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Research Paper on Thermal Comfort Analysis of Tractor Considering Multi-Parameters

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Abstract

The main functions of a vehicle cabin are to provide a comfortable and relaxing environment for its operator and to protect them from vibrations, noise, and other adverse influences. Modern agricultural tractor cabins are complicated, high-efficiency systems, and the goal of their development is to reduce their negative influence on the environment. Main factors for thermal comfort are the dry-bulb temperature, relative humidity, surrounding surface temperature, and air motion. A tractor cabin was created with help of CREO software. Material selected for the cabin is steel. Software used for meshing and analysis of tractor cabin is STAR CCM+. Parameters considered for this analysis are 1) Air flow rate, 2) Windshield coating configurations. We created thermocouple points on different body parts of manikin. Coating used on windshield is tinting. Location of Ac vents are on above the windshield, On the dashboard and under the dashboard. Main goals are achieving higher fueleconomy and lower emissions. After the completion of general setting, pre-processing, and post-processing procedure. We got the average temperature value 26.4°C for validation and we tried different airflow rates, their average temperatures are following in summer: 22.63°C and in winter: 22.65°C.

Keywords: Dry-bulb temperature, relative humidity, air motion, thermal comfort, tractor cabin

INTRODUCTION

One of the most critical and important concerns about human efficiency in daily life is thermal comfort. Studies show that generally, farmers work between 1 and 8 hours inside tractor every day. Research suggests that establishing thermal comfort at a reasonable cost is among the most critical factors for modern vehicle design. Farmers have to work in harsh conditions such as rain, heat & dust. So closed cab is protected driver from heat, noise, and air pollution.Thermal comfort is the condition where our mind is feeling satisfying with the surrounding environment. Without proper comfort humans not focusing on his work. While considering thermal comfort you should focus on relative humidity, dry-bulb temperature, surrounding temperature. In the project we have done analysis using twoparameters different air flow rates and windshield coating which is tinting [1–5].

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AFFECTING FACTORS

Thermal comfort inside the agriculture tractor cab is affected by few factors. Every changing surrounding atmosphere of tractor makes achieving thermal comfort even more challenging than previous.

Several measurable factors for determining thermal comfort are air temperature, air velocity and relative humidity. Whereas personal activity level and clothing insulation are considered as human experience factors. The operator inside cabin partially receives heat flux transmitted through windshield andwindows of tractor [6–10].

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Some Measurable Factors

1. *Air temperature:* In simple words it isthe temperature of the environmentaround human body in cabin. Air temperature should be in range of 23°C to 26°C to fulfill the thermal comfort requirements. Air temperature inside vehicle also depends on factors like, dimensions of vehicle cabin, fabricinterior inside cabin, tinted area. An outside air temperature of 32°C can cause an inside temperature about to 50°C in summer.
2. *Relative humidity:* It is the amount ofwater present in the air relative to the water vapor quantity that the air could hold. Only when RH falls outside of the 30–70 percent range does thermal comfort suffer. It prevents evaporation from human skin above 70%, causing pain to the vehicle operator. Below 30% RH inside vehicle creates a dry sensationamong operator resulting adverse effects.
3. *Mean radiant temperature:* It is the consistent temperature of a virtual dark compound which would result in same heat loss by heat emission from the person as the actual cage. The mean radiant temperature can be calculated if the following terms are known-the surrounding surface around the vehicle operator or driver, body temperature of the operator and for every surface aroundoperator or driver inside cabin.

PARAMETERS

Windshield Coating Configurations

Heating and cooling systems have energy costs and window films can be used to increase insulation. They can provide thermal comfort and are one of the most cost-competitive and environmentally friendly improvements, especially in hot and mixed climates. There are many types of windshield coatings. Such as glazing, tinting, nano coating, low emissivity coating. Tinting is a simple process where a thin, transparent sheet of film is applied on a vehicle's window to reduce radiation andheat comes from the sun. Tinting film is effective at blocking sunlight and effective to reducing glare from headlights and other light sources on the road, but it is somewhat prone to discoloration over time. Thickness ranging from 0.0025 to 0.0102 cm.

Air Flow Rates

The volume of air that passes through a fan or duct over a unit of time the speed of the air. Flow rate is the actual volume of fluid that passes a given point on given pressure and temperature. Multiplying air velocity bythe area of a channel allows you to determinethe air volume flowing past in the duct per unit of time. Calculated air flow rate using different velocities. We used 0.5 to 1.5 m/s in airflow rates.

MODELING

Geometry

The tractor cabin was designed in CREO after finding out dimensions and then importeddesign in STAR CCM+. Several meshes with tetrahedral elements were tested to check the solution. A

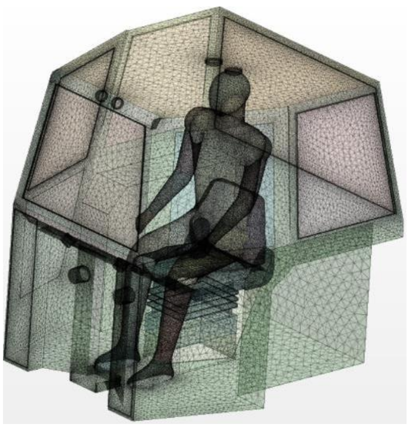

Figure 1. Meshed geometry.

mannequin was installed in the operator's seat to analyze the flow changes under the different conditions in which the operator boarded. The total volume of the tractor cabin model was approximately 2.1 m^3 and tetrahedral core meshes, 1,72,425 interior faces, 86,236 vertices were created to simulate the complex flow inside cabin shown in Figure 1.

Sensing Points

Seven thermocouples were used in the test which is on torso, left and right foot, head and back side of head, left and right hand. The detailed locations of the thermocouples are shown in Figure 2 Thermocouples were attached to the body to check changes in body temperatures.

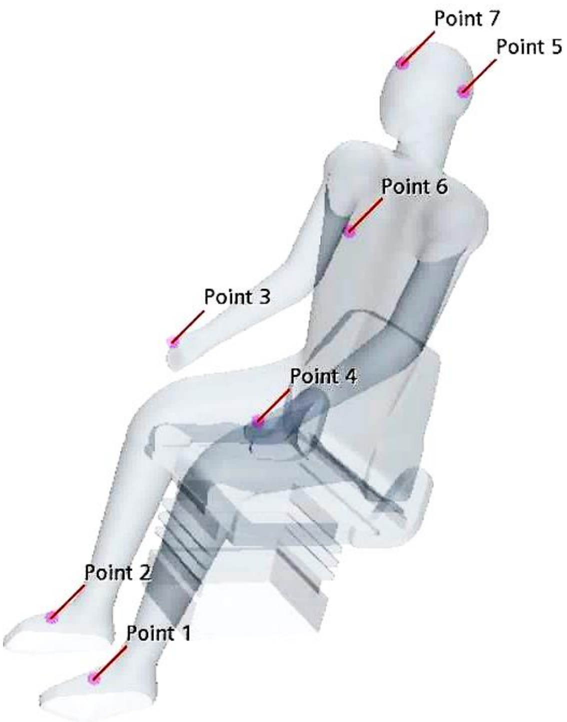

Figure 2. Sensing points.

RESULTS AND DISCUSSIONS

Case 1: Summer Conditions

The temperature measurement analysis was performed in STAR CCM+ with temperature and humidity control. The ambient temperature was set as 32°C, and humidity was set as 35%. Solar heat was simulated by supplying a heat of 5502 W/m^2 for tinted glass and 5760 W/m^2, which is the solar radiation condition, from the windshield. In addition, a manikin was installed in the cabin to test the effect of thehuman body on flow.

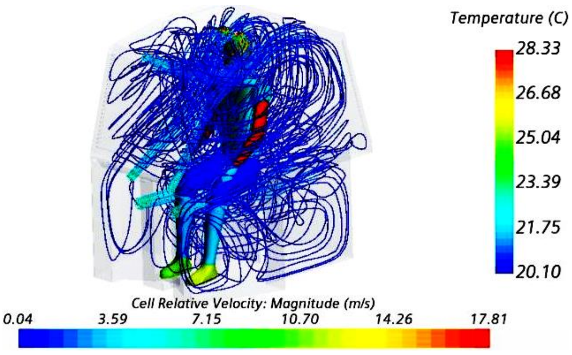

Figure 3. Without tinted glass in summer.

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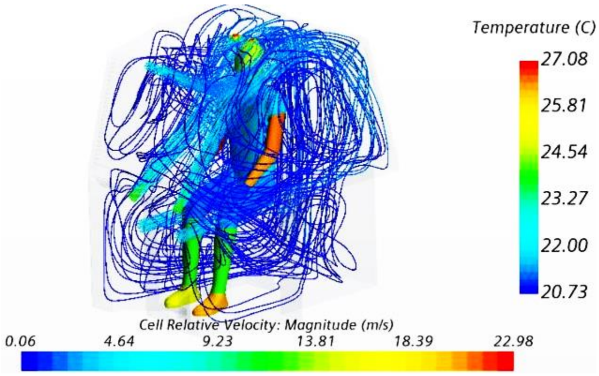

Figure 4. Tinted glass in summer.

Average body temperature got with tintedglass was 22.63°C and average temperature gets with tinted glass was 25.01°C shown in Figures 3 and 4.

Case 2: Winter Conditions

The ambient temperature was set as 28°C, andhumidity was set as 35%. Solar heat was simulated by supplying a heat of 3943.3 W/m^{2}for tinted glass and 4160 W/m^2, which is the solar radiation condition, from the windshield shown in Figures 5 and 6.

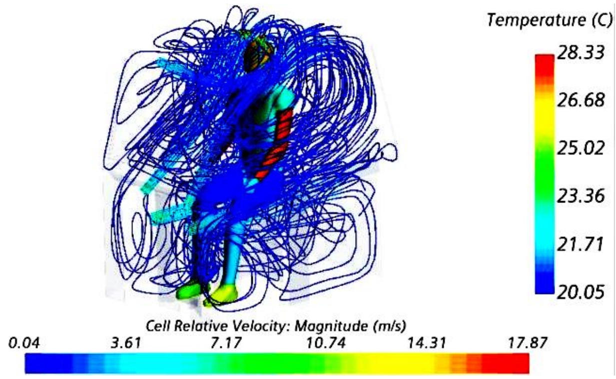

Figure 5. Without tinted glass in winter.

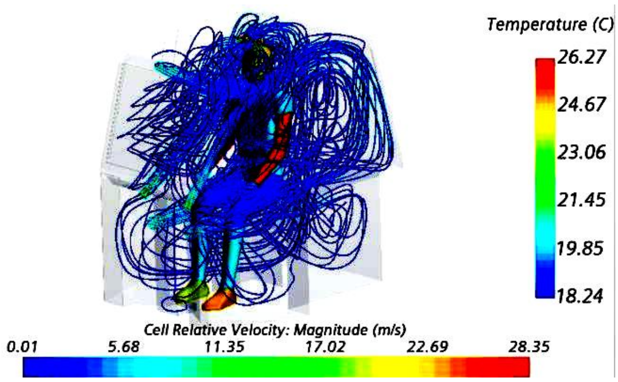

Figure 6. Tinted glass in winter.

Average body temperature got with tintedglass was 22.65°C, and average temperaturegets with tinted glass was 25°C.

RESULTS

Tables 1 and 2 show the temperature at sensing points, respectively.

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Table 1. Temperature at sensing points (summer condition).

Sensing points	Summer conditions	
	Without tinting	*With tinting*
P1	25.79	24.89
P2	24.96	23.63
P3	22.85	20.33
P4	22.75	19.63
P5	27.89	24.79
P6	22.88	20.39
P7	27.89	24.79
Average	25.01	22.63

Table 2. Temperature at sensing points (winter condition).

Sensing points	Winter conditions	
	Without tinting	*With tinting*
P1	25.70	24.89
P2	24.97	23.73
P3	22.04	20.33
P4	22.74	19.63
P5	27.25	24.79
P6	22.91	20.39
P7	27.25	24.79
Average	25	22.65

CONCLUSION

- Glass in modern tractors takesapproximately 60% of the total cab surface area.
- If the temperature difference between theair and the body surface is higher than heat loss from the body is higher.
- The average temperature of manikin in Summer conditions with tinted glass is 22.63°C and non-tinted glass is 25.01°C.
- The average temperature of manikin in winter conditions with tinted glass is 22.65°C and non-tinted glass is 25°C.
- There is a difference of about 16% drop in the temperature values we have achieved as compared to the previous research.
- The driver feels comfortable so he can work more than 8 hours in any condition.

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