Improving Fuel Consumption While using Air Conditioning in Vehicles

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Abstract: ***Automobile air conditioning systems do not run "free of charge." In fact in the hot parts of the world they can account for up to thirty per cent of fuel consumption. Even in Switzerland, with its temperate climate, the use of air conditioning systems is responsible for about five per cent of total fuel usage, rising to around ten per cent in urban traffic, as shown by a new study undertaken by Emphaon behalf of the Swiss Federal Office forthe Environment (FOEN). Furthermore, two thirds of the additional fuel usage could be saved if air conditioning systems were simply turned off when the air temperature falls below 18 degrees Celsius. Generally, Ac usage does increases the fuel consumption as the compressor is coupled to engine and to run the compressor, engine has to do more work. More work means more power required to do more work which in turn means more fuel required to generate more power. So longer the ac usage, more fuel is consumed. So this paper studies the variation in fuel consumption of an automobile when using air conditioner and gives the idea to reduce fuel consumption while using ac in automobiles.***

1. Issues

The ac usage can affect us in many ways. Some of them are listed here.

- The use of air conditioner increases the fuel consumption in automobiles. (generally upto 10%)
- Ac usage increases more CO2 emissions as it uses more fuel.
- Regular usage and exposing to ac causes minor respiratory problems (also skin dryness, allergies, asthama)

2. Introduction

How a Car AC works?

AC employs the use of a phenomenon which involves the use of pressure to change temperature. We will study this phenomenon further down the line while we study the overall working.

Car AC Parts

There are a lot of parts involved in making the air you share the car with comfortable. The parts needed are stated below.
AC Compressor
AC Condenser
Receiver Dryer
Expansion Valve
Evaporator

All of those work in tandem to push a fluid called refrigerant changing its state of matter to achieve the goal. Before we begin
how they perform such a task we need to understand how they are placed with respect to the car and each other.

Car AC Construction | How and Where they all fit

The AC compressor is the first part that makes the system work. It is situated close to the engine of the car and has a shaft coming into it from the engine. This shaft rotates the pulley in the engine allowing it to start working.
Next comes the AC condenser which is situated in front of the car just like a radiator.

Located after the condenser it is situated in the lower part of the car.

On top of it, all is the Expansion valve as it needs to stay away from the next part which is the evaporator to get correct readings.

The evaporator is present in the car closer to the passenger sometimes as close as the dashboard as it is the final part of the puzzle that is the AC in a car.

Car AC Working | How does it all come together

As we mentioned above it all starts with the engine. The engine is a necessary part of the car AC as it powers it all. The power provided is the input for the AC compressor making it run which is followed by the actions which are given below.

AC Compressor | Gas gains High Pressure and High Temperature

AC compressor as the name makes it obvious compresses the refrigerant which is a gas. This gas is compressed by increasing the pressure which in turns increases the temperature. How does the temperature increase if you change the pressure? It does so because of the energy needed to change increase the pressure is absorbed by the gas thus increasing its temperature. Another possible explanation is that by reducing the area but keeping the same quantity of gas (refrigerant) the less space causes more collisions within the gas thus increasing temperature.

AC Condensor| Liquid- High Pressure and Normal Temperature

The job of the condenser is to convert the gas that AC compressor provided it into liquid. It does so with the help of an AC fan which blows cool air into the condenser. It is to be noted that the condenser does nothing to pressure state. The cooling, however, has an effect on the gas converting it into a liquid which is at a normal temperature.

Receiver Drier | Liquid-High Pressure and Normal Temperature

This step doesn't do anything to the refrigerant but to clean it. The Receiver dryer removes any contaminants from the system which can harm the system and cause it to fail. The liquid passes through after being cleaned. This contaminant is moisture and is cleaned by aproduct called a desiccant. It absorbs moisture if any present thus cleaning the refrigerant.

Expansion Valve | Liquid converts into Low Pressure and Low Temperature

The job of the expansion valve is to convert the high-pressure gas into a low-pressure one. It does so by limiting the flow of the gas making it pass through a small valve to the other side which becomes low pressure at it has more room and fewer molecules.

Now, this refrigerant is at the condition that we need it at and this triggers the final step of the Car AC system.

Evaporator | Liquid converts into Warm and Saturated Low-Pressure Gas

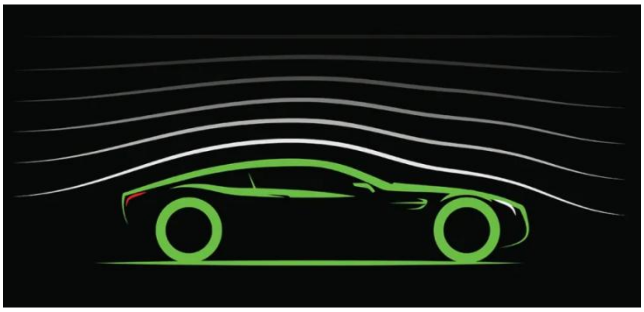
The principle of evaporation is that when the liquid evaporates into a gas it cools the surface it was on. Humans use this principle to cool down by sweating. The same is used by the AC to cool the air. When it expands rapidly the liquid refrigerant converts into a gaseous state. The gaseous state is still in the same temperature and pressure range which changes after it starts to boil as the refrigerant has a low boiling point (-23 degree Celcius). This is performed by a blower pushing air through the evaporator which causes the remaining liquid to evaporate thus cooling the air. This air is then pushed into your AC vents giving you cool and conditioned air.

I'm sure you might have heard something about keeping your windows open at higher speeds and in places like a highway is worse than keeping them close and using an AC. While that is true the conditions were .It is worse are really limited and often not possible to achieve unless you are actively trying to do so. Below we will discuss some reasons for that and how this idea about an open window and the closed window came about.

Open windows might be worse

When a car is designed to be aerodynamic the consideration taken into factor is that the windows will be closed. These are the ideal conditions and the car is designed keeping this in mind. So whathappens when you keep the windows open.The air which was supposed to go through normally now faces two options, to go through unhindered from the outside or go inside the car through the open windows. We will now talk in brief about aerodynamics to help you explain why the air chooses the long way around instead of a shorter one.

Concept of Aerodynamics | A brief explanation



The flow of air in a certain manner according to the shapes it faces is called not aerodynamics rather the study of it. When a car is driven at high speeds it faces an opposite force called air drag. This air drag is detrimental to the fuel economy as it causes the engine to output more power to counter it. At a small time frame, it's not much but over a long time, it causes enough opposing force to make a dent into your fuel economy (pun intended).

Race cars and other high functioning cars are made in such a way that they have minimal air resistance that's why they are edged and are rounded at corners unlike the normal day to day use cars which sometimes look like a box. These designs are not random though they go through rigorous testing in wind tunnel tubes where the study on the airflow is done and then the designs are approved.

So what happens to your fuel mileage when you keep the window open?

Consider this, your car has air in it but it's not as much as outside. When you pull the windows down the air outside tends to come inside the car as its the area with a lower concentration. This air now puts a force on your rear mirror which is opposite to the direction you are moving. All the pieces are coming together now! The car will face more drag the more the speed increases which should be obvious why. This air drag over a long time starts causing a noticeable difference in your economy.

Keeping windows closed with AC Turned On | What will happen to Fuel Mileage?

Could it be that keeping windows closed with AC on is a better option if you are trying to save your fuel? Aerodynamically yes, however, AC uses the engine to power itself which means using fuel. So, a comparison between those two cases need to be done and the results matched to get a better understanding of what will take more fuel. One of the ways it can be done is by comparing the acceleration of a car with windows open and windows closed with AC on. The difference in acceleration timing will let us know which is taking more power from the engine, in turn, causing more fuel drain.

3. Literature Review

A/C can also reduce the fuel economy of advanced vehicles by as much as 35%.

Testing of a 2000 Honda Insight and 2001 Toyota Prius over the SC03 drive cycle show
a 1.9 l/100km increase in fuel consumption due to the operation of the A/C. Test results from more recent hybrid vehicles assessed by the U.S. Department of Energy's Idaho National Laboratory show a similar 1.8 l/100kmincrease in fuel use over the SAE J1634 drive cycle.

The analysis showed that the United States uses approximately 7.0 billion gallons of gasoline every year for air conditioning vehicles, equivalent to 5.5% of domestic light-duty vehicle petroleum consumption. It would take 9.5% of U.S. imported crude oil to produce this much gasoline. We expanded the analysis to cover Europe and Japan in 2003 and more recently investigated India, Mexico City, and Australia.

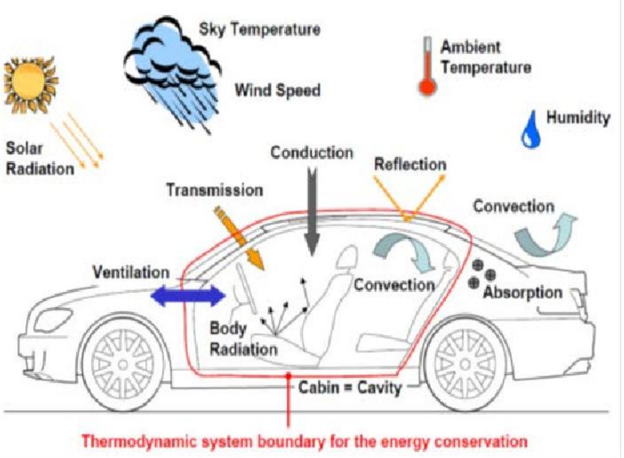
4. Approach to Reduce Mobile Air-Conditioning Fuel Use

1) Solar-Reflective Glazing

When a vehicle is parked, typically 50 to 75% of the thermal energy entering thepassenger compartment is from the transmitted and absorbed solar energy at the glazings. Transmitted energy is primarily absorbed directly by the interior mass.The absorbed energy at the glazing is transferred to the interior by convection and reradiation in the thermal infrared wavelength range. Reflecting the incident solarradiation at the vehicle glazings is a critical step to making significant reductions in thethermal loads. With lower thermal loads, there is potential to reduce the capacity of theA/C system. Sungate is a solar-reflective coating consistingof a double stack of silver and dielectric layers. The vehicle with the solar-reflectiveglazing at all locations had a maximum breath temperature 2.7°C (4.9°F) lower than thebaseline vehicle. Solar-reflective glass would also reduce the steady state thermal loads when the vehicleis being driven with the A/C on. In cold environments, solar-reflective glass would alsoreduce the temperature of the interior compared to traditional glazings.

2) Parked car ventilation

One of the major thermal loads acting on the passenger cabinis due to the solar radiation and this solar radiation fluctuatesdepending on the parking conditions. Parking condition is afactor of the amount of shade, availability of air flow, velocityof air flow, ambient conditions & parked duration. A carparked in natural shade will have relatively less cabin temperatures as compared to the same car parked in scorching sun.This has a significant effect on the thermal load acting on thepassenger cabin.



3) Solar-Reflective Opaque Surface Coatings:

If the exterior vehicle skin temperature is warmer than the interior surfaces, the resultingconduction heat transfer will warm the vehicle interior. This is more likely to occurwhen solar-reflective glazings and/or parked car ventilation are used and the interior iscooler. Using a 2001 Lincoln Navigator, NREL investigated the impact of solarreflective coatings on interior cabin temperatures on a parked vehicle. We used twoidentical vehicles: one baseline and the other modified. A 3M visibly reflecting rooffilm reduced the breath air temperature 12% of the maximum possible temperaturereduction, which is defined as the difference between the baseline vehicle breath airtemperature and ambient. The exterior surfaces were covered with aluminium foil todetermine the largest potential reduction. The breath air temperature was reduced 28%relative to the maximum possible reduction for this case.

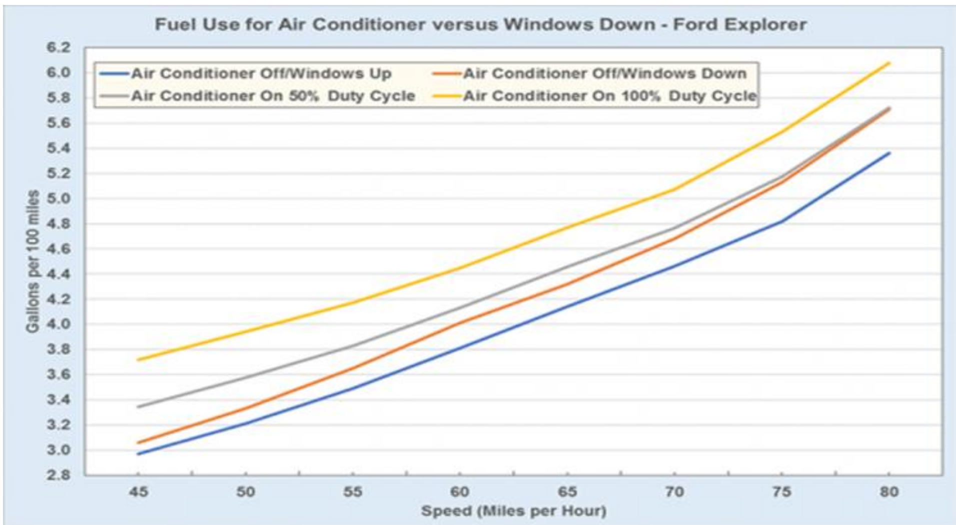
4) Insulation

For reducing the parked car thermal loads in conventional vehicles, insulation was notvery effective. If the thermal loads are reduced with solar-reflective glass or ventilation,insulation may become more important. When the vehicle is in use, the case where theinterior is cooler (A/C on in a warm environment) is common. In this case, insulationwould reduce the thermal loads. Also in winter when the interior is warm and theenvironment is cold, insulation would help to reduce the heating load. In the UnitedStates, cabin heating is not an issue with today's vehicles due to the available wasteheat, but will be a challenge for advanced vehicles and small diesels that have less (orno) available waste heat for cabin warming.

5) Instrument Panel Heat Pipe Cooling

When a vehicle is parked, the instrument panel can absorb a large amount of heat, attaintemperatures approaching 100ºC, and impact driver thermal comfort and cool-downperformance. A mock-up of a passenger compartment and instrument panel was built toassess the impact of cooling the instrument panel with heat pipes. Outdoor test resultsshow that heat pipes cooled the instrument panel by nearly 20°C and the air temperatureby 9°C to 12°C while maintaining a uniform temperature across the instrument panelduring the day. Beside lower surface temperatures, the electronic components in theinstrument panel would benefit from the lower temperatures as well as the reduced heatpickup of the A/C ducts. Barriers to incorporating heat pipes in the instrument panelinclude where to locate of the condensing section outside the cabin and the increasedmass/volume of the heat pipes.

Apart from the above situations,this paper also studies about the fuel consumption of our automobiles under various conditions. The following graphical representation clearly givesan idea about fuel consumption for vehicle use.



6) Recirculated Air

After reducing the peak thermal load and the solar gain, the next most important approach to minimizing air conditioning loads is to reduce the amount of outside air brought in for ventilation. It is more effective to condition recirculated cabin air than to treat very cold or very hot air from outside. As the percentage of recirculated air is increased, the amount of heating or cooling thermal power required is reduced.The thermal power required is a function of theambient temperature, total air flow rate, percent recirculated air, humidity (cooling only), and the heat gain/loss ofthe passenger compartment.

By using advanced heating and cooling techniques and alternative means of de-icing and defogging glazings, highair flow rates become unnecessary for achieving thermal comfort Intelligent sensors may be used to controlthe amount of outdoor air as a function of the number of occupants, ambient conditions, or the contaminantconcentration levels in the passenger compartment.

7) Thermal Comfort

After safety considerations such as defogging and deicing the windows, the next most important function of theclimate control system is to provide comfort to the occupant. Thermal comfort effects driver alertness. In one study , drivers of a moving vehicle missed 50% of test signals at 27°C with reaction times 22% slower than at21°C. The focus should be on the comfort of the occupant and not on achieving a uniform thermal environmentwithin the cabin, regardless of the number of occupants. An advanced climate control systemmight minimizeradiant loads on the occupant, remove moisture from the occupant (such as from a ventilated seat), and include direct heating and cooling of the occupants.

5. Air Efficient Delivery of Conditioned

The goal of efficient delivery is to more effectively deliver climate control to eachoccupant, increasing thermal comfort with little energy cost, thereby reducing fuel use.Automotive seats have potential to improve delivery efficiency because of their largecontact area with and close proximity to the occupants. Standard automotive seatsthermally insulate the occupant and reduce evaporative cooling of sweat, increasing theoccupant/seat contact temperature. Both actively ventilated seats and meshed seats arepotentially low-energy approaches to improving thermal comfort and achieving efficientdelivery of climate control.

A prototype meshed backseat was tested and thermal benefitgained through ventilation could be achieved using low-mass meshed seats whileavoiding energy costs. A lack of thermal control, physical ergonomics, and safety is asignificant challenge for mesh seats.

Waste Heat Utilization –Thermoacoustics

Thermoacoustics is an innovative technology that uses sound to cool the interior of thevehicle or produce electricity. Thermoacoustic effects, which convert heat energy tosound, have been understood for over a hundred years. However, only over the past twodecades has substantial improvements been made to the design of thermoacoustic.

Thermoacoustics has many potential advantages over a conventional A/C system. Ituses waste heat, is reliable and inexpensive, does not entail the use of an extra energyload on the engine, relies on gases that are environmentally benign, has no moving parts (and thus should have a long lifetime), and requires no lubrication. The downside is, because of its low energy density, the device could take up significant volume. If wecan overcome that barrier, it could be one of the cooling technologies in your nextgeneration car.

6. Results and Discussion

- The glasses and surfaces of the automobile should be tinted.(solar reflective glazings, surface coatings, insulations etc,.) (for example, black colour is a good insulator of heat so that it doesn't radiates heat)
- The seat materials/coveringsand ceiling materials should have the property to gain more coolness than heat.
- Pipes from compressor /radiator to outlet should favour very low temperature loss.
- Switching ON/OFF ac automatically using sensors can reduce fuel consumption.
- Going in moderate speeds and avoiding unnecessary loads on the engine can also reduce fuel consumption.
- Low emission capacity vehicles get better fuel savings.
- Generally, keeping 5 degrees Celsius less than the outer temperature in automobiles is optimum for better fuel consumption.

7. Conclusion

Current air conditioning systems reduces the fuel economy ofa conventional vehicle by at least 1.52 km per litre , and has anunacceptable impact on high fuel economy vehicle where themileage was found to be reduced by 2.54 km per litre. Therefore, reduction in the air conditioning load can have a significant benefit especially because of the large number of new carssold each year. Air conditioning systems also cause extra CO_2emissions in and thus fuel consumptions that increase significantly with temperature & solar irradiation.In a country like India where fleet penetration has reachedhigh level, we can save substantial amount in foreign exchange & reduce the dependence on crude oil imports & reduce the extra atmospheric pollution caused due to the use ofautomobile air conditioning systems.

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