Verifying Air Temperature Measured by Embedded Sensors Adopted by Pig Transporting Vehicles in a Scaled Compartment Model

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Introduction

Billions of live animals are transported annually. Legislation to protect animals during transportation has been adopted by the EU, but one of the challenges noticed is if the embedded sensors used to measure the air temperature inside the transport vehicles can provide the reasonable value. In previous measurements conducted in a weaner transport vehicle, it was observed that the temperature difference of air (ΔT_{air}) measured by embedded sensors (ESs) and thermocouples installed by researchers could be up to 20 ºC. However, regulating fans and shutter openings of transport vehicles highly depends on the monitoring of indoor air temperature by those embedded sensors.

In our previous study focusing on the weaner transport vehicles, we noticed that the embedded sensors are installed as shown in Fig. 1(c) and (e). The questions, which could be asked, are (1) how to place the ESs so the air temperature measured by EMs reflects the indoor air temperature reasonably? (2) if changes should be made, what are they?

Objectives

Motivated by the questions raised earlier, a group of experimental tests were designed by employing a scaled compartment. The objectives are: (1) to assess the air temperature measured by the ESs, which were placed in a way mimicking the two positions shown in Fig. 1, and air temperature measured by thermocouples (TCs) at the exhaust of the scaled compartment model; (2) to investigate the impact of insulating walls surrounding the embedded sensor (sensor box hereafter) and air circulation through the sensor box on the measured air temperature.

Methodology-Scaled Compartment Model

A scaled compartment model with dimensions 1.2 m (L) x 1.2 m (W) x 0.7 m (H), which were half of the length and width and identical height of a full compartment used in some weaner transport vehicles, was employed for our experimental measurements. In Fig. 1, the outline of the scaled compartment model is displayed in (a) and (b), in which (b) shows how the air circulation was achieved through the sensor box. How the placement of embedded sensors was mimicked in our tests is shown in Fig. 1 (c) ES-P1 and (e) ES-P2. The insulation of inner walls of sensor box is shown in Fig. 1 (d) with enlargement and the insulation on the contacting wall by embedded sensors is revealed in Fig. 1 (f). As highlighted in Fig. 1 (a), the air was supplied from the slots on both sides and exhausted via a connected tube with an installed fan. The measurements were tested with outdoor air temperatures mimicking winter and summer scenarios.

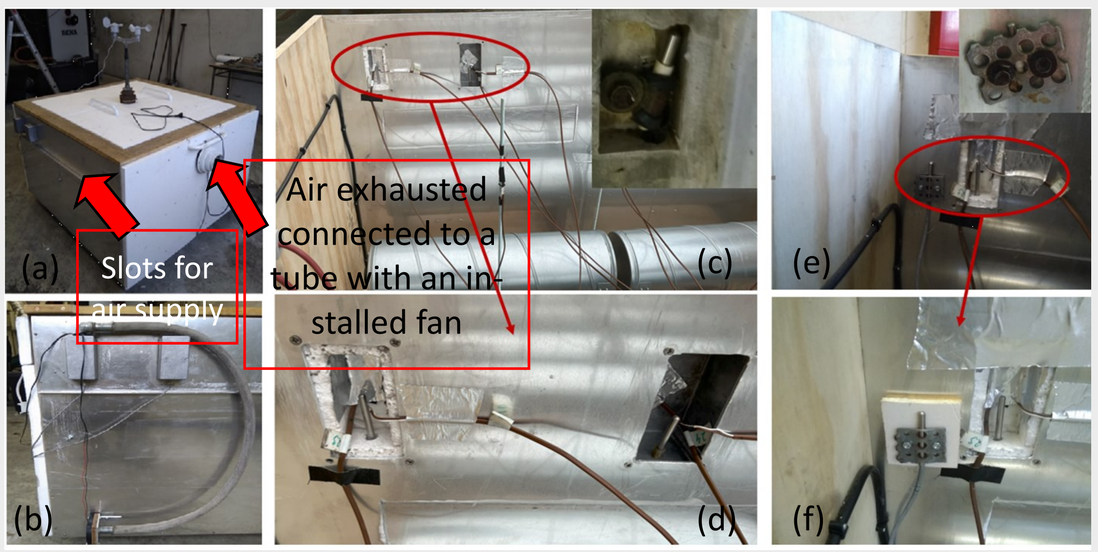

Fig. 1 Scaled compartment model adopted in measurements. (a) outline without air circulation; (b) air circulation; (c) ESs placement to mimic the position ES-P1 right-top corner; (d) enlargement of sensors placement in sensor box; (e) ESs placement to mimic the position ES-P2 (right-top corner); (f) enlargement of sensor placement for insulating the contact between the sensor and the compartment wall.

Conclusions

The insulation has slight influence on the air temperature measured by ESs but the air temperature difference between the values measured by ESs and by TCs at the exhaust is noticeable, especially for winter scenarios. Air circulation can significantly reduce the ΔT_{air} but the challenge could be how to implement it into practice.

Methodology-Placement of ESs and TCs

The placements of ESs and TCs to measure the air temperature and surface temperature of walls are shown in Fig. 2 and the number in bracket indicated the marked sensor numbers. Y (yes) and N (no) indicates if the inner walls of sensor boxes was insulated or not.

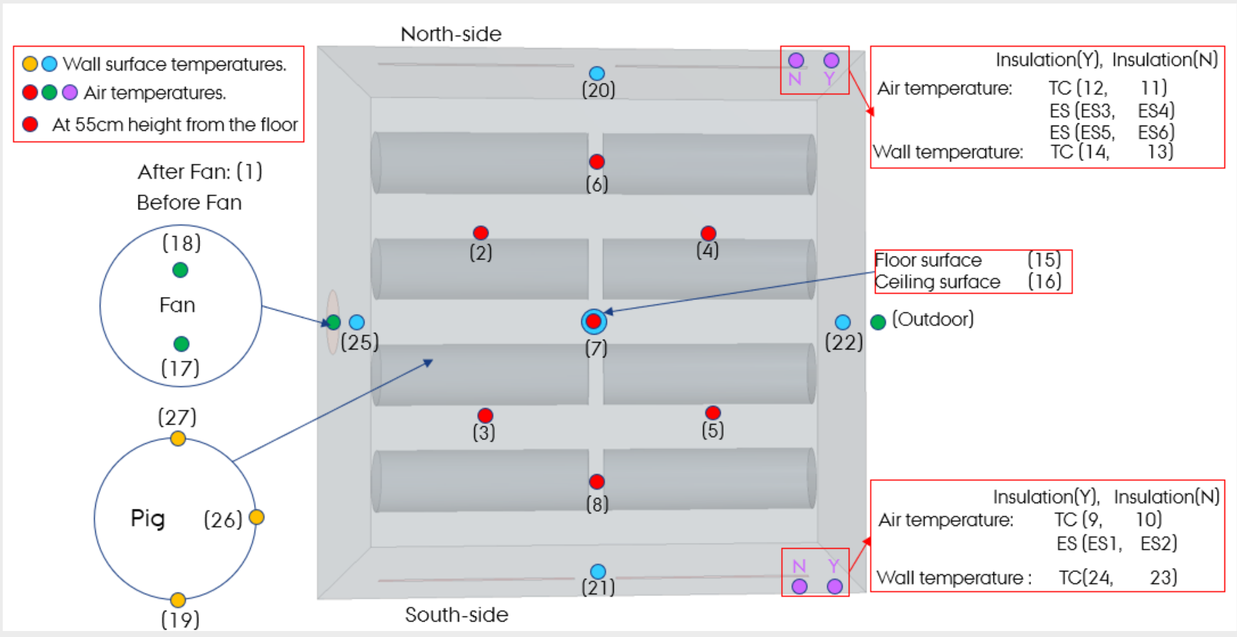

Fig. 2 Placement of ESs and TCs to measure air temperature and surface temperature scaled compartment model walls and artificial pigs. ES6 and ES5 showed the air temperature measured by ESs to mimic the placement presented in Figure 1(b).

Results

The scenarios to study the influence of insulation on air temperature measured by ESs, shown in Fig. 3, include (a) mimic winter case, fan off and opening slots closed (Sa); (b) mimic winter case, fan on and opening slots height in 2 mm (Sb); and (c) mimic summer case, fan on and opening slots height in 75 mm (Sc). The insulation has little influence on air temperature measured by ESs for ES-P1 shown by yellow solid and dash lines in Fig. 3 (a), (b) and (c), which was about 5-8 ºC lower than the air temperature at the exhaust measured by TC18. The influence of insulation on temperature measured by ESs for ES-P2 was noticed, shown by green solid and dash lines for Sa and Sb, but the values were about 8-12 ºC lower than the air temperature measured by TC18. For summer Scenario Sc (Fig. 3c), the air temperature difference between ESs and TCs is smaller than those in winter scenarios.

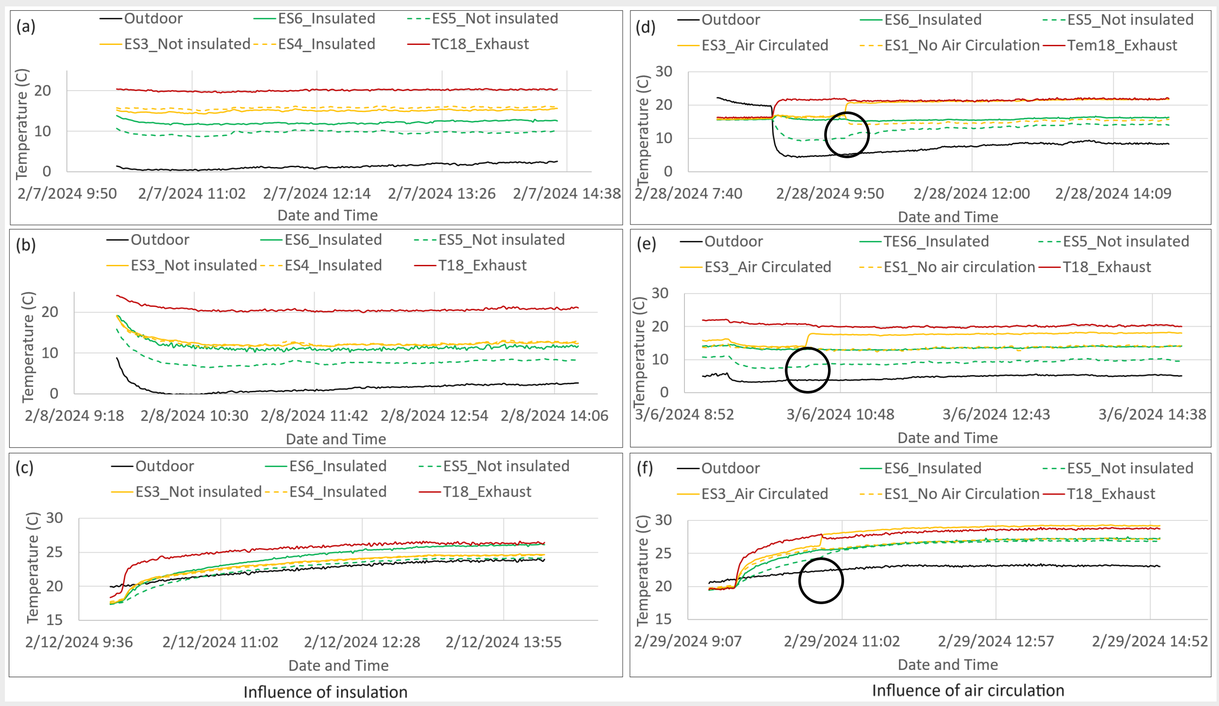

Fig. 3 Influence of insulation and air circulation on air temperature measured by EMs and TCs. The part highlighted by black circles on the right column indicates the air circulation started.

The Scenarios investigating the influence of air circulation in Fig. 3 include (d) mimic winter case, fan off and opening slots closed (Sd); (e) mimic winter case, fan on and opening slot height in 2 mm (Se) and (f) mimic summer case, fan on and opening slot height in 75 mm. The black circles highlighted when the air circulation was started and flowing through the sensor box on the North-side (ES3). The air temperature measured by ES is about 4-6 ºC lower than the air temperature at exhaust TC18, depending on the outdoor temperature before air circulation was started. After the air circulation was started, the air temperature measured by ES (yellow solid line) was nearly identical to the exhaust air temperature with fan off, and about 1.5 ºC lower than the exhaust air temperature with fan on. The air temperature measured by ES in summer scenario Sf with air circulation is about 0.5 ºC higher than the exhaust air temperature.