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Experimental Investigation of Roof-Top Heat Resistant Cover for Sedan Vehicle

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Abstract: Nowadays, the earth's surface receives UV radiation directly due to ozone layer depletion, which raises temperatures and heat at the equator and the tropic of cancer, regions like the Indian sub-continent. It consequently hampers the steady vehicles by damaging their working components. Therefore, this investigation focuses on the selection of roof-top heat-resistant covers for sedan cars in the Indian sub-continent. Four different types of heat-resistant covers viz. Taffeta material, Fibreglass cloth, Silicone rubber sheet, and Double-sided silicone-coated fibreglass cloth (DSFC) are studied in correlation with the external and internal temperatures with different time intervals such as 10min, 30min, 60min, and 180min respectively. The internal and external temperatures were measured using a temperature sensor. In conclusion, the heat-resistant roof-top has significance in resisting heat. The overall results showed that the double-sided silicone-coated fibreglass cloth was found to be more effective than other materials.
Keywords: Temperature, Silicone rubber, Fiberglass cloth, Heat-resistant material, Sedan vehicles, Reflectivity

I. INTRODUCTION

Due to the advancement in technology, people tend to use more automatic systems these days. Thus, engineers try to change manual systems to automatic systems to make people's lives easier. In this, vehicles have become a primary factor in our lifestyle. It is one the best means of transportation daily. In consideration of this, parking cars is a major concern. There is no guarantee that the shed will be available to provide shade and security for the parking of each vehicle. Most of the time cars are in open parking which is prone to direct sunlight. Every decade that has passed by has seen a rise in the temperature during summers by about 4° Celsius. That has also affected the driving conditions and maintenance of car components such as tires, AC, wipers, coolant, engine temperature, cabin temperature, etc.

To protect vehicles from the direct impact of sunlight, various heat-resistant materials are studied. Wherein, the lightweight taffeta material car cover fabric employs a patented encapsulation process, originally developed for high-performance outdoor sportswear. The result is a car cover fabric that delivers maximum paint protection from the elements without the bulk, making it easier to handle and store. The high-strength, polyester base fabric is naturally UV-resistant. To make the taffeta material car cover more resistant to the rigours of sun exposure, UV inhibitors have been added to the polymers to help slow down naturally occurring degradation. Glass fibres and fibreglass cloth consist of bulk, chopped fibres, or continuous strands of glass. Glass fibres and fibreglass cloth is used in reinforced plastics and composites as well as other specialized electrical and thermal applications. Silicon Rubber consists of elastomers containing silicon, carbon, hydrogen, and oxygen in the form of polymer. It remains flexible at low temperatures of -40°C and has good heat-resistant properties. Silicone, on the fibreglass cloth on one side or double sides, the fibre cloth develops new properties to provide higher resistance against ozone, oxygen, light, heat, temperature, etc. The material can be manufactured in a roll or tape as required.

Fibreglass cloth is a fabric, which is very lightweight, have high strength, a high level of abrasion and chemical resistance, and excellent dimensional stability. This product range includes cloths, tapes, sleeving, and rope in knit, braided and woven configurations. The fibreglass cloth material and paper provide a continuous operating temperature of 1000°F. It is high-temperature, heat, and flame resistant, and works as a thermally insulating material. It is used to protect equipment, wires, cables, hoses, tubing, and pipes. This high temperature-resistant fabric provides thermal insulation and personnel protection. They also protect acids, alkalis, bleaches, and solvents. They are also highly flexible and comfortable.

However, day by day the depletion of the ozone layer is growing which results in the UV rays from the sun directly entering the atmosphere. Due to this, there is a sudden rise in the atmospheric temperature. The increase in temperature adversely affects sedan vehicles at stationary positions. This leads to various problems for the vehicle and the passengers inside the vehicle. Various systems such as tinted glasses, heat shields, sun shade curtains, Sunshades, reflective paint, etc. were developed to overcome this issue but they did not perform up to the mark, main factor for their failure was they all were very costly.

This investigation focuses to find out an appropriate solution for the vehicle to overcome the heating issue and provide it at a lower cost to the customer by selecting the excellent heat-resistant roof-top material.

II. LITERATURE

Fibreglass cloth is a fabric, very lightweight, have high strength, a high level of abrasion, and chemical resistance, and excellent dimensional stability. This product range includes cloth, tape, sleeping, and rope in knit, braided and woven configurations.
The fibreglass cloth's mat and paper provide a continuous operating temperature of 1000°F.

1) It is high temperature, heat, and flame resistant as well as working as thermal insulting.
2) High temperature, heat, and flame-resistant thermal insulating fibreglass fabric fabricated from high quality, that will not burn and will withstand continuous exposure to a temperature of 1000°F/520°C. It is used to protect equipment, wires, cables, hoses, tubing, and pipes. This high-temperature fabric provides thermal insulation and personnel protection.
3) These high-temperature fabrics are often used to fabricate insulted equipment covers, welding curtains, and blankets.
4) These materials resist more acids and alkalis and are unaffected by most bleaches and solvents. It is highly flexible and comfortable.

III. METHODS AND MATERIALS

This investigation uses four types of heat-resistant materials for roof-top sedan vehicles. The base layer of taffeta material and the other three materials viz. Fibreglass cloth, Silicone rubber, and DSFC were used to perform experiments for the internal and external temperatures of the vehicle at different time intervals. The time intervals were 10 minutes, 30 minutes, 60 minutes, and 180 minutes respectively. The test was carried out under direct sunlight in the month of May. The ambient temperatures were observed about 40℃ - 41℃ during the tests. Figure 1 shows the taffeta material used in the experiments, whereas table 1 represents the physical properties of taffeta material. Figures 2, 3, 4 and tables 2, 3, and 4 show photographs of fibreglass cloth, silicone rubber sheet, and double-sided silicone-coated fibreglass cloth and their physical properties respectively. A sedan vehicle is considered for this experimental investigation as it has the maximum windshield surface area.

Table 1 Dimensions of a sedan vehicle [11]

Sr. No.	Parameters	Corresponding Values
1	Length	4.3m
2	Width	1.7m

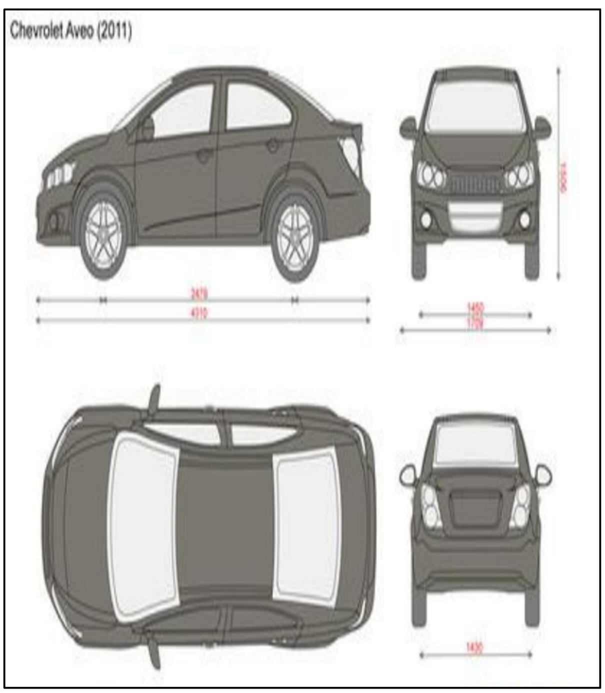


Fig 1 Dimension of a sedan vehicle [11]

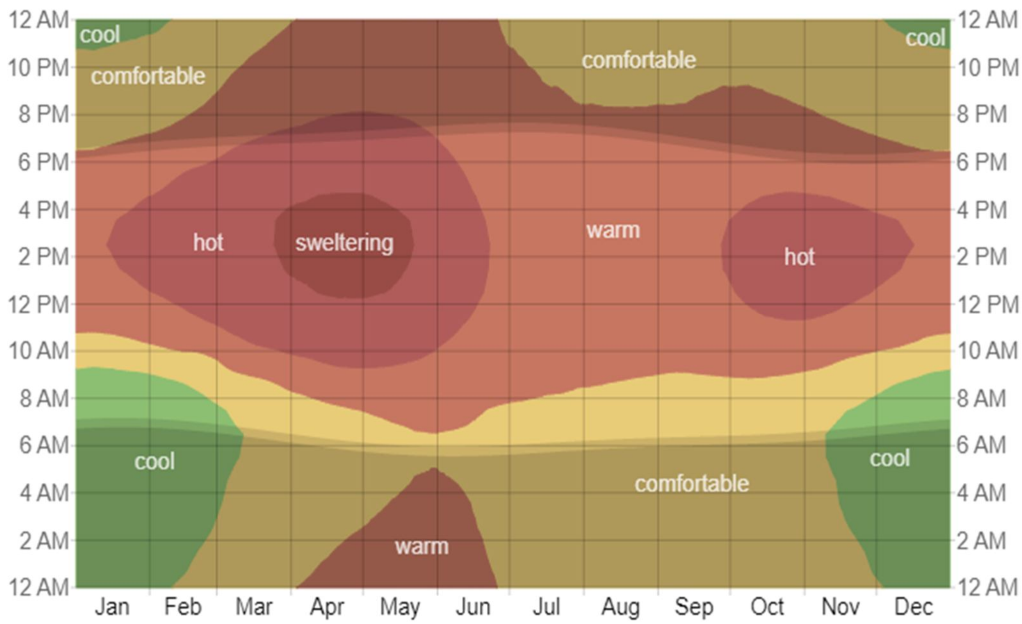


Fig 2 Temperature contour plot month-wise of Pune region (Indian sub-continent) [12]

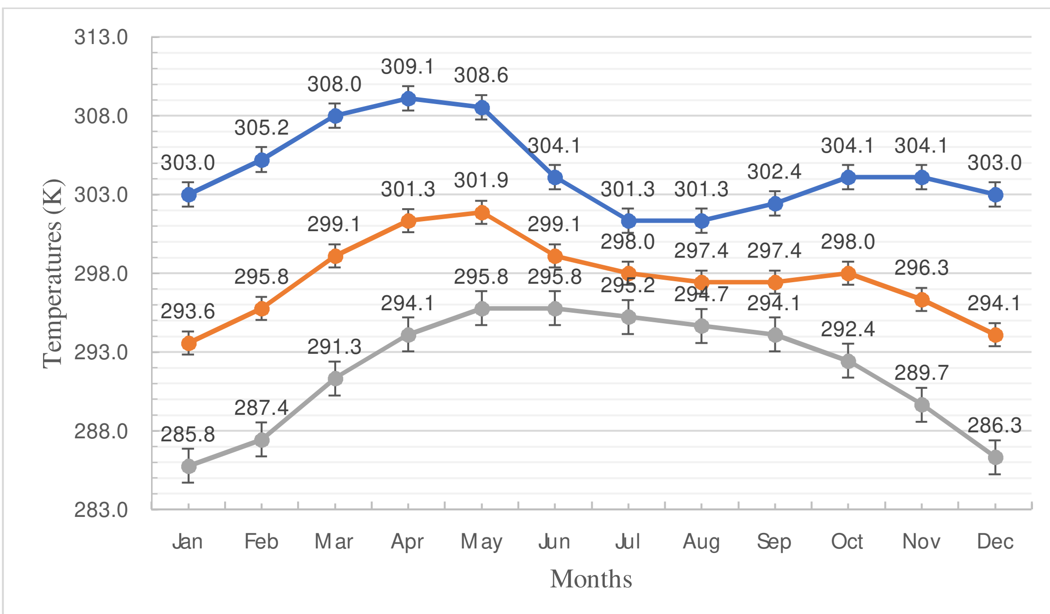
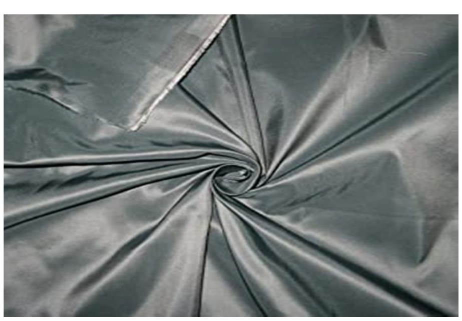
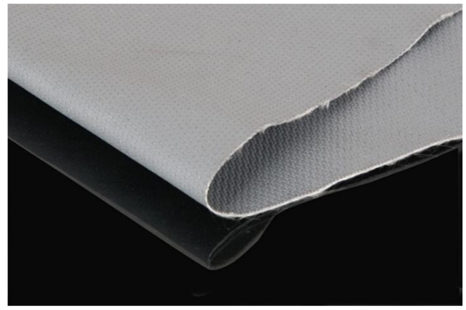


Fig 3 Temperature changes month-wise in Indian sub-continent


(a)


(b)

(c)



(d)

Fig 4 (a)Taffeta material, (b)Fiberglass cloth, (c)Silicon rubber sheet, (d)Double sided silicon coated fibreglass cloth (DSFC)

Table 2 Physical properties of (a)Taffeta material, (b)Fiberglass cloth, (c)Silicon rubber sheet, (d)DSFC

Sr. No.	Materials	Properties			
		Lifespan (years)	Standing Temperature (°C)	Thermal Resistance (K.m/W)	Reflectivity
1	Taffeta	2-3	15 to 50	20	0.20
2	Fibreglass cloth	8-9	-30 to 230	7.14	0.51
3	Silicon rubber sheet	7-8	-40 to 200	4.76	1.39
4	DSFC	10-11	-60 to 250	2.85	1.58

A digital thermometer (make: Mextech PM-10) is a portable temperature-sensing instrument, that has a permanent probe, and a convenient digital display. The digital thermometer works on resistance temperature detectors (RTD), thermocouples, and thermistors sensors. It has a temperature range of -50°C to +110°C with an accuracy of ±1°C. Whereas, it has a usage range of -10°C to +50°C with a usage humidity of 5% to 80%.

A sedan vehicle is placed under direct sunlight. To measure both external and internal temperatures, a digital thermometer was used. After completion of the specific time, both temperatures would be measured for a material. The same procedure was carried out for all different types of materials considered for this research. The materials were Taffeta material, Fibreglass cloth, DSFC, and Silicon rubber sheet.

Fig 5 Sedan vehicle covered with heat-resistant roof-top taffeta material

Fig 6 Sedan vehicle covered with heat-resistant roof-top double-sided silicone-coated fibreglass cloth

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IV. RESULTS AND DISCUSSION

A. Internal and External temperature

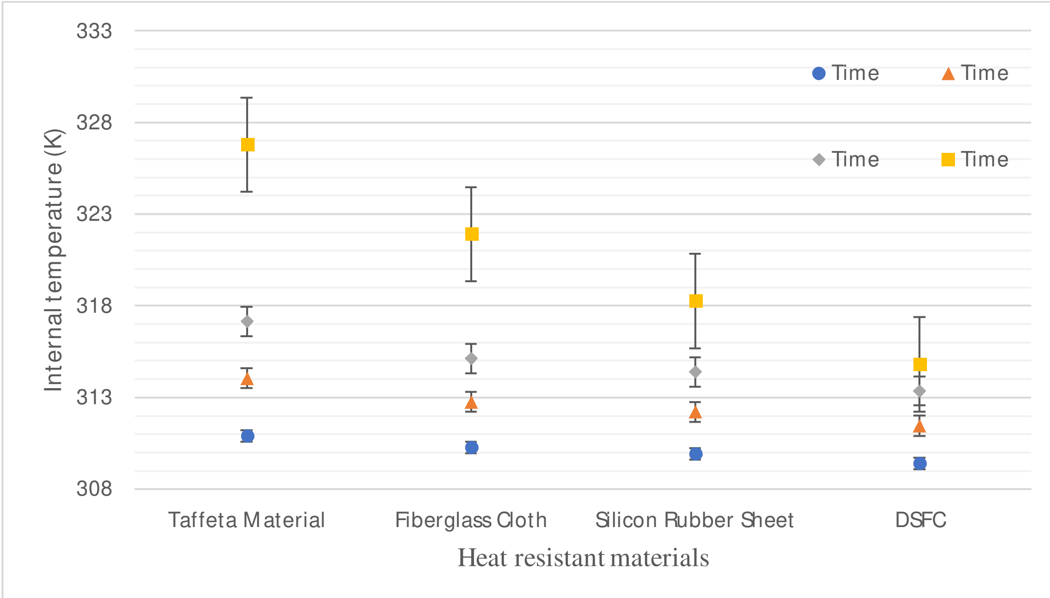

Fig 7 Internal temperature observed in vehicle cabin by heat-resistant materials

While the car is parked during day hours, the car interior absorbs the heat produced by the sun. This effect is a scientific phenomenon that occurs because of the thermal radiation caused by solar energy and it is called the greenhouse effect. As the thermal radiation travels from one medium to another in the car window, it changes its waveform. Thus, the wavelength gets shorter whereby it cannot pass through the glass to go back outside the car, which causes the heat to be trapped inside. At this point, the interior of the car experiences a constant increase in temperature, adding that the interior lacks air flow circulation as the car windows are closed. The more time the car is exposed to the sun while there is no air flow circulation, the higher the temperature gets trapped inside the car.

Silicon has a low thermal conductivity, which means that it transfers heat at a low rate compared to other materials. This low thermal conductivity can also be described as high thermal (high) resistance. In addition, silicon also exhibits thermal stability, or the ability to maintain its properties and structure over a wide temperature range.

Fundamentally, this heat resistance is due to the highly stable chemical structure of silicone. In specific, silicon has a backbone that consists of repeating units of siloxane bonds (alternating silicon and oxygen atoms) that are tightly bonded together. It is its highly-stable formation that is partly responsible for the heat-resisting characteristic of silicone. Furthermore, the coiled structure of silicone molecules, combined with low levels of force between molecules, also provides good resistance to cold temperatures, these aspects of the chemical structure are also responsible for many of the other properties of silicone.

Table 3 External temperature observed at ambient temperature

Sr. No.	Material	Time			
		at 10 min	at 30 min	at 60 min	at 180 min
1	Taffeta Material	298.3	303.2	308.86	315.86
2	Fibreglass Cloth	297.6	300.2	303.66	307.36
3	Silicon Rubber Sheet	295.5	297.4	300.16	303.16
4	DSFC	294.1	295.3	297.26	299.96

B. Heat transfer rates

1) Heat is the flow of thermal energy driven by thermal non-equilibrium. The rate of heat flow is the amount of heat transferred per unit of time in a material, and it is measured in Joule/ seconds or (J/sec). The significance of the heat transfer rate in this experimental investigation is to analyse and compare the heat-resistant capacity of the materials.
2) The rate of heat transfer between two surfaces is directly related to the temperature difference between the upper and lower surface and mass of the material, whereas it is inversely proportional to the thermal resistance of the material. The thermal resistance concept is widely used in practice; however, its use is limited to systems through which the rate of heat transfer remains constant.

$$H = m \times c \times \Delta T \text{.....................Eq. (1)}$$

3) Where H is the heat transfer rate (Joule/sec), m is the mass of the heat-resistant material (kg), c is the thermal resistance (K.m/W) of the heat-resistant material, and ΔT is the difference between internal temperatures and external temperatures (K).

(A) Taffeta Material

Heat transfer rate for 10 min; Heat transfer rate as per materials considering 1kg of mass

From the eq. 1

$$H = 1 \times 20 \times (298.3 - 310.9)$$
$$H = -252 \ J/\,sec$$

Heat transfer rate for 30 min; Heat transfer rate as per materials considering 1kg of mass

From the eq. 1

$$H = 1 \times 20 \times (303.2 - 314.05)$$
$$H = -217 \ J/\,sec$$

Heat transfer rate for 60 min; Heat transfer rate as per materials considering 1kg of mass

From the eq. 1

$$H = 1 \times 20 \times (308.86 - 317.15)$$
$$H = -165.8 \ J/\,sec$$

Heat transfer rate for 180 min; Heat transfer rate as per materials considering 1kg of mass

From the eq. 1

$$H = 1 \times 20 \times (315.86 - 326.8)$$
$$H = -218.8 \ J/\,sec$$

Table 4 Heat transfer rates of heat-resistant materials for various time intervals

Sr. No.	Material	Heat Transfer rate (J/sec) w.r.t. Time(min)			
		at 10min	at 30min	at 60min	at 180min
1	Taffeta Material	-252	-217	-165.8	-218.8
2	Fiberglass Cloth	-90.39	-89.68	-81.75	-103.89
3	Silicon Rubber Sheet	-68.59	-70.50	-67.73	-71.88
4	DSFC	-43.63	-46.06	-45.89	-42.32

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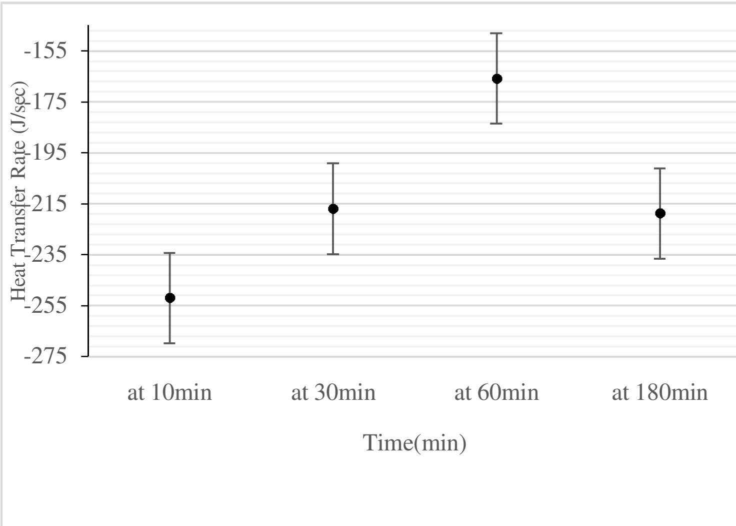
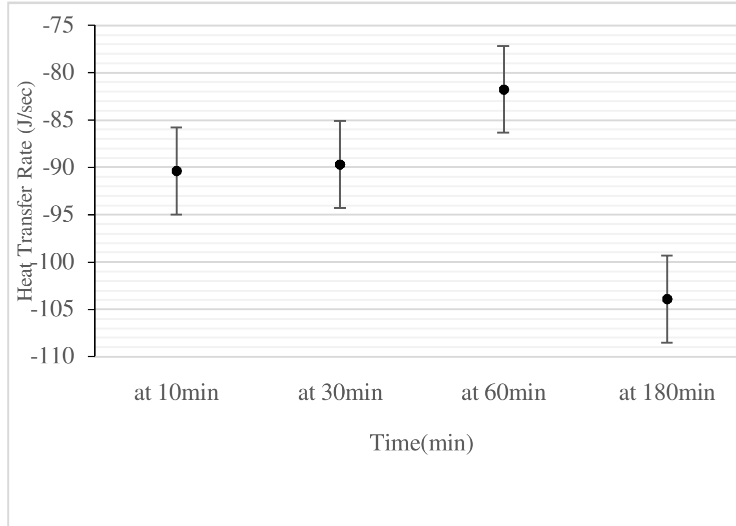
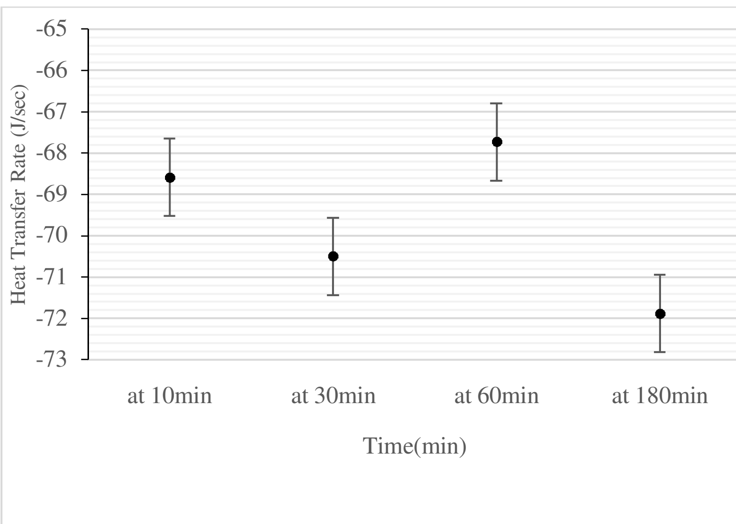


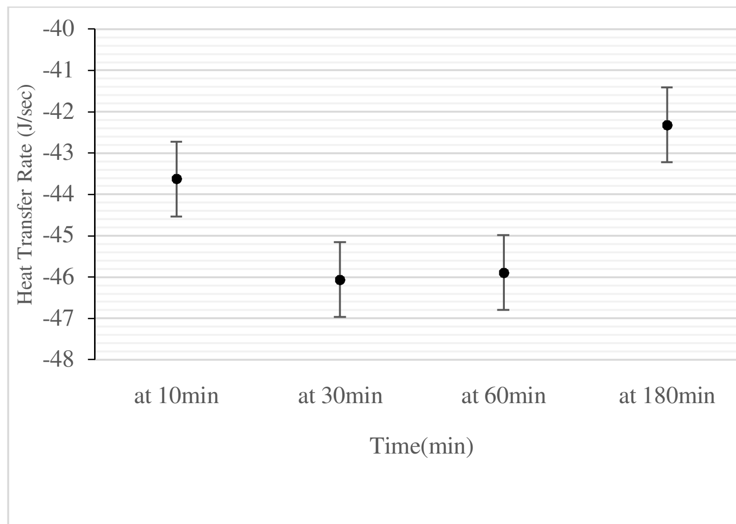
(A) Taffeta Material



(B) Fiberglass Cloth



(C) Silicon Rubber Sheet



(D) DSFC

Fig 8 Heat transfer rate of heat-resistant materials at various time intervals

The heat transfer rates are calculated for all four heat-resistant materials viz. Taffeta, Fibreglass cloth, Silicon rubber sheet, and DSFC for different time intervals of 10 min, 30 min, 60 min, and 180 min as shown in Fig 8.
The taffeta shows a heat transfer rate of -252, -217, -165.8, and -218.8 J/sec for 10, 30, 60, and 180 min. These variations in heat transfer rates within the materials are found of different due to temperature differences observed at different time intervals. While DSFC has very minimal heat transfer rates of -43.63, -46.06, -45.89, and -42.32 J/sec for periods of 10, 30, 60, and 180 min. However, fibreglass cloth and silicon rubber sheets have heat transfer rates of -90.39, -89.68, -81.75, and -103.89 J/sec and -68.59, -70.5, -67.73, and -71.88 J/sec for periods of 10, 30, 60, and 180 min.
A comparative study of heat transfer rates of different materials shows that the DSFC has maximum heat resistant capacity than others.

C. Reflectivity Of The Material

Reflectivity is a physical property of a material which reflects light or radiation. It is the measurement of reflectance independent of the thickness of the material. Reflectivity helps in thermal resistance as it reflects the heat passing through the material. It reduces the heat transfer from the material as it acts as an insulation property. If an object has high reflectivity, it reflects a large amount of light energy into the atmosphere.

If an object has low reflectivity, it absorbs most of the light that hits its surface. As more, light is reflected off an object, less heat energy is stored. When more light is absorbed more heat energy is stored in the object. The interface of a very rough surface will tend to reflect light at many different angles because light meets the surface at many different angles.

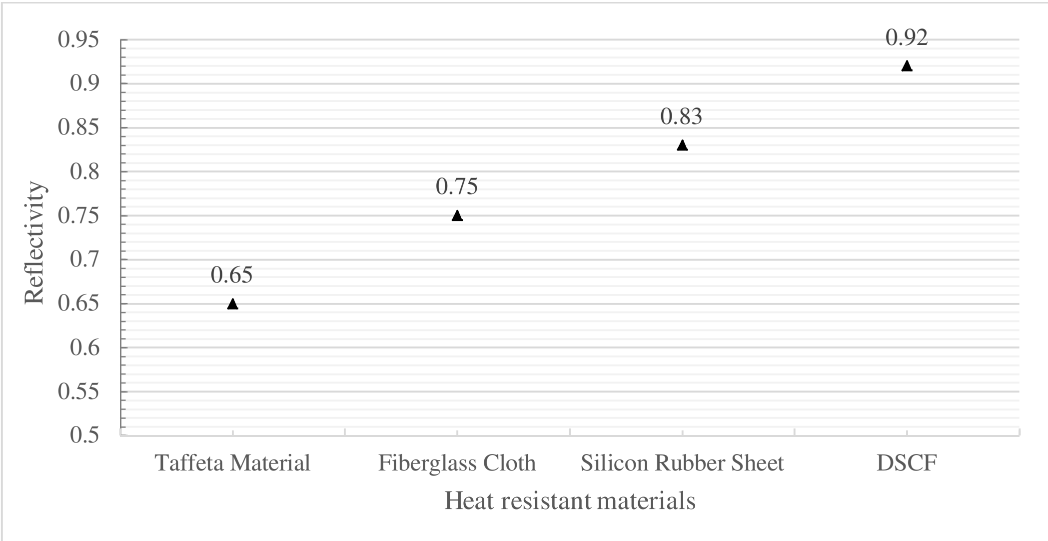


Fig 9 Reflectivity of the heat-resistant material

V. CONCLUSION

In this study, the experimental investigation of roof-top heat-resistant covers for sedan vehicles has been studied in correlation with the internal and external temperatures, heat transfer rates, and reflectivity of the materials, to protect the vehicle from direct sunlight and high temperature. From this investigation, the following conclusions are drawn:

1) The internal temperature of the cabin was found to be 326.8, 321.9, 318.26, and 314.81 for taffeta, fibreglass cloth, silicon rubber sheet, and DSFC for 180 minutes.
2) The external temperature of the cabin was found to be 315.86, 307.36, 303.16, and 299.96 for taffeta, fibreglass cloth, silicon rubber sheet, and DSFC for 180 minutes.
3) The variation in the temperature i.e., ambient temperature and the measured temperatures were found to be 2.1, 2.74, 3.09, and 3.59 for the internal cabin temperature and 14.7, 15.4, 17.5, and 18.9 for the external cabin temperature.

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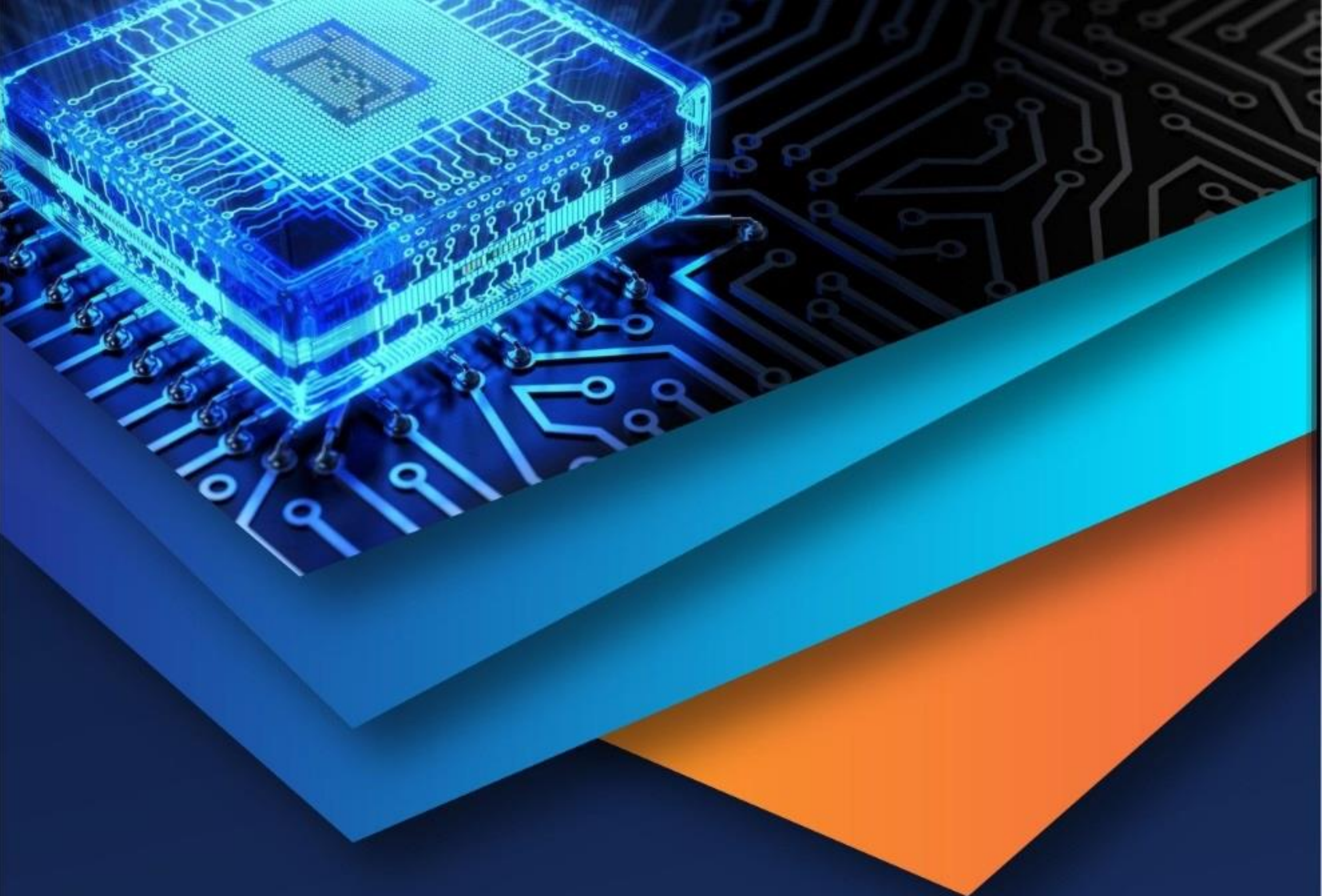

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