Research Article

Role of Liquid Nitrogen in Instant-Cooling System for Automobile Vehicles

Akshay Agrawal[*2], Chandan Kumar[1], Ashutosh Sharma[2], Vipin Kumar Saini[2]

[1]Assistant Professor, Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India. [2] UG Student, Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India.

***Corresponding author's E-mail:** akshayagrawal111@gmail.com

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ABSTRACT

When the vehicle is parked in an open environment especially in summer season, the inner atmosphere gets warmer and results in human discomfort, it finds the solution as air– conditioner is used for reduction of human discomfort but every new technology comes with certain advantages as well as disadvantages therefore due to the limitations of AC that it takes almost 7-8 minutes to cool the inner environment and within this time person feels discomfort. In such a situation, we had invented a system for instant cooling with cryogenic fluid (liquid nitrogen) that can be easily integrated into the present cooling system. The use of liquid nitrogen increases the cooling efficiency of the vehicle as well as reduces the time for cooling to 2-3 minutes, which results in the increment of human comfort.

Keywords: Air – conditioner, Human discomfort, Instant – cooling, Cryogenic fluid.

INTRODUCTION

Basic overview

This paper suggests a new control strategy to diminish the human discomfort in cabin of vehicle due to the boundaries of the air-conditioning system. The difficulty of reducing the energy consumption of AC system is primarily proposed by multi-objective optimization problem which is dignified to achieve the best fuel economy, while assuring the human relief in terms of cabin temperature. [1] The necessity of Instant-Cooling system increased with the limitations followed by Once the engine stops in the idle-stop mode, the AC also stops working. To keep cabin comfort, the engine is revived to work AC cycle, which moderates the fuel saving effects. [2] Some traditional methods are available for this problem as Localized–cooling concentrations on keeping the passenger calm by creating a micro-climate nearby the passenger. Such an arrangement also easily adjusts the number of passengers in the car and permits zonal control. The net effect of the localized cooling is that corresponding comfort can be reached at reduced HVAC energy consumption frequency. [3] Due to the inherent nature of technology, all the solutions are also followed by limitations which increase the necessity of Instant-Cooling system in which cooling effect is obtained by liquid nitrogen, the cryogenic fluid. Cryogenic liquids *(also known as cryogens)* are gases at standard temperatures and pressures. However, at low temperatures, they are in their liquid state. These liquids are enormously cold and have boiling points less than –150°C (- 238°F). Even the vapors and gases liberated from cryogenic liquids are very cold. They often condense the humidity in the air, generating a highly visible fog. Dissimilar cryogens become liquids under altered conditions of temperature and pressure, but all take two properties in common; extremely cold and lesser amounts of liquid can enlarge into very large volumes of gas. Everyone who works by cryogenic liquids must be aware of their threats and know how to work carefully with them.[4]

Software used

Solid works

Solid Works is a solid and utilizes a parametric feature – founded approach to making models and assemblies. The software is printed on Para solid – Kernel. It is a dense modelling computer – aided design (CAD) and Computer aided engineering (CAE) computer database that runs on Microsoft Windows. Parameters denote to constraints whose ethics determine the shape or geometry of the model or assembly. Parameters can be also numeric parameters, such as line sizes or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be related to each other through the use of a relation, which permits them to capture design motive. Building a model in Solid Works generally starts with a 2D sketch (although 3D sketches are accessible for power users). The sketch lies of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. [5] According to the market survey done, the drawings of Blower, cooling device and water tank made in Solid Works.

System Overview

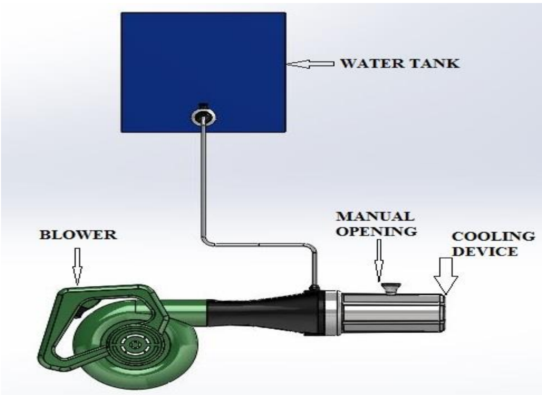

Figure 1: Instant – Cooling System (Drawn itself in Solid Works)

Fig 1 shows the assembly of the Instant-Cooling system. The opening and closing of water from the water tank are controlled by an ON/OFF valve. This water is filled in cooling device up to 60% of its capacity, and liquid N_2 is added to it by a manual opening. Mixture results in the formation of ice water. The sensor is used to measure the temperature of surrounding air. The AC supply is given to the blower which gives the final result required. The testing outcome shows that this system will definitely increase the cooling efficiency by reducing the cooling time required which in turn increases the human comfort, the prime objective.

Main Components

Portable Blower

Blower used in this system is a portable type blower. The unit is used for cleaning or cold shouldering machines and instruments of various industries. The Blower is shown in Fig 2 contain following specification:

- 230 V, 50 Hz AC supply
- 13000 rpm
- 2.3 m^3/min. Flow rate
- 500 W Power
- Easy handling
- Eco friendly
- Heavy duty motor
- Powerful air pressure

Figure 2: Blower (Drawn itself in Solid Works)

No operator fatigue from long use because it's small in size and light in weight. Powerful motor produces great wind pressure and volume to double work efficiency. Double insulated for added safety and convenience.[6]

Cooling Device

A cooling device used in this system is basically a Filter, which is made up of Plastic and has the capacity of 1.2 liters. In prototype, this is main components in which mixture of water and liquid nitrogen takes place. Fig 3 shows the drawing of Aqua Guard filter which is the main cooling device.

Figure 3: Cooling Device (Drawn itself in Solid Works)

Water Tank

Water tank used in the prototype is a simple tank of 5-liter capacity. In the vehicle the size of tank can vary.

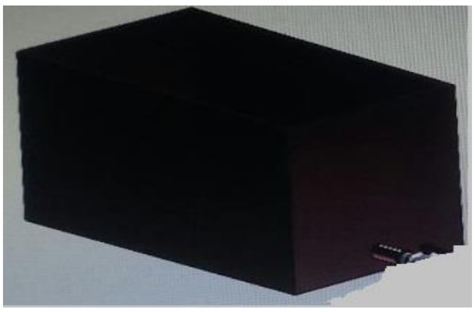

Figure 4: Water tank (Drawn itself in Solid Works)

MATERIALS AND METHODS

Liquid Nitrogen

Liquid nitrogen is nitrogen in a liquid state at a very low temperature. It is a colourless clear liquid with a density of 0.807 g/ml at its boiling point (−195.79 °C (77 K; −320 °F)) and a dielectric constant of 1.43.The temperature of liquid nitrogen can simply be condensed to its freezing point 63 K (−210 °C; −346 °F) by pumping it in a vacuum chamber by a vacuum pump. Liquid nitrogen is produced from the cryogenic distillation of liquefied air or by the liquefaction of clean nitrogen derived from air using pressure swing adsorption. For compress filtered air to high pressure with the help of an air compressor; the high-pressure gas is cooled back to ambient temperature, and permitted to expand to a low pressure. The expanding air cools significantly (the Joule–Thomson effect), and oxygen, nitrogen, and argon are separated by additional stages of expansion and distillation. Using this principle we can easily achieve small-scale production of liquid nitrogen. [7] The electrical features and insulation design power of liquid-nitrogen-impregnated artificial insulation were considered. The impregnation of fluid nitrogen into protection paper can be observed by determining the electrostatic capacitance of the cable or conductor. It was found that the drop of the thickness necessity of the breakdown power of the liquid-nitrogen-impregnated protecting cable was sharper than that of the other cables. It is conceivable to design the insulation strength of the 66 kV cable to be 10 kV/mm. [8]

Liquid nitrogen is inert gas type cryogenic fluid and the properties of it are listed below:

Table 1: Properties of Liquid nitrogen [9]

Properties	Normal boiling point (K)	Liquid density (kg/m^3)	Enthalpy of vaporization (kJ/kg)	Dynamic viscosity of liquid (μNsec/m^2)	Surface tension (mN/m)	Thermal conductivity of liquid (mWm^{-1}K^{-1})	Enthalpy of vaporization (kJ/kg-mole)
Values of liquid N_2	77.3	809	199	152	8.9	135	5565

Fabrication

Fabrication is the manufacturing processes in which include building of metal structures by cutting, bending, and assembling processes. By this a value added process is done that involves the construction of machines and structures through various raw materials. [10] Fabrication of Instant-Cooling system was started with the base frame modulation and this process is continued until the completion of desired structure. The raw materials used are listed below:

- Galvanized iron sheets
- Mild Steel metal strips
- Blower (Portable Blower)
- Aqua guard filter (Cooling device)
- Copper tubes
- Thermocol Sheets
- Plywood
- Small wheels

Figure 5: Fabricated assembly (Actual image after completion of work)

The machines and tools used in the whole fabrication process are as follows:

- MIG Welding
- Spot welding machine
- Power hacksaw
- Grinding machine
- Hand cutter
- Radial drilling machine
- Bench vice

The final assembly after fabrication is shown in Figure 5.

RESULTS AND DISCUSSION

Observations & Calculations

Instant-Cooling system is basically a heat exchanger system in which calculation module includes the estimation of various factor like decrement of temperature with respect to time for a specified volume.

The other factor such as latent heat of glass, the heat of the engine, the window should be closed, other heat conduction sources.

There are certain parameters which are taken into consideration for the estimation of Effectiveness which are as follows:

Maximum speed of blower (N_{max}) = 13000 rpm

$N_{min.}$ = Minimum speed of blower = 450 rpm

Q_i = Initial flow rate from blower = 2.3 m^3/min.

Q_f = Final flow rate from cooling device = 0.0795m^3/min.

Temperature drop per second is 0.2°C for a volume of .226 m^3.

Standardization

All calculation is repeated on the standard parameter like 1 m^3 of volume and decrement in temperature should be 1°C which leads to the determination of the time of operation which is calculated.

Standard time of operation (t) =0.464 ms.

Testing and Outcome

The testing was done to obtain the cooling air temperature from the system which is measured by the temperature sensor and testing procedure consists of following steps:

Vehicle temperature testing after and before AC on.

(1) Flow rate from 10 copper tubes used in cooling device is $Q_{final} = 0.00795 m^3/min$.

(2) Heat transfer rate is Q = 1.675 W.

(3) Standard time of operation for the decrement of temperature by 1°C for a standard volume of 1 m^3 = 0.464ms

The testing outcome is shown in figure 6 below:

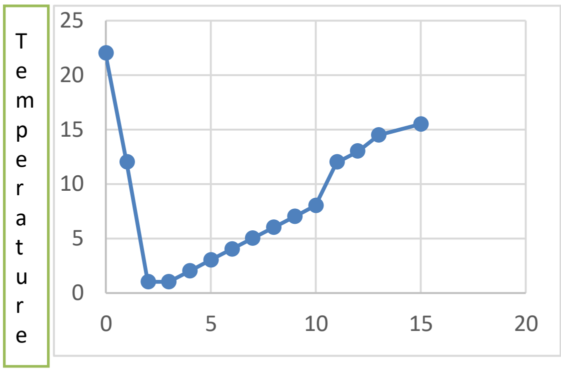

Figure 6: Result outcome graph between Time and Temperature

SUMMARY AND CONCLUSION

This system can be used to provide a cool temperature medium inside of any automobile vehicle; where nitrogen is used as cooling agents which lead to the decrement of temperature at rate of 0.2°C/s for a volume of 0.226m^3.

The other factors can be drawn as:

1) Flow rate from 10 copper tubes used in the cooling device is $Q_{final} = 0.00795 m^3/min$.
2) Heat transfer rate is Q = 1.675 W.
3) Standard time of operation for decrement of temperature by 1°C for standard volume of 1 m^3 = 0.464ms

Nomenclature:

AC	Air-Conditioning
CAD	Computer aided design
CAE	Computer aided engineering
Fig	Figure
g	Gram
HVAC	Heating ventilation and air-conditioning
Hz	Hertz
K	Kelvin
kg	Kilogram
KJ	Kilo Joule
kV	Kilo voltage
m	Meter
MIG	Metal inert gas
mm	Millimeter
ml	Milliliter
ms	Millisecond
N	Newton
N_2	Nitrogen
$N_{max.}$	Maximum Speed
$N_{min.}$	Minimum Speed
Q	Flow rate
rpm	Revolution per minute
s	Second
t	Time
V	Voltage
W	Watt
2D	Two dimension
3D	Three dimension
%	Percentage
°C	Degree Celsius
°F	Degree Fahrenheit
µ	Micro

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