Development of Air-Conditioning System for Automobiles

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Abstract

HVAC is an acronym that stands for heating, ventilation and air-conditioning. It is often installed into a single system and these three functions of the HVAC system are closely interrelated to provide thermal comfort and to maintain good indoor air quality.

Heating is significant in maintaining adequate cabin temperature especially during colder weather conditions. It is also required to defreeze the windshields which are very critical Ventilation, on the other hand, is associated with air movement. There are many types of ventilation, but they all function similarly.

Ventilation is necessary to allow carbon dioxide to go out and oxygen to get in, making sure that people are inhaling fresh air. Insufficient ventilation usually promotes the growth of` bacteria and fungi such as molds because of high humidity.

The air-conditioning system controls the heat as well as ventilation. HVAC is sometimes referred to as climate control because it provides heating, cooling, humidity control, filtration, fresh air, building pressure control and comfort control.

In this report the different stages involved in developing a HVAC will be discussed. Initially a concept is evolved based on the space constraints and based on this basic concept the system is further developed, tested and will be produced after achieving all specifications.

Declaration

I here by confirm that this work is an independent contribution. All the external sources of help used in this work have been explicitly mentioned.

Muenchen, January 2010 Vijay Ramasamy

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Chapter 1: Concept Phase

The basic concept of the HVAC system is to take in fresh air, filter it and is passed on to the blower section. In this section the air is pressurized and due to which it picks up speed. Pressurized air is now passed on to the core of the HVAC system where it is initially passed through evaporator and later on to Heat exchanger. In this part of the system the air is mixed based on the temperature requirements and passed on to different outlets of the system. The common outlets which can be found in any automobile are Face, Defrost (for windshields), Foot and if necessary to the rear HVAC system (for rear passengers). The flowchart below will show us a clear picture of what happens inside a HVAC system. During concept phase the basic layout of the system is developed based on the packaging constraints of the automobile and several other factors. Development of the layout involves several iterations. The following items are optimized in the concept phase.

- Air How distribution
- Temperature distribution
- Pressure loss
- Noise analysis

1.1 Air flow distribution

Air flows generally frown a high pressure section to a low pressure section. As told earlier the air is first sucked through the inlet where it is filtered for dust, moisture and other contaminants. The air is then distributed to different parts of the system in correct amount with the help of doors and air guides. An air guide is a part which guides the air in to a particular section of the system and is designed to achieve the guidance. To analyze the air How a simulation is performed using Computational Fluid Dynamics, and with the help of this simulation we can roughly estimate the behavior of air. Based on the simulation results the layout is optimized. The important aspect in optimizing the basic layout of the HVAC system is to correctly position the Evaporator and Heat exchanger in the path of the air flow. A slight variation in the angle can also lead to mysterious results as air inside the system is very sensitive to changes. The basic layout is hence evolved with the help of simulation and the concept design of HVAC system is started. The CAD model was developed with the initial position of Evaporator, Heat exchanger and doors. The hardware will be produced with proper fixing points and strengthening ribs. The real sample is then tested by the testing department to compare the Results of the simulation.

1.2 Temperature Distribution

Temperature distribution is an important issue which is optimized during the concept phase of the system. Correct temperature distribution is essential for the comfort of the passengers and has to be achieved with high tolerance, for example the face outlet needs more temperature than the foot outlet or defrost outlet. So the air how has to be guided in such a way that these requirements are met. To achieve this hot air from heat exchanger and cold air from evaporator has to be mixed and guided properly through air guides and doors. The doors play an important role in achieving an optimal temperature as well as air flow distribution. The doors are usually actuated through some levers and actuators from outside the HVAC system. The kinematics is designed by a separate team of engineers which will take care of the TCC (Temperature control curve). If the TCC is optimized then it guarantees the correct temperature distribution of the system. The door operating angle (total rotation angle of the door), air guide and the shape of the system all influence the TCC.

The temperature distribution is also first roughly estimated through the Computational Fluid Dynamics and is later compared with the results obtained from testing (real sample). While optimizing temperature distribution one should also take care that it does not disturb the airflow optimization which was done earlier. Usually the system is very sensitive to changes but it also depends on the system design which influences the sensitivity of a HVAC system.

1.3 Pressure loss

Pressure loss is another aspect which will require a lot of attention at this stage of development. It is one of the major characteristic which will ensure a smooth flow of air inside the HVAC system. Different customers have different specification and to achieve that requires a lot of skill and patience. Pressure loss occurs after Evaporator, Heat exchanger and also throughout the system where there are hurdles in the path of airflow. As already told all these parameters (airflow, temperature and pressure) are interrelated and changing one pa-parameter can affect the others. This might require a number of iteration before we reach an optimal level.

After air has been pressurized in blower section it is allowed to flow naturally to outlets. It can be guided through guides and doors but one has to be careful with pressure loss also. The cross section of the system increases gradually allowing the air to expand and a smooth laminar flow is obtained. Initially the results from the CFD show us the critical areas otherwise called bottle neck situations inside the system. Such bottle necks have to be solved by changing the design which will assure a smooth flow.

Too much pressure loss will result in less amount of air in the outlet and less pressure loss will disturb mass distribution and temperature distribution. The position of the Evaporator and Heat exchanger play a major role in pressure loss. Experiments show that a small change in angle (l°) can also affect the pressure loss greatly and disturbs the flow inside the System.

During development stages the pressure loss will be calculated at various sections and the total pressure loss of the system is calculated at the end. This gives us the information where the optimization can be done and what is the influence of this optimization. The total pressure loss is also calculated once the 3D CAD model is finished and the results are compared. The system can still be optimized based on the total pressure but splitting the system gives us more options and more information for optimization.

1.4 Noise analysis

Noise discomforts the passengers in the cabin and hence has to be kept at internal level. At this stage of development not much attention is given to noise analysis as the actual noise generated by the system can be different from the sample which was produced for concept phase. There is a huge difference in material used to produce a sample system and the final one. So even though not much attention is given to noise reduction during this stage some common areas where noise can occur is identified and taken care.

Any sharp edges or turns can create noise and vibrations can propagate noise from one part of the system to the other. It is always advantageous to avoid sharp corners and design the system as smooth as possible. Several noise reduction methods are adopted later on to bring the noise to a internal level.

Chapter 2: Development phase

The HVAC system is really developed and designed in detail in this period. Till now not much attention was paid towards the material of the parts, and in general the system consists of several plastic parts. Plastic parts are produced using various molding techniques and one of the most common methods is Injection molding. The splitting of HVAC system into several parts takes place during development phase and a parting line is designed which will run through the whole system and dividing the HVAC system in to several parts. The two main factors which influence the parting line are listed below.

• Cost calculation (Increases as number of parts increases)

• Feasibility of producing the part

• Assemblies of parts

The cost of the system is directly proportional to the number of` parts. So defining a parting line requires a lot of skill and experience so that the system can be designed with minimum number of parts. The parts which are divided should also be feasible to produce from injection molding, so again the parting line defines this and a huge attention to be paid towards this area. If the parts are difficult to produce then the cost will increase rapidly as several other techniques has to be implemented to get the part done. There is a special team which works on this area to reduce the total production cost of the HVAC system. Assembling the parts without much difficulty can reduce a lot of time in the assembly line. A complex assembling procedure can lead to various troubles; hence the parting line should make sure that the parts are assembled with not much difficulty. Before going in detail about different parts of the HVAC system it is essential to throw some light on the process used to manufacture plastic parts (injection molding).

2.1 Injection molding

Injection molding is a manufacturing process for producing parts from both thermoplastic and thermostatic plastic materials. Material is fed into a heated barrel, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the mold cavity. After a product is designed, usually by a design engineer, molds are made by a mold maker (or toolmaker) from metal, usually either steel or aluminum, and precision-machined to form the features of the desired part.

Injection molding is the primary method in producing parts, using large machines called injection-molding machines. The process of injection molding is an economical and quick way of producing varieties of plastic materials in a high quality precision manner.

The process of injection molding was first used in the early 1900s for producing plastic tooth-brushes, combs and other small industrial items. Since then, the basic process and principles of injection molding has not changed much. Due to the developments of different kinds of plastics and state-of-the-art injection molding machines, the process of injection molding have become a common method in producing objects for many markets and industries. Although the steps in injection molding may sound simple, the process involved in making these intricate molds are actually complicated. Plastics can be injected into the molds even with low pressure. However, many injection-molding machines use high pressure (30,000 PSI upwards).

A wide variety of plastic injection molding machines makes it possible to produce different kinds of injection molding in the market. Common plastic moldings include insert molding, standard mold injection, resulting-color molding, plastic extrusion, stack and rotary molding, material molding and blow molding.

However, there are custom plastics being produced as well. They range from the commonly used plastic resins to high quality grades of resins for automobiles and other engineering materials. Today, manufacturers are experimenting on other kinds of injection molding grades, such as metals.
To produce different kinds of molded plastics, many types of injection molding machines are used. The standard machine is the horizontal injection molding, which sizes range from hundreds of tons to over 7,500 thousand tons.

Another common machine is the vertical injection molding, which are usually used for insert molding. These kinds of machines are designed with a common cover that is shared by two ejection parts of the mold. This design was developed to save production time. Meaning, while one part of the ejection allows de-molding and loading of the inserts, the other part is producing the next pieces. Regardless of machine type, producing a plastic injection-molded item involves seven basic steps.

• Heat the plastic or other kind of resin using the required heat range for the object being produced.

• Determine the size of the mold by using a reciprocating screw, which will convey the melted plastics into the front of the screw.

• The plastics are injected into the mold, under necessary pressure. This will fill the cavities of the molds.

• Pack the plastics, creating a fuller part inside the molds.

• Let the plastics cool down in the mold using the desired cooling channel.

• Eject the cooled plastics from the molds.

• Pack the product and repeat the process.

These steps may sound simple, but there are many more things involved with an injection molding process. This should give a basic overview over the process involved. Injection-molded parts vary in sizes. It can be as small as an object hardly visible to the naked eye or as huge as the exterior of a car's body panel.

Since these plastic molds are processed in high intensities of heat and pressure, the results are guaranteed to be heavy-duty construction materials. For this reason, any item produced from injection molding machines can be expensive. If you need only a few items, injection molding is not a practical option. This is the reason why the samples are produced using other techniques where the number of pieces required was very less, also large quantities of plastics are needed to pay off the costs and allow for economical finished products. Plastic injection molding may cost anywhere from a few hundred dollars to thousands of dollars, depending on the size of the molds.
Plastic molds are made with high precision. For this reason, new injection molding machines are designed to control temperature and pressure strictly. In addition, plastic materials are made with high-class specifications. Because of these improvements, a single injection-molding machine can produce thousands of the same objects, which are identical in quality, appearance, integrity and performance.

2.2 Different HVAC system Parts

As mentioned earlier the parting line defines the splitting of HVAC into several parts. Each part has its own function and importance. Each system is splitted based on various factors like cost, easy assemblies and easy to manufacture. The parts are fitted to each other with the help of screws, guiding pins and tongue and groove.

Tongue and groove

Tongue and groove refers to strip or plank flooring where each plank has a 'tongue' or convex side and a 'groove' or concave side on the opposite edge. Two or more planks can then be pushed together to provide a secure and smooth joint.

It is a special method to fit mating parts correctly and ensures no leakage of air. This design standard is followed strictly with high tolerance. The standard was established after several tests and analysis. The basic parts are listed as below.

• Air Intake case

• Blower case

• Evaporator case

• Main Distribution case

2.2.1 Air Intake case

As the name itself suggests that this part of the HVAC system helps in air intake. Air can either be taken from outside (Fresh air) or recalculated from inside of the cabin. It depends on the passenger's requirement. Normally these two modes (Fresh mode and recirculation mode) is controlled by two different doors inside the air intake case but in some rare occasion it is also achieved by a single door. A filter is placed inside this case to filter the air from moisture, Dusts and other pollutants. The air after filter is passed on to the blower section.

2.2.2 Blower case

The blower case holds the blower motor with fan and is designed with at most care and perfection, because this design defines the air how, pressure loss and several other important characteristics of a HVAC system. It has a strange 3Dimension shape which is defined by complex calculation and separate teams who are specialized in blower area are assigned to define the shape of the blower. This blower case can be further splitted into blower upper case and lower case and the parting line defines this split. The air is then passed on to evaporator case.

2.2.3 Evaporator case

This case holds the evaporator and is also fitted to blower cases. Based on the size of the HVAC system it can either be integrated to the main distribution case or can be a separate entity. From here the air gets splitted and some How's through the heat exchanger in the main distribution case and the rest bypasses the heat exchanger and goes directly in to the core of the system. So, Main function of this case is to hold the evaporator exactly in its position. This case is also designed in such a way that the condense water from evaporator is drained through a hole called as drain port. Water inside a HVAC system is not good. It can lead to bacterial formation and can stink. So draining the condense water from evaporator is also a major function of this evaporator case.

2.2.4 Main distribution case

The air from evaporator case is passed on to the main distribution case where some stream of air passes through the heat exchanger and the rest directly to the main core where the mixing of air takes place. This again is controlled by doors and based on the passenger requirement the air can be diverted. For example in cold countries mostly people prefer to heat up the air so the doors are operated in such a way that all air coming from evaporator case is allowed to pass through the heat exchanger. This makes the air very hot and if the passenger wishes to reduce the temperature of the

air then some air from evaporator is allowed to bypass the heat exchanger. All these can be achieved with the help of doors insides the HVAC system. In hot countries the operation is vice versa, most or all of the air is allowed to bypass the heat exchanger and is directly fed to the outlet.
The main distribution case delivers the air to the outlet ducts and the ducts transfer it to the cabin. the most cornrow outlets are ’Face’, ’Foot’ and ’Defrost’. In some luxury cars there are additional outlets like ’Side face’, ’Indirect’, etc. Indirect outlet is useful if the passenger does not like the air coming straight on to his /her face. So the air is not allowed to pass through Face outlet but indirect outlet. The cabin gets air conditioned indirectly and hence the name ’Indirect’. So in this development phase the splitting up of the system takes place and the design task are performed as per standard. All major issues are solved during this phase and the HVAC system gets ready to manufacture. There can be so many iterations in the design due to other parts in the vehicle or due to increased noise level etc. As told earlier during this phase more attention to noise reduction is given and efforts are made to keep the noise under control. Another factor which needs attention here is the vibration, which should also be monitored throughout the development phase. During this period several samples (or Prototypes) are produced and tested. During testing various problems crops up which are analyzed and solved.

Chapter 3: Production phase

Once the design is completed during the development period the 3D CAD model is sent to the mold maker to make the mold. This is again a tedious process because the mold maker may request various modifications based on the mold strength and other factors. These modifications cannot be implemented as such because the design department should take care that these modification does not affect the functionality of the part. lf so then the mold maker and design department should come to an agreement and an optimal solution is reached. This can drive lot of other changes in other unaffected part also. During these process the 2D drawings of the part is also created with at most care and precision. Some design mistakes which is not visible in 3D model can be found with 2D drawing check. The important or functionally important dimensions are highly tolerances which might make the mold maker job more difficult and which might increase the cost of the mold. To achieve high precision cost involved is always high due to the complex mechanisms involved in making the mold.

The plastic parts are finally produced and assembled. The HVAC system also consists of parts other than plastic parts like Heat exchanger pipes, Evaporator tubes, blower motor, actuators for driving the doors, wire harness which gives information and power to the actuators, rubber bushes to dampen vibration, and sornetirnes steel brackets to hold the pipes, etc. The fully assembled system will be tested again for noise, temperature distribution and vibration. Other tests like winter tests, summer tests and crash tests are also carried out. Some new problems can crop up during real testing because not all practical issues can be found during the bench testing. Real testing in the automobile can produce a different result and this sometimes can be really tough to solve. lt can also lead to major design change in some parts and a lot of rework is required. As the whole automobile is developed concurrently problems might arise from neighboring part’s design change also.

Every time the design is changed the corresponding drawing is also updated mentioning the reason for the change and the updated 3D model and 2D drawing is finally given to mold maker. Once all the specifications is achieved the HVAC system is given a go for the final SOP (Start of Production). Parallel the design team will prepare some drawings which will help in assembling the parts in the assembly line. Such drawings are called as explosion drawings. These drawings clearly depict which part is assembled to which part and these drawings are so self explanatory that even a layman can assemble the HVAC system with the help of this drawing.

Chapter 4: Conclusion

Air conditioning system in an automobile was once upon a time a luxury but not any more. Any basic model has an air conditioning system installed and has now become a basic amenity.

The complex process involved in the development of a HVAC system is briefed in this report. Starting from the concept phase to production phase the various steps involved has been detailed in this report. From an empty computer screen, the full design of HVAC system is done by the design team with able support from CFD, Testing department and Tooling department (mold maker). Later it is manufactured and assembled in the automobile in the assembly line.