when the input data such as head available, various number of fittings, actual lengths of pipe run and assumed pipe diameter are provided. This has been used to provide a pathway to easy plumbing design.

Key words: Plumbing design, pipe network, computer, simulation

INTRODUCTION

Pipe network in plumbing system refers to the arrangement of pipe either in series, parallel or mixture of both for the purpose of transferring water from one place to another (McGraw-Hill, 2002), as well as reduce the increasing problem of water distribution, transportation and contamination (Terence, 1991).

According to Barry (1999), the destruction of the organized pipe arrangement for water distribution belonging to the Briton's in the twelfth century led to the development and use of woods, earthenware and lead pipes for the purpose of transporting water from source to a reservoir where people came to fetch for domestic and other uses (Terence, 1991). This obsolete water distribution system continued until the eighteen-century when tankers, yoked animals and human shoulders were used as means of transportation of water from source (which may be a river, lake or stream) to the point of need. The nineteenth century however, witnessed the introduction of network systems that was convenient for water transportation and distribution (Terence, 1991; Barry, 1999). This stable pipe network system continued until the middle of the nineteenth century when the problem of distribution became heightened owing to increased population and higher demand (Terence, 1991; Barry, 1999). This then prompted a stemming up of the available design to accommodate the high demand. Thus, leading to the development of various formulae, that can be used in plumbing design analysis.

Such formulae includes: the Darcy Weisbach's for calculating head loss, the Bernoulli's for estimating flow heads and the Hazen-Williams' for evaluating and designing water distribution system (Dickenson, 1999; Finnemore and Franzini, 2002; Bansal, 2002). However, each of these equations has shortcomings associated with it that makes it unsuitable for today's design processes (Finnemore and Franzini, 2002; White, 2003), hence, making the time consumption in design process variable and rigorous. In designing pipe network system, it is imperative to know the suitable material of pipe to be used. This aids the knowledge of pipe selection side by side the pipe requirement for any particular pipe installation. Such requirement can be found in (British Standard Org., 1977; McGraw-Hill, 1996; Chadley and Greeno, 2001; Patterson, 2004).

Corresponding Author: O.O. Ajayi, Department of Mechanical Engineering, Covenant University, P.O. Box 1023, Ota, Ogun State, Nigeria Tel: +234-803 620 8899

Moreover, pipe systems in most cases contains more than straight pipes. They have additional components which can be valves, bends, tees, elbows and so on. These components add to the overall head loss of the system (Munson *et al*., 1990; Dickenson, 1999; White, 2003). These additional losses are generally termed minor losses with the apparent implication that, the majority of the system losses are associated with the friction in the straight portion of the pipes and called major losses (Finnemore and Franzini, 2002; White, 2003). The head loss information for essentially all components is based on experimental data and is usually given in dimensionless form (Finnemore and Franzini, 2002; White, 2003). The most common method used to determine these head losses or pressure drops is to specify the loss coefficient, K_L as defined by Bansal (2002), Fennimore and Franzini (2002) and White (2003). Minor losses can be sometimes given in terms of equivalent length l_{eq} of the pipe that would produce the same head loss as the components. Meaning that:

$h_L = K_L (V^2/2g) = \mu\ [l_{eq} V^2/(2gD)]$ (Streeter *et al*., 1998; Finnemore and Franzini, 2002).

Therefore,

$$l_{eq} = K_L D/\mu \tag{1}$$

where D = pipe diameter, μ = friction coefficient, V = flow velocity, g = acceleration due to gravity. The head loss of a pipe system is therefore the same as that produced in a straight pipe whose length is equal to the expression below if the pipe sizes are the same, else they are summed separately (Munson *et al*., 1990; White, 2003).

$$h_L = L_s + \Sigma\, l_{eq} \tag{2}$$

where, L_s = total length of pipes making the system and l_{eq} = individual length of each component. Losses could occur as a result of a change in pipe diameter and may be mathematically expressed using fundamental equations of mass, energy and momentum (Streeter *et al*., 1998; Bansal, 2002; Finnemore and Franzini, 2002). Valves are known to control the flow rate by providing a means of adjusting the overall system loss coefficient to the desired value (Dickenson, 1999; White, 2003). This situation is explained mathematically as:

$dP/d\varphi = K_L$ (*) Assuming that $\varphi = \frac{1}{2}\rho V^2$ (the dynamic pressure)

Hence, $d\varphi = \rho V dV$

Therefore, (*) becomes,

$$(1/\rho V)\,[dP/dV] = K_L \tag{3}$$

Where V = velocity of flow and ρ = density

Thus, if the valve is closed V = 0. Then K_L becomes infinitely large. Typical values of K_L for components are given in Finnemore and Franzini (2002), White (2003) and Patterson, 2004).

Previous designers of plumbing systems spend a lot of time putting basic theories and parameters together, checking charts and graphs, analyzing processes, evaluating old designs and correcting design errors, before coming up with a full, new plumbing design work. These processes are repeated every time there is a need for design work, making it time consuming, repetitive and highly computationally demanding. Thus, a method which can be used to carry out this task at reduced time will be a plus. The computer and its power of computation can aid adequately, if employed, in design (Mano and

Kime, 2001). These will remove stress, repetitive computational task and add ease and pleasantness to the process (Pressman, 2005). The aim of this study is to use the computer to eliminate the various repetitive and computational task involved in plumbing design, thereby making it a very interesting and quick process.

MATERIALS AND METHODS

The problem of how to distribute water effectively without contamination in transit is a need which has been recognized. Several contributions have been made and many equations have been developed for determination of pipe and pump parameters, suitable for plumbing systems' design (Munson *et al*., 1990; Streeter *et al*., 1998; Bansal, 2002; Finnemore and Franzini, 2002). The approach here is not to focus on and use these numerous computation techniques but to adapt the computer with the available standard codes, charts and tables and some simple equations to carry out effective plumbing design. The parameters that are essentially needed are; the loading units, equivalent lengths and head available. These are available in charts, tables and graphs (Barry, 1999; Dickenson, 1999; White, 2003). The various standard codes used in this study are those of the British Standard Organization (British Standard Org., 1977). The readers can consult with their local Standard Organization and Associations for acceptable standard codes. The graph the authors used for selection of pipe sizes and flow rates against head loss per length value is found in (Barry, 1999). The standard codes and graph are stored in the computer memory and it is automatically called up by the program when it is needed. This study was conducted in Ile Ife, Osun State, Nigeria, between 1998 and 1999.

RESULTS AND DISCUSSION

Mathematical Modelling

A model for evaluating flow rate and head loss is described as follows:

- Determination of flow rate value: Let the sum of all the individual loading units corresponding to each appliance or fitting in a flat or building be $\Sigma X_i = X$, then, from (Fawehinmi, 1997), the flow rate corresponding to X is determined as Y (l/s)
- Determination of head loss value: Let the head loss value be H_L. Therefore,

$$H_L = \text{head (h)/effective length } (l_t) = h/l_t$$

where h = head available = height distance from source to point of need and

l_t = effective length = sum of actual length(l_a) of pipe and equivalent length of fittings. The equivalent length of fittings l_{eq} = sum of all individual head losses in pipe fittings expressed in equivalent pipe length i.e. $l_{eq} = \Sigma h_{Li}$

Therefore, $$H_L = h/[\, l_a + \Sigma h_{Li}]$$

This flow rate and head loss calculated is then used with the aid of the graph (Barry, 1999) to determine the pipe diameter suitable for the plumbing design.

Times are when a pump is to be installed, most especially for multi-storey buildings (Barry, 1999). Adequate pump selection must of necessity be carried out. The mathematical model for pump selection follows as:

$$\text{Pump power} = \text{Flow Rate X Total Head X acceleration due to gravity.}$$

$$P_P = Q \times th \times g \quad (a)$$

$$\text{But } Q = \text{velocity of flow} \times \text{Area of pipe} = V \times (\pi d^2/4) \quad (b)$$

Where d = pipe diameter.

$$\text{Total head } (th) = \text{friction head } (f) + \text{static height } (h_s) + \text{head due to fittings } (h_f) \quad (c)$$

$$\text{But friction head } (f) = \text{length of pipe } (tl) \times \text{loss of head } (h_L) \quad (d)$$

Combining (a-d)

$$P_P = [V\times(\pi d^2/4)]\times[(tl\times h_L) + h_S + h_f]\times g$$

This pump power is then used to select the pump to be used.

Computer Program Structure

This consists of one main and eight sub programs. The respective sub-programs are called into the main program in the course of execution.

Main Program

This reads in the data for calculating the loading units, the effective length of pipe run and the head loss. It automatically generates the flow rates, plots the weibull graph on the screen and hence shows the pipe diameter required for the design on the screen. On line 20 of the program is the arithmetic statement: Y! = 0.009×X! + 0.298.

This is used in lieu of the graph (Fawehinmi, 1997) to generate flow rate from available loading units(X). The pump selection aspect of the main program, reads in data for calculating friction head and total head, hence, it generates the pump power and flow velocity automatically.

Sub-programs

These are programs within the main programs. They assist the main program in carrying out its function easily and faster with adequate management of computer resources. It is divided into

FUNCTION Effectivelenth

Used to calculate the effective length of pipe run.

FUNCTION Gethedloss

Used to calculate the head loss value corresponding to the effective length of pipe run and available head.

FUNCTION Y Value

Used to plot the Y-axis of the weibull graph.

FUNCTION X Value

Used to plot the X-axis of the weibull graph.

Sub View Graph

Used to plot the entire graph based on the X and Y-axes.

FUNCTION Galvaval

Used to calculate the equivalent length of galvanized steel pipe.

FUNCTION Copperval

Used to calculate the equivalent length of copper pipe.

FUNCTION Getx

Used to calculate the loading units of the overall fittings in a particular reference flat or building. The high level language used to write the program is the Q version of Basic.

Algorithm for the Plumbing Design Program

Sum all inputted loading units of individual fittings = X. Using $Y = 0.009X + 0.298$, determine the flow rate value (Y) corresponding to (X). With the flow rate value determined and a desired pipe diameter (d), get the corresponding head loss (h_L) value from the weibull graph. Determine the effective length of pipe run (l_t) by summing the inputted actual length (l_a) and the summation of equivalent length of pipe fitting (l_{eq}) using the equation: $l_t = \Sigma\, l_{eqi} + l_a$.

With the effective length (l_{eq}) determined and the inputted head available (h), determine the head loss (h_L) value using: $h_L = h/l_t$.

With the flow rate value (Y) and the head loss value (h_L), get the intersection of flow rate (Y) and head loss (h_L) values, i.e. the point (h_L, y) on the weibull graph. Thence, determine the pipe diameter needed or to be used for the design.

Algorithm for the Pump Selection Program

Sum all inputted loading units of individual fittings = X. Using $Y = 0.009X + 0.298$, determine the flow rate value (Y) corresponding to (X). With the flow rate value determined and a desired pipe diameter (d), get the corresponding head loss (h_L) value from the weibull graph. Determine the effective length of pipe run (l_t) by summing the inputted actual length (l_a) and the summation of equivalent length of pipe fitting (l_{eq}) using the equation: $l_t = \Sigma\, l_{eqi}+l_a$.

Determine the friction head using:

$$\text{Friction head (f)} = \text{effective length of pipe } (l_t) * \text{head loss } (h_L)$$

$$f = l_t * h_L$$

Determine the total head using:

Total head (th) = friction head (f) + static head (h_s) + head due to fittings (h_f)

$$th = f + h_s + h_f$$

Then, the pump power is: Pp = (flow rate (fr) * total head (th) * 9.81)/1000 KW

$$Pp = (fr * th * 9.81)/1000$$

The area of pipe to be used is: Area = 3.142* $(\text{diameter})^2/4$

$$\text{Area} = 3.142^* d^2/4$$

The flow velocity is: Vel = flow rate/Area

$$\text{Vel} = \text{fr}/\text{Area}$$

Flowchart

The flowchart (Mano and Kime, 2001; Bradley and Milspaugh, 2004) of the main program for both plumbing design and pump selection program are presented below (Fig. 1 and 2). Those for the individual sub program are excluded from this research.

Comparing the findings from this study with that obtained from traditional method of manual evaluation using flow formulae, checking of charts, graphs and etc, gives the same result, however, that from this study was obtained quicker, less than 2 min, compared to the other which is more than 30 min. This time can be much higher in the case of redesigning, when series of comparison and adjustments would have to be made, including cases of correction of old designs. This shows that, the computer, when employed in plumbing design, can be used to eliminate numerous repetitive and computational tasks involved in the process of design and also save much time. However, this study has been done for only cold water supply and distribution. Work can still be done to include hot water and a combination of both.

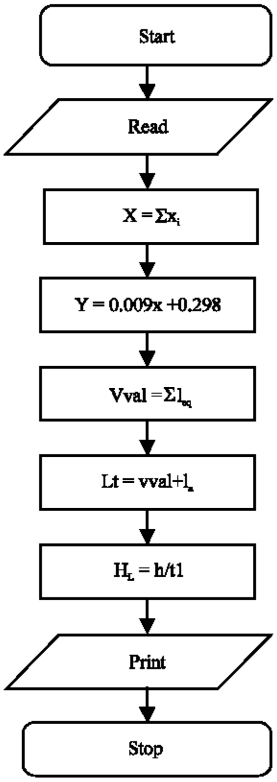

Fig. 1: Flowchart of plumbing design program

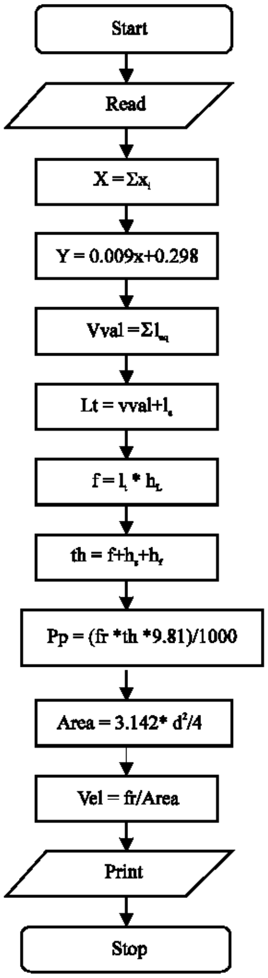

Fig 2: Flowchart of pump selection program

CONCLUSIONS

The design of pipe networks for the purpose of domestic water supply using the computer has been carried out. Numerous repetitive and computational tasks involved in the process of design have been eliminated leading to the development of interactive software that can be employed at all times for the purpose of plumbing system design. The result was compared with that from traditional method and found to be precise, easy, time saving, not requiring knowledge of flow process and very flexible. Thus, a good design using this method can be done without going through the rigorous computational, theoretical and repetitive steps involved in traditional method. This is a plus to the Nigeria plumbing industry.

REFERENCES

Bansal, R.K., 2002. Fluid Mechanics and Hydraulic Machines. Lexmi Publications (P) Ltd., New Delhi, pp: 260-267, 394, 420.

Barry, R., 1999. The Construction of Buildings. Vol. 5, 3rd Edn. East-West Press, New Delhi, pp: 174.

Bradley, C.J. and C.A. Milspaugh, 2004. Programming in C#. Net. McGraw-Hill Book Company New York, pp: 134.

British Standard Organization, 1977. Plumbing Design. British Standard Organization, Britain.

Chadley, R. and R. Greeno, 2001. Building Construction Handbook. 4th Edn. Butterworth Heinemann, Oxford, pp: 624-639.

Dickenson, T.C., 1999. Valves, Piping and Pipelines. Handbook. 3rd Edn. Elsevier Advance Technology, U.K., pp: 533-636, 693-727.

Fawehinmi, O.B., 1997. Plumbing design: Industrial training report. Obafemi Awolowo University, Ile-Ife, Nigeria.

Finnemore, E.J. and J.B. Franzini, 2002. Fluid Mechanics with Engineering Applications, 10th Edn. McGraw-Hill Book Company, New York, pp: 790.

Mano, M.M. and C.R. Kime, 2001. Logic and Computer Design Fundamentals. 2nd Edn. Updated Prentice Hall, New Jersey, pp: 3-5.

McGraw-Hill Company Inc., 1996. Standard Handbook for Mechanical Engineers, 8: 43-215.

McGraw-Hill, Inc., 2002. McGraw-Hill Encyclopedia of Science and Technology. 9th Edn. 13 McGraw-Hill Book Company, New York, pp: 550-556.

Munson, V.L., D.F. Young and T.H. Okiishi, 1990. Fundamentals of fluid mechanics. John Wiley and Sons Inc, Canada.

Patterson, T.L., 2004. Illustrated 2003 Building Code Handbook. McGraw-Hill Book Company Inc, New York, pp: 1072-1089.

Pressman, R.S., 2005. Software Engineering: A Practitioner's Approach. 6th Edn. McGraw-Hill book Company, New York, pp: 258-259, 348-349.

Streeter, V.L., E.B. Wylie and W.K. Bedford, 1998. Fluid Mechanics, 9th Edn. McGraw-Hill Book Company, Singapore, pp: 541-604.

Terence, J.M., 1991. Water Supply Engineering. 6th Edn., McGraw-Hill Book Company, Singapore, pp: 602.

White, F.M., 2003. Fluid Mechanics. 5th Edn., McGraw-Hill Book Company, New York, pp: 866.