CAPSTONE EXPERIENCE 2011
CNH ROUND BALER TEST STAND

PURDUE UNIVERSITY

Agricultural & Biological ENGINEERING

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Problem Statement: Sensing and generating uniform round bales is a challenge. The team will design, fabricate, and test a testing stand that will simulate a round baler to test a new infrared density scanner which counts forage stems as they cross the scanner. The test stand will be light and maneuverable and will turn packed forage across the scanner mount. This test stand will allow CNH to collect data with their new density scanner in a chamber which mimics a round baler.

Background Information: CNH is a world leader in agriculture and construction equipment business. Figure 1 is a diagram of the design of a CNH round baler that shows how a bale is formed in the bale chamber. The project sponsor is attempting to accurately measure bale density in round balers with an infrared (IR) sensor. IR sensors measure bale density and shape more accurately than mechanical sensors. Current mechanical bale density sensors are inefficient and need to be replaced often because they are in direct contact with the bale surface and the belts within the baler. An IR sensor could be placed in a remote location where it is not in direct contact with the bale or baler mechanisms. Currently the baler operators have to drive in a zig-zag pattern to evenly distribute the windrow into a bale. An IR sensor that could accurately measure bale density would save the operator money because it would reduce operator fatigue. The IR sensor would take the guesswork out of trying to evenly distribute the forage within the chamber. Additionally, an IR sensor would need to be replaced less frequently, reducing repair and maintenance costs. Also, it would produce uniform bales, in both shape and density, which will have a longer storage life and have better market value.

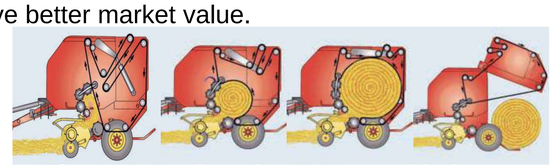

Figure 1. Design of a CNH round baler

Use of Appropriate Tools: In the design of the CNH round baler test stand, the 2009 version of AutoCAD was used. AutoCAD made it possible to put the team's ideas into a scaled visual design. As seen in Figure 2, AutoCAD was used to design the original solution, which included all mechanical components. After analyzing the drawing and determining that the design would not be a suitable solution to the problem, the team decided to change designs. The final design was also produced by using AutoCAD, as seen in Figure 3. This design was approved by the project sponsor and construction began. AutoCAD allowed for the construction of the test stand itself. Also, Holes were able to be drilled according to the drawing, in addition to cutting and fabricating of metal.

Figure 2. Original Design

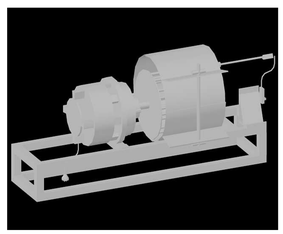

Figure 3. Final Design

Alternative Solutions: The original design was going to involve a bale chamber constructed of steel with an electric actuator to compress forage materials. Figure 2 is the drawing of the original test stand design. A 120V power supply was to be used to power the actuator. An electric motor was intended to rotate the forage across the IR sensor on the opposite side of the bale chamber. The second alternative solution included an elaborate design of pulleys connected in a circular pattern. The pulleys would be extended out 12 inches to another identical pulley system. The connecting bars to the two pulleys will be covered in actual round baler belt material to be able to grab and rotate forage. The pulleys will be connected with a belt to a motor to be able to rotate the pulleys simultaneously. As the pulleys turn, and forage is placed at the mouth being drawn in to make a rotating round bale. The IR sensor will be placed on the end of one of the circular 1/8" thick flat plate to gather readings.

Figure 4. IR Sensor

Figure 5. Multi-Meter for Sensor Readings

Final Solution: In order to compress the forage around the circumference of the bale, a cylindrical chamber that can be compressed will be used. A bale chamber will be installed that has a 11.5 inch diameter tube that overlaps into itself, and when the bolt is tightened the diameter can be decreased to 9.5 inches. The bolt will include a compression spring to ensure that adequate force is applied to the circumference of the bale. The stand will need to replicate the 20-50 psi force that an actual round baler exerts on a round bale. The chamber will be split into two halves and hinges installed so the top half can swing away and be loaded with forage. The chamber will be packed full of forage and the lid shut. The bolt will be tightened to shrink the chamber diameter, which will also increase the density of the forage. To accurately simulate a round baler, a density of 10 pounds/cubic foot will need to be achieved. The forage will be rotated across the IR sensor using a 120 V motor. To reproduce the bale surface speed of a round baler, 424 feet/minute, the motor will operate at a speed of 130 RPM. The motor has a 9 inch diameter plate with 4-6 inch long "teeth" to grip and rotate the forage. On the opposite side of the motor, a 9 inch stationary plate will be mounted to the chamber. This plate will have three different ports to place to the IR sensor in to take density readings. The IR sensor, as seen in Figure 4, will be connected to a 5 V power source and the sensor's output will range from 0.5 volts to 4.5 volts. The IR sensor output will be read using a multi-meter, shown in Figure 5.

Application of Engineering/Management Principles:

Speed requirement for motor needed to replicate bale surface speed of 424 ft/min by converting ft/min to rpm to properly size a motor for test stand.

RPM = FPM (Pi x Diameter)
RPM = 424 FPM (Pi X 1 ft)
RPM = 135

Hp Requirement for Motor

Hp = (T x N) 5252 ~~ Hp = [(600 in-lbs) x (1 ft/12 inches) x 135 rpm] 5252
Hp = 1.28

Purchased a 1.5 hp motor that produces 130 RPM and 727 in-lbs of torque

Economics:

In the livestock industry, forage as feed ranks among the top input costs for production. The construction of round bales needs to be dense and uniform to allow for proper storage. The money saved due to uniform and dense bales has not been calculated due to the need for testing of the new IR sensor. If a producer can consistently make a uniformly dense bale his bottom line will increase. Table 1 is a parts list and a cost breakdown of the supplies used to build the test stand. This test stand will be used to test the feasibility of using IR sensors to measure bale density.

Table 1. Supply list and costs for test stand

Item	Price
Steel (Chamber/Frame/End Plates)	$90.75
66 Frame Gearbox	$640.75
UHMW Plastic	$43.82
Hardware (Bolts/Washers/Nuts/Etc)	$44.87
Primer &Paint	$14.91
Electrical	$76.83
Total	**$895.61**

Sponsor: Kevin Smith, CNH Round Baler Innovation Group
Technical Advisor: Dr. Dennis Buckmaster, Associate Professor of Agricultural and Biological Engineering
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