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Effect of Modification in Refrigerant Passage of an Automotive Air Conditioning Compressor

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EFFECT OF MODIFICATION IN REFRIGERANT PASSAGE OF AN AUTOMOTIVE AIR CONDITIONING COMPRESSOR

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ABSTRACT

Automotive air conditioning system generally uses a multi-cylinder swash plate compressor. The performance of automotive air-conditioning is having high level of correlation to the performance of the compressor. The major performance parameters of compressor are *cooling capacity, power consumption and volumetric efficiency.* All these parameters are highly sensitive to the pressure losses within a compressor. As every vehicle manufacturer strives to improve the fuel efficiency by means of reducing power consumption and improve comfort level of passenger, it is necessary for automotive air-conditioning designers to evaluate the effect of the flow pressure losses in the compressor on the stated performance parameters.

The objective of the exercise, described in this paper, was to design a new compressor with reduce flow pressure losses and study the effect of reduction in flow losses on stated performance parameters. The study was conducted evaluating both the compressors, the existing compressor and the newly designed compressor, keeping the rest of automotive air-conditioning kit same and maintaining the same test parameters.

It was observed that all the performance parameters showed significant improvement by reducing flow pressure losses, as expected at all the operating speeds.

The further scope of study is to study the effect of flow pressure losses on compressor operating noise, which will be done in future at NVH.

1. INTRODUCTION

An air conditioning compressor is provided to raise the pressure to appropriate level and circulate the refrigerants with minimum work. Compression process in a swash plate-reciprocating compressor can be assumed to be adiabatic with air-cooling (Arora, 2000). In actual process there are various losses associated with the compression process. These losses are mechanical losses due to friction, re-expansion losses, pressure losses across the valves and refrigerants flow paths and heat transfer to the surrounding. Present exercise is carried to find out the effect of pressure losses on the compressor performance.

In a multi-cylinder swash plate compressor, there are basically three regions: suction plenum, cylinder and discharge plenum. Refrigerants enter the suction plenum (buffer volume provided in head covers) of compressor through suction port. Reed suction valve is provided to selectively charge the refrigerant gas based on pressure differential from the suction plenum into the cylinder. Refrigerant gas is compressed to discharge pressure in the cylinder by reciprocating motion of the piston and it is selectively charged out to the discharge plenum by discharge reed valve.

There are pressure losses across the suction passage, reed valves, and discharge passage. Pressure losses on the discharge passage are higher as compared to those on suction passage. And these pressure losses depend greatly on the flow passage geometry and flow values. Since, sharp bends, sudden contraction and expansion results in higher-pressure losses. So, gradual contraction and expansion in the fluid passage is always recommended.

With the usage of advanced computational fluid dynamics (CFD) tools like STAR CD, it is possible to predict theses losses as summation of losses in subsystems of the compressor but not with compressor as single entity. Shiva Prasad (2004) discussed the need for CFD and its current status with reference to positive displacement compressor. Rao *et al.* (2004) conducted the analysis of a refrigerator compressor using CFD tool.

Present study is conducted to design a new compressor with reduced pressure loss and study the effect of reduction in these losses on compressor performance. STAR CD is used as CFD tool to simulate and predict the pressure and velocity at various section of the discharge passage. Flow analysis is done on three different layout of discharge passage. Discharge passage with minimum pressure drop was selected for proto making. Calorimeter testing is done to validate CFD results and compare the compressor performance of existing and proposed design under similar operating conditions.

2. FLOW SIMULATION

In order to simulate the refrigerants flow, three dimensional cad model of the existing and proposed design of the compressor is made on CATIA V5 software. Surfaces of the discharge passage were extracted to represent the flow model. This model is then converted in to IGES (Initial Graphic Exchange Specification) format. Fluid geometry in IGES format is imported in STAR CD and mesh is generated. Boundary conditions are applied before performing the iterations to solve the problem.

Discharge passage layout consists of two inlets (from front and rear side of compressor) and one outlet passage. Cross section at inlet and outlet is closed for specifying the boundary condition. Cylinder discharge pressure and temperature is taken to calculate the refrigerant physical property at discharge inlet. Refrigerant properties required for solving governing equation in CFD are density, viscosity, specific heat and thermal conductivity. Refrigerant mass flow rate is converted to volume flow rate by dividing it with refrigerant density. Refrigerant flow velocity is calculated as the ratio of volume flow rate and cross sectional area.

The existing compressor as shown in figure 1 is a multi-cylinder, double acting swash plate type. Discharge stream have one inlet from front cylinders side and second inlet from rear cylinder side. Connector volume is provided in order to reduce the pressure pulsation in discharge stream.

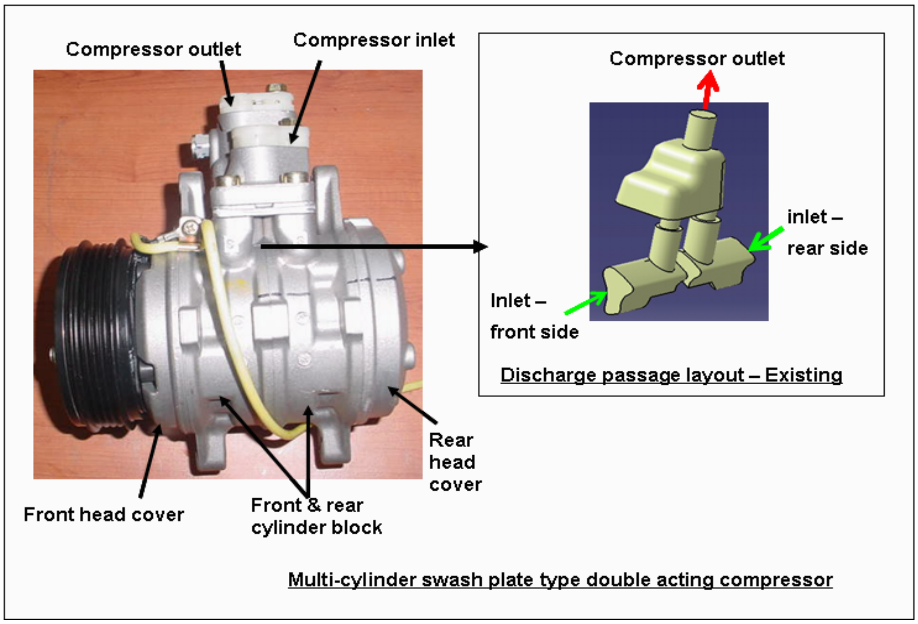

Figure 1: Existing compressor with its discharge passage layout

This connector volume is provided in a separate part which is used to combine two discharge passages. This additional part is eliminated to reduce the flow length and make our compressor more compact. Pressure pulsation in the new design is reduced as the discharge stream from collide with each other from opposite direction (Iwamori and Hidekazu, 1986). Proto compressors are assembled as shown in figure 2 for the calorimeter testing. Pressure die casting is process used for manufacturing parts of compressor housing. Hence, proto sample for the proposed design is manufactured by making design modification in die of the cylinder housings.

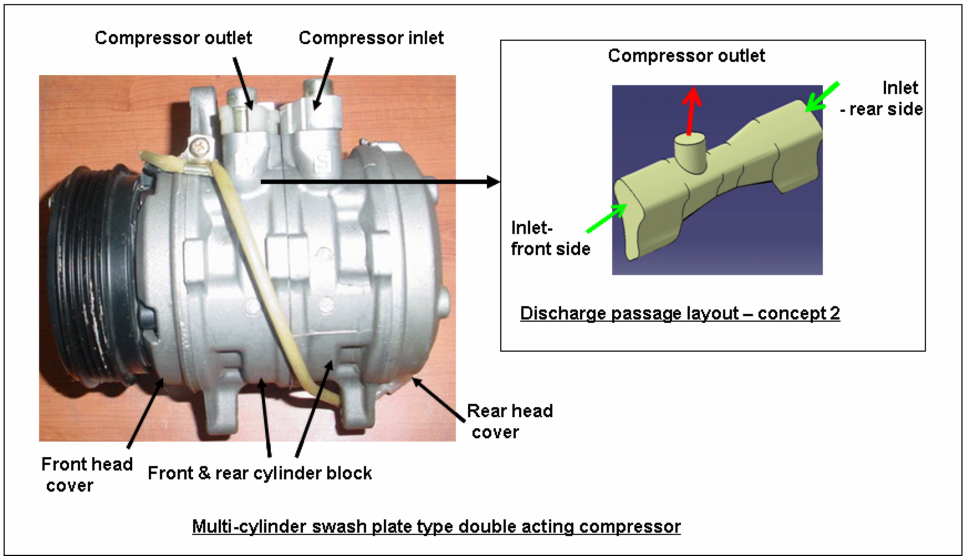

Figure 2: Proposed compressor with its discharge passage layout

Pressure and temperature corresponding to compressor discharge were taken to specify the fluid properties at the entry of discharge passage. Refrigerant flow velocities corresponding to compressor speed of 1000, 2000 and 3000 rpm are calculated. Figure 3 show the pressure drop between inlet and outlet of the discharge passage at different compressor speed.

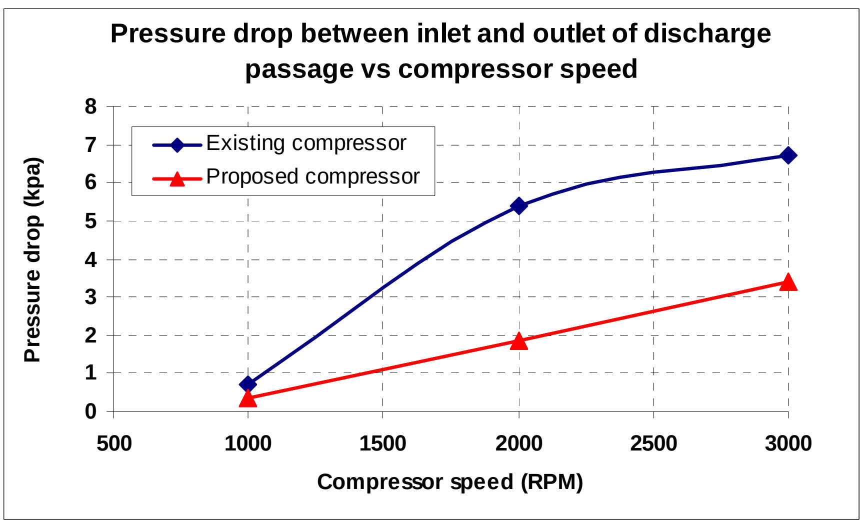

Figure 3: CFD results - Pressure drop vs rpm for existing and proposed compressor

3. EXPERIMENTS

Figure 4 shows the block diagram of system calorimeter test rig. System calorimeter consists of three separate air conditioned chambers for compressor, condenser and evaporator. Additional refrigerating unit is provided to control the temperature and humidity level of the evaporator room. While heating coils are provided in the condenser and compressor room to simulate the engine room temperatures.

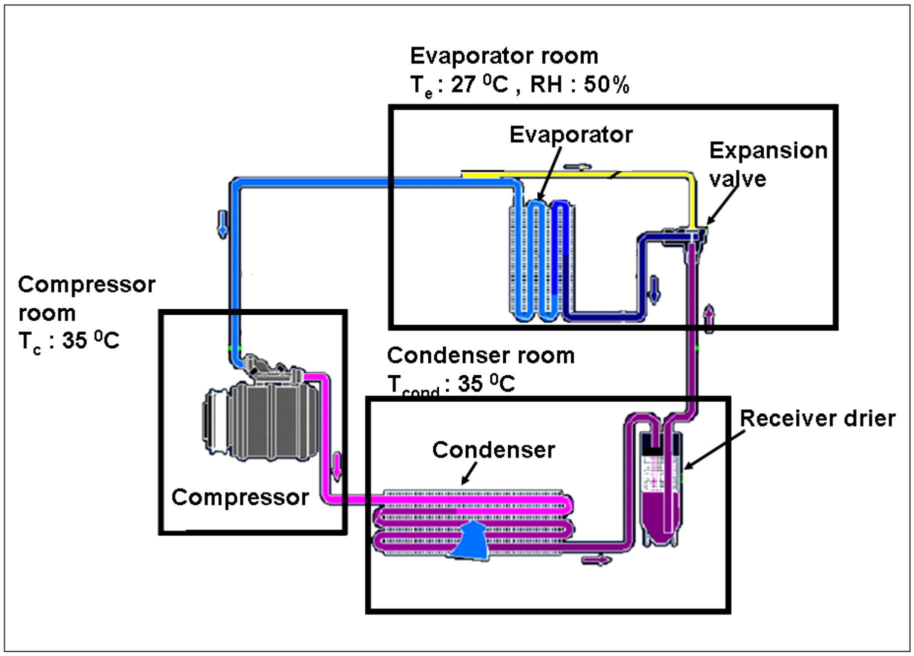

Figure 4: Block diagram of system calorimeter test rig.

Pressure and temperature transducers are provided at each entry and exit of the compressor, evaporator and condensers to measure parameters on refrigerants side. Refrigerants mass flow rate is measured with the help of mass flow meter which is fitted in between the condenser and the receiver drier bottle.

Air side parameters are measured at both entry and exit of the condenser and evaporator. A duct of uniform cross section is installed in condenser room along with the blower to provide uniform air flow rate across the condenser. Cold box with the blower is put inside the evaporator room to control and measure uniform air flow rate and maintain desired humidity level.

Both compressors (existing and proposed) were tested on system calorimeter using the same auto air-conditioning kit. This kit consists of multi-flow type condensers, serpentine evaporator, thermal expansion valve and fixed capacity swash plate type compressor.

Swash plate type compressor is very compact and manufactured using ADC-12 material for its housing. We have observed difficulty to measure pressure in suction and discharge plenum to validate CFD simulation. However we have measured pressure/temperature at inlet and outlet of compressor together with cooling capacity and power consumption. Reduction in pressure losses is reflected in improvement in cooling capacity for the same power consumption.

4. RESULTS

Experimental results shows 2.5 to 3 % improvement in cooling capacity with any significant difference in power consumption of two compressors. On comparing CFD and experimental results as shown in figure 3 and 5, we have observed that there is noticeable improvement in compressor performance at higher speed because at higher rpm pressure losses are significant.

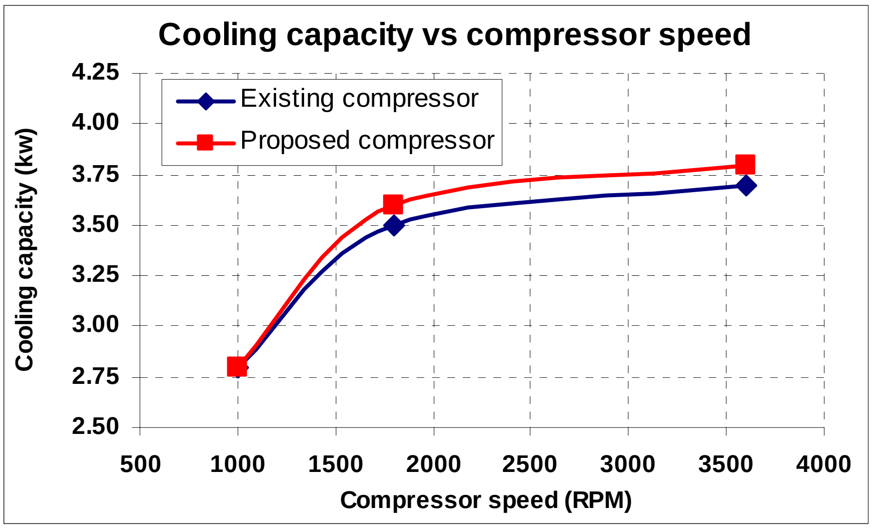

Figure 5: Experimental test results showing cooling capacity vs compressor speed

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