THE RESEARCH AND APPLICATION SURVEY OF FLUIDIC AMPLIFIER

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ABSTRACT

Fluidic amplifiers are devices which have no moving parts and use a gas or liquid as the working medium. In this paper, the operating principle, structure, advantages and properties of fluidic amplifiers are briefly depicted, then the main researching activities and applying status of fluidic amplifiers are emphatically introduced based on many materials summarized. Finally, the development trends of fluidic amplifiers are discussed in researching and application.

INTRODUCTION

Since its discovery at Harry Diamond Laboratories in late 1950's, fluidic has gradually been developed into a viable technology. This technology provides sensing, computing, and controlling functions with fluid power through the interaction of fluid (liquid or gas) streams. Consequently, fluidics can perform these functions without mechanical moving parts.

During the last 40 years, a wide variety of fluidic components have been used in many areas, which include the aerospace industry, nuclear industry, medicine, personal-use items, and factory automation. Generally, fluidic components are classified as sensor, amplifiers and interface devices. Among these components, fluidic amplifiers play an important role in the application of fluidics. They perform logic and control functions. Moreover, they can directly produce adequate flux or force to satisfy some cases in term of control signals.

AMPLIFICATION PRINCIPLE, CLASSIFICATION AND STRUCTURE

(1) Amplification Principle

Fluidic amplifiers are devices which have no moving parts and use a gas or liquid as the working medium. A high energy stream of fluid is accelerated in a nozzle in the amplifier to create a power jet. Lower energy control jet or jets are supplied transverse to the power jet flow to produce a change in direction of the power jet and a corresponding change of the flow in various output ports in the device. Hence, an amplification of signal is obtained. This amplification process is similar to that occurring in an electronic tube.

(2) Classification and Structure

In general, a fluidic amplifier may be categorized in either of two ways: by the function it perform or by the fluid phenomenon that is the basis for its operation.

Categorized by function, amplifiers are either analog (proportional) or digital (bistable). Proportional amplifiers operate on the jet interaction principle. The power jet and continuous control jet streams interact with the resulting output signal being proportional in the linear range of the device to the strength of the control. The output thus is a continuous function of the control jet signal. Digital or "on-off" amplifiers have two distinct output states for a constant power jet signal. When the control signal is put on the amplifier, the direction of the power jet is changed and the power jet leaves the amplifier through a different out port than before application of the control signal.

Identifying amplifiers by fluid phenomena produces the following major categories[1]: jet deflection, wall attachment, impact modulation, flow model control, and vortex flow. Of the five, jet deflection (Fig.1) can result in proportion or analog performance, and wall attachment amplifiers (Fig.2) can produce most of the common digital logic functions, such as flip-flop, AND, OR/NOR, and so on.

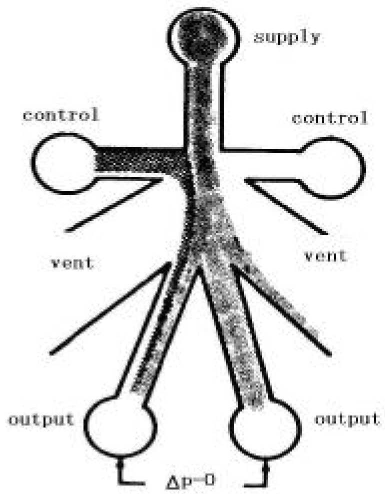

Fig.1 Jet-deflection fluidic proportional amplifier

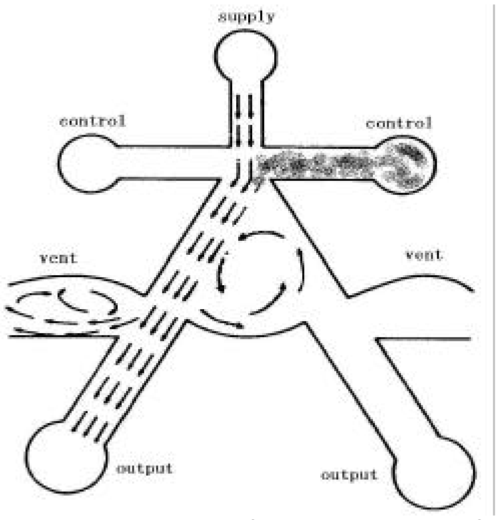

Fig.2 Wall-attachment fluidic bistable amplifier

In addition, according to switching phenomena, bistable wall attachment amplifier, one of amplifiers widely used, is categorized into end wall amplifier, splitter amplifier, and opposite wall amplifier.

THE INVESTIGATION AND APPLICATION SURVEY

Due to having no moving mechanical parts and requiring no electricity, fluidic amplifiers hold many inherent advantages as the following: high reliability, low cost, environmental insensitivity, and so on. Since it was discovered in 1959 by a group of scientists at the U.S. Army Harry Diamond Laboratories, fluidic amplifier has attracted many people to research and develop it.

Initial studies mainly investigated the effects of amplifier geometry on steady state performance, and attempted to establish a general mathematical model for steady state. The work of Bourque and Newman had served as the basis for much of these types of studies.

The next phase of research dealt with the switching process and its characteristics on attachment amplifiers, a number of papers had been written on the subject. Kirshner defined three types of switching, namely terminated wall, contacting-both-walls and splitter switching, while Muller described a critical attachment angle type of switching.

In early 1970s, most studies concentrated on the dynamic modeling of the switching process itself. Savker, Hansen and Kller reported some experimental values for switching times while James obtained an analytical model for the dynamical response of a bistable fluidic amplifier[2]. Shiraz, Rehmani and James conducted an analytical and experimental study for predicting the steady state and dynamic response of a jet interaction proportional fluid amplifier. Although many investigators have contributed to the study, a complete description of the switching process has not been obtained.

It had been the height of power and splendor for fluidic amplifier to be developed from beginning of 1960s to middle of 1970s. During this period, many countries had spent lots of money and time to research fluidic technology.

With the military support, many departments and institutions undertook a lot of theory research and experiment investigation in U.S. and U.K. Their emphases were fluidic amplifiers which were the logic components of pure fluid control systems. They achieved great success, and a wide variety of fluidic amplifiers had been used in machine controls, process controls, production-line controls, air condition controls, medical equipment and personal-use items as well as in aerospace controls, missile controls and other military applications. In late 1970s, for limitation of machining technique, complexity of analyzing and designing fluidic amplifiers, and cutting of investment from military authorities, the investigation of fluidic amplifiers was almost stagnated.

Former Soviet embarked on studying fluidic amplifiers early. Although it is very difficult to find their relative reports, they had made a great progress in applying fluidics, and especially, they obtained breakthrough in supersonic fluidic amplifier. In 1980s, they successfully applied supersonic fluidic amplifier to the control system of a long-distance rocket. In addition, it was reported that there were fluidics to be used in their spaceships.

Japan did not start to investigate fluidic amplifiers until in late 1960s. However, their research has never been halted. In 1980s, they did many experiments, released a lot of valuable reports, and developed numerous products in commercial applications.

DEVELOPMENT TREND

With the improvement of science and technology, fluidic amplifiers are meeting an opportunity to be developed. The following are the main development trend for fluidic amplifier.

(1) Small size, lightweight and quick response: Although fluidic amplifiers have a considerably fast speed of operation than mechanical or conventional moving part pneumatic/hydraulic system, it is difficult for fluidic amplifier to fit the modern control systems which demand more and more quick response.

(2) Development of laminar-flow amplifiers: Turbulent flow is characterized by a “noisy” jet, in contrast, laminar flow is characterized by a “quiet” well-defined jet. Laminar flow amplifiers have the ability to detect and process extremely small pressure signals, and Turbulent flow amplifiers are only used where high power levers are required. Moreover, test

results indicate that power consumption can be reduced by a factor of 10 or more if laminar proportional amplifiers are substituted for equivalent turbulent digital logic elements.

(3) Investigating supersonic fluidic amplifier: supersonic fluidic amplifier can produce adequate power to meet some special applications, such as the missile guidance control systems[3], which demands enough thrust to control the pitch and yaw of missile in a short time. For the complexity of the flow in supersonic amplifier, there are few studies on this subject by the now.

(4) Combining with electronic, mechanical or conventional moving part pneumatic/hydraulic devices to constitute an efficient system. There were some investigators who tried their best to establish pure fluid control systems early in 1960s and 1970s, but these systems were very limited in application.

(5) Modularization, integration and standardization. On one hand, these are the demands of modern design method, on the other hand, these will make the fluidic amplifiers be used more conveniently.

(6) Utilizing numerical simulation technique to analyze the flow in fluidic amplifier and to guide the design of fluidic amplifier.

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