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OPTIMISATION OF GAS FLOW USING NETWORK ANALYSIS (NEWTON LOOP-NODE METHOD)

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ABSTRACT

Gas transport and distribution networks around the world present a large set of highly integrated pipe networks operating over a wide range of pressures. Growing demand for gas makes it necessary to adapt and expand these systems while ensuring safe delivery and cost-effective engineering. Simulation and analysis play a major role in system planning and design, enabling the designer to optimize the network and the pipelines themselves. Simulation allows us to predict the behavior of gas network systems under different conditions. Such predictions can then be used to guide decisions regarding the design and operation of the real system. A computer program was developed to cater for the needs of computer aided design for gas distribution studies, which apply the Newton loop-node method to solve the gas networks problem. This computer software program also incorporate drawing features, which describe the accurate network configuration with speed. This package is used for selecting pipe sizes, calculating pressures and flows in gas distribution networks for steady state condition. The Newton loop-node method essentially solves the set of loop equations. The loop method has the disadvantage of having to define the loops in the networks. The advantage of the loop method over the nodal method is its good convergence characteristics. The nodal method having easy to solves the set of equation but the main disadvantage of the nodal method is the poor convergence characteristics. The algorithm used the Hardy-Cross technique, which is widely used in distribution system. The Hardy-Cross method solves the same set of loop and nodal equations as do the Newton-loop and Newton-nodal multi-dimensional methods. However, the Hardy-Cross method solves each equation of the set individually, whereas the Newton multi-dimensional method solves the set of equations as a whole.

INTRODUCTION

The complex networks of pipes that comprise gas distribution system present formidable flow analysis problem. Gas may be fed into a system from several transmissions pipeline city-gate stations, from one or more peak-load gas production plants or from storage facilities scattered through the system. In addition, many distribution systems consist of several superimposed networks of piping operated at different pressure levels. Networks of 200-300 loops and 500-600 pipe section are very common. Many networks contain over 1000 pipe sections and some larger cities have interconnected piping networks containing tens of thousands of pipe section. At one time the only method of solving network flow problem was a manual trial-and-error procedure. However, since 1951 analog and digital computers have been applied to the solution of this problem, IGT, (1982). However, with the evolution of micro or personal computer, performing a network analysis on this desktop computer has become very viable alternative. A lot of commercial software has been developed by the personal computer but the cost to purchase them is considerably high. The most common software used locally is GDNAP developed by CONGAS (Canada Oil and Gas Company) and NASS developed by Tokyo Gas. Both of the software uses the Hardy Cross technique in solving network analysis problem.

FORMULAS AND METHODS

The steady state gas flow rate can be described by many formulas, but none are universal. The effects of friction are difficult to quantify and are the main reason for variations in the flow formula. Most of the flow equation is derived from Bernoulli’s equation. The following general flow equation is the expressions usually used for network analysis in the gas industry.

$$Q_n = \sqrt{\left(\frac{\pi^2 R_{air}}{64}\right)} x \frac{T_n}{p_n} \sqrt{\frac{\left\{[(p_1^2 - p_2^2) - \frac{2 p_{av}^2 Sgh}{ZR_{air}T}]D^5\right\}}{fSLTZ}} \qquad (1)$$

The network formulation was solving by the Node-Loop method where base on first and second Kirchhoff's laws. The Node-Loop method is the combination of Nodal and Loop method, which is essentially, solves the set of loop equations. The Node-Loop method has the advantage of having to define the loops easily and good convergence characteristics in the networks, Osiadaz, A.j. (1987). The Newton loop-node method essentially solves the set of loop equations:

$$F(q) = B[\phi(Q)] \quad (2)$$

The process of making a loop flow synonymous to a chord flow in the network is quite complex. The following graph Figure 1 identical the chord flow and loop flow in gas network.

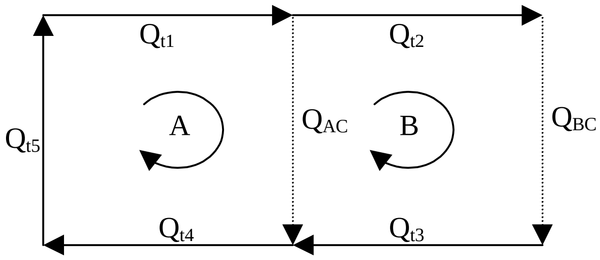

FIGURE 1 Graph of gas

Q_{t1} , Q_{t2} ....Q_{t5} -- Branch flow
Q_{AC} -- Chord flow identical to flow in loop A
Q_{BC} -- Chord flow identical to flow in loop B

Several orderly numerical methods of solving network flow problems have been developing. These methods solve the simultaneous equations obtained by the application of Kirchoff's laws to a specific network problem; the equation represents a mathematical description of a network flow problem. In this research, the Newton Method was selected to solving the roots of equation in the network formulas. Newton method can be derived from Taylor Series of expansion for the function f (x_{I+1}), such that;

$$f(x_{i+1}) = f(x_i) + hf'(x_i) + \frac{h}{2!} f''(x_i) + ... \quad (3)$$

Where h = x_{I+1}-x_i. In order to obtain x_{I+1} such that f (x_{I+1}) = 0, the above equation can be approximately reduce by,

$$0 \approx f(x_i) + hf'(x_i)$$

$$\approx f(x_i) + (x_{i+1} - x_i) f'(x_i)$$

$$x_{i+1} \approx x_i - \frac{f(x_i)}{f'(x_i)} \tag{4}$$

The are many numerical methods which can be used for solving a set of simultaneous linear equations. Numerical methods for solving systems of linear equations fall into the direct methods. It led to an exact solution in a finite number of steps if a round off error is not involved. Most direct method are base on Gaussian elimination which yields a system of equation with a triangular coefficient matrix allowing their easy solution. The Gaussian elimination procedure is as follow;

$$\left[\begin{array}{ccc|c} a_{11} & a_{12} & a_{13} & c_1 \\ a_{21} & a_{22} & a_{23} & c_2 \\ a_{31} & a_{32} & a_{33} & c_3 \end{array}\right] \Rightarrow \left[\begin{array}{ccc|c} a_{11} & a_{12} & a_{13} & c_1 \\ & a_{22} & a_{23} & c_2 \\ & & a_{33} & c_3 \end{array}\right] \Rightarrow \begin{array}{c} x_3 = c_3'' / a_{33}'' \\ x_2 = (c_2' - a_{23}' x_3) / a_{22}' \\ x_1 = (c_1 - a_{12} x_1 - a_{13} x_3) / a_{11} \end{array}$$

RESULT AND DISCUSSION

The development of software to analyse the gas network for steady state gas flow system is being done namely GASNETT. In order to solve the network analysis problem with this software, it requires simple drawing of network on the screen and then inputs of various gas flow, nodes, and pipe parameters. It can be graphically displayed and results such as node pressures or pipe flow rates can be printed. After drawing a network, simply click on any node, pipe, or other object with the Edit tool to display a data entry window.

The following is a summary of the information needed. General Information-Fluid Type (GAS); Friction Factor Equation; Node Information-Pressures, Elevations, Flow Rates; Gas Properties-Specific gravity, Temperature, Compressible factor; Pipe Information-Lengths, Diameters.

The Newton Loop-Node method offered a greater convergence and speed. Additional proprietary algorithms developed by this research provide increased efficiency, performance, and stability. This software requires a 486 or higher computer, 4 MB of RAM, VGA or better graphics (color), Windows 3.1/95/98 and a mouse. The following are the dialog box created by this software and the tables for the comparison of accuracy data with the NASS software.

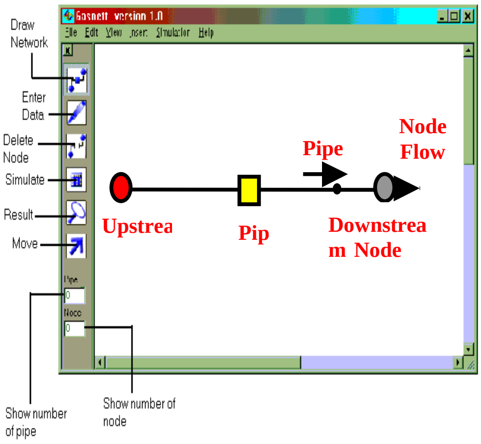

FIGURE 2 Dialog box for inserting the networks

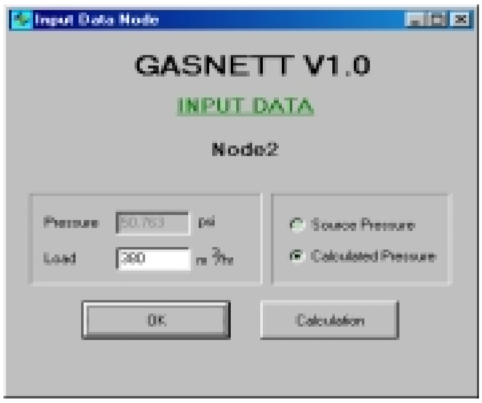

FIGURE 3 Dialog box for inserting data input of nodes.

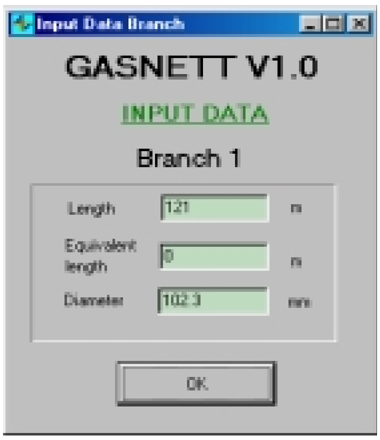

FIGURE 4 Dialog box for inserting the data input of branch.

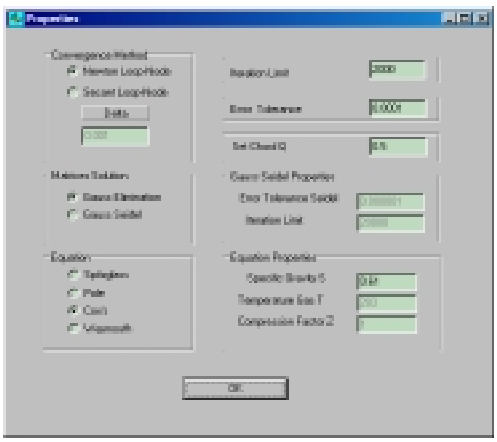

FIGURE 5 Dialog box for properties.

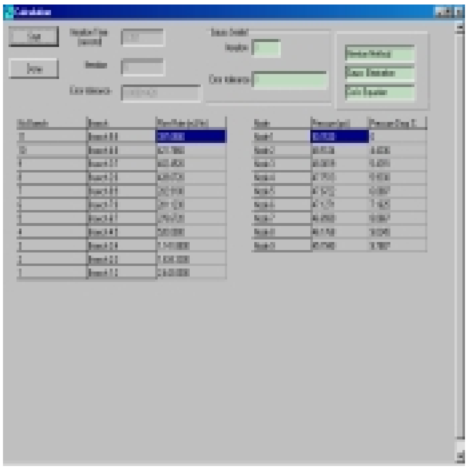

FIGURE 6 Dialog box of calculation.

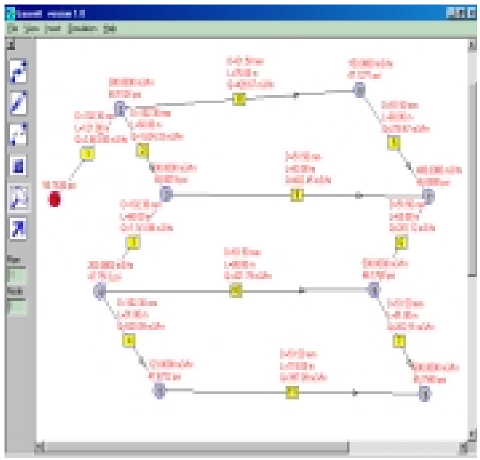

FIGURE 7 Dialog box for viewing data.

TABLE 1 Data input of branch.

No Branch	Branch	Diameter (mm)	Length (m)
1	1:02	102.3	121
2	2:03	102.3	60
3	3:04	102.3	60
4	4:05	102.3	91
5	6:07	51.5	60
6	7:08	51.5	60
7	8:09	51.5	91
8	2:06	51.5	76
9	3:07	51.5	83
10	4:08	51.5	88
11	5:09	51.5	118

TABLE 2 Data input of node.

No Node	Status	Load	
1	Source	50.76	psi
2	Load	380.00	m^3/hr
3	Load	90.00	m^3/hr
4	Load	200.00	m^3/hr
5	Load	123.00	m^3/hr
6	Load	150.00	m^3/hr
7	Load	400.00	m^3/hr
8	Load	500.00	m^3/hr
9	Load	600.00	m^3/hr

TABLE 3 Result of branch between GASNETT and NASS.

No Branch	Branch	GASNETT Flow Rate	NASS Flow Rate	Accuracy (%)
1	1:02	2443.00	2443.00	100.00
2	2:03	1634.33	1635.20	99.95
3	3:04	1141.88	1142.50	99.95
4	4:05	520.09	520.90	99.84
5	6:07	278.67	277.80	99.69
6	7:08	281.12	280.50	99.78
7	8:09	202.91	202.10	99.60
8	2:06	428.67	427.80	99.80
9	3:07	402.45	402.70	99.94
10	4:08	421.79	421.60	99.96
11	5:09	397.09	397.90	99.80
				99.84

TABLE 4 Result of node between GASNETT and NASS.

No Node	GASNETT Pressure(psi)	NASS Pressure(psi)	Accuracy (%)
1	50.76	50.76	100.00
2	48.51	48.49	99.95
3	48.00	47.97	99.93
4	47.75	47.72	99.93
5	47.67	47.64	99.92
6	47.13	47.09	99.92
7	46.66	46.61	99.89
8	46.18	46.12	99.88
9	45.79	45.73	99.85
			99.92

CONCLUSION

Optimisation of gas flow network analysis for steady state system will be easier by using this software. This user-friendly software has been developed by the Newton Loop-Node method which is capable to predict the flow rate and the pressure drop. The time taken for the number of iteration required to converge within the desire tolerance is fast with the current computer model: Pentium 400 MMX and 256 M RAM. This user-friendly software which runs on windows environment enables the end-users to input data and view the gas network graphics more conveniently.

NOTATIONS

Q	Flow Rate	m^3/hr
P	Pressure	kpa
D	Diameter	mm
L	Length	m
T	Temperature	K

R Gas constant
S Specific gravity
Z Compressibility factor
f Friction factor

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