# Motorcycle helmet ventilation and heat transfer characteristics

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## 1. Abstract

Heat transfer characteristics of 10 motorcycle helmets were measured. Each helmet was tested three times on a manikin headform placed in a climate chamber (22 ºC and 50% RH) at the exit of a wind tunnel (50 ± 1.1 km·h$^{-1}$). In every measurement a helmet was evaluated with the ventilation openings closed and open. Heat transfer ($\dot{Q}$) in the scalp and face sections, along with temperature measured with 10 thermocouples on different locations, were registered in a 20 min steady state period. The heat transfer ranged from $0 < \dot{Q} < 4$ and $8 < \dot{Q} < 16$ for the scalp and face sections, respectively. Closing or opening the ventilation openings did not have a significant effect on heat transfer for most of the helmets. Similar results were found for temperature.

## 2. Introduction

The head is one of the body's strongest thermal comfort sensors (Cotter and Taylor, 2005). Not surprisingly, a common complain about headgear in warm environments is impairment of thermal comfort, as investigated for industrial (Liu, 1997) and bicycle helmets (Ellis et al., 2000). This has motivated a number of studies of the heat transfer characteristics of headgear (Liu, 1997; Brühwiler et al., In press). In the presence of wind, optimizing headgear ventilation has been shown, e.g., for bicycle helmets to improve heat loss and increase thermal comfort in a warm environment (Brühwiler et al., 2004).

A COST 327 survey suggested that physiological aspects associated with motorcycle helmets, e.g., microclimate heat stress and/or $CO_2$ concentration in the re-breathed air might affect the safety of the wearer (Chinn et al., 2003). Optimizing the ventilation of motorcycle helmets could address both of these concerns, and is therefore a traffic safety issue. A manikin study of two motorcycle helmets (Brühwiler, 2003) showed that ventilation of the scalp section of the head can be very poor (for both motorcycle helmets, in that case), whereas 20% variations were observed for the face. The present study was carried out in order to evaluate the heat transfer characteristics of 10 modern full-face motorcycle helmets, using a thermal manikin headform augmented by local temperature measurements.

## 3. Methods

Ten full-face motorcycle helmets from 7 manufacturers (4 flip-up and 6 integral models) were examined on a thermal manikin headform described previously (Brühwiler, 2003). The surface temperature of the headform was set to 35 °C, and the power needed to maintain this temperature in steady state was recorded. This heating power corresponds to the heat transfer ($\dot{Q}$). Values for the scalp and face sections were obtained separately. The neck section of the headform was also heated to prevent conductive heat transfer to the support. The headform was placed at the exit of a wind tunnel with air speed set to 50 ± 1 km·h$^{-1}$ (14.0 ± 0.3 m·s$^{-1}$), and which was in turn located in a climate chamber at 22 °C and 50% RH.

A scarf covered the neck section to reduce an unnecessarily large convective heat loss in this section and to simulate a realistic situation. The headform was instrumented with 10 K-type thermocouples (figure 1); 6 on the face section (forehead, eye, nose, cheek, ear and chin) and 4 on the scalp section. In the text the temperature measured by a thermocouple will be referred to as T1, T2, … T10, corresponding to the numbers shown in figure 1. These temperatures were measured in an attempt to characterize the airflow between headform and helmet.

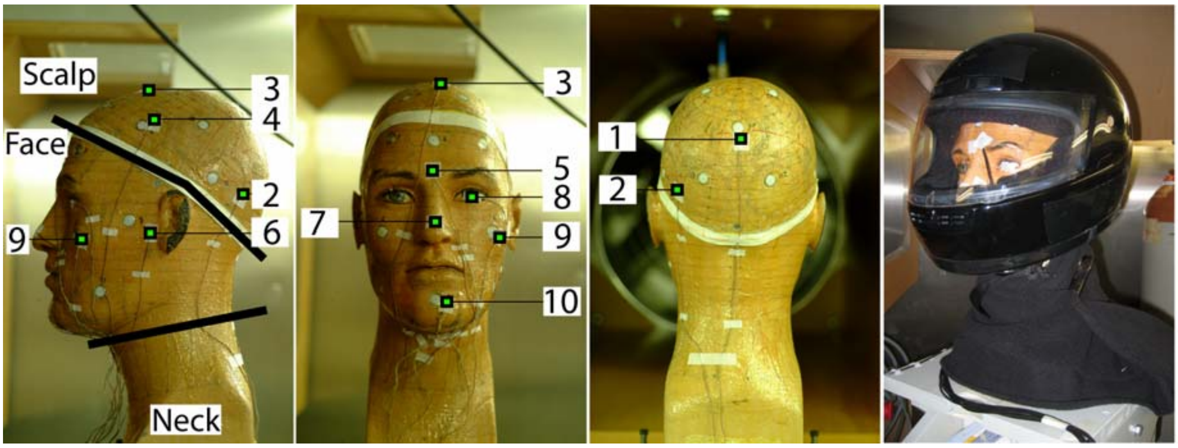


Figure 1: Thermocouple location on the thermal manikin headform. The locations of the 10 thermocouples are indicated with squares and corresponding numbers. The three sections are also indicated. In the right most picture the headform is shown with a motorcycle helmet.

Each helmet was tested with all ventilation openings alternately closed and opened in random order. Three such measurements were carried out, with fresh helmet placement between the measurements; each subsequent measurement of a given helmet was interceded by a measurement on at least one other helmet. After every intervention the headform was allowed to reach steady state, usually taking 30 min. From the following 20 min period the steady-state power and temperature values were extracted. All helmets were placed according to a broadly-used impact test standard (ECE324, 2002), with a specified gap of about 3 cm between the bridge of the nose and the upper edge of the helmet facial opening. In order to ensure anonymity, numbers have been assigned to the helmets. ANOVA was used for statistical analysis, with a Tukey test for post hoc comparisons if a significant difference was found ($p < 0.05$). The statistical analysis was carried out with SPSS 13.0.1 for Windows.

## 4. Results and discussion

### 4.1 Heat transfer

The heat transfer data are shown in figure 2. As could be expected based on the construction of such helmets, large differences in heat transfer were observed between the face and scalp sections, ranging roughly from $0 < \dot{Q} < 4$ W for the scalp section and $8 < \dot{Q} < 16$ W for the face section. Also immediately apparent is the large variability among the different models. Strikingly, closing or opening the ventilation openings is unimportant for heat transfer for most of the helmets. For the scalp section, only helmet 110 ($\Delta\dot{Q} = 3.5 \pm 0.1$ W) and helmet 201 ($\Delta\dot{Q} = 0.8 \pm 0.1$ W) display a significant effect of closing/opening the ventilation openings. Only helmet 132 ($\Delta\dot{Q} = 2.2 \pm 0.2$ W) shows a significant effect of closing/opening the ventilation openings in the face section. The combined heat transfer ranged from 8.0 to 18.9 W.

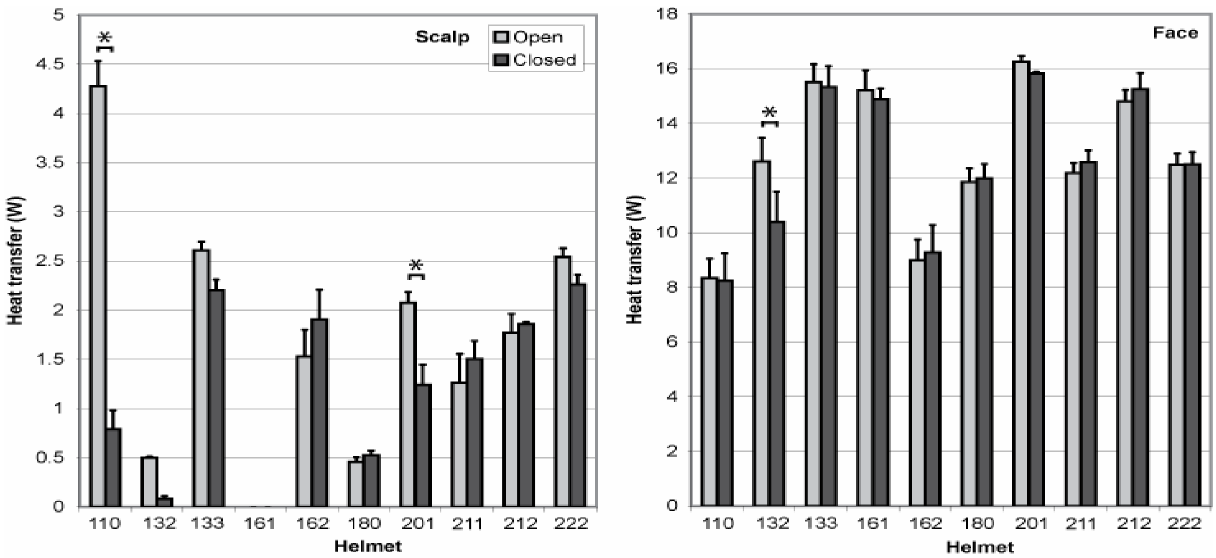


Figure 2: Steady state heat transfer for the scalp and face sections as indicated, measured for all motorcycle helmets with ventilation openings closed and open. A * indicates a significant difference ($p < 0.05$) upon changing the ventilation openings.

### 4.2 Temperature

The temperatures show similar trends for inter-helmet variability, as well as a generally weak role for the ventilation openings. A representative set of temperature measurements (T3) is visualized in figure

3 for all helmets and conditions. Variations in temperature on the different locations showed an average standard deviation of 1.8 ºC. In the scalp section helmet 110 and 212 showed significant differences for closing and opening the ventilation opening for locations T2 / T3 and T3, respectively. Only helmet 110 showed a significant difference in the face section (T5). In two of these cases the temperatures were higher with the ventilation openings open. Because the manikin is constructed to maintain an average constant surface temperature, we cannot determine if the present observations reflect compensation for lower temperatures elsewhere in the same section of the headform, or transport of heated air under the helmet, or a combination of the two.

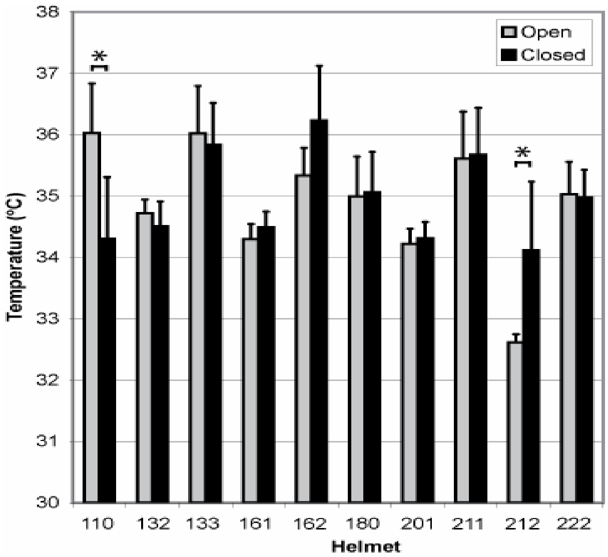


Figure 3: Steady state temperature measured on the top of the scalp (T3) for all motorcycle helmets with ventilation openings closed and open. A * indicates a significant difference ($p < 0.05$) upon changing the ventilation openings.

## 5. Conclusion

The large variations in heat transfer observed among the tested helmets show that there are different strategies being used for ventilation. Furthermore, the small effect of closing or opening all the ventilation openings for most helmets is clearly not an ideal result. It is yet to be determined if the airflow patterns change even if the heat transfer remains the same, or if closing or opening individual ventilation openings would induce greater differences in those cases. Further analysis of the temperature variations might provide insight into this question.

## 6. Acknowledgments

We gratefully acknowledge the support of the COST 357 Action (www.cost357.org) and the manufacturers who donated helmets for this study.

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