UTILIZATION OF PNEUMATIC ACTUATOR

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ABSTRACT

The pneumatic actuator represents the main force control operator in many industrial applications, where its static and dynamic characteristics play an important role in the overall behavior of the control system. Therefore improving the dynamic behavior of the pneumatic actuator is of prime interest to control system designers. This paper is a review of literature that related of the pneumatic actuator systems. In particular, the innovations in different control strategies applied to pneumatic actuators along with the modeling, controlling and simulation techniques developed for different applications of pneumatic actuators are reviewed. The review concentrates also on the analysis, investigation, performance, practical constraints, nonlinearities, uncertainties and the new applications of the pneumatic actuators.

1. INTRODUCTION

Most of the earlier pneumatic control systems were used in the process control industries, where the low pressure air of the order 7-bar was easily obtainable and give sufficiently fast response. Pneumatic systems are extensively used in the automation of production machinery and in the field of automatic controllers. For instance, pneumatic circuits that convert the energy of compressed air into mechanical energy enjoy wide usage, and various types of pneumatic controllers are found in industry. Certain performance characteristics such as fuel consumption, dynamic response and output stiffness can be compared for general types of pneumatic actuators, such as piston-cylinder and rotary types. Nowadays, pneumatic actuators have become an important driving element that extensively used in industrial robotics and automation. Due to their special attributes, pneumatic actuators have become alternate actuator in automated material handling task. The compressibility of air and friction in the pneumatic actuators are the main factors to the nonlinearities in the system that makes the pneumatic actuators difficult to control. A high number of unknown parameters need to be identified in order to achieve a dynamical response closed to real systems. In 1950s, the study on the pneumatic actuators has become vigorous due to the increasing demands of automation in industrial production lines. The first theoretical basis of the pneumatic system dynamic control was initially made by Prof. J. L. Shearer in 1956 .

2. PNEUMATIC ACTUATOR MODELING

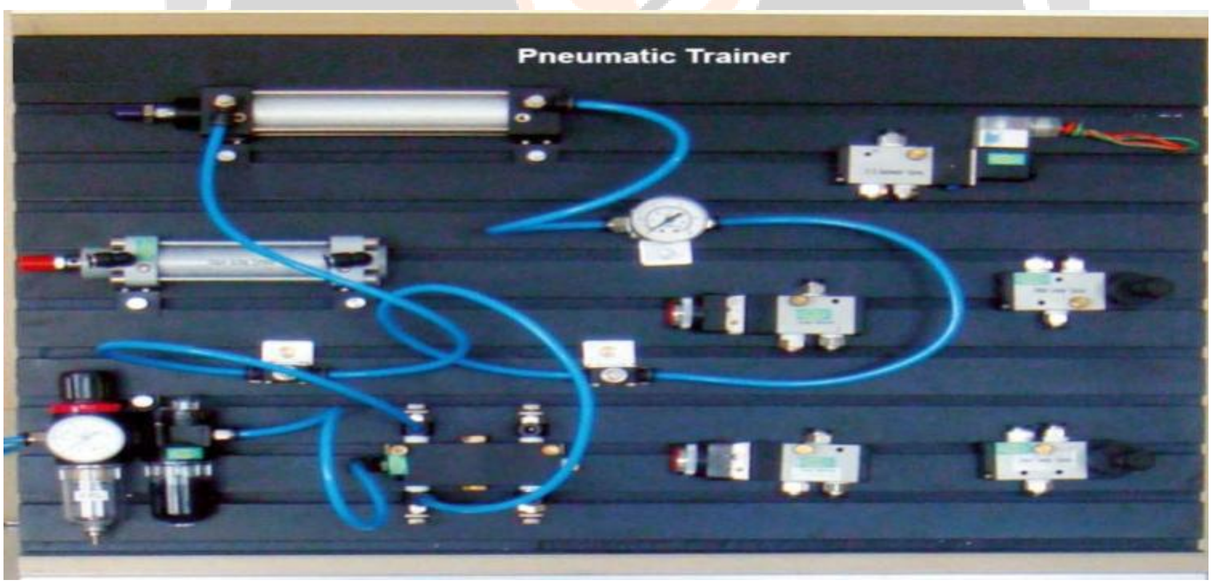
Pneumatic actuator can be modeled from theoretical mathematical analysis or system identification. Many approaches have been proposed for pneumatic actuators modeling. Most of researchers used theoretical mathematical analyses for modeling the pneumatic actuator. Three major considerations on obtaining the pneumatic actuator system: (1) the dynamic of the load, (2) the pressure, volumes and temperature of the air in cylinder, and (3) the mass flow rate through the valve [12]. Friction force exist in the pneumatic actuator system makes it difficult to control. Several researchers modeled friction force in order to develop friction compensation for high accuracy of controller performance. This modeling review starts with review for theoretical mathematical model. Then the model review continued with linear modeling method and system identification method. Next, the review of friction force modeling and pneumatic actuator model due to the physical or mechanical enhancement.

3. PNEUMATIC ACTUATOR CONTRIBUTIONS

Lots of attributes offered by pneumatic actuators compared to hydraulic actuators and magnetic actuators. Pneumatic actuators used air as its source of energy. The preferences of using air compare to conventional actuator that used water and magnetic due to air is a free source and is easy availability.
Hydraulic actuators need an external source of water supply to run a hydraulic system, while no external source required for pneumatic actuator to run a pneumatic system. These lead to cost effective of pneumatic actuators compare to hydraulic actuators.

4. PNEUMATIC ACTUATOR APPLICATIONS

In 1999, an application of pneumatic actuator was investigated for food packaging in production line. The control strategy was applied in a combination with a modified PID controller to a pusher mechanism in the packaging of confectionery product. In 2005, pneumatic actuator was developed in construction robot. A construction robot used in the work of attaching the ceramic tile. Other applications of pneumatic actuator was applied in Jack hammer, power drills and blow molding process as a manufacturing applications. Instead of manufacturing application, pneumatic actuators also have been applied to a physical human interface. Distributed physical human interface machine interaction was investigated using intelligent pneumatic cylinder to form an Intelligent Chair Tool in 2008. In earlier 2010, pneumatic actuators have been applied to a clinical robot assistant. For the enhanced detection and treatment, pneumatic actuator has been applied to an Magnetic Resonance Imaging (MRI) guided prostate biopsy and brachytherapy for accurate needle positioning control. Next, another application of pneumatic actuator has been reported to develop an active 80-faced Polyhedron for haptic physical human interface.



5. Air Production System

The component parts and their main functions are:

1. Compressor

Air taken it, at atmospheric pressure is compressed and delivered at a higher pressure to the pneumatic system. It thus transforms mechanical energy into pneumatic energy.

2. Electric Motor

Supplies the mechanical power to the compressor. It transforms electrical energy into mechanical energy.

3. Pressure Switch

Controls the electric motor by sensing the pressure in the tank. It is set to a maximum pressure at which it stops the motor and a minimum pressure at which it restarts it.

4. Check Valve

Let’s the compressed air from the compressor into the tank and prevents it leaking back when the compressor is stopped.

5. Tank

Stores the compressed air. Its size is defined by the capacity of the compressor the larger the volume, the longer the intervals between compressor runs.

6. Pressure Gauge

Indicates the tank pressure.

7. Auto Drain

Drains all the water from the tank without supervision.

8. Safety Valve

Blows compressed air off if the pressure in the tank should rise above the allowed pressure.

9. Refrigerated Air Dryer

Cools the compressed air to a few degrees above freezing point and condenses most of the air humidity. This avoids having water in the downstream system.

10. Line filter

Being in the main pipe, this filter must have a minimal pressure drop and the capability of oil mist removal. It helps to keep the line free from dust, water and oil.

6. COMPRESSED AIR GENERATION, PREPARATION AND DISTRIBUTION AIR COMPRESSOR

Air compressor converts mechanical energy of an electric motor or any prime mover into the potential energy of compressed air.
Air compressor fall into two main categories: Reciprocating and Rotary. The principal types of compressor within these categories are shown below:

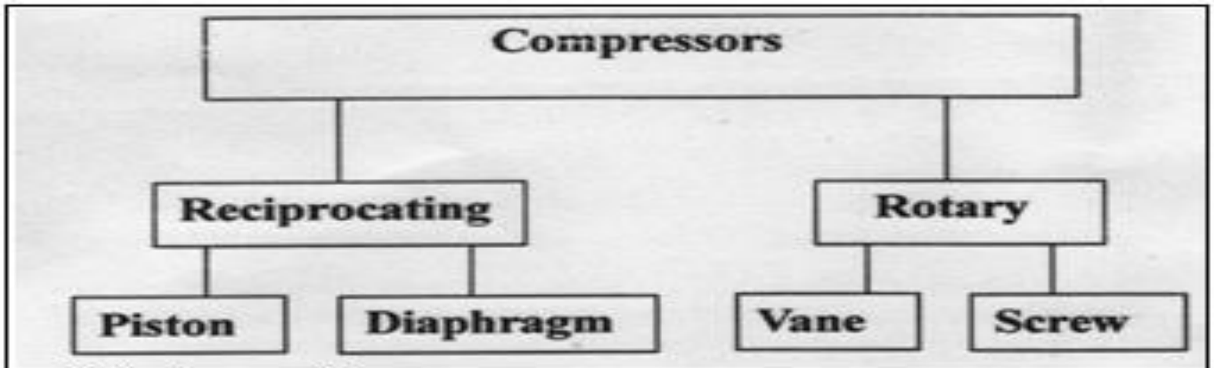


Fig.1. Types of Compressors

The Air Consuming System

1. Air Take off

For consumers, air is taken off from the top of the main pipe to allow occasional condensate to stay in the main pipe, when it reaches a low point water off from beneath the pipe will flow into an Automatic drain and the condensate will be removed.

2. Auto Drain

Every descending tube should have a drain at its lowest point. The most efficient method is an auto drain which prevents water from remaining in the tube.

3. Air Service Unit

Conditions the compressed air to provide clean air at optimum pressure and occasionally adds lubricant to extend the life of those pneumatic system components which need lubrication.

4. Directional Valve

Alternately pressurizes and exhaust the cylinder connections to control the direction of movement.

5. Actuator

Transforms the potential energy of the compressed air into mechanical work. The figure shown is a linear cylinder; it can also be a rotary actuator or an air motor.

6. Speed Controllers

Allow an easy and step less speed adjustment of the actuator movement.

7. Pneumatic Actuators: The Control Strategies:

The advantages of pneumatic systems are well known as clear, cheap, easily maintained, safe in operation, etc. But for their highly nonlinear properties such as compressibility of medium, friction effect and nonlinearity of valves, pneumatic actuators are seldom used in industrial servo applications. Moreover, some of their

properties, e.g., poor damping, low stiffness, and limited bandwidth, are unfavourable in the servo control system design.
Some other difficulties in the control of pneumatic servo systems are the possible presence of unknown Disturbances coming from leakage of valves, time-varying payloads, and external perturbations. Besides, uncertainties in system parameters make the controller design problem more challenging. To cope with some of these problems, several advanced control algorithms have been proposed. Recent trends within the process industry, and in particular the introduction of smaller and more efficient plant, have brought about increasing occurrences where the response characteristics of commercially available actuators are not able to meet the performance requirements of the plant. It is this latter observation which motivated (French *et al.*, 1988). to apply optimal regulator and sensitivity reduction methods to the design of a control scheme for an electropneumatic quarter-turn actuator which satisfies both the regulatory and the emergency slam shut/open requirements of the modern process application. The controller developed is of a novel structure incorporating a conditioned integrator whose performance depends on an adaptive feed forward element. The new system response time for a full 90 of rotation is about 0.1 seconds, which is extremely fast compared with the original unmodified system of 1.2 seconds. Microprocessor based controls can be used to produce low cost pneumatic servo drives which could find wide application in manufacturing industries as reported by (Weston *et al.*, 1984). Incorporating digital compensation for system nonlinearities so that, when positioning loads in a point-to-point mode, it is possible to achieve a significant improvement in both the static and dynamic performance of the drive. For the compensation algorithms implemented a theoretical foundation was presented based on a linearized model of pneumatic drives. Microprocessor based hardware and software were constructed to evaluate performance criteria. This test facility has allowed the software implementation of the compensation algorithms to be refined so that satisfactory performance can be achieved with both translational and rotational drives utilizing various forms of transmission. The test facility has also allowed various control system elements to be evaluated so that pneumatic drives suitable for industrial application, can be specified. To improve the dynamic characteristic of pneumatic servo drives described an approach based on an outer decision loop, which modifies the command issued to an existing closed loop drive. Experimental results are presented which show that the scheme can improve the quality of response in terms of overshoot and positioning time.

7. PNEUMATIC TECHNOLOGY RESEARCH AND APPLICATION

Vacuum and Pressure Continuous Control

Research in this sector is aimed to implement semi-physical flight height simulation technology of flight of aircraft. The technology is researched to master the flight condition and characteristics to avoid danger and ensure stable control of flight. In the research, the pressure and vacuum continuous control system is studied, which can implement continuous control of pressure and vacuum with high accuracy and fast response.
Initially, an idea is presented to solve the problems mentioned above, that is, making use of pneumatic servo technology to control vacuum, the vacuum servo control system is founded with servo valve and vacuum generator. The research solves the key problem of developing vacuum servo control system with high accuracy and fast response. The further advances have been made in studies the pressure and vacuum continuous control system, which is shown in the Figure 2. The system adopted compressor and vacuum pump as pressure and vacuum source respectively. The research results demonstrated that the system behaved with desirable static and dynamic characteristics. When absolute pressure in closed chamber declines from 100 kPa to 20 kPa, the transition time is 1.4 s and static error is less than 30 Pa. When system traces sin wave signal (frequency is 1 Hz and amplitude is 0.2 kPa), amplitude frequency error and phase frequency error are 0.37% and 4.939 3° respectively.

APPLICATIONS OF PNEUMATIC SYSTEM

General methods of Material handling

- Clamping
- Shifting
- Positioning

• Orienting

General applications

• Opening of system valves for Air, Water or Chemicals
• Packaging
• Door or Chute control
• Forming operations like bending, drawing etc.,
• Stamping and embossing of components
• Feeding and Transfer of materials.
• Turning and inverting of parts.
• Stacking of components.
• Sorting of parts.
• Spot welding
• Pick and place operations
• Work or tool feeding in Machine tools
• Dental drills etc.

6. CONCLUSIONS

The pneumatic actuator represents the main force control operator in many industrial applications and its static and dynamic characteristics play an important role in the overall behaviour of the control system. Therefore improving the dynamic behaviour of the actuator is of prime interest to control system designers. The pneumatic actuators offer numerous advantages such as cleanliness, low cost, high ratio of power to weight, easy to maintain, safe, long anti explosion, working life and working overload. But on the other hand, the control accuracy is affected badly by its nonlinear characteristics. The nonlinear characteristics, especially the nonlinear friction and the thermodynamics of the pressure air in the chambers of the cylinder have a bad influence on control accuracy of the displacement controlling of the cylinder. In addition, there are a series of nonlinear and time varying factors such as load force, temperature, position of the piston, staying time at still and wearing out during working procedure. Also the pneumatic actuators are uncertain systems. A review of many researches that are conducted to study, model and design the accurate control algorithms for obtaining a high performance pneumatic actuator are presented in this paper. New applications of the pneumatic actuators are also reviewed.
In most research filed in the center, the theory research achievements have been developed to production, which is applied in some important technology area in China. And as the development of center, more complex systems and more precision components in the pneumatic field will be researched to meet demand of important domestic research institution. For Ocean research is the development focus in China in during the next decade, the center will stress pneumatic research which service to ocean technology.

5. REFERENCES

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