NAME: **Marco A. Baez**

PARENTS' NAMES: **Alberto and Brandi Baez**

HOMETOWN: **Peru, Indiana**

CAREER OBJECTIVE: **I want to be a Structural Design Engineer and develop safe and efficient structures.**

BIOGRAPHY: **I was a three-sport athlete in high school and enjoyed working effectively with others. I was intrigued by mathematics and sciences, as well, and I was told I should be an engineer, when I got older by many of my elders and peers. Engineers work closely with each other and their customers to successfully complete an objective. The hardest decision that I had to make was the type of engineer I wanted to be. I've always enjoyed computers and technology, but I've also been fascinated by physical structures because I didn't quite understand how some of them were able to stay erect. In the end, I decided that I wanted to be a Civil Engineer. I applied to Purdue University's engineering program. However, I was not accepted into their program, because I didn't fully meet their requirements. That didn't stop me from pursuing my dreams. My strong network of people encouraged and expected me to do well. I then found the Rising Scholars Program, and my network of people continued to grow. If I ever encountered hardship, I could always find someone that had a similar experience. They'd mentor me and help me overcome the hardship. The Rising Scholars Program helped me traverse a new path toward my dream of being an engineer. They've given me countless lessons and experiences that will last a life time and help me in my future endeavors. I've successfully obtained a position as a Design Engineer at Nucor with their steel joist and deck division, Vulcraft.**

FACULTY LSAMP SPONSOR: **Dr. Robert M. Stwalley III, Assistant Clinical Professor of Agricultural and Biological Engineering**

LSAMP GRADUATE STUDENT NAME: **Tyler C. Field**

GOAL OF THE WORK: **During this experience, I was looking to gain work experience and knowledge on designing a project.**

PERSONAL STATEMENT ABOUT THE LESSONS LEARNED FROM THIS EXPERIENCE: **I learned many things from working on this research project. The first thing that I learned was that it is essential to have effective communication skills. If you aren't able to effectively communicate your ideas and thoughts, then it is extremely difficult to progress. It's impossible for other people to know what you're thinking. I also learned that it is vital to stay organized. Several things can come-up, and they all have a specific time at which they need to be completed. This is important for the entire team, because the team is dependent on each others' work. If someone doesn't perform to the best of their capabilities, the entire team is impacted. Things have to be pushed-back, and the schedule adjusted for a project, if all members aren't communicating properly. Lastly, I learned how important it was to ensure that each detail of a project is understood. If something is misunderstood, it could again delay the project's completion. Each detail on a project is there for a reason, and it shouldn't be ignored or not considered, simply because it doesn't pertain to the specific part that you're working on.**

Purdue Hog Cooling Pad Experience

By Marco Baez

Abstract

The demand for food is increasing with the growing population. The pork industry is currently thriving and will continue to prosper as long as sows continue to reproduce. However, the reproduction of pigs is currently facing the problem of heat stress. Environmental temperatures are reaching extremes, and lactating sows produce less milk for offspring when they are in hot weather. The main reason that they produce less is because of undernourishment. Sows eat less when hot, because when they do eat, it actually causes them to heat-up. The goal of the overall cooling pad effort is to reduce the heat stress on the sows by allowing them to eat more and improving their performance. Researchers have developed a cooling pad made of high-density polyethylene (HDPE), copper piping, and an aluminum plate. These materials allow for easy waste heat transfer away from the sow. Cool water is pumped through the piping. When the hot sow lays on the pad, the water begins to warm and is eventually flushed with cool water. Various coolant flow patterns were tried in order to find the most effective way to use the pad, either by time interval or temperature threshold control. The primary goal of the summer research was aiding in the development of a cooling pad in resolving the problem of heat stress in sows and improving the manufacturability of multiple units to aid in large scale testing of the device.

Keywords

control system; cooling pad; electrical isolation; swine production

Introduction

This paper outlines the author's experiences during a faculty-directed research program through the Louis Stokes Alliance for Minority Participation (LSAMP) project under the supervision of Dr. Allan Schinckel of Animal Sciences and Dr. Robert Stwalley of Agricultural & Biological Engineering in the Precision Livestock Instrumentation and Nano-Climate (PLINC) Lab to improve the design of the Purdue hog cooling pad. With a growing population and continuously increasing need for protein-based food, pork is one agricultural product that is heavily consumed across the planet in many cultures. Sows undergoing thermal heat stress limit overall productivity, especially during summer weather at various warmer places around the world.

Swine are more prone to heat stress, because they do not sweat and have relatively small lungs (Division of Agriculture and Food, 2018). Barns can reach relatively high temperatures, and the cost to cool an entire barn is extreme and potentially dangerous to piglets after they are born. This is because piglets cannot maintain their body temperature in a cool environment. However, with the development of the Purdue sow cooling pad, the sows will be able to stay comfortable in a warmer environment, and the piglets can be held at thermally stable conditions while infants. The cooling pad is a device that will allow animal managers to extract waste metabolic heat from the sows to cool them off. The cooling pad base is constructed from an insulating 2.5 *cm* thick, high density polyethylene (HDPE) plastic. Copper piping is embedded within the HDPE, and an aluminum tread plate is laid over the top of the two materials. When sows lay on the pad, cool water is introduced into the piping, where heat transfer is directed from the sows into the water, cooling them off. It has been found that when sows are within a specific comfort range, they are able to lactate more, as well as produce larger eventually weaned offspring. The reason they don't lactate as much while under heat stress is thought to be because of the redirection of blood away from skin tissues and mammary glands (Black et al., 2003). They also have a loss of appetite while they are undergoing heat stress, which can cause a form of malnutrition. Heat stress is a significant problem for the domestic swine industry. Ultimately, if they are too hot, the animals can expire. A model for the thermal generation by swine is still under development, but everyone agrees that overheated animals suffer. Trials with the cooling pad are currently being conducted. Decisions on control protocols need to be made on whether a time interval or a temperature threshold should be used to trigger the pad coolant flush. Successful cooling pad development should lead to higher pork production rates and the production of more food for the world, possibly reducing the amount of struggling for people to secure food in third world countries.

Cooling Pad Development and Testing

It is well-established that heat stress on pregnant sows reduces their production of milk and litter sizes. At Purdue, this led to the development of a cooling pad that can remove heat from the animal and maintain a decent body temperature. The cooling pad base was composed of 2.5 *cm* HDPE. There were copper coolant tubing pieces embedded throughout channels in this plastic base. An aluminum plate, which is what the sow will lay-on, was screwed on top of the HDPE and copper piping. Copper and aluminum were chosen for the heat transfer components, because they have a low specific heat capacity and high thermal conductivity, meaning they are good at transferring heat (Cabezon et al., 2017). The pad functions by intermittently moving the coolant water through the copper tubing. The heat from the sow transfers into the water and begins to warm, while the sow begins to cool-off. The controller for the pad can then be set to run cool water through after so much time has passed or when the water reaches a specific temperature.

To test the cooling pad and different methods of controlling the cooling, the researchers developed an "artificial sow" (Cabezon et al., 2017). This was composed of a box that had a lining made of a rubber-like material that represents the skin of a sow. To see how the artificial sow reacted to the different methods of cooling, multiple temperature probes were used to collect data. How the temperature changed throughout the device's profile, from the "skin" interface, to under the plate, and on the pipe surface, were examined. Several tests were done with the initial temperature of the artificial sow starting at different points. One test was done while the sow was experiencing extreme heat stress, around $40^{o}C$, and the other was done while the sow was experiencing mild heat stress, at $37^{o}C$ (Cabezon et al., 2017). The support equipment consisted of a cooling water supply system, a water heater for the "artificial sow", and the various instruments to take the experimental different measurements. The water heater kept the sow at the specific "body" temperature test point, and the cooling water supply provided uniform flush condition coolant to the pad for heat removal. The cooling pad on the artificial sow testing apparatus is shown in Figure 1, along with the 'virtual' pig in Figure 2.

Figure 1 - Purdue hog cooling pad on testing apparatus.

Figure 2 - Virtual pig constant temperature heat source for testing apparatus.

After completion of these bench tests, some live animal testing was performed to see how the animal physiology data correlated with the heat removal data. Measurements for the sow's respiration rate, rectal temperature, and the heat removal were collected. These measurements indicated how much the ambient heat was affecting the sow. The more the sows pant (breath very rapidly, like a hot dog) during a time period, the more heat stress they are experiencing. Panting is their means of trying to reject excess heat. Rectal temperature provides the relative temperature of the sow in general, and pad measurements yielded the temperatures in various parts of the cooling pad, allowing researchers to calculate the amount of heat being removed from the sow, hopefully relieving them from thermal stress.

The researchers discovered that the cooling pad did decrease the heat stress among the sows, when they took the measurements of control sows versus the experimental sows. They measured the sow's respiration rate, rectal temperature, and the heat removal that occurred. Between the control and experimental animals, they saw a decrease in the respiration rate and rectal temperature, while seeing an increase in the heat removal within the experimental group (Cabezon et al., 2017). The heat removal was correlated with the two other variables that also decreased, demonstrating relief of the sow from extreme heat stress.

The downside of this animal cooling method is that it produces a lot of additional waste water. In operation, all the water in piping is flushed-out and is replenished with new water. The water that is flushed goes down into the waste pit and is not used again. If a farmer only had a small waste pit, this could be a problem. If the temperature is high, then the time intervals are going to be very close to each other, producing more waste water than on a day where the temperature is mild. When the flushes are done with the temperature of the water inside the piping reaching a certain temperature, the waste water is reduced. This could be used when the temperatures are lower, because there will be less heat transfer need. A coolant heat rejection and recirculation system could eliminate this potential problem in the long run.

Design Improvement Project Results

The researchers needed to improve their techniques to manufacture the cooling pad, producing them in larger numbers suitable to conducting large scale animal testing. The original prototype control box had been constructed from breadboards and jumper wires and was unorganized and cluttered. Some components needed to become more organized within the controller assembly, as well as replacing certain components which weren't suitable for the pad within the farrowing barn environment. Changes were made to make manufacturing of the controller box easier, keeping the delicate electronics isolated from the corrosive gasses in the barn environment, and making the overall appearance more professional. The change in the overall control box was the primary design improvement accomplished within this LSAMP experience.

The electronic materials within the control box were not properly specified for the projected use and were assembled in positions where multiple things could interfere when creating more of the boxes. There was less than 2 *cm* internal clearance within the original control box. A more suitable solution for the control box was designed using Fusion 360®. The researchers wanted a control box with sufficient internal space that could be easily attachable to the pad. The final design allowed for a minimum internal clearance of 2.5 *cm* for all of the initial projected components that needed to be within it. The redesigned box parts are shown in Figure 3. These pieces had complementary mating interfaces to properly seal. The lid had a positive side, and the bottom piece had a negative side. These two details allowed for easy line-up when assembling them into a sealed box, as shown in Figure 4. Figure 5 shows the internal components within the bottom two piece of the assembly. Finally, attachment for the control box to the cooling pad base consisted of just two screws. The lid was made bigger in one direction, which acted as an attachment overhang used to screw the controller box to the pad base.

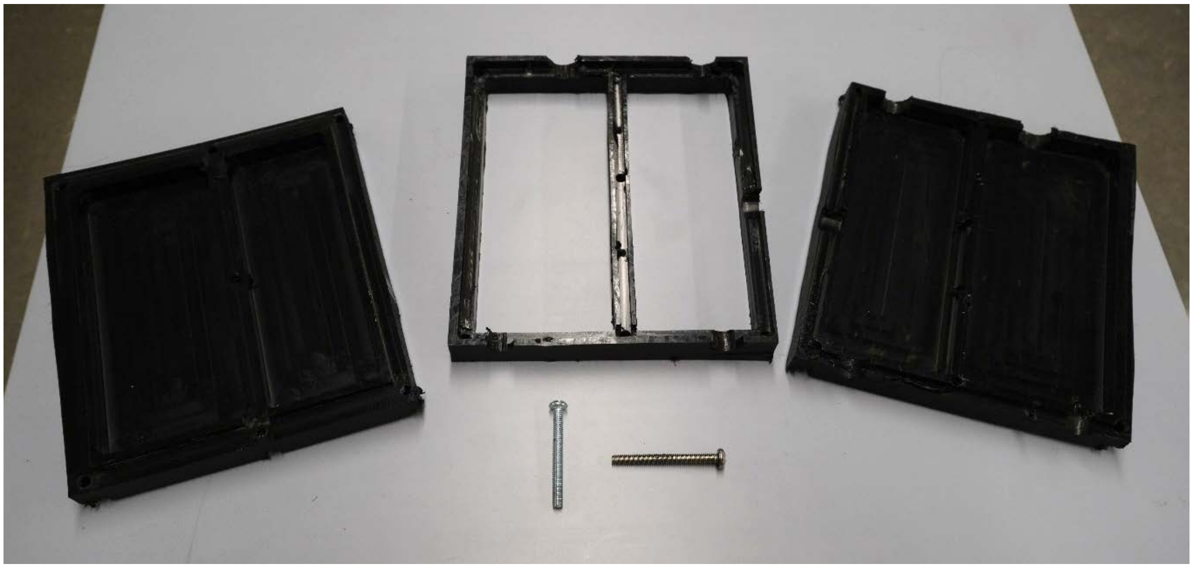

Figure 3 - This is the redesigned three-piece control box, with the lid on the left, the riser in the middle, and the base on the right. The riser has six holes to attach to the base and hold the components internally. These pieces are designed for simple alignment with tongue and groove joints. There is a longer attachment side on the edge with the flow control valve.

Figure 4 - This is the assembled box, which has a lid attachment consisting of only four screws, with an additional two screws to attach the overall box to the farrowing crate framework.

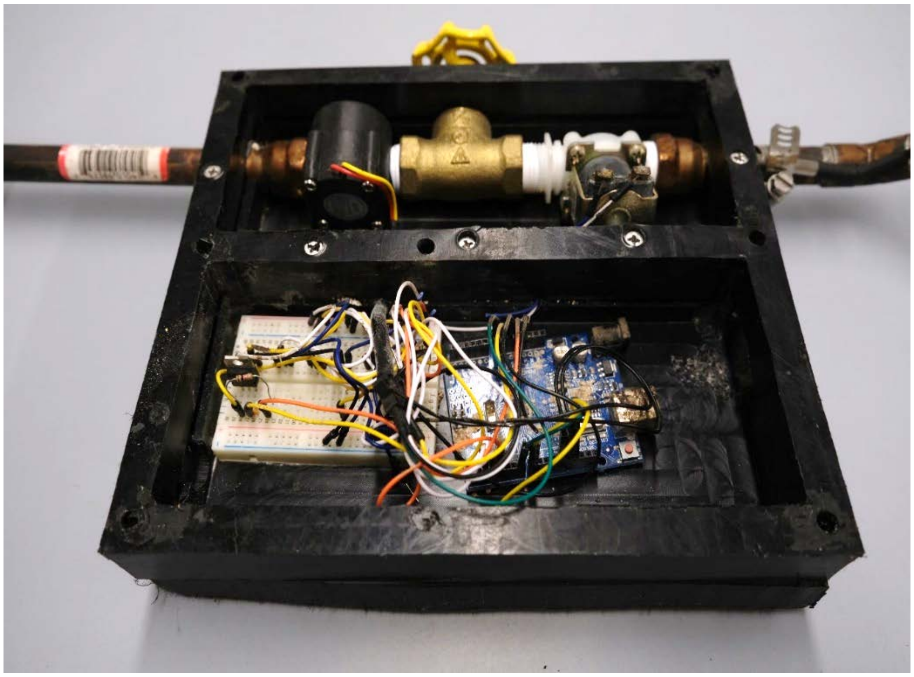

Figure 5 - This is the base and riser with the internal components in their operational positions. The connector breadboards and integrated circuit boards are in the compartment facing down, and the flow shut-off solenoid, flow rate control valve, and flow sensor are in the upper compartment, separate from the electronics.

Conclusion

Researchers have discovered that a sow cooling pad is an effective way to reduce heat stress within lactating sows. From measurements and data collection between treated and control sows, rectal temperature and respiration rates of thermally stressed animals have been reduced. This means that heat was removed from the heat stressed sows by use of the cooling pads. An unfortunate downside to this animal cooling technique is that the water waste produced by the device will need to be reduced. The cost to run multiple pads will be high, if the coolant system does not become a closed circulation system. There are different ways to be able to cool the water. One option is recirculating geothermally cooled water, while another is natural cooling over time by displacing the water in a container underground. Another means to cool the water would be by using a mechanical water cooler. However, this would produce additional operational expenses. Several other alternatives can be considered for the ultimate rejection of the animals' heat. However, under any heat rejection pad control protocol, the researchers would need to more accurately control the amount of water circulated through the pads and to be able to provide continuously available coolant.

The design of the cooling pad is nearly complete and is ready for prototype manufacturing to test larger numbers of the units in the field. The improved controller box design will aid the researchers in accelerated testing of the unit. There are several options that the researchers need to examine for manufacturing the pads. Currently, a CNC table router machine is what manufactures the pads. It takes nearly eight hours to make one. An improved option in the future would be injection molding. This process is simple and quick. It is fair to say that the pad is well designed from a functional standpoint, and it effectively reduces heat stress among sows. In the future, positive outcomes for the pork industry will come from this cooling pad.

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