Application of computer simulation to evaluate potential measures for improving energy efficiency in hog production

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SUMMARY

Results from previous work of Navia (2008) showed that many of the barns currently in use are not optimized for using energy as efficiently as possible, mainly because the cost of energy in the past has been very minimal. In view of emerging concern regarding the increasing trends in global energy prices, there is a need to re-examine existing barn building design and management to use less energy and more efficiently. As part of the on-going effort to reduce the cost of production in swine operations, this study aims to optimize energy efficiency and reduce overall energy use in swine barns. Computer simulation is being utilized to examine various energy conservation strategies that can be applied in a barn. Preliminary results show that the use of air to air heat exchangers and lighting modifications have high potential for reducing the annual energy consumption in the barn. From the simulation results, the most promising measures will be retro-fitted into the barn to enable collection of actual barn data that will serve as the basis for the development of a decision software tool.

"The model predicts savings of 1956 kWh ($200) to 12 468 kWh ($1,250) per year by switiching to compact flourescent bulbs"

INTRODUCTION

Energy prices have steadily risen in recent years and have not returned to levels seen in previous decades. Because swine production is an energy-intensive industry, this global trend resulted in a steady increase in the utility cost component of total production cost when calculated on a per pig sold basis. A survey of energy usage in 28 Saskatchewan swine barns conducted by Navia (2008) showed a wide range of variability in energy use in different types of operations, implying the potential for numerous opportunities for improving energy use practices to reduce energy cost.

The overall goal of this project is to reduce the cost of production in swine operations by optimizing energy efficiency and reducing energy use in swine barns. This particular part of the study specifically aims to use numerical computer simulation techniques to evaluate measures and strategies that can be employed in swine barns.

EXPERIMENTAL PROCEDURES

This part involves the examination of various strategies related to barn design, construction materials, equipment, and management to make a barn building more energy efficient. However, the main challenge with using a conventional research approach to evaluate various barn design strategies is the expense

Table 1. Annual heating consumption and savings (compared to base barn room) associated with increasing the wall and ceiling insulation and using air to air heat exchanger.

Applied Measures	Annual Heating (kWh)	% Decrease in Annual Heating	Annual Heating (m^3 natural gas)	Savings (m^3 natural gas)
Base barn room	12,980	-	1221	-
Wall insulation (add 90mm of R20 ins)	12,831	1.2	1207	14
Ceiling insulation (increase to R30)	12,541	3.4	1180	41
Wall + Ceiling insulation	12,429	4.2	1169	52
50% eff. Heat exchanger	5,103	60.7	480	741
60% eff. Heat exchanger	3,952	69.6	372	849
70% eff. Heat exchanger	2,976	77.1	280	941

Table 2. Electrical energy savings associated with modifications in lighting

Applied Measures	Annual electricity savings (kWh)					
	150 W Incandescent		90 W Incandescent		23 W CFL	
	24 h	8 h	24 h	8 h	24 h	8 h
Operate lights for 8 h instead of 24 h / day	-	8,760	-	5,256	-	1,343
Use CFL instead of incandescent	11,125	3,708	5,869	1,956	-	-
Use CFL for 8 h/day instead of 24 h/day incandescent	12,468		7,212		-	-

24 h - lights are operated 24 hours per day
8 h - lights are operated only for 8 hours per day

associated with setting up the different alternatives to be able to collect data from each option being tested. For this study, numerical computer simulation was used as a tool to examine various strategies to determine their effectiveness in improving the energy efficiency of a barn building. A computer model of a typical grow-finish room at the Prairie Swine Centre (19.75m by 7.0 m; 100-head capacity) was generated. Using numerical simulation software, the overall energy use in this baseline case (operated using conventional management practices) was calculated and served as the reference against which other alternative cases were compared. The measures being evaluated in terms of annual energy use when applied to the baseline room are categorized as follows:

a. building construction and materials

b. equipment systems - standard models vs. new high-efficiency models (e.g., heaters, fans, motors, light fixtures); use of heat exchangers

c. operational management aspects – temperature set-points, stocking density, manure management, cleaning and maintenance schedule.

The evaluation of the measures in terms of the annual energy use was done with the use of a simulation program (TRNSYS®) which is based on steady state energy conservation laws and formulated in thermodynamic quantities. Inputs into the program include building characteristics (materials, orientation, and dimensions), weather data, internal heat gains in the building, air infiltration rate, ventilation rate, and temperature set points. Using successive substitution, the program solves for the following outputs: resulting room conditions (temperature and relative humidity) and heating required to meet the room set points on an hourly basis for 8,760 hours (one year). From these outputs, the annual heating requirement of the room with the applied measure is calculated.

To evaluate the effect of different barn room designs on the resulting in-barn conditions (temperature and air distribution), a commercially-available computer simulation package ANSYS 11.0 was used. This simulation package utilizes computational fluid dynamics (CFD) principles to numerically simulate the flow of heat and air in the barn based on the physical characteristics and operational aspects of the barn, as well as on the prevailing environmental conditions. The parameters considered in the evaluation of barn room design were: room size and lay-out (large vs. small rooms); floor type (fully-slatted vs. partially-slatted); pen partition (solid vs. open partition); ventilation air inlet and outlet locations (sidewall vs. ceiling), and manure handling system (deep-pit vs. shallow-pit manure channels).

PRELIMINARY RESULTS

Preliminary results of the simulation using TRNSYS® in evaluating the impact of adding insulation and use of air to air heat exchanger are presented in Table 1. Adding insulation to the barn walls and ceiling resulted to minimal decrease in the annual heating consumption. The use of heat exchangers resulted to more than 60% decrease in the annual heating requirement.

The annual energy savings that can be realized by reducing the numbers of hours of operation and changing the type of light fixtures used are presented in Table 2. The wattage and hours of operation of the different bulbs satisfy the minimum requirement for lighting in a grow-finish room (100 lux for 8 hours per day). Shifting to compact fluorescent light (CFL) was shown to result in large annual electrical energy savings ranging from 1,956 kWh (if 8h/day 90W incandescent lighting is previously used) to 12,468 kWh (if 24 h/day 150W incandescent lighting is previously used).

Plots of the preliminary results in evaluating the effect of the position of the inlets and outlets are shown in Figures 1 and 2. These plots show that with this layout, there are areas where the air is stagnant; evaluation of other layouts will be completed to determine which layout provides the best in-barn condition.

IMPLICATION

The following preliminary conclusions can be made from the initial results of the simulation:

1. Increasing the insulation of the barn walls and ceilings results in minimal decrease in annual heating consumption.

2. Modifications in lighting and use of heat exchanger have high potential in decreasing heating energy consumption.

The simulation of other measures to determine annual energy use and resulting in-barn conditions will be completed and the most promising measures will be retrofitted into the barn for data collection which would be the basis for the development of decision support software tool.

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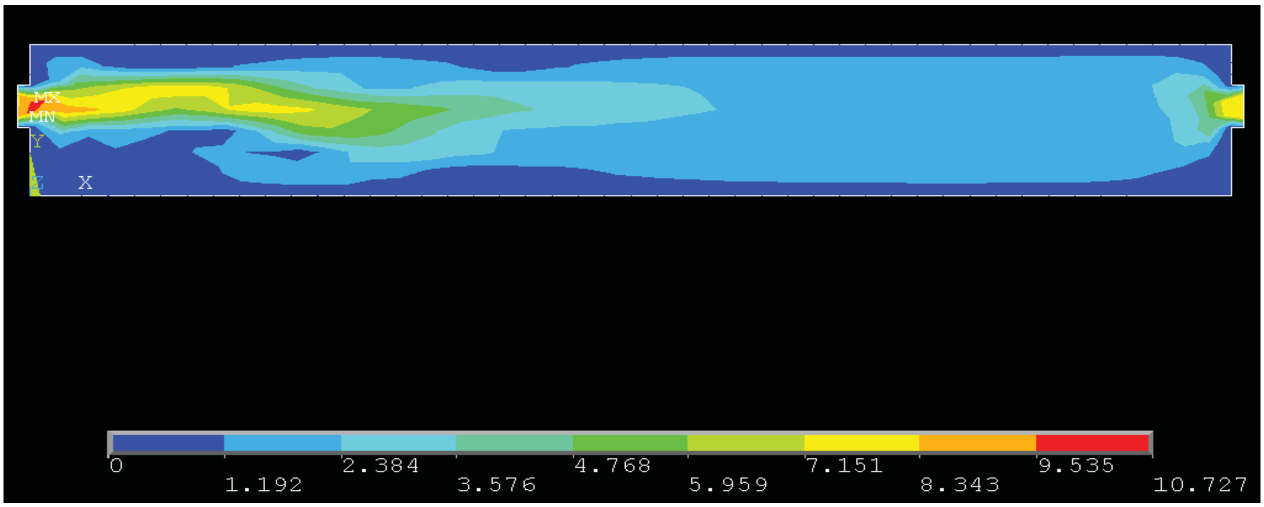

Figure 1. Side view of a 2D model of the baseline grow-finish room showing the air velocity (m/s) distribution with the inlet (left) and outlet (right) located on the side-walls.

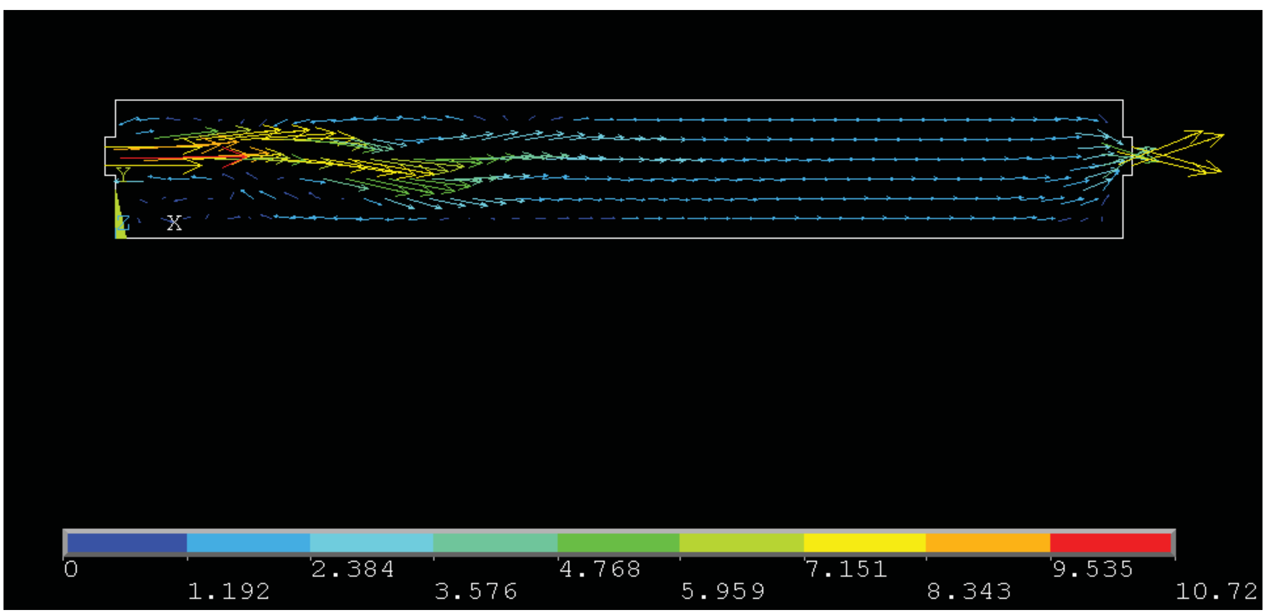

Figure 2. Contour plot of air velocity (m/s) in a 2D model of the baseline grow-finish room with the inlet (left) and outlet (right) located on the side-walls.