A New Algorithm of Auto-Modelling for Fluid Network

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The analysis of the solution of fluid network model is carried out to match the need of graphically modular auto-modelling for power plant simulators. Because of the symmetry and sparsity of the linear system of equations, a new method of improved Gauss elimination is presented for the solution of large scale sparse matrices. Comparison of the new method with the classical Gauss elimination method, the Gauss-Seidel iterative method are given. The results show that the algorithm provided is better than the others and is suitable for auto-modelling of fluid networks of power plants.

Keywords: fluid network, auto-modelling, simulation.

INTRODUCTION

With the development of simulation technology, the graphical modelling software of power plant simulators is improving rapidly. The simulation model can be created automatically by incorporating the diagram of the power plant and the parameters of the equipments, without actually writing programs. Therefore, the modelling period is shortened, the quality of the model is increased and the power plant simulation technology is developed to a new level. The model of power plants mainly include equipment models and network models. The equipment models can be achieved by putting the actual equipment parameters into the equipment module. The network models can be achieved directly and automatically from the diagram of the power plant and the topological analysis of the flow network system. The algorithm of network models is very important for auto-modelling because it directly influences the quality of the model of the power plant and the proficiency of auto-modelling.

LINEARIZATION OF THE FLUID NETWORK

Fig.1 shows a schematic diagram of a branch of the fluid network. For branch j, the branch pressure-flow relation can be expressed as:

\[ P_i - P_0 = G_j/R + C \]

where

\[ R = 1/(f_1|G_j| + f_2) \]

This equation can be modified as:

\[ P_i - P_0 = G/R + C \] (1)

while, for the moment, \( G_j \) is

\[ G_j = R(P_i - P_0) - RC \] (2)

For the example presented on Fig.1, the equation for the conservation of mass for an internal node is:

\[ \frac{dM_i}{dt} = V_i \frac{dp_i}{dt} = V_i \left( \frac{\partial p_i}{\partial t} + \frac{\partial p_i}{\partial h_i} \right) \]
Generally, the variation of enthalpy is much slower than that of pressure, i.e. \( \frac{dh}{dt} \ll \frac{dp}{dt} \), so \( \frac{dp}{dt} \approx \frac{\partial p_i}{\partial t} = \frac{\partial p_i}{\partial t} \) and

\[
\frac{\partial p_i}{\partial t} \frac{d p_i}{dt} V_i = \sum G_j - C_{pi}(P_i - P_a)/T_{pl}
\]

With the above, the closed linear equations for any internal node pressure are obtained. By solving the equations, we get the internal node pressures at present and by returning them into equation (2), we get the flowrate of each branch.

**SOLUTION OF THE LINEAR SYSTEM OF EQUATIONS**

Solving the linear system of equations is a key step in fluid network simulation because its speed and accuracy are directly related to the simulation time and precision of the whole fluid network. In this paper, we analyse the characteristics of three methods. The corresponding computational times are listed in Table 1.

1. **Gauss Elimination Method**
   
   In this method, the equation \( A \cdot X = B \) is modified to the equivalent triangular system of equations by eliminating column elements step by step. The advantage of this method is that the computer code is short, the results are accurate and the memory occupation is small. The disadvantage is the long computational time. The results are shown in Table 1, where the computational time increases with a power function as the number of equations increases.

2. **Gauss-Seidel Iterative Method**
   
   In this method, the equation \( A \cdot X = B \) is transformed into \( X = G \cdot X + F \) and is solved using an iterative process. The computational time is short under normal conditions, but increases slightly as the number of equations increases. The disadvantage of this method is that an iteration process is needed. In some abnormal situation, such as for ill-conditioned matrices, the convergence is affected.

3. **Improved Gauss Elimination Method**
   
   The method presented in this paper takes into consideration the symmetry and sparsity of the coefficient matrix and is based on the original Gauss elimination method. In this new algorithm, before eliminating column elements, the non-zero column elements on a line are distinguished and the position of the non-zero column element with the biggest subscript is recorded. The elimination process will stop at the column elements afterwards must be zeros. Before eliminating the last non-zero column element, if column element is found to be zero, the corresponding line will not need eliminating. Because of the symmetry and sparsity of the coefficient matrix of a typical power plant fluid network, the non-zero elements will be concentrated near the diagonal line of the matrix if the number of nodes is chosen carefully. With the above method, the calculation speed will be improved and the program will be relatively simple.

**THE RULES OF AUTO-MODELLING OF FLUID NETWORKS**

According to the analysis and comparison mentioned above, the direct linearization method for the fluid network and improved Gauss elimination method for the solution of the system of equations are adopted in this paper. The calculation of the flows in the complete network must obey the following rules in order to automatically create the simulation program:

1. In the equipment branch module, the pressure-flow property of the branch should be expressed as:

\[
P - P_0 = f_1/g^2 + f_2 \cdot g + f_3
\]