LONGITUDINAL VENTILATION OF BROILER HOUSE – SIMULATION OF VARIANTS

Milan Zajicek[1], Pavel Kic[2]
[1]Academy of Science of the Czech Republic; [2]Czech University of Life Sciences
zajicek@utia.cas.cz, kic@tf.czu.cz

Abstract. This paper is focused to the broiler house ventilation during the summer period, when the maximum amount of ventilation air exchange is needed and also the higher air velocities are required for intensive cooling of animals. The basic parameters of the analyzed cases are set up with respect to the technical standards. Several 2D CFD (computer fluid dynamics) models for every configuration are solved using the Ansys Fluent software and discussed from different points of view with the focus to the welfare of animals. The model variables are mainly the size and shape of the inlets and outlets and their position. The changing area of the ventilated cross-section is also included into the models presented here. The main part of the work is focused onto finding the most usable configuration according to the shape of velocity and temperature profile inside the zone of animals. The 3D model is also prepared and solved for the most important case and the results are compared with the results of an existing broiler house analysis, which was tuned according to the measurement made also in such broiler house. Some universal conclusions usable for designing and improvement of the existing broiler houses are given.

Keywords: tunnel ventilation, computational fluid dynamics, broiler house.

Introduction

This paper is focused only onto longitudinal ventilation of a broiler house, which can be used mainly in a very hot period of the year.

The goal of tunnel ventilation is to keep birds comfortable in hot weather by using the cooling effect of high-velocity airflow. The tunnel setup is especially suited to warmer areas and where larger birds are being grown. Tunnel systems are designed first to handle the expected need for heat removal, providing the air exchange rate needed to exhaust excess heat in hot weather. Full tunnel mode operation, with all fans running, may produce a complete house air exchange very quickly and therefore there is no need to think about CO_2 or NH_3 emissions.

The results presented here are based on previous research and experimental work [1] which were provided in the existing broiler house shown in Fig. 1. Geometry presented here is similar to the crossection of this facility and the knowledge about building CFD model which corresponds with the existing state is also used into the model presented here.

Fig. 1. **Broiler house: the length of this building is 60 m**

Materials and methods

The Ansys Fluent – computer fluid dynamics (CFD) software – is used to solve variants of broiler house ventilation. The longitudinal cross section of a typical broiler house is used for this simulation. It is a 60 m long and 3 m height rectangle with the inlet and outlet at opposite sides. The used variants are marked with letters from A, B, C and the solution of CFD model was made for summer conditions, when external temperature is extremely hot (32 ºC). Case A is only rectangular crossection with no barriers inside and is mentioned as a reference model. Case B is characterized by 5 equidistantly mounted barriers, which are hanging from the top of the roof and leave a 1.5 m height gap for the airflow. Case C has the same amount of barriers, but they reduce the gap for airflow continuously changing the crossection height from 2 m, to 1.75 m, 1.5 m, 1.25 m and 1 m continuously, as it is shown in Fig. 2.

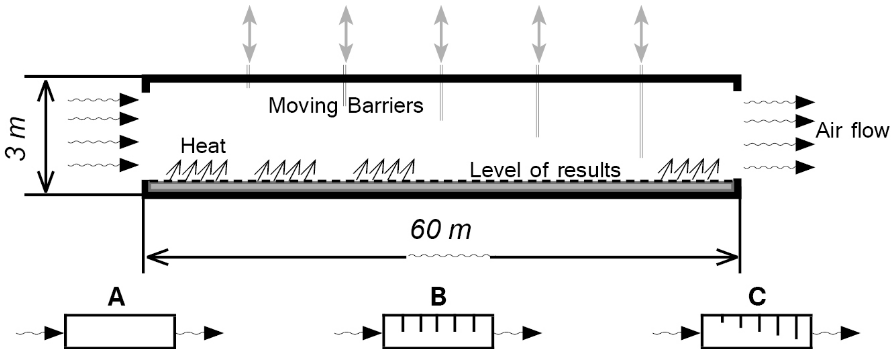

Fig. 2. **Configuration for variants:** A – without barriers; B – all barriers are at the same level (1.5 m); C – barriers gradually reduce the crossection as it is shown in this figure

Gradual throttling of the air stream has the reason in fact, that flowing air can make animals in a state of thermal comfort zone even if the real measured temperature is higher than recommended. The wind-chill effect created by high-velocity air can reduce the effective temperature felt by fully-feathered birds by as much as 5.5-7.0 ºC [2]. Fig. 3 shows estimated effective temperatures that result with different air velocities, for four week and seven week birds. As Fig. 3 shows, caution must be used in tunnel ventilating with younger birds, since they feel greater wind-chill effect for the given air velocity. Note that the "effective" temperature can only be estimated, not read from a thermometer or calculated. Bird behavior must be the guide to judging the right number of fans to turn on to create the air velocity and air exchange rate that is needed to keep the birds comfortable.

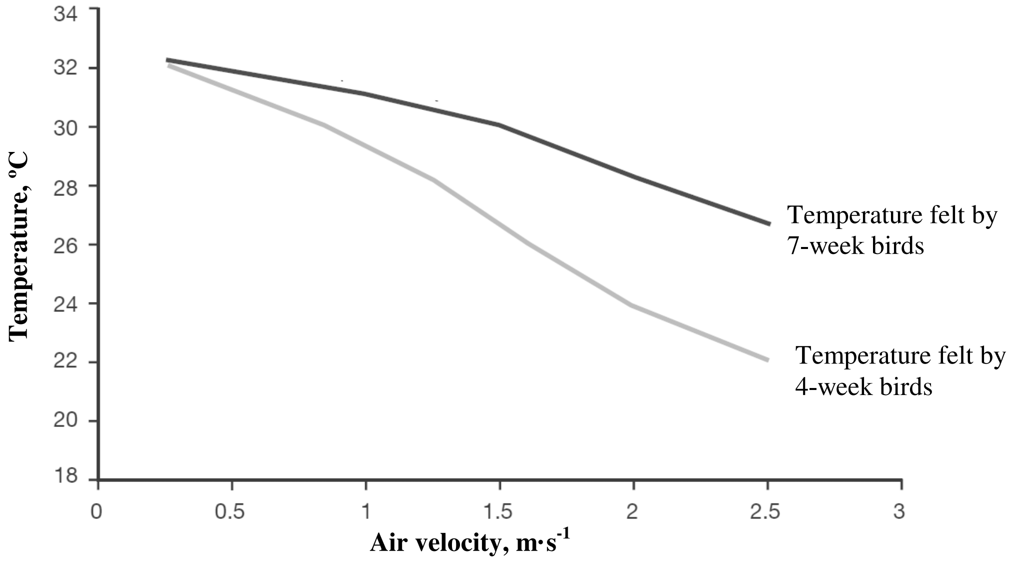

Fig. 3. **Wind-chill effect: younger birds are more sensitive to air flow velocity, outside temperature is 32 ºC – reprint from original publication [2]**

The curves from Fig. 3 can be recalculated as difference values and fitted with polynomial regression and are used for obtaining the temperature difference, which arises due to the flow velocity.

$$\Delta T^4 = 0.66v^3 - 3.28v^2 + 0.19v - 0.4, \tag{1}$$

$$\Delta T^7 = 0.17v^3 - 1.75v^2 + 1.1v - 0.4. \tag{2}$$

ΔT^4 and ΔT^7 are values of temperature which can be subtracted from total temperature to obtain real feel temperature which is felt by poultry. Index 4 and 7 belongs to the 4 and 7 week old chicken.

The analysis shown here includes the effect of the natural convection, but it can be neglected, because there are rather great velocities in the longitudinal direction. Air is considered as ideal gas and the thermal analysis includes the sensible heat generation caused by poultry. The density of animals is assumed as 12 chickens per square meter and the heat generation is 5.8 W per animal [3].

Results and discussion

The typical result from CFD simulation can be obtained as a graphical output of contours, where the color scale represents the numerical scale of variable values. Fig. 4 shows contours of the velocity field and contours of the temperature field. The outlet stream (on right side of the figure) has a given velocity 1 $m.s^{-1}$. Total heat flow from the animal's zone is distributed uniformly through the whole bottom of the model.

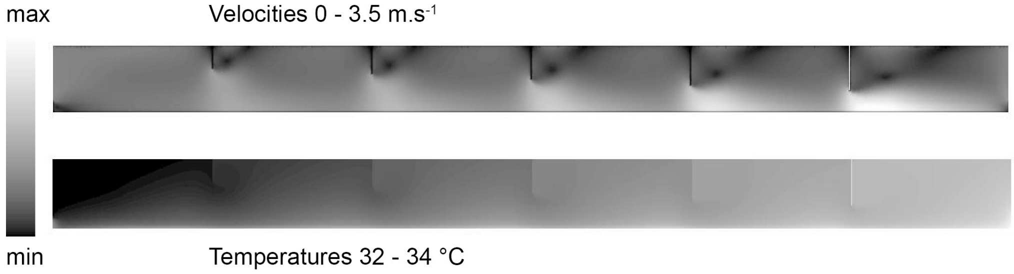

Fig. 4. **Results from numerical simulation:** Contours of velocity magnitude and contours of temperature from 2D model, case C

Fig. 5 and Fig. 6 show the temperature profile across the line, at the height 0.3 m above the floor. It is seen, that the maxima of velocity waves which correspond to the places under barriers has only a small influence onto the changes of local temperatures. The distance between the barriers (10 m) is enough to let the flow come back to the steady state (shown at velocity profile contours) and therefore each barrier can be seen as a separately usable result. The most usable result from this work can be seen in Fig. 7. The real feel temperature profile is obtained as a temperature profile from numerical simulation lowered by the value calculated according to (1) and (2). It should be mentioned, that this correlation works well for velocities between approximately 0.5 and 2.5 $m \cdot s^{-1}$ and therefore the computed shape of temperature under maximally lowered barrier is deformed.

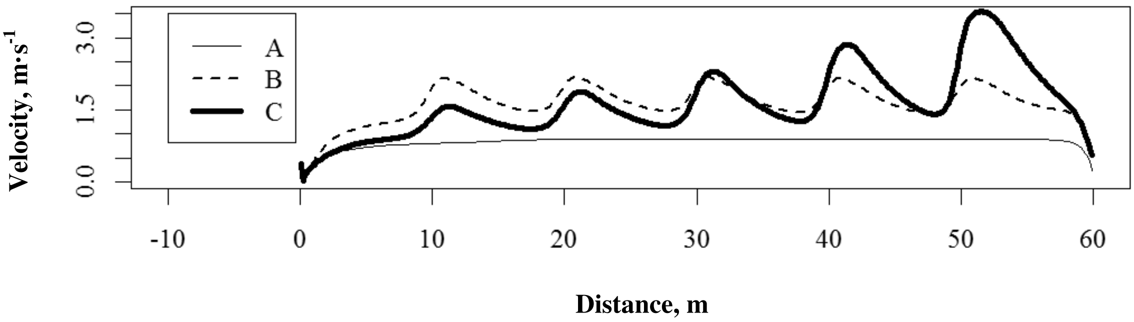

Fig. 5. **Velocity profile: computed velocity profile at the height 0.3 m from the floor**

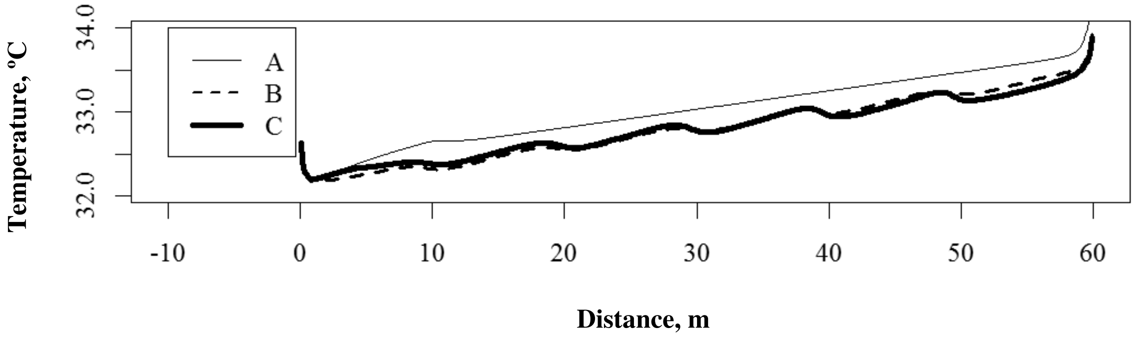

Fig. 6. **Temperature profile: computed temperature profile at the height 0.3 m from the floor**

The effect of intensive longitudinal ventilation can be seen, for example, at the maximum velocity point under the barrier at 30 m distance. The temperature computed from the model is 32.8 ºC, the real feel temperature for 4 weeks old chicken is about 23 ºC and for 7 weeks old chicken about 26 ºC. It is very important to include this fact into ventilation regulation, because too high velocities can lead to thermal shock for animals and it is very important to observe the behavior of animals and correct the cooling effect of the air stream due to such individual conditions for each ventilated broiler house. It is clear, that it is possible to use the results from these 2D models to a more complex 3D model, which is shown, for example, in Fig. 8. The complexity of such model has a greater demand for specifying of boundary conditions, computational power and also time to obtain usable results. It can be very useful if such detailed simulation is made as a part of the project, because it can demonstrate potentially the problematic aspects of the project.

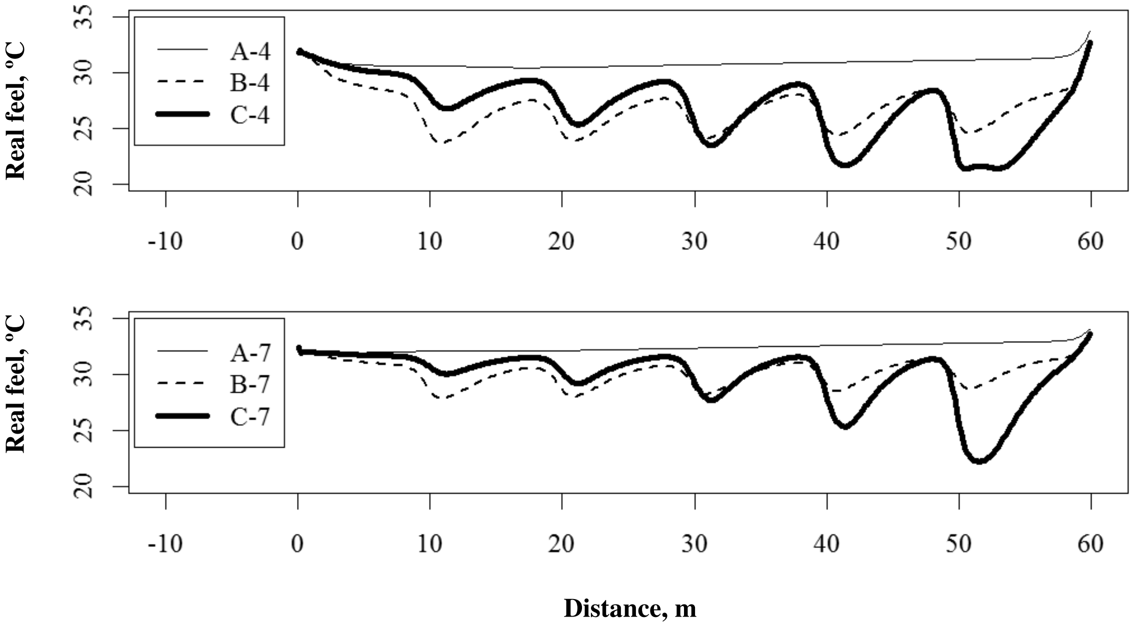

Fig. 7. **Real feel temperature of broilers: results obtained as computed values decreased by ΔT^4 and ΔT^7 from equation (1) and (2)**

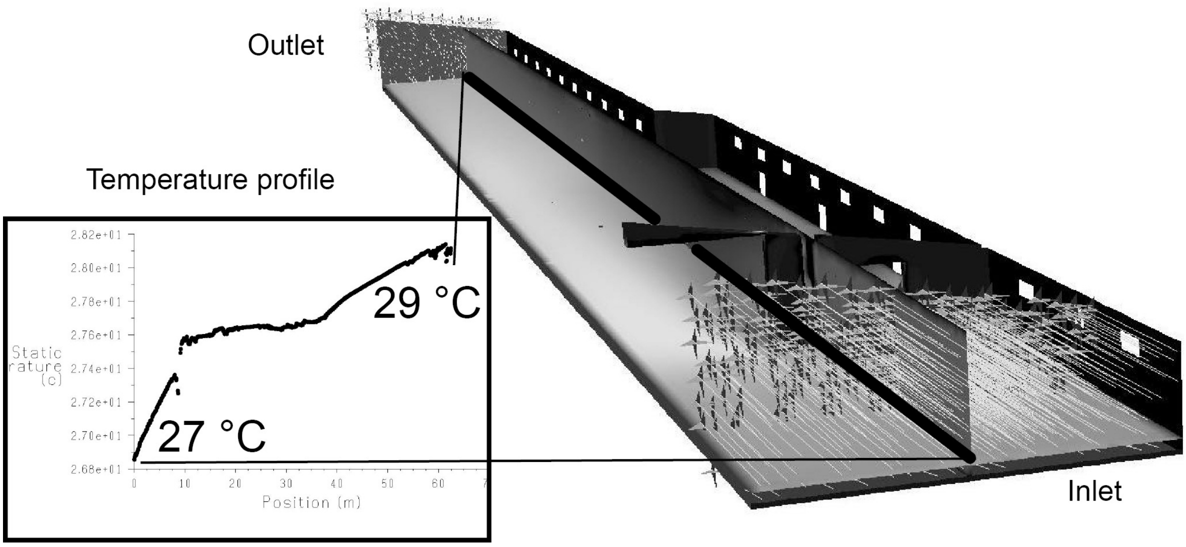

Fig. 8. **Contours of temperature: illustration of the results for the 3D model based on a real broiler house, the length is 60 m, temperature of the input stream is 27 ºC and outlet stream is about 29 ºC**

Conclusion

The cooling effect of tunnel longitudinal ventilation is a very effective method how to increase the welfare of animals on very hot days during the fattening period. It is important to take care about the age of the broilers and their sensibility to the velocity of the air flow. Computer fluid dynamic as a simulation tool can bring obvious and clear benefit because of the possibility to compare the variants of the solution. From this point of view it can be very helpful for increase the quality of ventilation control and regulation. The results presented here also show, that the relatively simple 2D model gives a useful result for engineering decision and can be used as a good basis for more complex and more difficult cases.

References

1. Zajicek M., Kic P. Improvement of the broiler house ventilation using the CFD simulation. Agronomy Research, Volume 10, Issue SPEC. ISS. 1, 2012, pp. 235-242.
2. Donald J.O. Broiler – Ross Environmental Management in the Broiler House. Aviagen, 2010. [online version] [28.2.2013] Available at: http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross_Environmental_Management_in_the_Broiler_House.pdf.
3. Chiumenti R. Construzioni rurali (Rural buildings). Edagricole scolestico, Milano, 2004, 479 p. ISBN 88-529-0005-5 (In Italian).