Optimum Model Selecting Tool of Pneumatic System

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ABSTRACT

In designing pneumatic systems, how to select matched models which meet requirements easily, swiftly and appropriately becomes increasingly important from the point of view to reduce the designing time and cost. In this paper, an optimum model selection tool for pneumatic systems named Pneumatic Model Selection Program (PMSP) will be introduced. If a user inputs some requirements, the program automatically selects matched models such as cylinder, valve, speed controller, piping and shock absorber. If the user inputs a circuit and part number of components, the program calculates the dynamic performance of the system and indicates various characteristics such as full stroke time, stroke end velocity and air consumption. Besides, the user can also calculate the cushion ability of the cylinder and the condensation probability of the system by using this program.

KEY WORDS

Pneumatic System, Model Selection, Simulation Program, Dynamic Characteristics

INTRODUCTION

It is important for pneumatic system engineers to easily and appropriately select the equipment that meets the requirement and to predict the system characteristics precisely during the designing phase. On the other hand, pneumatic equipment manufactureres are requested to be able to provide not only highly advanced or diversified equipment, but also simple and effective selecting method. Therefore, various selection programs have been developed as a kind of tool for designing pneumatic circuit mainly by pneumatic manufacturers[1]-[7].

Three years ago, we developed a program named Pneumatic Model Selection Program (PMSP), which can select the equipment and calculate the characteristics for cylinder operating system more precisely, by applying dynamic characteristics simulation method[1][2]. Recently, the version of the program has been modified by adding functions and models and by updating the calculation method. This report introduces functions and features and selecting method for the PMSP’s Ver.2.

OUTLINE OF PMSP

Functional configuration
PMSP’s Ver.2 has been released in the form of CD-ROM operable with Windows 98/Me/2000/NT4.0, and on the
WEB simultaneously. Figure 1 shows the functional configuration of the program. Main functions are as follows:

**Model Selection**: Automatically selects the optimum models such as cylinder, solenoid valve, speed controller, piping, fitting, silencer, etc, which meet requirements

**Characteristic Calculation**: Calculates the system characteristics by dynamic characteristic simulation for specified circuit and model.

**Cushion Calculation**: Calculates the cylinder kinetic energy and thrust energy at the end of the cylinder stroke to evaluate the cushion capacity.

**Condensation Calculation**: Calculates the quantity of water mist generated in the system and the ratio of the volume of the cylinder to the volume of the piping to predict the possibility of condensation.

**Shock Absorber Selection**: Automatically selects the part number of shock absorber which satisfies impact style and operating conditions.

In addition to them, supporting functions such as limiting models, general master and unit master are available.

**Major features**

1. Introduction of dynamic characteristics calculation:
   To calculate the characteristics of system, dynamic characteristic simulation method was used, in which piping was treated as distributed-parameter model and the basic equations of equipment were solved simultaneously. Thereby, the accuracy and reliability of calculated results became high and the range of applicable circuits was enlarged.

2. Optimization of model size:
   In selecting the cylinder actuation system, the size of each model was optimized so that full stroke time was shorter than the required value yet as close to it as possible by changing model size repeatedly.

3. Link between functions:
   It goes without saying that main functions can be used separately. Since the functions, which relate Selection of Cylinder Operation System with Selection of Shock Absorber, and Model Selection with Characteristic Calculation, were linked, the transition between functions can be performed easily.

4. Flow characteristics notation complying with ISO:
   Instead of conventional flow-characteristic expression based on effective area $S$, new method was used, which is based on sonic conductance $C$ and critical pressure ratio $b$ complying with ISO6358. Therefore, the flow-characteristic of equipment can be expressed more practically, and the globalization becomes easier.

5. Easy operation:
   Since the system has been constructed for designers, the priority was placed on practicability and simplicity. Users need neither advanced knowledge of computer programming, nor the knowledge concerning the modeling and calculation of pneumatic system.

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**SELECTION OF CYLINDER OPERATING SYSTEM**

**Flow of selection**

For selecting a cylinder operating system, it is important to select the minimum size equipment with minimum air consumption, which can move required load to the stroke end within the required time.

Figure 2 shows the flow chart for the selection of cylinder operating system. To select the appropriate model size, it is necessary to check the capability of work, the strength and the safety after considering equipment specification range, and to optimize the equipment size by repeating calculation. Also, it is necessary to consider model selection systematically, because it is related not only to its own characteristics but also to other components' characteristics.
Model Selection

Figure 3 shows the input screen of Model Selection. A circuit is selected here, and required full stroke time, supply pressure, piping length, and load mass are inputted. The example shows the model selection conditions of the following system: This meter-out circuit, whose supply pressure is 0.4MPa, moves a load mass of 5kg horizontally with a stroke of 100mm in 0.5s or less.

After inputting the conditions, only by specifying requested product series on the screen for the selection of cylinder, solenoid valve and piping, the dynamic characteristic simulation for the system is conducted automatically, and equipment size is optimized so that full stroke time is less than required value yet closest to it by changing equipment size and iterating calculation.

Figure 4 shows the output screen of Model Selection. The part numbers of product group with optimum size which satisfy input conditions are listed. The charts of the piston displacement, speed and acceleration, those of the pressures in the cylinder, and the system main characteristics such as full stroke time, mean velocity,
stroke end velocity, maximum pressure, and air consumption are displayed as well. The example shows that the response time of selected system is 0.37s for required full stroke time of 0.5s when the orifice of the speed controller is fully opened.

The results can be stored and printed on the output screen. From this screen, the user can also enter other screens such as Cushion Calculation, Condensation Calculation, Characteristics Calculation and Shock Absorber Selection.

Cushion Calculation
If a heavy load is moved in a high speed, the collision at the end of the stroke may destroy the cylinder. Therefore, in case where a cylinder is selected, it is necessary to check its cushion capacity for safety.

For the Cushion Calculation of PMSP, the absorbed energy is calculated based on the speed and pressure at the cylinder stroke end. The cushion capacity is determined by comparing the calculated value with the allowable value registered in the cylinder database.

Figure 5 shows the screen of Cushion Calculation. There are the following style of cushion structures: built-in rubber cushion, air cushion and externally installed shock absorber. Here, the cushion capacity is automatically calculated just by selecting corresponding cushion style.

When the cushion capacity exceeds the allowable range, it is necessary to change the cushion style or component size, or to apply a shock absorber.

Condensation Calculation
In a cylinder operating system, moist drop may be generated in the actuator and piping and do harm with equipment operation and life. The condensation is mainly dependent on the size of the cylinder and piping. Therefore, it is important to predict the possibility of condensation during the phase of circuit designing and model selection.

Figure 6 shows the screen of Condensation Calculation. If the humidity of the supplied air is additionally inputted a value selecting one of ‘Absolute humidity’, ‘Relative humidity’, ‘Atmospheric dew point’ or ‘Pressure dew point’, the moist mist generated in the system and the volume ratio of the cylinder to piping are calculated and the probability of condensation is displayed. If the probability of condensation is high, the advice concerning condensation mechanism and preventive action is available from the help information of the program.

APPLICATION OF CHARACTERISTIC CALCULATION FUNCTION

Characteristic Calculation
In order to select a cylinder operating system more flexibly, the PMSP has a characteristic calculation function, that is, the characteristic of a system is calculated if the circuit and model numbers are inputted. Figure 7 shows the input screen of Characteristic Calculation. The circuit configuration and conditions are inputted like as the input screen of Model Selection. Model numbers are selected from database, and the opening of the needle of an adjustment device such as speed controller, is inputted. After inputting, simulation is automatically made, and the system dynamic characteristics and characteristic value of the system are displayed like as the output screen of Model Selection (Fig. 4)

By making use of this function, it is possible to change the result of the above-mentioned automatic selection, to evaluate the characteristics and to review model for an existing system. Furthermore, energy saving and various
optimization in the design of a pneumatic system are also possible by changing some parameters and carrying out the simulation.

**Study of LCA total cost minimization**

Figure 8 shows an example in which the LCA (Life Cycle Assessment) total cost from manufacturing to disposal is minimized by using the Characteristic Calculation function[8]. It shows the relation between running cost (air consumption) and production plus disposal costs (sonic conductance) versus supply pressure when the same load is driven in the same cycle for different bore size providing a load of 30kg is driven vertically for a stroke of 200mm in 1 s or less.

For the same cylinder bore, since the air consumption is directly proportional to supply pressure, and sonic conductance is inversely proportional to it, total cost minimum value exists. Table 1 compares minimum points for various diameters. It turns out that both the sonic conductance and air consumption are lowest at C point, that is, the drive of high load factor with small bore cylinder and high supply pressure saves energy effectively.

**Fig. 8 Study of LCA total cost minimization**

<table>
<thead>
<tr>
<th>Point</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply pressure [MPa]</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Cylinder bore [mm]</td>
<td>50</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>Sonic conductance [dm³/(s·bar)]</td>
<td>0.58</td>
<td>0.44</td>
<td>0.38</td>
</tr>
<tr>
<td>Air consumption [dm³/(ANR)/cycle]</td>
<td>2.9</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Load ratio [%]</td>
<td>50</td>
<td>59</td>
<td>73</td>
</tr>
</tbody>
</table>

**Study of shortest time drive**

The shortest time drive is often required in the design of a cylinder operating system. In this case, the model numbers with the fastest response can be found out by changing the size of equipment in Characteristic Calculation.

**Fig. 9 Study of minimum actuation time**

Figure 9 shows full stroke times calculated by varying the sizes of cylinder, solenoid valve and piping. An increase in the size of solenoid valve increases the response. Cylinder and piping, however, have a minimum value for the fastest response. Therefore, it is not necessary for every component to be large for the shortest drive. A system composed by model numbers corresponding with the fastest response will lead to the fastest system. In this example, the system with a cylinder bore of 50 mm, a solenoid valve sonic conductance of 7.6 dm³/(s·bar), and a piping inner diameter of 9 mm, has the shortest full stroke time of 0.35s.

**SELECTION OF A SHOCK ABSORBER**

**Flow chart of selecting procedure**

Figure 10 shows the flow chart of the shock absorber selecting procedure. When impact style, operating conditions and requested series are inputted, various checks and evaluations are made and an optimally sized shock absorber which satisfies the request is selected. Specification check confirms whether impact velocity, thrust, operation frequency, and ambient temperature are within the shock absorber specification range. Absorbed energy check compares the calculated value with the allowable value of database based on impact velocity and relative weight. Table 2 shows the type of impact style that the program is applicable for.

**Selecting program**

Shock absorber selecting program is separately available, and can be called from the output screen of the Model Selection and Characteristic Calculation. Figure 11 shows the input screen of Shock Absorber Selection. Impact style, load mass and impact velocity are inputted here. In this example, a shock absorber will be selected for the case where a cylinder of ø32 drives a load of 5kg sliding down on the 45-degree slope at 500mm/s.
Figure 12 shows the output screen of Shock Absorber Selection. The calculated results and selected shock absorbers are displayed in order of size. The mounting dimension of shock absorber and main specifications are displayed as well.

**CONCLUSION**

PMSP’s Ver.2 has been introduced as optimum model selecting tool of a pneumatic system. This is applicable for selecting cylinder, solenoid valve, silencer, speed controller, piping, fitting, shock absorber, etc. In regard to the selection of regulator, air dryer and tank, the optimization of air blow system and the calculation of factory piping network, please refer to “Energy Saving Program”[3].

In the future, we will continue enriching the variety of applicable components and circuits, and focus on the optimization of pneumatic system design and the improvement of customer satisfaction.

**REFERENCES**


