Comfort Suits for Racers

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1. Introduction

Imagine a hot summer Kansas day, when the temperature is well over 38°C, the humidity is high, and one places a plastic bag over the body. This is exactly what a race car driver experiences when driving on the track. Cooling suits have been used in the past to help cool down the driver to make the driver more comfortable and also to help decrease the possibility of dehydration, heat exhaustion, heat stroke and fatigue. These conditions can jeopardize the drivers' health. Not only jeopardize the driver physically and mentally, but can also slow reaction times and cause the driver to lose the race due to fatigue and lack of concentration.

A formula car can get to 50°C inside the cockpit, which is very hot, considering these drivers are required to wear fire proof gear from head to toe. Since the driver is exposed to these extreme conditions, a cooling suit has been used to help reduce the possibility of overheating. A cooling suit is a garment with small diameter tubes running all over the garment which carries either water or refrigerant over the body. The following is a list of the problems with current cooling systems: extra components (cooler, bulky hoses, pump), two separate systems, one for the body and one for the head (means extra parts) and bulky and large components, adds weight to the formula car, and many drivers dislike it because there is too much work to use and assemble. The purpose of this design is to develop a cooling suit without the extra components, one system for the body and head, light weight, more efficient and is easy to put on and remove, making it easier on the driver, while maintaining the existing safety requirements.

2. Experiment, Results, Discussion, and Significance

Due to the conditions of a formula style race car and the cooling needs of the driver, it would be best to use a thermosyphon system. A Thermosyphon is a two-phase passive loop that uses liquid as a working fluid for indirect and direct cooling. Heat from the components enters the evaporator in which two-phase exists (liquid and vapor), the vapor rises in the vapor line to the condenser. The condenser dissipates the heat and returns the fluid back down the liquid line into the evaporator inlet. A Thermosyphon is a continuous cooling system using natural convection. The natural convection works because as the fluid is heated up it will begin to enter the vapor state. As more heat is added the bubbles increase in size and begin to rise (since vapor is less dense than liquid) up the tube into the condenser. Once the vapor goes back to the liquid state it falls back to the evaporator where the cycle repeats.

In the design of a thermosyphon a coolant must be chosen. Water would seem to be a natural choice because of its inexpensiveness and its high latent heats. The only problem with water in a system like this is the high boiling temperature. At atmospheric pressure water boils at 100°C [1]. To bring the boiling temperature of water down to a value that is close to the skin surface temperature, which is approximately 35°C, the system must be vacuumed to approximately 5.6 kPa before use [2]. The amount of heat removed by our thermosyphon system will be what defines our system. The rate of heat removal from any refrigeration system depends on the latent heat of the fluid used and the heat flux of the source combined with the surface area covered by the thermosyphon [3]. Due to the fact that our evaporator is the human body, there is no option of improving on the evaporator. However, what can be done is devise a way to increase the surface area covered by the cooling system to decrease the flow rate of the fluid while maintaining the human body temperature. As stated previously, the amount of heat removal desired is 475W. We will achieve this with water vacuumed to 5.6 kPa. The latent heat of water at this pressure is 2418.6 kJ/kg, and with this value a flow rate can be found [2]. The flow rate needed is as follows in Equation (1).

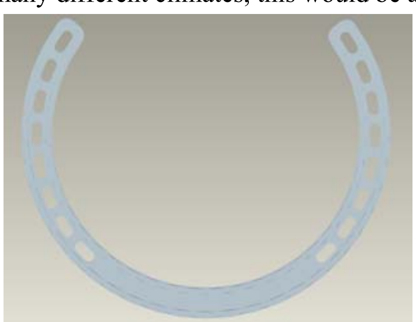
$$\dot{W} = Q \cdot h_{fg} \Rightarrow 475\, J/s = Q \cdot 2418.6\, kJ/kg \Rightarrow Q = .1963\, g/\sec \Rightarrow$$
$$.1963\, g/\sec * 3600\, \sec/hr * 1.006\, m^3/kg * 1\, kg/1000 g * 1000\, L/1m^3 = .7109 L/hr \quad \text{(1) Flow Rate Equation}$$

It is apparent from the calculations that we must achieve a flow rate of .7109L/hour from our thermosyphon system, or a pump will be required.

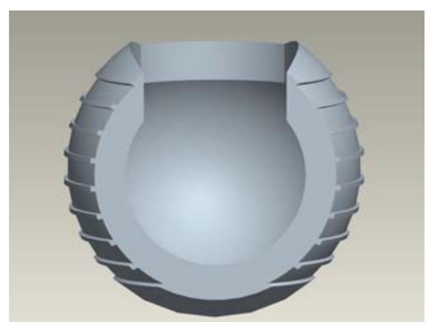
The thermosyphon design to be used for the cooling suit will consist of the body as the evaporator, the helmet as the condenser and tubing that is incorporated into the suit and helmet. The tubing will flow from mid-thigh across the chest and back, where it will terminate into a bracket. The bracket will attach to a specially designed helmet containing cooling tubes. The tubes will run from the bottom of one side, across the top to the bottom of the other side, into another bracket. The fluid will then flow back down to complete the cycle of flow for the system. Water will be used as the medium to maximize heat removal from the body because of its high heat capacity. Pulling the system down to 0.07 bar will keep the body temperature between 36-38^{o}C. This will be an operating system that will keep the driver comfortable for the duration of the race. Assuming the driver looses 475 W of energy during a race, a mass flow rate of 2.5e-5 (kg/s) is needed to absorb the 475 W of energy and change from a liquid state to a vapor state. Where the mass flow rate is lower than expected, increasing the pressure to obtain a higher mass flow rate will not keep the body temperature within its ideal range.

The selection of tubing to carry the water from the suit to the helmet and back down the suit was based on flexibility, conduction coefficient, cost and availability. PVC will be the selected tubing. The PVC tubing has one of the highest thermal conduction coefficients (1.7 W/mK) compared to tubing, inexpensive, easy to obtain and has an oval cross section to allow a larger surface area to be in contact with the body when compared to circular tubing. Connecting the suit to the helmet to transmit the liquid vapor was a difficult task. A two-bracket system was designed. One bracket provides the termination for the tubing that runs through the suit. This bracket then attaches to a mirror image of itself that is permanently fixed in the helmet (Figure 1). This setup provides a means to disconnect the helmet so the driver is able to maneuver around the event before and after the race with the suit on and the helmet off. The material chosen for the bracket should be Cordierite ($2MgO\ 2Al_2O_3\ 5SiO_2$). This material has a thermal conductivity of 1.80 (W/m*k), and would reduce the thermal interaction between with the tubing.

The helmet design will consist of a permanently attached bracket that will attach to the bracket terminating the tubing of the suit. Aluminum tubing will then be molded inside the helmet to carry the liquid from one side to the other. The aluminum tubing would be fit against the outside shell of the helmet with the padding underneath to give maximum protection to the drivers head (Figure 2). Initial considerations for the material of the helmet was a filament wound epoxy shell with a thermal conductivity of approximately 0.3024 W/mK. With a conduction coefficient for aluminum of 177 W/mK, this leads to a heat loss of 234 W of energy. If the driver puts out 475 W of energy, then this would be a minimum requirement for energy lost in the helmet. Changing the material of the helmet will increase or decrease the heat lost in the helmet which means that several different helmets could be manufactured, so depending on the conditions of the race different helmets could be used. Because the formula race is held in many different climates, this would be an ideal situation.



Bracket Permanently Fixed (Figure 1)



Drivers helmet (Figure 2)

3. Conclusions

From the design objectives this design has developed a cooling suit without the bulky extra components, one system for the body and head, light weight, more efficient to put on and remove while maintaining the existing safety requirements. This development makes it easier on the driver when using this cooling system. Even though it is not required that drivers have a cooling suit it is hoped that this design will encourage drivers that having a cooling system is not so bad when taking into consideration the drivers perspective.

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[2] Moran, Michael J. and Howard N. Shapiro Fundamentals of Engineering Thermodynamics: 5th Edition. 2004. John Wiley & Sons. Von Hoffman Corporation. United States. p. 760
[3] ASHRAE Handbook. American Society of Heating, Refrigerating and Air-Conditioning Engineers. 11/4/2005. http://www.ashrae.org/