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A Study on Characteristics of Automotive Electromagnetic Control Valve(ECV)

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Abstract

Automotive air conditioners are essential products used in vehicles as it provides drivers with pleasant indoor temperatures. While the automotive air conditioner has a simple structure where ambient temperatures are lowered by undergoing two phase transformations using a compressor, an expansion valve, a condenser, and an evaporator with a supply of power from the engine, consumption of power used in the process of compressing the refrigerant among air conditioner components becomes a factor for dropping fuel efficiency so that studies to reduce power consumption are being actively conducted at present. When power consumption of the compressor in the air conditioner is reduced, the fuel efficiency of the vehicle is improved. Among such studies, research and development has continued for electromagnetic control valve (ECV) of variable capacity-styled swash type compressor. In the present article, the automotive air conditioning system for which much research and development is carried out considering environmental problems and fuel economy will be introduced, and a study has been made concerning characteristics and recent development trends of ECV (electromagnetic control valve) as an automotive compressor control valve in which many changes are being made aware of among components for the air conditioning system.

Keywords: ECV; Air conditioning system; Swash plate angle; Air compressor;

INTRODUCTION

Recently, global warming is being accelerated, one of the causes for which is the exhaust gas produced from automobiles. Thus, many studies with focus on improvement of fuel economy and vehicle efficiency are being conducted by automobile companies in consideration of environmental problems. Among parts and systems inside automobiles, automotive air conditioners are frequently used for pleasantness and passengers' comfort in vehicle used. It is transmitted of power from the engine to lower the engine output and discharges a large amount of exhaust gas. To reduce automotive exhaust gas and improve fuel efficiency, the electromagnetic control valve (ECV) is employed which electromagnetically controls variable capacity-style swash type compressor and the amounts of compressor compression through the compressor.

The variable capacity-style swash type compressor controls piston strokes in a step-less manner without control steps of the clutch, and continuously changes tilt angles of the swash plate according to cooling loads. Thus, it is the compressor where the supply amounts of refrigerant are automatically controlled from the maximum to the minimum by continuously changing the tilt angles [1]. The compression valve controlling this compressor is the electromagnetic control valve (ECV), and the ECV is a mechanical element which uses electromagnetic control functions by being mounted on the automotive air conditioning compressor, and efficiently controls the discharge capacity by controlling pressures and swash plate angles of the swash chamber.

In the present article, features of the basic automotive air conditioning system, variable capacity-style swash type compressor, and electromagnetic control valve (ECV) will be introduced, and trends from the past to the recent times as well as development processes in the future will be discussed.

COMPONENTS AIR CONDITIONG SYSTEM

The air conditioning employs a method where ambient temperatures are lowered by taking heat off when the refrigerant in liquid state inside the evaporator is evaporated again as vapor by lowering pressures after the refrigerant, which was in gas state, greatly transforms pressure with the compressor.

The basic cycle for an automotive air conditioner is shown in the structure shown in Fig. 1. and the process compresses high-temperature refrigerant to high temperature and high pressure in the compressor first in which the refrigerant is made into a state that's easy to liquefy. Subsequently, the high-temperature, high-pressure refrigerant enters the

condenser positioned in the outdoor unit to meet air inhaled from outside with temperatures being lowered to become a liquid. At this time, heat of the refrigerant is released with hot air escaping to the outside unit, while the refrigerant in liquid state is sent to the expansion valve lowering pressure by moving the refrigerant which was in a narrow place to the wide expansion valve at one go. With production of a situation where a liquid evaporates readily by lowering pressures in this way, it is sent to the evaporator. The liquid refrigerant from the expansion valve has a low temperature and a low pressure, and such refrigerant absorbs heat from the hot air in its surroundings to be changed to a gaseous state, at which time the cooled air is flown indoors to lower the indoor temperatures. Repetition of such procedures provides the function of an air conditioner.

A. Air Compressor of Air Conditioning System

When the air conditioning system is in operation, the refrigerant flow makes the compressor continue to operate in accordance with general operation conditions. Among the components for an automotive air conditioner, there is a control valve connected to the outside variable compressor, and the position of this valve or the structure of the compressor can be seen through Fig. 2.

Since the existing mechanical control valves in use cannot control fluid flow more efficiently than the electronic control valves, efficiency of the automotive engine is lowered. Therefore, the contemporary automotive industry tends to use a variable-style swash type compressor employing an electromagnetic control valve with low energy consumption and high efficiency characteristics, and studies to develop more advanced compressors are being continued. When an air conditioning system is operating, the refrigerant flow makes the variable capacity compressor continue to operate by efficient change of the compressor in accordance with general operation conditions. This system controls the angle of the swash plate according to the crank. Capacity of the compressor varies with tilt angle of the swash plate that is changed by suction pressure of the crank chamber [2]. The electromagnetic control valve is an important element used for the air conditioning control system in the automotive air conditioning system.

B. Recent Trends of Air Compressor

Recently, studies on compressors are focused on provision of light-weight and small compressors which perform excellent capacity control with excellent durability while lowering manufacturing costs. As development proceeds, types and quantities of parts can be reduced, and compressor weight reduced through minimization of compressor components, while the operation mechanism of the swash plate can be simplified. In addition, the development of compressors can be expected by providing high revolution velocities and air tightness in refrigerant suction. Also, studies on the noise of compressors are being conducted actively.

Recently in the air conditioning system of H Company, an air conditioning company for domestic vehicles, emission of noise resulting from operation of the bearing which supported the driving shaft was prevented by installation of sound-absorbing members between housing and pulley to reduce operation noise and vibration of the bearing which supported the driving shaft of the automotive compressor. In addition, development of forming more pleasant environments was made aware of in the use of air conditioners through reduction of resonance sound resulting from bearing operation by controlling vibrations resulting from the bearing operation.

In H Motors for domestic finished automobiles, studies for fuel efficiency improvement are being conducted by changing the control device and methods for the compressor and the appearance of the compressor. First, as for the development on control, not only the vehicle's fuel efficiency was improved by accumulation of cold air energy upon occurrence of deceleration conditions in the vehicle and using cold air energy accumulated in the deceleration situation upon occurrence of clearing conditions for deceleration, accumulation efficiency of the cold air energy was also maximized by control of the compressor up to the temperature that prevented freezing. Further, maintenance of indoor pleasantness was made possible by controlling even the temperature controls. Also, as for the studies on appearance change, elements of the valves constituting the existing compressors were removed and the refrigerant that was inhaled and compressed according to reciprocating motions of the piston was allowed to flow to the cylinder block, leading to development of the compressor which alleviated operation noise due to the existing valve upon suction and compression of the refrigerant.

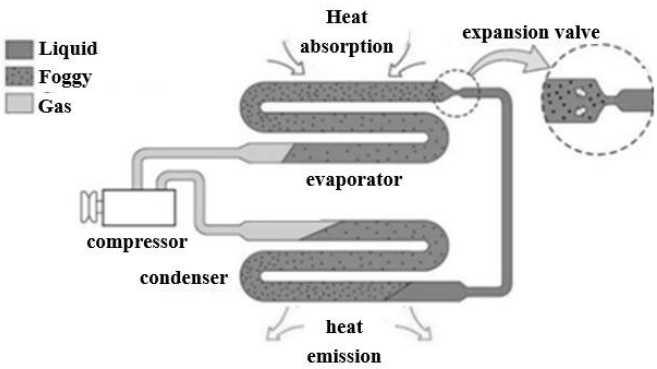


Figure 1: Air conditioning circuit in car

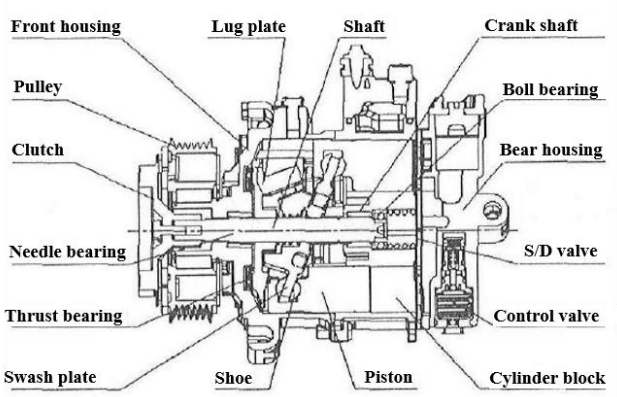
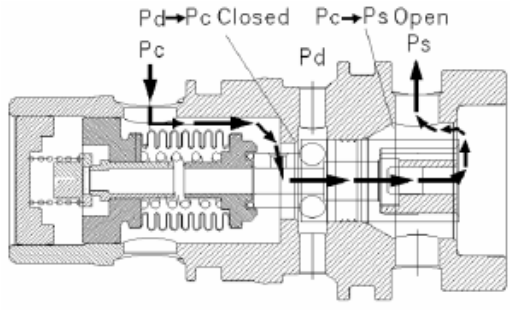


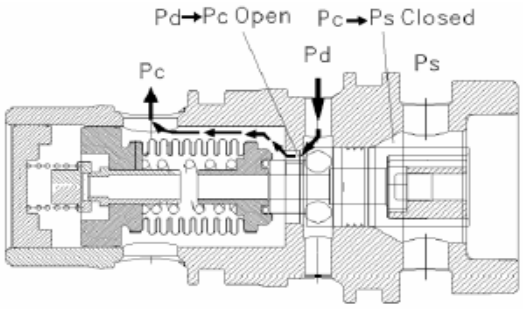
Figure 2: The internal structure of swash plate compressor

C. Electromagnetic Control Valve(ECV)

ECV controls the electromagnetic control valve through operation of solenoid by receiving signals from ECU. Basically, ECV mounted to the compressor maintains angles of the swash plate according to the average input power supply. Controls for the set pressure of ECV are realized by the solenoid valve, which determines operation status at ECU by taking into several external factors. As for the factors considered here, there are discharge pressure of the compressor, and ambient conditions such as the velocity extent of automotive engine, acceleration state, operation conditions of air conditioner, indoor temperature of automobile, and atmospheric temperature as the solar heat load, etc. and the suction pressure for compressor with operation of the pressure control valve is determined by applying the most appropriate electrical signal, i.e. current intensity to the solenoid valve by combination thereof. Based on the experiments on pressure control, Japan's Denso Company published the analysis result that variable swash type of external control style using a solenoid valve reduce fuel consumption used for 1 year by about 40 L [3]. Thus, the result of reduction in fuel consumption is obtained by appropriate control of the suction pressure. ECV is used for automotive air conditioner compressors without a separate clutch operation, and there are suction ports (Ps), crank ports (Pc), and discharge ports (Pd). ECV controls flow inside the valve by using such ports. Fig. 3. (a) shows the state of ECV with the power supply ON. Since the pressure of Pc (crank port) is larger than that of Ps (suction port) in the state with the power supply on, a flow path is formed in the direction from Pc to Ps. The released maximum pressure of Pd is formed by the motion of the piston connected to Pc, and the pressure drop of Pc caused by decreasing the angle of the swash plate inside the compressor. Fig. 3. (b) shows the state of ECV with the power supply OFF, in which a flow path from Pd to Pc is formed, at which time the pressure of Pd is larger than that of Pc, and the path from Pc to Ps is closed. Formation of a flow path from Pd to Pc is determined by PWM (Pulse Width Modulation) control with the power supply shut off and the current supplied, in which state it shows the maximum flux from Pd to Pc released by the pressure inside piston. As a result, the pressure of Pd is reduced and the pressure drop of Pd makes the swash plate angle inside the compressor reach the maximum. [4]. Due to such pressure controls, pressure differential is more efficiently controlled than when ECV is used, reducing fuel consumption while enhancing cooling efficiency. [5].



(a) Switched on condition



(b) Switched off condition

Figure 3: The flow of air: switched conditioned by the operation of the port

D. Development process of ECV

Past development of ECV was aimed at improvement of control stability of ECV by reducing the hysteresis phenomenon in the electronic actuator part. Through such development, the effect of enabling accurate control of temperatures derived from the evaporator was obtained, and the recent development of ECV is being made aware of based on past studies. First, as for the current development, flux and pressure of the refrigerant discharged though the control port became controllable according to the needs, and operation capability of the solenoid valve was improved by nickel plating treatment of the plunger surface. Subsequently, as much development is being made, studies on bellows having great effects on pressure control by ECV are being actively conducted in the country. As an example, there is a method where the phenomenon of degradation of bellows function due

to drop in vacuum during use can be prevented by not only improving weldability of bellows body and head but also improving air tightness through multi-stage insertion of oblique rods of ball and needle in the insertion hole on the inner face of the head. There is technology where oblique rods configured in ball and needle are fitted inside the oblique insertion hole to allow maintenance of 2-stage air tight means as well as position the flange configured on the needle on the jaw configured in the head to maintain the air tightness once more so that the vacuum inside bellows can be maintained satisfactorily, which configures spring catching jaw and weld in multi-stage on the outer face of the head and has the bellows body welded though weld on the top.

Recent studies on refrigerant control valves of bellows type in the ECV development by H Company for domestic finished automobiles is known to be aimed at improving initial operation performance of air conditioners upon vehicle start by shortening refrigerant discharge times, particularly in the refrigerant discharge structure inside the compressor and improving cooling rates of the air conditioner by initial operation delay of the compressor. In addition, studies will be implemented where improvement in compression performance and efficiency of ECV can be expected even by fine adjustment in a narrow range by controlling loads by a control screw after press fitting of the bellows.

CONCLUSION

In the present article, characteristics of the automotive air conditioner along with compressor and electromagnetic control valve as its components have been identified, and development processes from the past as well as recent trends have been studied. In the future, users' convenience for the air conditioning system will be evolved further, of which the compressor for which the domestic air conditioning control valve is being researched and developed will be studied so as to have high durability suitable for diversified operation characteristics simultaneously with the realization of mechanism simplification and miniaturization to reduce power consumption. For automotive compressor EV, PS test, operation and durability test, and high-temperature and low-temperature test etc. will be implemented for improvement of reliability of the specification. After method improvement for future processed items through the present study, studies for cost saving and process improvement are considered to be implemented.

ACKNOWLEDGMENT

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