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EFFECT OF POWER SUPPLY AND DUTY CONTROL IN CRANKCASE FLOW (CRANKCASE PRESSURE PORT) OF ECV

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Abstract

The electromagnetic control valve (ECV) operated by solenoid in the external variable compressor with the swash plate type is the rising phenomenon. ECV controls the air conditioning compressor for automobile on the basis of the input signal of the pulse width modulation (PWM) that supplied from the external controller. PWM technique is used to encode the information for transmission; its main use is to allow the control of the power to be supplied to electrical devices, especially to inertial loads. The mechanism changes the swash plate angle inside the compressor by increasing or reducing the pressure of swash plate chamber by use of the functions of different pressure port within the ECV. Increasing and reducing the swash plate angle finally depends on the solenoid force acting on the rate of supply of current. This research paper investigates the effect of power supply and duty control during the crankcase flowing at P_c pressure port of ECV.

Keywords: Electromagnetic control valve (ECV), Pulse width modulation (PWM), Crankcase, Crankcase flow, Current supply, Duty control.

1. Introduction

Air conditioning control system in modern automobiles is an important issue to consider while designing. Compressor, which is one of the important components for vehicle air conditioning operating system; consumes lot of engine power as it is a high efficiency requiring component. ECV is coupled with the compressor for vehicle air conditioning system [1]. Variable displacement compressor for automotive air conditioning system changes its piston stroke length infinitely to

Nomenclatures

P_c	Crankcase pressure port/ Crankcase flow, l/min
P_d	Discharge pressure port/ Discharge flow, l/min
P_s	Suction pressure port/ Suction flow, l/min
V_1~V_8	Flow control valves
V	Power supply, volts

Abbreviations

ECV	Electromagnetic control valve
MEST	Ministry of Education, Science and Technology
NRF	National Research Foundation
PWM	Pulse width modulation

satisfy the various demands of air conditioning, with which the system has great advantages such as smooth and continuous compressor operation, comfortable environment inside the car, and improved fuel economy [2]. ECV is generally suitable in external variable displacement swash plate type compressor than the fixed type one. Auto manufacturers prefer the variable type instead of fixed type because of its highly efficient technical and economic characteristics. Basically, ECV maintains a suction pressure in the compressor as a function of the average input current through it, within the limits of the air conditioning system capacity depending on different factors such as compressor RPM, evaporator air flow, condenser airflow, ambient condition, vehicle inside temperature, etc. ECV controls flow of air/refrigerant internally in the compressor from high pressure (compressor discharge) to compressor crankcase pressure. The compressor has a fixed bleed internally from crankcase to suction. The valve has a pressure sensing element (e.g. bellows), which induces pressure and acts as a feedback device. Variable capacity compressor runs constantly when the air conditioning system is switched on and air/refrigerant flow is controlled by effectively changing the displacement of the compressor to suit the prevailing operating conditions [3]. The compressor displacement is controlled by the pressure differential between crankcase pressure and suction pressure. To decrease compressor displacement, the average current supply to ECV is reduced, which increases the discharge to crankcase flow through the ECV. Operation of control valve is dependent on the difference in pressure [4]. Since the crankcase to suction flow is fixed, crankcase pressure will increase. This increases the pressure differential between crankcase and suction pressure, causing the compressor displacement to decrease. As the compressor displacement decreases, the suction pressure rises, flow out of the crankcase decreases (because the pressure differential is lower), until equilibrium is reached and the system operates at the new suction pressure set point. ECV is used for air conditioning compressors that can run without clutch [5]. Figure 1 shows the external variable displacement swash plate type compressor with ECV placement within it.

Three pressure ports in ECV are shown in Fig. 2. These are suction port (P_s), crankcase port (P_c) and discharge port (P_d). These ports are mainly the connecting passages through the ECV for air/refrigerant flow functions.

ECV consists of many internal components such as core, guide, plunger, guide pin, plunger spring, bellows, etc. [6]. After supplying the current, the internal parts (mainly plunger assay) start to move and create solenoid force for ECV operation. It allows the amount of air/refrigerant flow that result the air conditioning control procedures with various pressure ports. In switched on condition (engage the current with PWM to ECV) as shown in Fig. 3; maximum discharge of flow occurs and flow from P_c to P_s is open. Here, maximum stroke makes the flow pressure at P_d maximum because of the piston movement. Reduction of P_c pressure makes the swash plate angle maximum due to the flow from P_d to P_c [7].

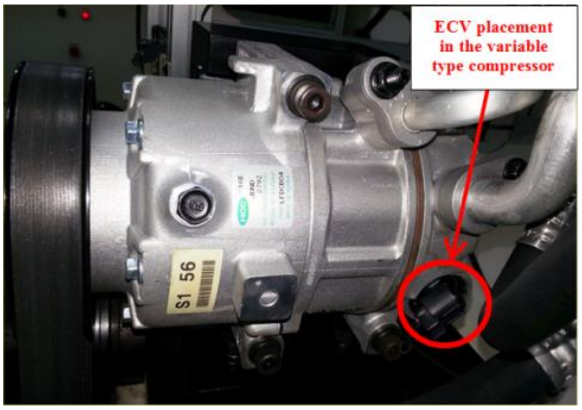

Fig. 1. External variable type compressor.

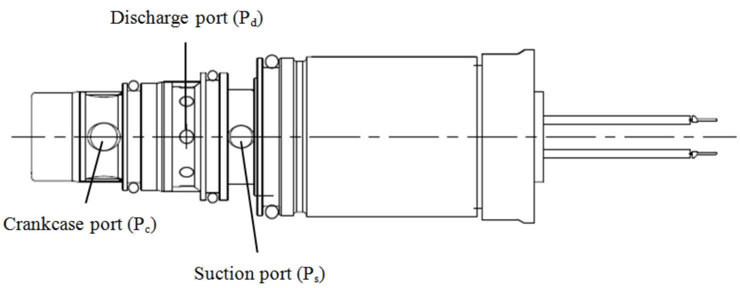

Fig. 2. ECV pressure ports.

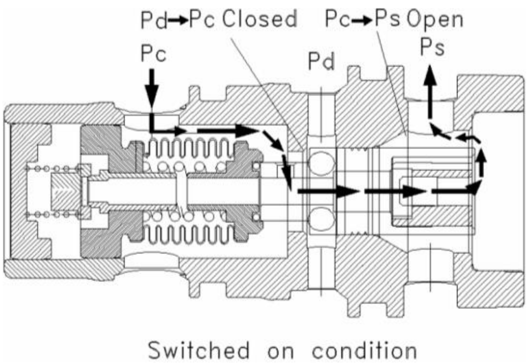

Fig. 3. Engage the current with PWM to ECV.

2. Experimental Analysis

For the experimental analysis, an air board tester is developed. Figure 4 shows the schematic diagram of the experimental set up.

Air is being supplied from external source (i.e., air compressor) for calibrating the crankcase flow through the ECV's P_c pressure port. Two ECV samples, Fig. 5(a) are used for the experimental tests. ECV sample is fixed into the test chamber of the air board tester and current is supplied, Fig. 5(b) from a DC power supply source, Fig. 5(c). Then based on a PWM input signal that is supplied from an external controller, Fig. 5(d), the duty control is used to measure the crankcase flow at P_c pressure port. And the readings are recorded from the flow switch placed on the board, Fig. 5(e).

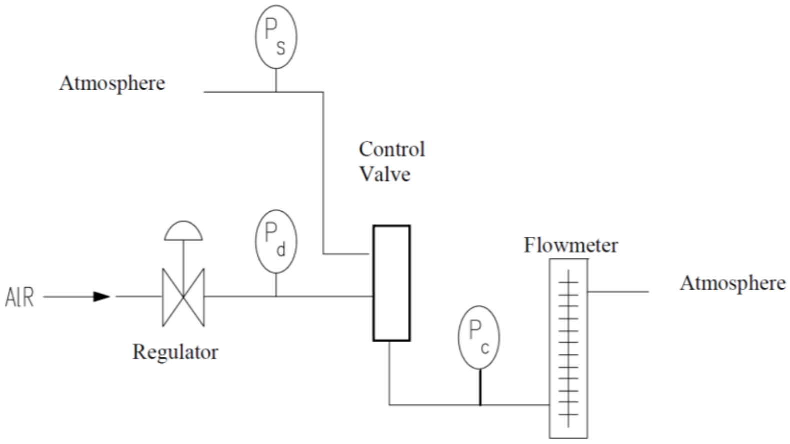

Fig. 4. Schematic diagram of the experimental set up.

(a) ECV test samples (b) ECV sample in flow testing

(c) DC power supply (d) Duty controller power supply (e) Flow switch for P_c flow readings

Fig. 5. Experimental procedures.

To obtain the crankcase flow the air board tester parameters set up is arranged as per following order:

Flow setting order: $V_1 \rightarrow$high; $V_2 \rightarrow P_d$; $V_3 \rightarrow$off; $V_4 \rightarrow P_c$ flow; $V_5 \rightarrow$off; $V_6 \rightarrow$flow; $V_7 \rightarrow$all; $V_8 \rightarrow$all

('V_1~V_8' refers to different flow control valves; 'high' refers to maximum input pressure; 'off' refers to valve is closed; 'flow' refers to air/refrigerant flow from P_d to P_s or P_c to P_s or P_d to P_c and 'all' refers to the flow of air/refrigerant to all ways except P_s)

Maximum high pressure: 0.069 MPa (0.69 bar)
DC power supply: 23.5 V
Duty controller power supply: 13.6 V
Frequency: 400±10 Hz
Duty cycle: 0~100%

After setting the parameters according to the specified order, with two different ECV samples, total six experimental tests were carried out. It was observed that the current supply has an effect on crankcase flow, while also displaying a relationship with duty control.

3. Result and Discussion

Figure 6 shows the relationship between duty control and supply of current. It is seen that for all the sample tests, the pattern is linear in nature. It means that the increase in current supply increases the duty.

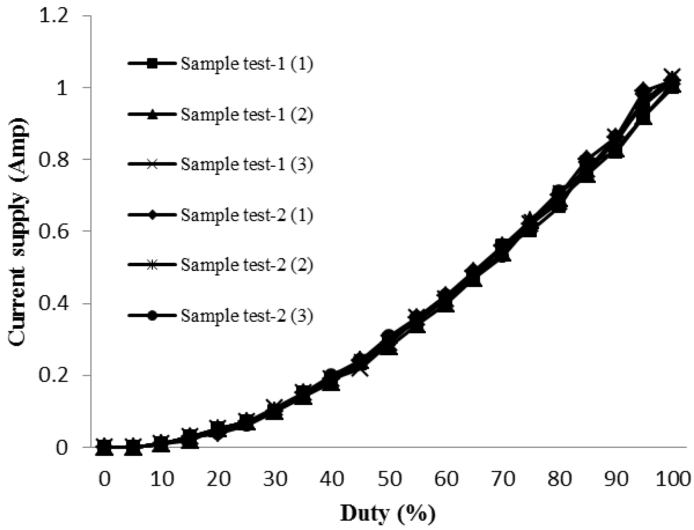

Fig. 6. Changes in duty with respect to current supply.

Figure 7 shows the relationship between duty control and crankcase flow at P_c pressure port (P_c flow). For test sample-1, after 60% duty control, crankcase flow starts to decrease and for sample-2, it starts after 45% duty control. In both the cases, at certain duty range P_c flow is constant. It occurs because of the valve is fully open. After that, when the plunger assay starts to move due to induce solenoid force; the valve pushes forward and the flow starts to decrease. For the two sample tests reduction of flow are different because of the dimensioning and tolerances issue.

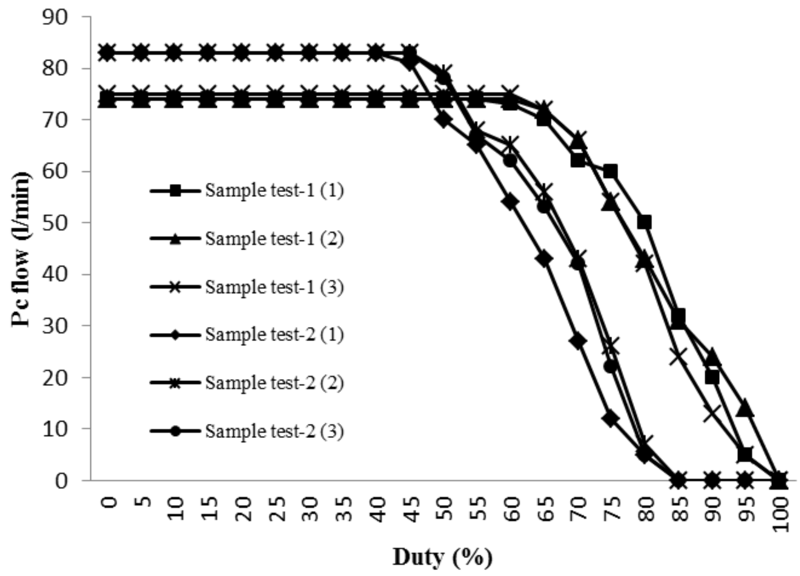

Fig. 7. Changes in P_c flow with respect to duty.

Figure 8 shows the relationship between supply of current and the P_c flow. Random values are taken from two test samples to observe the P_c flow with respect to supply of current.

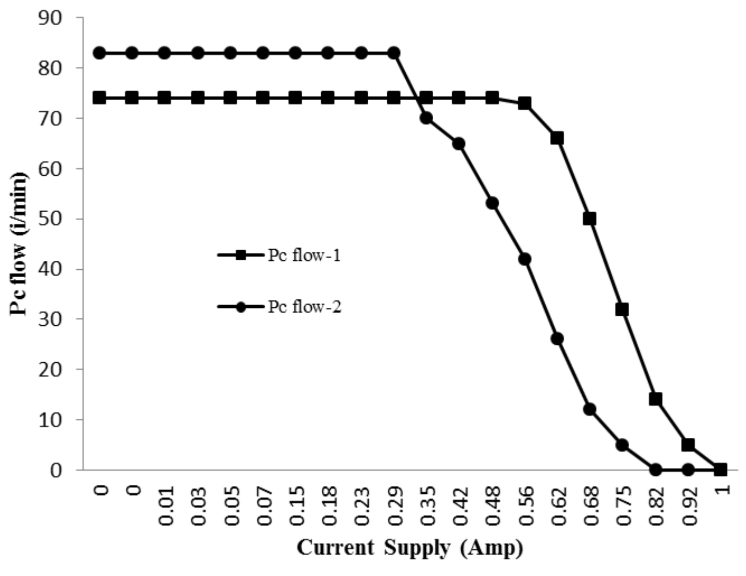

Fig. 8. P_c flow as a function of supply of current.

Current supply ranges between 0.0 and 1.0 Amp. It is seen that for sample-1, P_c flow starts to decrease from 0.56 Amp supply of current, while P_c flow starts to decrease from 0.29 Amp supply of current for sample-2. It can indicate that when the current supply is off, the plunger is not moving. Thus the valve guide is fully open up to 73 l/min and 82 l/min flow at the mentioned current supply for sample-1 and 2 respectively. The flow starts to decrease when the plunger assays start to move and create the solenoid force within them. Here, reduction of P_c port pressure makes the swash plate angle maximum as the flow moves from P_d to P_c initially. After that with the increase of current supply the flow decreases as the swash plate angle decreases due to the movement of the plunger assay; and finally the flow reaches to 0.0 l/min when swash plate stand at no angle position. Thus the amounts of air/refrigerant flow that result the air conditioning control all procedures with the help of the pressure port. It was also found that, both samples don't start to decrease the P_c flow the same way and reach 0.0 l/min flow at different supply of current. It happens because of the internal components design and dimension criteria.

4. Conclusions

The experimental analysis of crankcase flow at P_c pressure port of ECV for external variable capacity compressor is carried out to obtain the comparison results on the basis of the relationship between supply of current and duty control. Following concluding remarks can be made from the analysis:

- From the experimental results of both samples, it is found that the supply of current and duty control have correlation with the plunger strokes that induced solenoid magnetic force inside the ECV.
- The characteristic results show that with the increase of current, crankcase flow at P_c pressure port decreases. This occurs because of the decrease in opening length of the valve, when magnetic force increases.
- The same behaviour is observed, when the range of duty control values increases gradually. It means that the supply of current and the duty control are correlated with the crankcase flow with respect to solenoid magnetic force induced inside the ECV.
- Three important parameters such as P_c flow, supply of current and duty control varies according to the solenoid magnetic force operation. In other words, solenoid magnetic force has the impact on these parameters.

Acknowledgement

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