USDA Subsurface Banding Poultry Litter Implement

Critical Design Report

MECH 4240- Senior Design
Corp_10

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Fall 2010- Dr. David Beale

Corporate Sponsor- Dr. Thomas Way

Abstract:

Corp_10 was formed early in the 2010 Fall semester to work with the USDA-ARS National Soil Dynamics Laboratory on improving an implement designed to apply beneficial nutrients to the soil. Two main problems with the current design of the implement were identified by the USDA. The first deals with the nutrient application phase, and the second focuses on the soil recovery phase. Each problem requires a unique set of engineering abilities to appropriately solve.

To improve the nutrient application process, a redesign of the implement walls was proposed. Working with the industrial sponsor, an appropriate design was selected. The design bends the steel walls of the implement outward to remedy a pinching problem currently experienced. The new walls will be fabricated from quarter inch steel, which will reduce the deflection seen in the current eighth inch walls.

In the soil recovery phase, an adjustable dirt scooping system was proposed to aid the current press-wheel system. The design is simple and low-maintenance, while being very effective. Presented in this critical design report is the detailed design work done in coordination with the USDA, including appropriate engineering analysis, sizing of parts and components, and the formulation of a testing plan for the redesigned trencher implement.

As the design progresses and enters the detailed phase, the concepts become more concrete. However, it is the expectation of the group that minor changes will be made as the design continues and fabrication begins. The work presented in this report is the best available at this time; however, it is expected to evolve with the project.

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Introduction

Our sponsor, the USDA-ARS National Soil Dynamics Laboratory, has identified two problems encountered during normal use of an implement designed to supply beneficial nutrients to the soil. The implement, coined for the project purposes as a "poultry litter trencher", was designed and patented as an "Applicator System and Method for the Agricultural Distribution of Biodegradable and Non-Biodegradable Materials" [US Patent 7,721,662 B2]. The problems encountered include material bending in the litter depositing stage, and ineffective recovery in the soil restitution phase. Our task is to improve the design of the implement (shown below in Figure 1) to remedy these problems.

Figure 1- Subsurface Banding Poultry Litter Implement [Way, T. (2010) - Improvement of Soil Trenchers for a Subsurface Banding Poultry Litter Implement (6)]

Problem Specifications-

1) During the litter depositing stage, the force of the soil is causing inward bending of the 1/8th inch thick steel walls, leading to backup of the litter. The design chosen to fix this must be able to withstand the force from the soil (determined by implementing a force testing system) while allowing the poultry litter to travel unaffected to the soil. Considerations of the design include:

   - Weight
   - Manufacturability
   - Interface with existing components
   - Cost
   - Durability in rugged and caustic environment
   - Reliability
   - Accessibility

2) During the soil restitution phase, the current closing wheel system is not effectively recovering the dirt spread by the plowing portion of the implement. The result of this is a rut being formed as the implement travels. The goal of the design is to augment the current system, or design a replacement for it altogether. The design chosen will be more effective in recovering the soil, and will more accurately cover the litter band, ensuring a rut is not formed. Design considerations for the soil recovery system are:

   - Durability
   - Strength
   - Manufacturability
   - Cost
   - Reliability
   - Adjustability

In the preliminary design report, the engineering requirements of the project were presented, the feasible alternatives were shown and explained, and the concept(s) that were chosen to satisfy the project's needs were outlined. Presented in the critical design review is the detailed design work that was done on the chosen design concepts. This includes conceptual analysis, implementation of data from testing, force analysis, 3D modeling, finite-element analysis, and proof of concept through prototyping. With this work, it is hoped that fabrication can begin at start of the spring semester.

Mission Objective(s):

The mission objectives have remained the same throughout the design process. The objectives are instrumental in focusing the design and ensuring that the end product(s) will be useful when integrated into the poultry litter implement system. The objectives are presented below for each branch of the project.

Litter Application Component-

To improve or redesign the walls of the poultry litter implement so that litter can be more effectively distributed to the soil, mitigating the clogging that currently occurs under normal operation while

- Minimizing environmental impact
- Increasing the wall strength
- Providing reliable operation
- Being easily manufactured

Recovering Dirt Component-

To improve or replace the current press-wheel system used on the implement for dirt recovery so that the extricated soil is more effectively replaced over the deposited litter band. This must be accomplished considering

- Durability of the system
- Environmental impact
- Manufacturabiliy
- Effectiveness

Architectural Design and Development:

During the preliminary design phase, the group determined that using the angled bend trencher wall and the two-bar recovery system would be the most effective means to satisfy the mission objective(s). The architectural design was derived from these choices. The redesigned poultry litter trencher system can be seen in Figure XX.

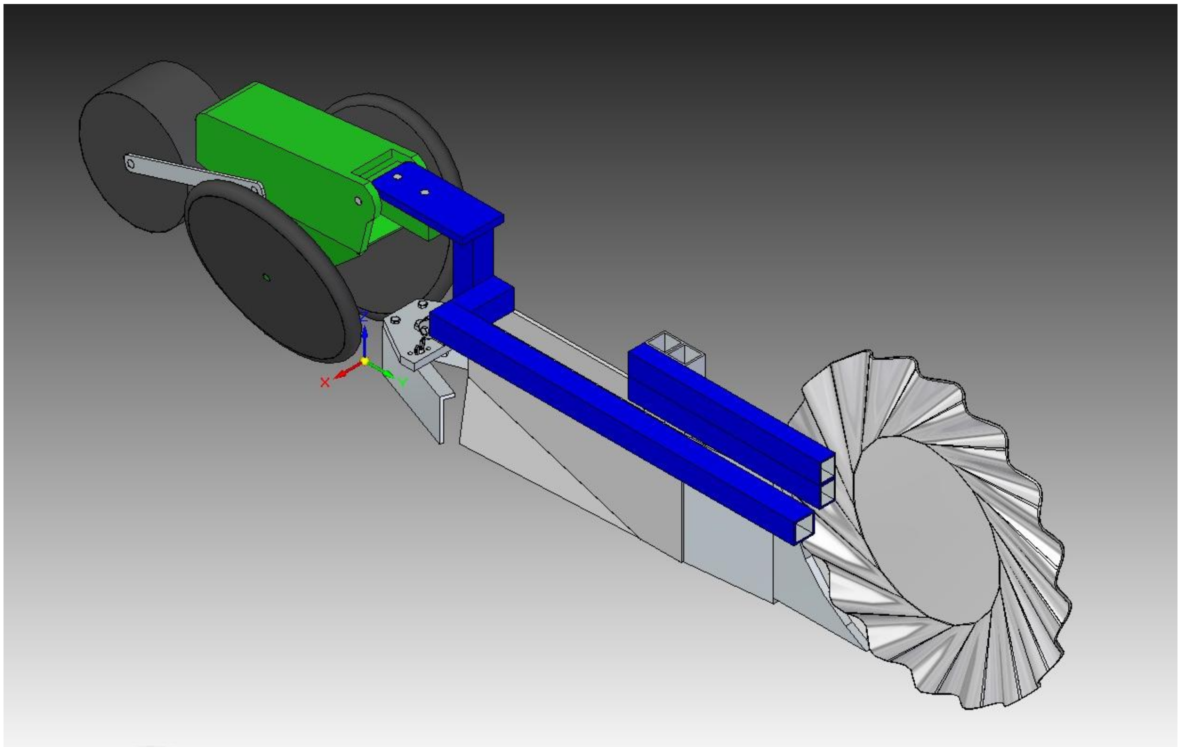


Figure XX- Isometric View of Redesigned Trencher

The two subsystems of importance to the project are the trencher walls subsystem and the soil recovery subsystem. The trencher walls were redesigned with an outward angled flare to remedy the pinching problem currently associated with the poultry litter application process.

The outward flare of the trencher walls effectively removes the previous pinching point by providing additional clearance for the poultry litter to disseminate through. The trencher walls can be seen in an isometric and back view below in Figure XX.

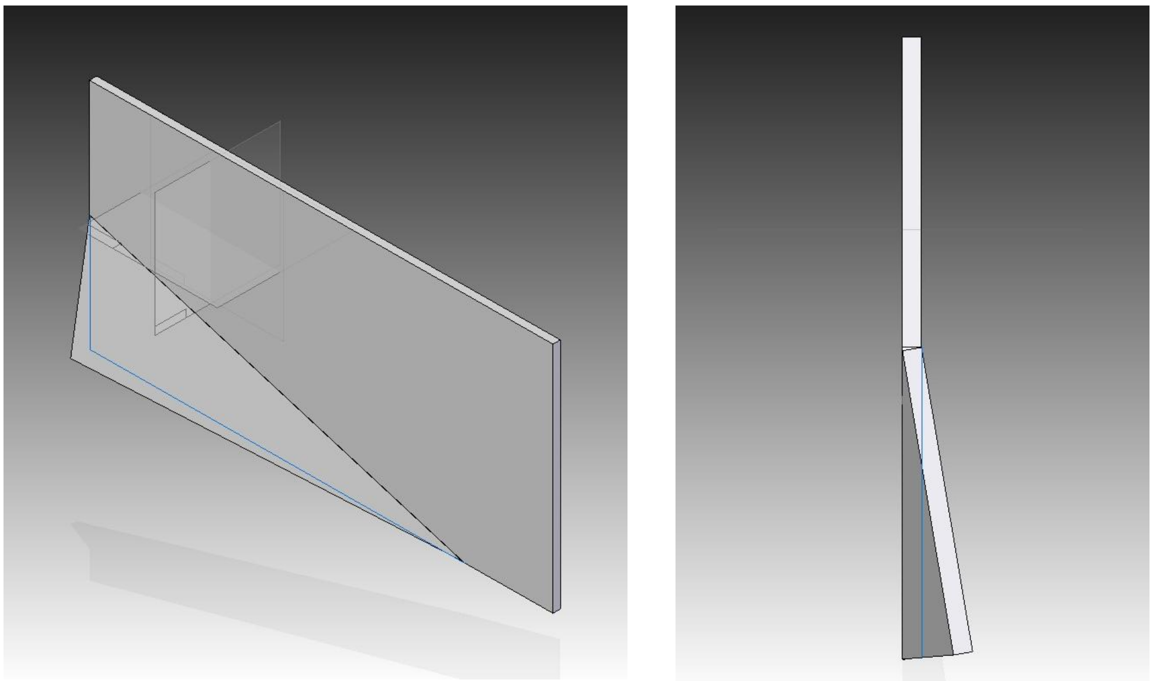


Figure XX- Isometric and Back View of Redesigned Trencher Wall

Working to capture any loose soil spread by the trencher walls, the soil recovery subsystem is found immediately behind the tail end of the trencher walls. Here, an adjustable mechanism is used to collect and focus any loose soil. This mechanism can be seen in an isometric view in Figure XX, and a front view in Figure XX on the next page.

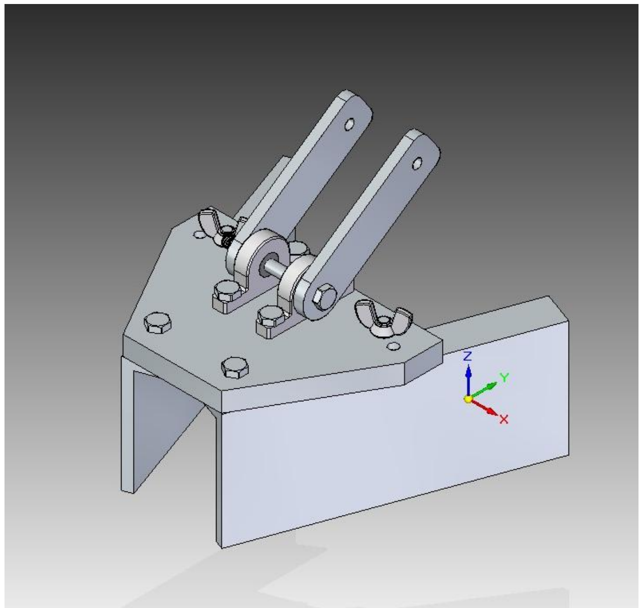


Figure XX- Isometric View of Soil Recovery Device

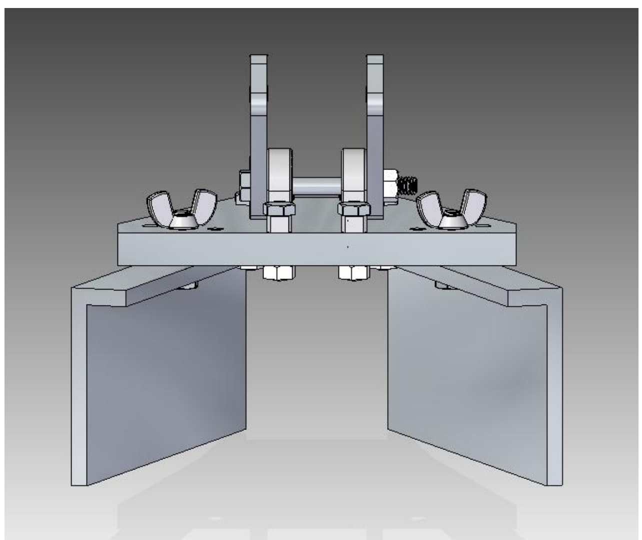


Figure XX- Front View of Soil Recovery Device

The soil recovery subsystem has an adjustable width feature to allow for use in varying terrains and soil types. Two pivots ensure the device stays in the horizontal position while allowing for vertical adjustment to the operating depth. For clarity, a top and bottom view of the soil recovery device is shown on the next page in Figure XX.

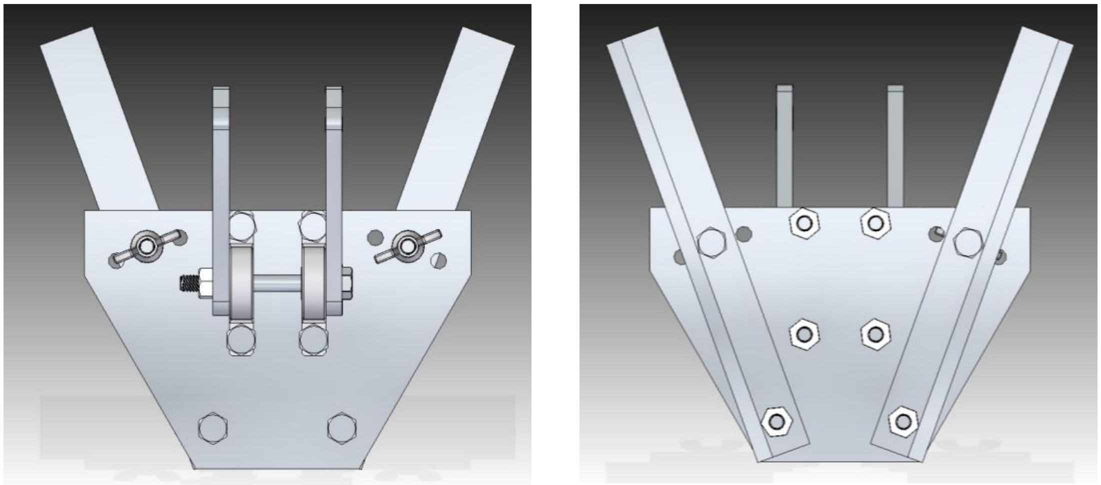


Figure XX- Top and Bottom View of Soil Recovery Device

With the architecture set for the trencher wall and soil recovery subsystems, economic and engineering analysis could be performed. As shown below, a product hierarchy and detailed economic analysis was completed for the individual subsystems. This is followed by engineering analysis, leading to detailed design later in the report.

Product Hierarchy

The project consists of two objectives: the trencher wall redesign, and the soil recovery component. As the trencher walls are considered a part in the trencher subsystem, there is no particular need for a product hierarchy. However, physically the trencher walls provide the exterior structure of the trencher implement. The walls separate and hold back the soil, and allow poultry litter to be deposited in the division. The walls have a physical interface with the trencher skeleton, and utilize welds to fix their position.

The soil recovery system is inherently more detailed. In fact, the soil recovery subsystem of the trencher implement has two further subsystems: the linkage bar, and the recovery scoops, as shown in Figure 6 on the next page.

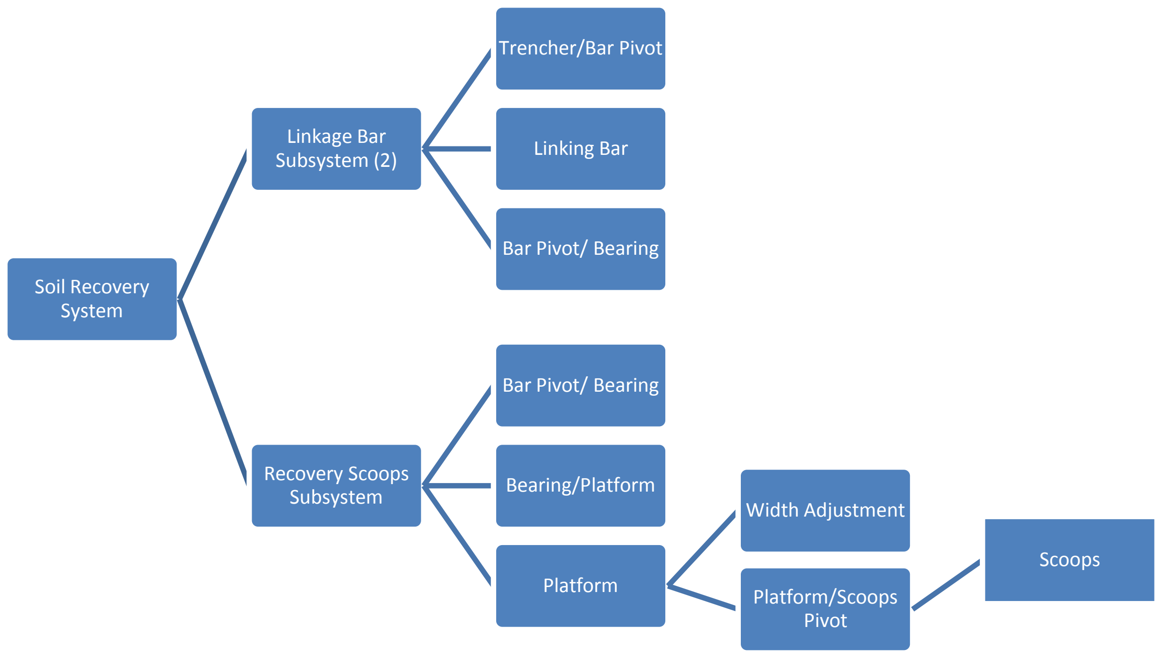


Figure 6- Product Hierarchy of the Soil Recovery Subsystem

Each linkage bar subsystem consists of two pivots, a machine bolt on the trencher end, and a mounted bearing on the soil recovery device end, with a linking bar which will span between the trencher pivot and the mounted bearing. The mounted bearings will be directly bolted to the recovery platform. The recovery platform will serve as the location for the width adjustment of the scoops, and to house the fixed pivot for the scoops. The components of the recovery scoop subsystem are as follows: a pivot connecting the linking bar to the mounted bearings, the mounted bearings, the recovery platform, a lockdown component that fixes the position of scoops, a pivot that connects the scoops to the platform, and the actual scoops themselves. The soil recovery system is located between the tailing edge of the trencher walls and the press-wheel system. The soil recovery system will be designed so that it cannot interfere with any other systems in the implement.

Bill of Materials

The expected Bill of Materials for the trencher wall system is presented in Table 1 below.

Materials	Qty.	Unit Cost	Supplier	Notes
Steel Plate	2	$19.20	onlinemetals.com	A36HR Steel 16x8x0.25" (onlinemetals.com)
Labor	2	$35.00		http://www.bls.gov/oco/ocos223.htm
	Total	**$108.40**		

Table 1- Bill of Materials for Trencher Wall System

The economic analysis for the soil recovery device is presented in Table 2 below.

Materials	Qty.	Unit Cost	Supplier	Notes
Steel Plate	1	$9.30	onlinemetals.com	A36HR Steel 6x4x1/2"
Square Steel Tube	1	$22.54	onlinemetals.com	A36HR Steel 4x1/4x7"
Steel Flat Bar	2	$0.96	onlinemetals.com	A36HR Steel 1/2x1x4"
Mounted Bearings	2	$9.41	McMaster-Carr	Base Mounted 1/4" Bearing
Zinc Coated Bolt	8	$0.08	McMaster-Carr	1/4" – 20, @ 1" length Priced individually from pack of 100
Zinc Coated Bolt	2	$0.12	McMaster-Carr	1/4" – 20, @ 2 1/2" length Priced individually from pack of 100
Zinc Plated Nut	10	$0.06	McMaster-Carr	1/4" - 20 Priced individually from pack of 100
Zinc Plated Wing Nut	2	$0.10	McMaster-Carr	1/4" - 20 Priced individually from pack of 100
Labor	4	$35.00		http://www.bls.gov/oco/ocos223.htm
	Total	**$194.06**		

Table 2- Bill of Materials for Soil Recovery System

Additional information on the purchased parts is available in Appendix XX.

Architectural Design Analysis

In order to quantify some of the requirements of the trencher implement, engineering analysis was performed on select areas of the project. The first undertaking was to measure the force exerted on the trencher walls by the soil. To complete this task, it was decided that a testing rig be created. The final design of the force testing rig uses four pressure transducers mounted to a plate of 1/8th inch steel sheet metal with a recess machined for each transducer, as shown in Figure 2.

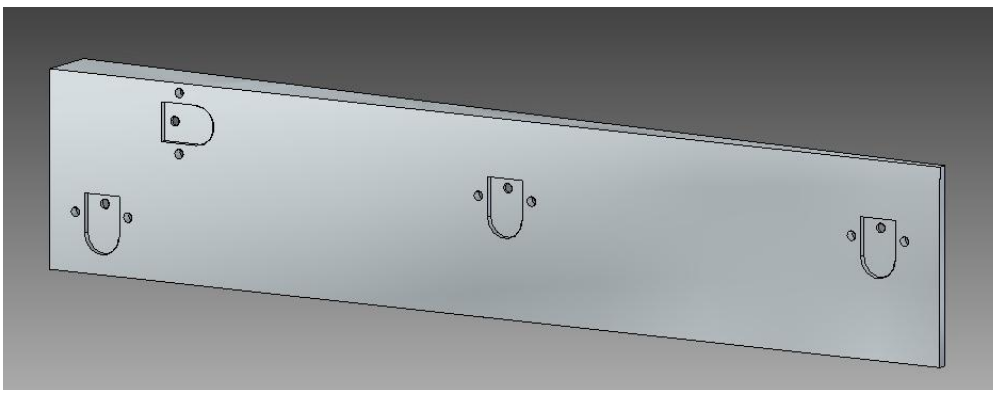


Figure 2- CAD Drawing of Force Testing Rig

The pressure transducers were mounted flush to the surface of the steel so that the reading will be accurate and the transducers will be protected from the soil. The force test rig was mounted in a configuration as close to the actual configuration of the bent trencher walls. As shown in Figure 3, this was done by mounting the rig to a straight trencher wall, using triangular spacers to achieve the desired angle.

Figure 3- Assembled Force Testing Rig

After mounting the force test rig to the trencher wall, the implement was pulled by a small tractor through varying types of soil. Data was collected using Honeywell Model F Subminiature low profile pressure transducers located as stated earlier. The pressure data was collected using a SoMat data acquisition system and loaded onto a laptop for analysis. Mr. Dexter LaGrand, the USDA-ARS National Soil Dynamics Laboratory electronics specialist, installed the data acquisition system and computer interfacing used during the experiment, as shown in Figure XX on the next page.

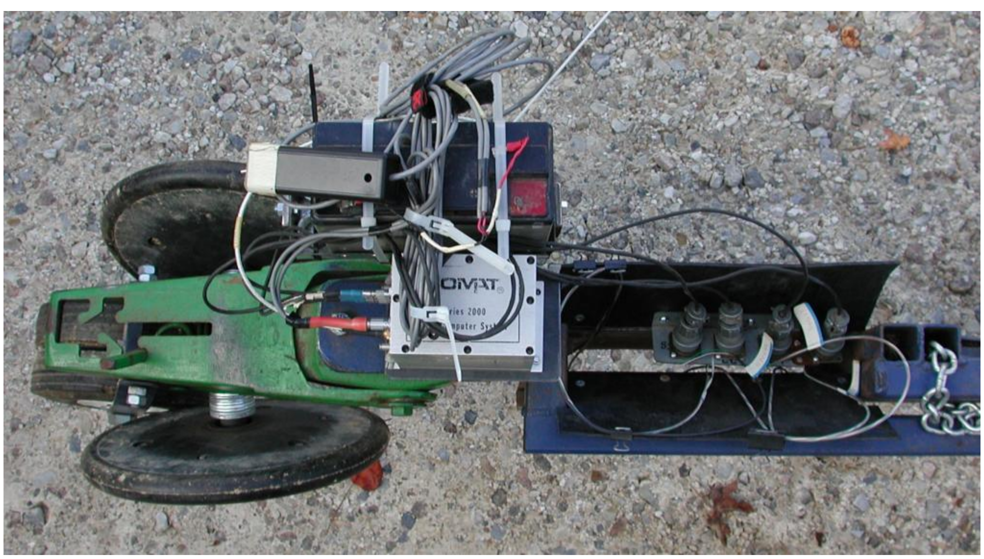


Figure XX- Data Acquisition System Installed on Trencher

The data collection was accomplished using a simple on/off switch to begin or stop the test. Once the data had been computerized, an analysis determined the average range of pressure exerted on the trencher wall. A graph of one set of data is shown in Figure XX below.

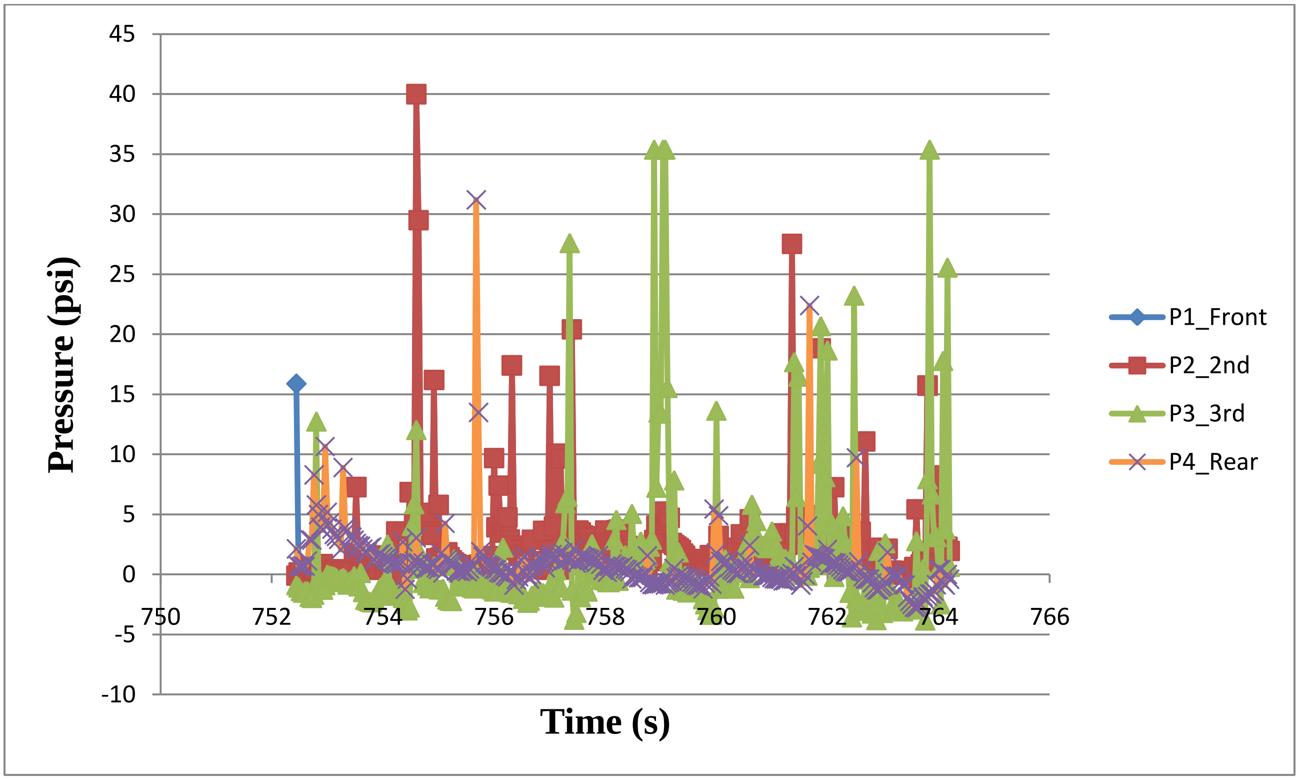


Figure XX- Oktibbeha Clay Soil, First Run (11/5/2010)

Figure XX shows a fairly uneven distribution of pressures ranging from -5.1 psi to 40.0 psi. It is unclear how the sensors detected a negative pressure and for now can only be explained as an anomaly. Also, the steep spikes are believed to be disturbances that were present in the soil, from the tractor, or the data acquisition system. The mean for each set of data was found to be approximately 2 psi. This value is much lower than expected for the Oktibbeha clay, one of the harder materials that the trencher could experience. For this reason, the peaks were taken into account when determining a pressure value to be used in ANSYS. It was agreed that 30 psi should be the pressure used for the deflection analysis in great part to design for a worst case scenario in which high pressure peaks are experienced. In using this elevated pressure range, detailed design can account for higher pressures exerted on the wall and strengthen it accordingly.

Detail design was completed on the trencher wall using several means. First, past experiences of Dr. Tom Way and Marlin Seigford on the trencher were used to guide various aspects such as the angle at which the wall was bent and how high the bend should be. Second, finite element analysis (ANSYS) was used to determine the thickness of the wall and its material. The wall was first modeled in Solid Edge and converted to and IGES file for importation to ANSYS. Next, boundary conditions were set such that the top and leading edges were constrained in all directions. This simulates the wall's attachment to the trencher via a weld on the leading edge and bolts on the top edge. Figure XX shows the boundary conditions as they appear in ANSYS.

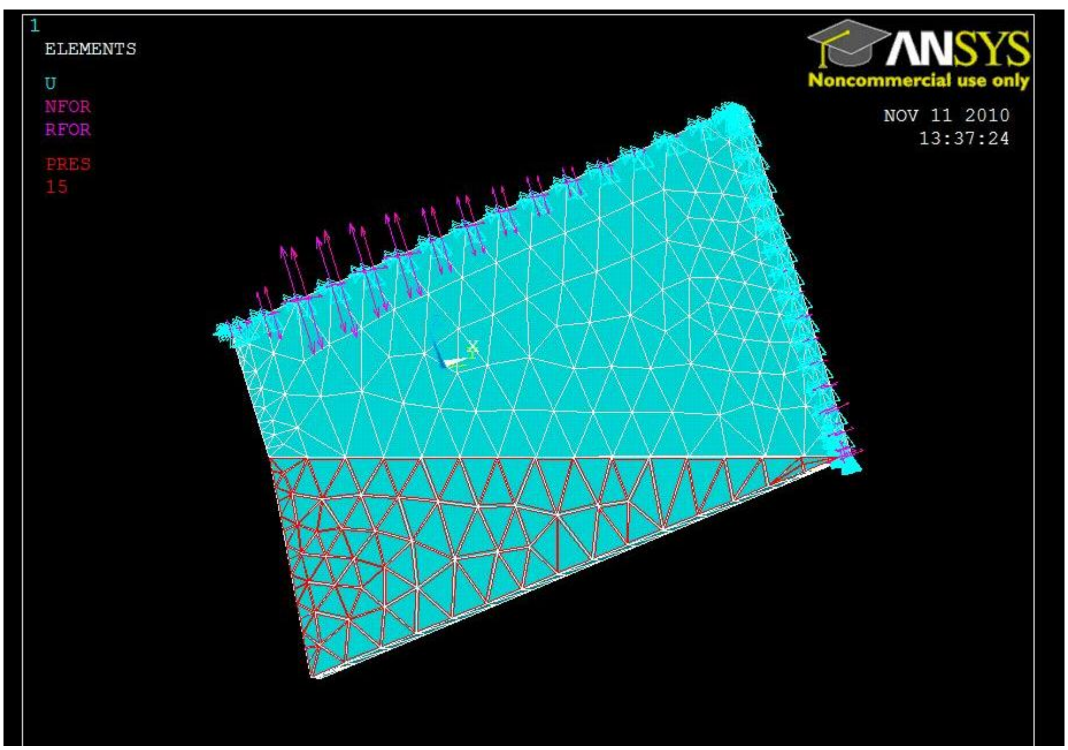


Figure XX- Boundary Conditions for Trencher Wall Deflection Analysis

It must be noted that the wall modeled for ANSYS was made purposefully two inches shorter in the vertical direction. This was done to maintain the boundary conditions because the actual trencher wall is bolted to square tubing along its top edge and two inches of the wall rest against those tubes. Thusly, the wall deflects as if it were two inches shorter.

Figure XX also shows the pressure applied as red lines over the bent section of the wall. A constant and even pressure of 15 psi and later 30 psi was placed on the bent area. Due to the geometry of the trencher walls, this situation is unlikely in reality because the ground will exert a larger pressure on the trailing end of the trencher wall as opposed to the leading end. However, for a maximum deflection prediction, an evenly distributed pressure was used. This will ensure that the results are will withstand a "worst-case" scenario.

When the solution to both the 15 and 30 psi tests was found and plotted, it was determined that the maximum deflection in the trencher walls was 0.091 and 0.202 inches respectively. This deflection happened at the trailing bottom edge of the wall. This point, when fully bent outward, allows a 2.688 inch gap between the walls of the trencher. This gap allows for each wall to deflect up to 0.344 inches without constricting the flow of the litter passing between the walls. Given that the maximum deflection for the analysis was 0.202 inches, under extreme conditions, the current design for the trencher walls is satisfactory and will be used. Figures XX on the next page shows the deformed shape of the wall under 30 psi of pressure.

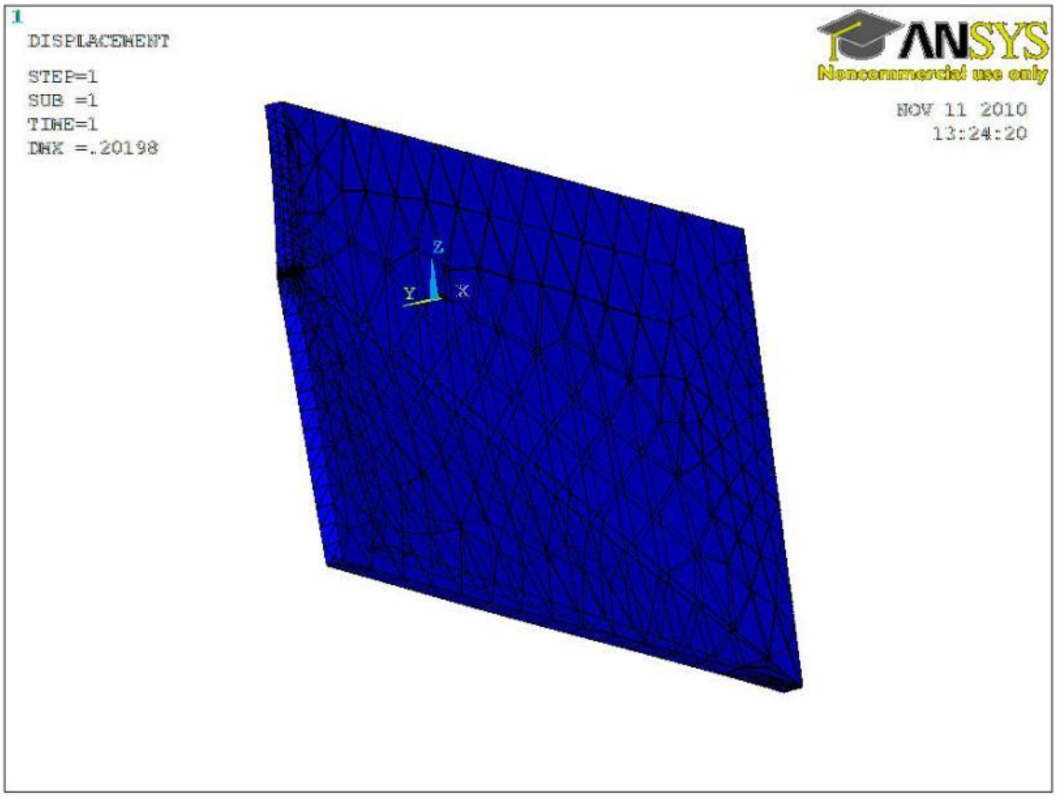


Figure XX- Deformed Trencher Wall with 30 psi of Pressure

For comparison, ANSYS tests were run with the original straight wall trencher design for both .25 and .125 inch sheets. A constant force was applied to the bottom edge of the wall that was equivalent to the pressure exerted on the bent wall design. The boundary constraints remained the same from the earlier test. Results showed that an increase in wall thickness significantly decreased deflection. However, the deflection in the .25 inch thick wall was still above the required specifications. Namely, any deflection by the straight wall design could result in clogging of the poultry litter as it passes through the walls. This result further proves that the bent wall design is the superior choice for the trencher.

To determine the impact that adding a soil recovery device would have on the trencher implement, and to help size components, a free body diagram was drawn of the soil recovery device, as seen on the next page in Figure XX.

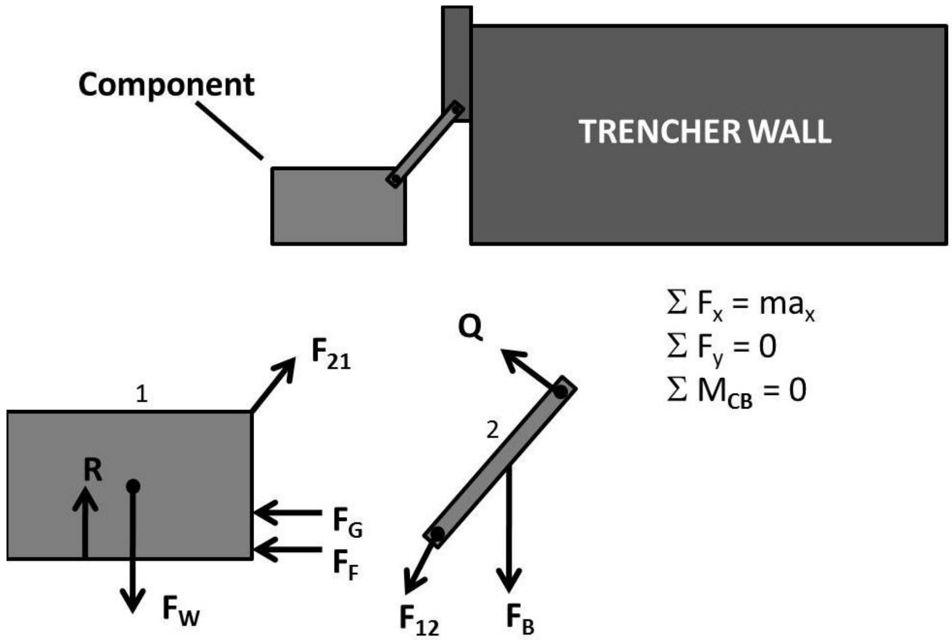


Figure XX- Free Body Diagram of the Soil Recovery Device

Notation:

- F_w Weight of the soil recovery component
- R Reaction force of the ground on the component
- F_g Force of the soil to be recovered
- F_f Frictional force on the soil recovery device
- F_{21} Force of the linking bar on the soil recovery device
- F_B Weight of the linking bar
- Q Force of the trencher on the linking bar
- g Gravity
- m Mass
- a Acceleration
- ρ density
- V volume
- μ Friction coefficient
- r_{AB} The position of B relative to A

Using Newton's law on the soil recovery device,

$$\sum F = ma \quad (1)$$

leads to an equation in the vertical and horizontal directions

$$\sum F_y = 0 \;\rightarrow R + F_{21y} - F_w = 0 \quad (2)$$

$$\sum F_x = ma_x \;\rightarrow\; F_{21x} - F_g - F_f = m_c a_c \tag{3}$$

From equations (2) and (3), the following basic equations were established:

$$m_c = \frac{F_w}{g} \tag{4}$$

where

$$F_w = \rho_{steel} V_{steel} \tag{5}$$

$$F_f = R\square \tag{6}$$

The assumption is made that the force of the soil resisting motion is negligible

$$F_g = 0 \tag{7}$$

The force on the pivot can be found by the free body diagram of the pivoting bar:

$$\sum F_y = 0 \;\rightarrow\; F_{12y} - F_B - F_{Qy} = 0 \tag{8}$$

where

$$F_B = \rho_{steel} V_{steel,Bar} \tag{9}$$

$$\sum F_x = ma_x \;\rightarrow\; F_{12x} + F_{Qx} = m_b a_c \tag{10}$$

$$\sum M_c = 0 \;\rightarrow (r_{BC} \times F_{12}) + (r_{BT} \times F_Q) = 0 \tag{11}$$

$$Q_{Pivot} = \sqrt{{F_{Qx}}^2 + {F_{Qy}}^2} \tag{12}$$

Assuming that R = 0 (the minimum weight when the ground doesn't provide any reaction), there are 5 equations and 5 unknowns. Naturally this is a perfect set-up for a MATLAB program (see Appendix XX for code). Using a symbolic solver, the pertinent forces were found. The shear in the pivot connecting the trencher to the pivoting bars was found to be 14.3 lbs (safety factor of 3). This is well below the shearing strength of the suggested pivot connections. As is such, the design can progress accordingly.

Requirements:

Trencher (System)

- Apply litter band to soil at desired depth
- Work in corrosive environment
- Perform with little or no maintenance
- Minimize damage to environment during operation
- Perform under various soil conditions
- Must be affordable for eventual manufacture and market (approximately $25,000 for the implement)
- Be reliable in operation
- Must be adjustable to different terrain
- Needs to operate safely

Trencher Walls

- Prevent clogging of poultry litter during application to soil
- Withstand pressure from soil
- Work in corrosive environment
- Perform with little or no maintenance
- Minimize damage to environment during operation
- Perform under various soil conditions
- Be compatible with current trencher design
- Must be affordable

Soil Recovery System

- Recover soil displaced by leading edge and trencher walls
- Support or replace current press-wheel system
- Operate reliably under different soil conditions
- Avoid interference with crops
- Minimize environmental impact of trencher
- Require minimal maintenance
- Cost effective
- Needs to be easily manufacturable

Concept of Operation

The subsurface banding poultry litter implement, as the name implies, delivers poultry litter from a hopper to a trench dug by the implement between rows of crops. There are a series of four implements, known as trenchers, attached to a main structure. The system is pulled behind a farm tractor and hydraulic power is provided by a pump located within the tractor.

Upon the main structure sits the hopper that distributes the poultry litter to the four trenchers via a series of conveyor belts. The belts are propelled by a series of motors powered by the aforementioned hydraulic system. For each trencher, a coulter produced by Yetter (2995 Series Coulter) breaks the soil surface [1]. The coulter is attached to the main structure by a four-bar mechanism [not shown] that allows the trencher to travel in the vertical direction with changing soil height or obstacles. Also attached to the four-bar mechanism and located directly behind the coulter is an expansion wedge [2]. The wedge, composed of sheet metal, spreads the broken soil to the necessary width for the trench. It is supported on the bottom by a plastic insert that keeps unwanted dirt from entering the wedge.

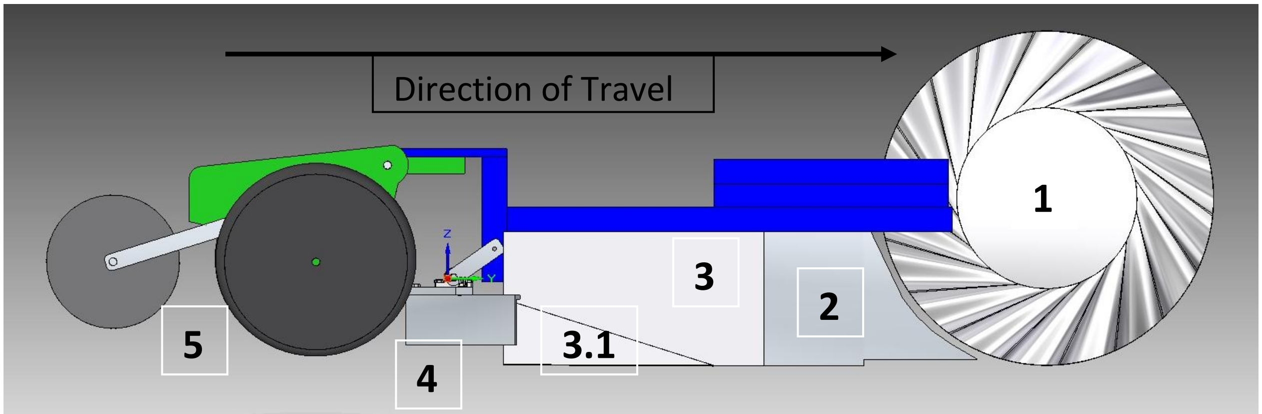


Figure 7- CAD Drawing of Poultry Litter Trencher

Sheet metal welded to the rear edge of the wedge serves as the trencher walls [3]. Between these parallel walls, the poultry litter can be deposited to the trench. The trencher walls are bent out at a slight angle towards the rear of the wall to prohibit pinching of the walls together [3.1]. This type of pinching would constrict the flow of litter and create clogging. Behind the trencher walls is a two-bar mechanism that serves to collect the dirt pushed aside by the coulter and wedge [4]. Moreover, the collector's goal is to move the dirt inwardly so that a John Deere closing disk assembly may place it in the trench.

The closing disk assembly, from a John Deere Pro-Series XP Row Unit, is connected to the trencher structure and pivots on a spring assembly that allows for vertical translation with changing elevation and obstacles. Attached to the disk assembly is a set of wheels that compact the soil once it has been returned to the trench [5]. The compaction occurs solely under the weight of the wheels so as not to overly compress the soil.

Validation and Verification:

To verify that the redesigned implement is meeting the requirements set forth, a simple testing plan will be implemented. The redesigned trencher implement will be tested in conditions that simulate those found in the operating environment. The trencher will be run in various soil types, and at various soil depths. For the trencher walls, deflection and potential litter backup will be accessed visually to determine if the implement will perform as expected. At the same time, the recovery implement will be comparatively checked for effectiveness in guiding the loose dirt back over the trench. This will be done by visual inspection, side-by-side testing of the current trencher design and the redesigned trencher, and by comparing photographic evidence of the current and redesigned trencher's environmental impact.

The testing plan for system validation is also quite simple. The redesigned trencher will be placed in the original system, run under various soil conditions, and compared with the original trencher based on performance, environmental impact, effectiveness, and maintainability. No interfacing problems are expected as the redesigned trencher will mount using the same connections; however, the joints will be monitored for signs of fatigue or other failure.

Interfaces and ICD:

The interfaces found in this system are strictly mechanical, as shown in Figure 9 below.

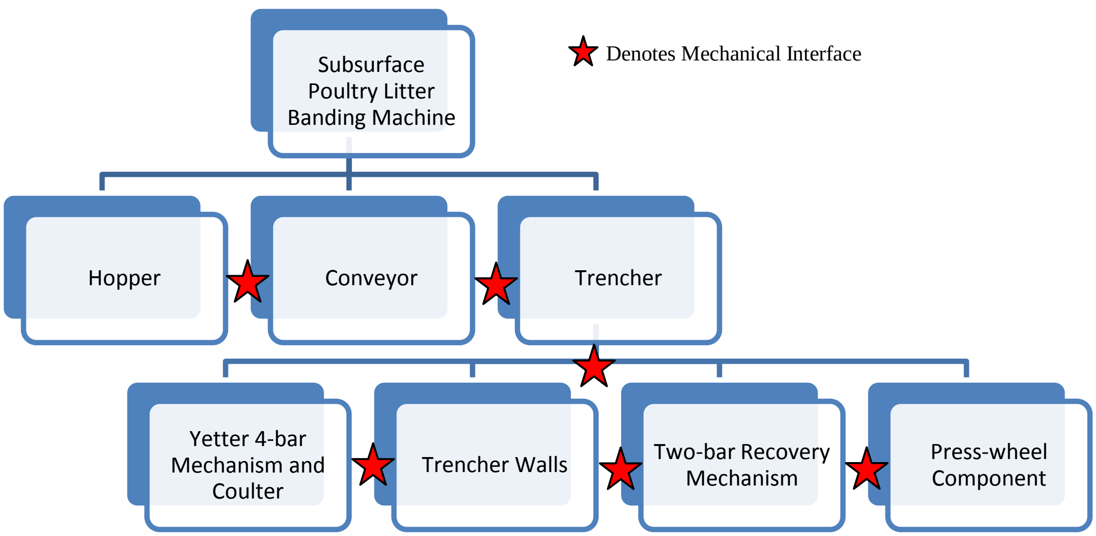


Figure 9- Interfaces and Operational Boundaries of System

The interfaces that are of importance to the project are mainly at the component level. Little is expected to change in the mechanical interface between the trencher and Yetter 4-bar mechanism and coulter. The same is true with the press-wheel component. The trencher walls are expected to change in shape, but the same technique for mounting (namely welding) is expected to be employed, and connection points will remain in relatively the same location. The two-bar recovery mechanism will mount to the trencher by use of pivot. It is thought that a simple bolt will provide the means for the pivoting action. The bolt will be sized according to a "worst-case" force analysis performed on the two-bar mechanism; however, preliminary results show that the shear forces will be small, and no additional support will need to be added to the trencher structure.

Mission Environment:

Our mission environment is very corrosive. The chemicals from the chicken feed, compounded with the occasional dampness of the soil, make for a rough environment for steel (as of now the main metal of the system). Our goal is to reduce the effects of the corrosion on the material (either by choosing a new, more corrosion resistant metal, or applying a corrosion resistant coating), while at the same time ensuring we don't add any harmful materials (mainly from any coating) to the environment.

Risk Management:

During normal operation, the trencher poses little risk to the operator and/or onlookers. More important to consider in this application is the risk due to mechanical or other failure. Presented in Table 4 is an outline describing the potential failures of the system, their severity, and possible solutions to remedy the problem.

Rank	Risk Title	Risk Exp.	Action	Risk Type	Status
1	Component separation from trencher system	Likelihood: Low Consequence: Mod	Watch	Technical	Redesign fasteners, components, or subsystems
2	Clogging of trencher walls	Likelihood: Mod Consequence: Mod	Watch/ Research	Technical/ Program	Redesign of trencher walls

3	Soil not sufficiently collected by soil recovery subsystem	Likelihood: Low Consequence: Mod	Watch/ Research	Technical	Adjust recovery device
4	Damage to crops by soil recovery subsystem	Likelihood: Low Consequence: Low	Watch	Technical/ Program	Adjust soil recovery subsystem
5	Soil over-tilled by soil recovery subsystem	Likelihood: Low Consequence: Low	Watch	Technical/ Environmental	Adjust soil recovery subsystem
6	Deformation of trencher walls	Likelihood: Mod Consequence: Mod	Research	Technical/ Program	Redesign of trencher walls
7	Soil over-tilled by trencher walls	Likelihood: Low Consequence: Mod	Watch/ Research	Technical/ Environmental	Redesign of trencher walls
8	Damage to crops by trencher walls	Likelihood: Low Consequence: Mod	Watch	Technical/ Program	Redesign of trencher walls

Table 4- Risk Management Structure

Personal safety is of upmost importance to the USDA-ARS and Corp_10. When working in the machine shop, the group is under the supervision of Marlon Siegford, the shop safety advisor. Additionally, the group conforms to training learned in MECH 3210 (Design and Manufacturing Lab). Table XX outlines some of the risks that group members could encounter, and the appropriate actions that should be taken to ensure that personal safety is upheld.

Rank	Risk Title	Risk Exp.	Action	Risk Type
1	Lacerations caused by sharp edges	Likelihood: Low Consequence: Low	Watch/ wear gloves	Safety
2	Injury caused by lifting heavy equipment	Likelihood: Low Consequence: Mod	Watch/ use aids	Safety
3	Eye injuries caused by metal chips or intense light	Likelihood: Low Consequence: High	Wear eye protection at all times	Safety
4	Injury caused by pinch points	Likelihood: Low Consequence: Mod	Watch	Safety
5	Injury caused by rotating shop equipment (Lathes, drills)	Likelihood: Low Consequence: High	Observe shop safety rules and have a safety observer	Safety
6	Burns caused by contact to hot metal parts or tools during fabrication	Likelihood: Low Consequence: Mod	Watch, use safety equipment	Safety

Configuration Management:

Please see the website for information regarding how the configuration is managed.

Subsystems Design Engineering:

The structure of this project has two main branches: the trencher walls, and the soil recovery device. Each subsystem must not only be able to complete its assigned task, but also interface with the entire system. To ensure that each subsystem would function on its own, and in the context of the whole system, careful methodology in systems engineering was employed.

This began in the Pre-Phase A stage, where the mission objectives and concepts were generated. Each mission objective was treated as its own entity, and the focus of concept generation was solely on completing the objective. Multiple concepts were generated for both subsystems.

In Phase A, the requirements for the entire system were formed. A trade study of the materials and methods available for use in fabrication was completed as well. The generated concepts were discussed with the industrial sponsor, and the focus of the project was narrowed to one concept for each subsystem. This allowed the group to move forward to Phase B.

In Phase B, the subsystem level requirements were formed. For the trencher walls, it was determined that the mission environment needed to be quantified, specifically in determining the force exerted on the walls by the soil. To accomplish this, a pressure testing rig was designed and fabricated in coordination with the industrial sponsor. Finite element analysis was performed on the trencher wall concept to determine if it was suited for the environment. For the soil recovery device, the requirements were easier to obtain. Proof-of-concept prototypes were created, and the soil recovery design was tested for effectiveness.

Phase C began the detailed design work on the trencher implement. For the purposes of the project, the system has two main branches: the trencher walls, and the soil recovery device. The trencher walls were redesigned with an outward bend that will ensure that an unobstructed path remains for the poultry litter during operation. Based on the previous experience of our industrial sponsor, a target width of two and seven eighths (2 7/8”) inches was set for the gap between the walls at the bottom trailing edge, as shown in Figure XX.

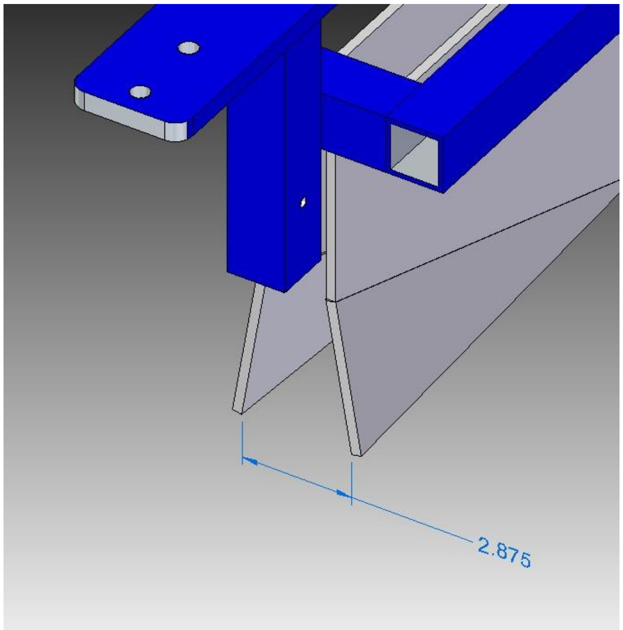


Figure XX- Desired Gap between the Trencher Walls

This requirement allowed the group to determine the desired geometry of the trencher walls. For ease of manufacturing, a ten degree bend in the walls was chosen. The walls were also thickened to help reduce deflection and increase durability. Based on the results of a trade study performed by the group, it was decided that quarter inch ASTM 36HR steel be used for manufacturing. ASTM 36HR steel will be used for its desirable structural properties, low cost, and accessibility (see Appendix XX for material properties). The redesigned trencher wall will mount to the frame of the trencher in the same way as the current walls, namely by welding. The complete draft for the trencher wall can be seen in Figure XX, as well as an assembly schematic in (Figure XX).

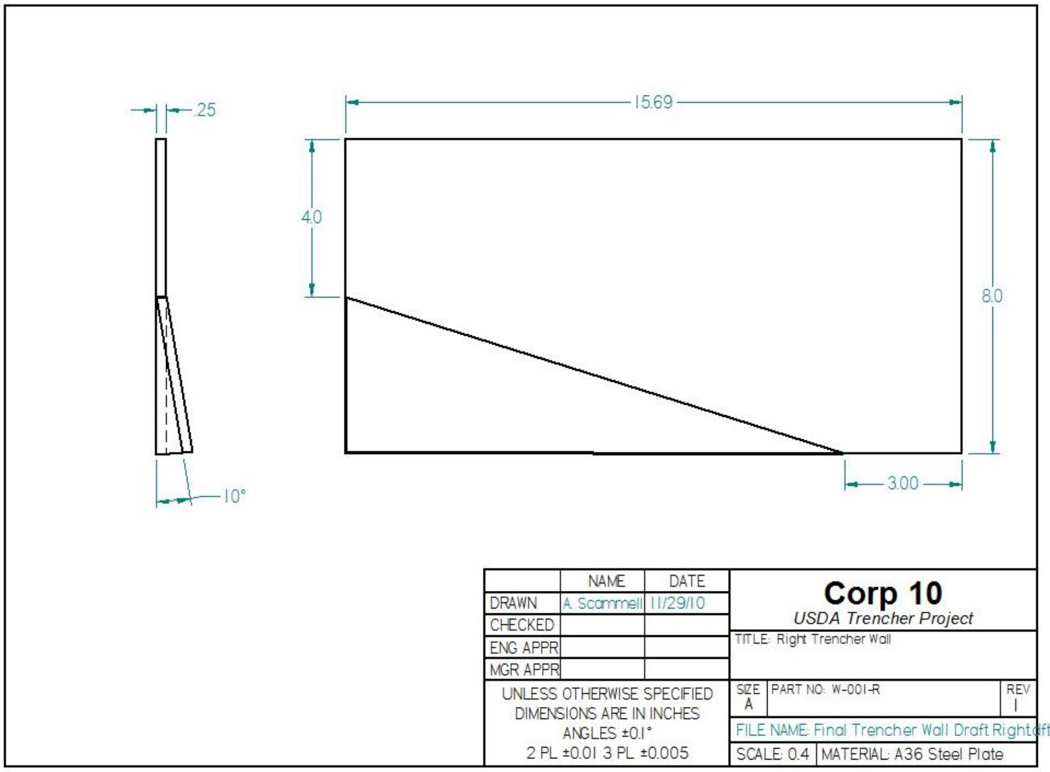


Figure XX- Draft of Trencher Wall (Right)

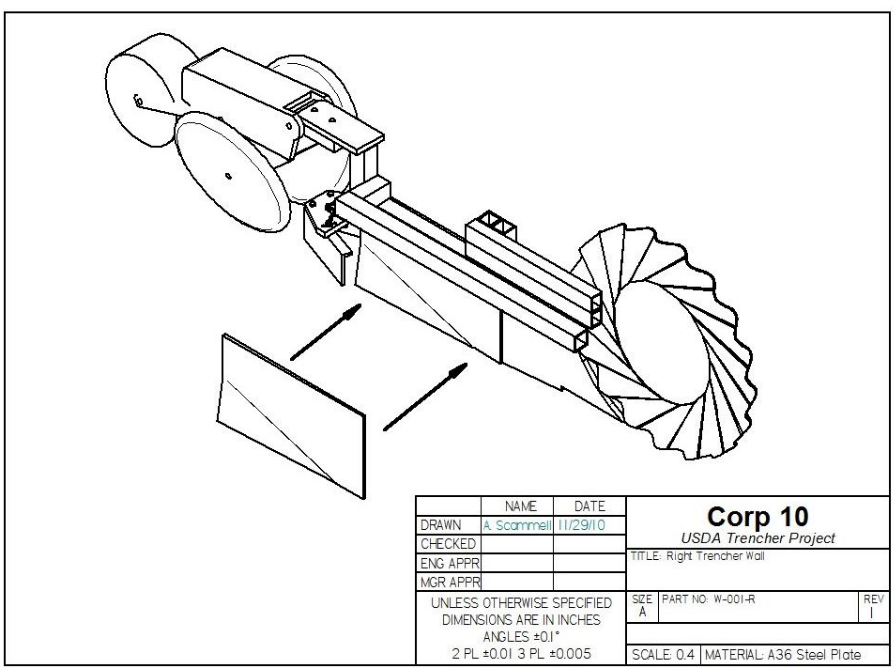


Figure XX- Assembly Schematic for Trencher Wall

The soil recovery subsystem contains multiple parts that must be fabricated. The results of the force analysis of the component were used to size the parts appropriately. The shear force generated by dragging the recovery component was of particular importance for sizing the pivots between the trencher and component. It was decided that quarter-twenty (1/4-20) bolts be used for the trencher to linking bar attachment, and the pivot to linking bar attachment. Additionally, quarter-twenty bolts will be used for the soil recovery platform and scoops attachment. The bolts where chosen for their strength, consistency, and accessibility.

With the free body analysis performed, the materials and sizes of parts could begin to be determined. For simplicity, ASTM 36HR steel was chosen for the parts needing to be fabricated. ASTM 36HR offers the best combination of durability, strength, and low cost as determined by the requirements. The pivoting bars were made to allow the soil recovery component to adjust to different terrain heights without interfering with the row closing mechanism. Using Solid Edge, and the wooden prototype, it was determined that the linking bars should have three inches between pivots, as shown in Figure XX.

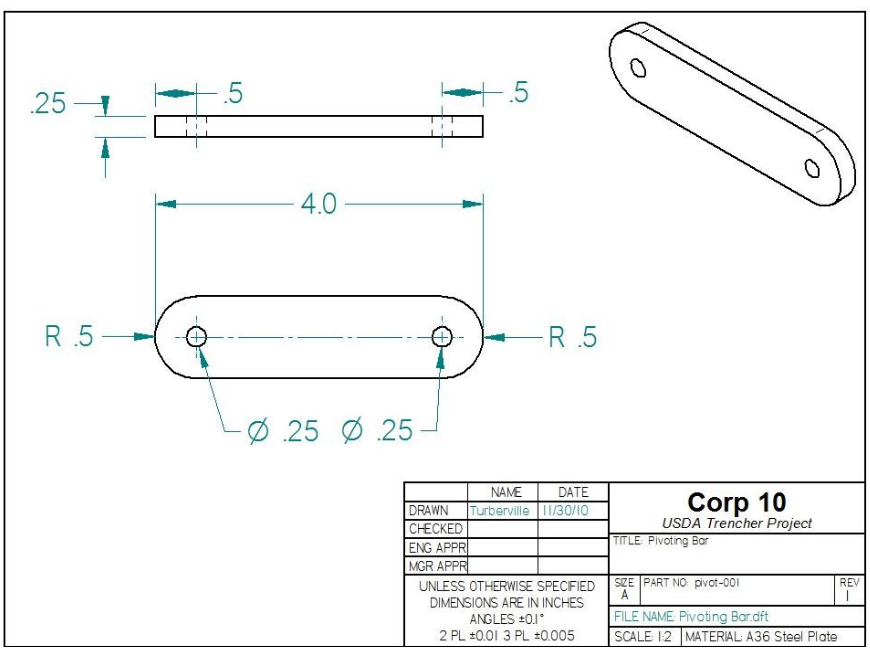


Figure XX- Draft of Linking Bar

Pre-manufactured mounted bearings will be purchased to connect the pivoting bars to the soil recovery plate. The product specifications for these bearings can be found in Appendix XX. The soil recovery plate will be manufactured from half inch (1/2") thick steel plate. Half inch steel was chosen to provide weight and stability to the soil recovery system. The recovery plate is an important part in the assembly, and must be fabricated to relatively strict tolerances in certain areas, as shown in Figure XX. An array of standard nuts and bolts will be used to connect components. The product specifications of these can also be found in Appendix XX.

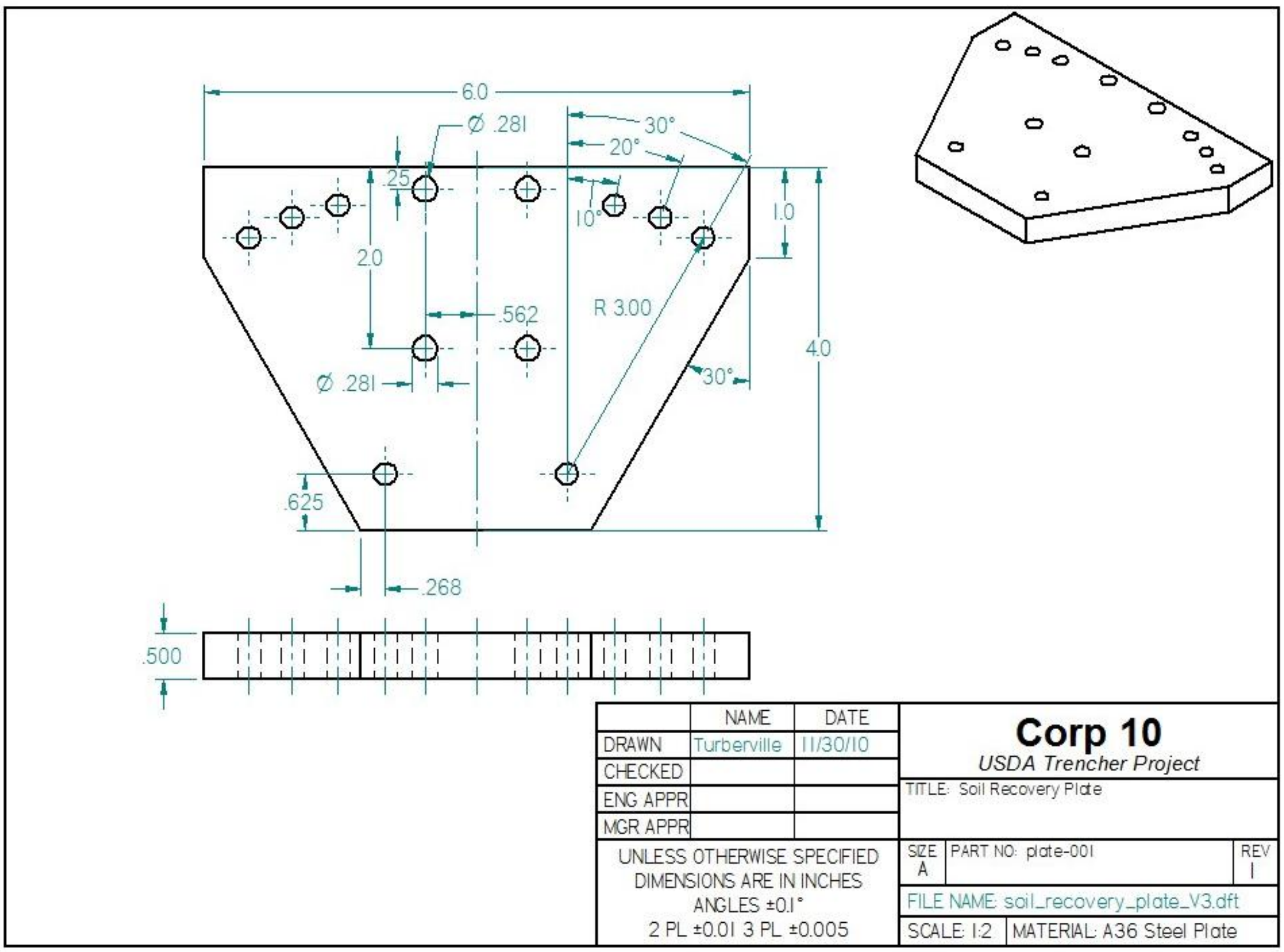


Figure XX- Draft of Soil Recovery Platform

The final parts to be fabricated are the recovery scoops. These relatively straightforward parts will be made from quarter inch (1/4") angled bend, and cut down to size. The draft of the left scoop can be found in Figure XX. The complete drafts are included in Appendix XX. An overall assembly drawing for the soil recovery component is available in Figure XX.

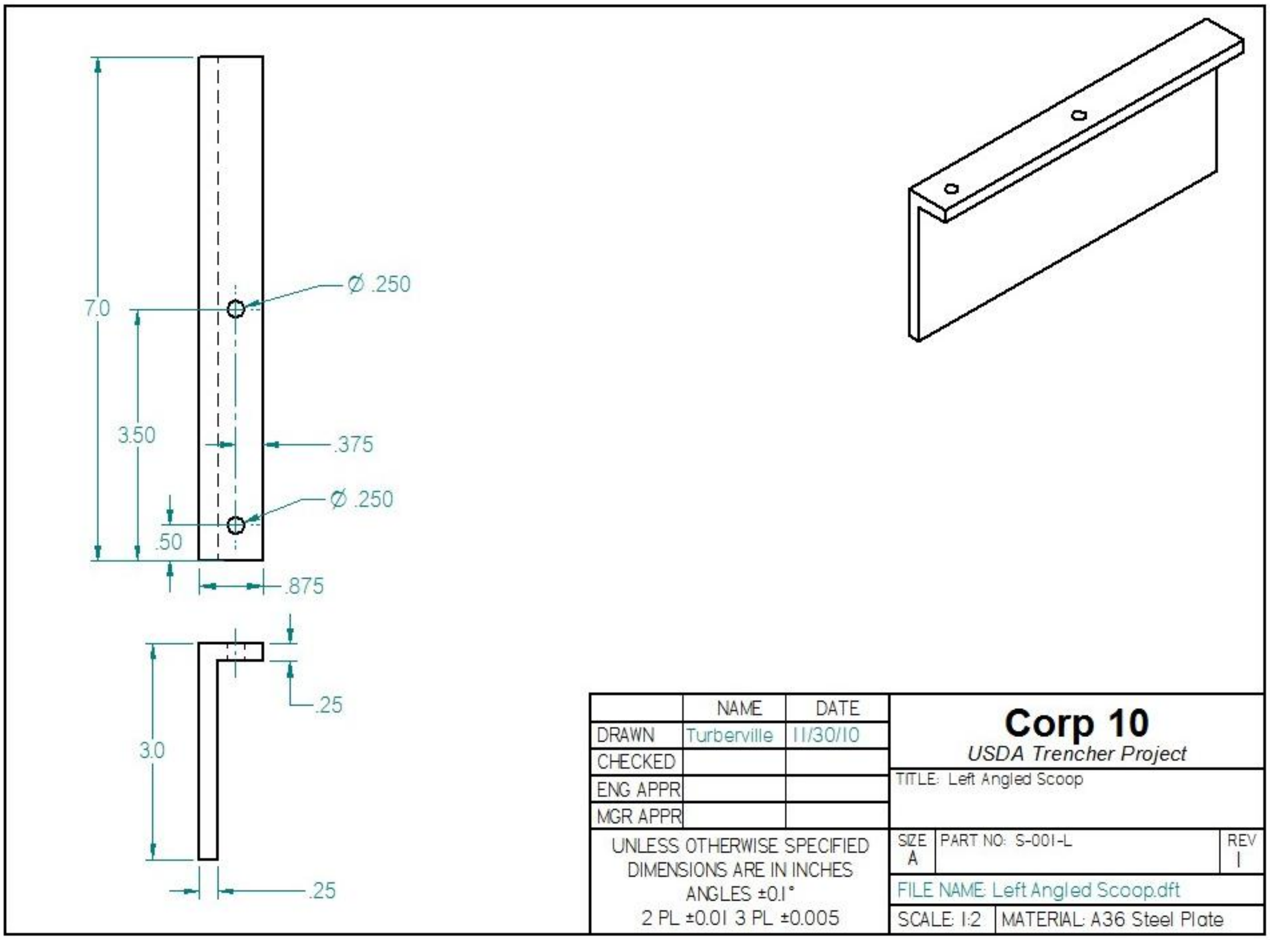


Figure XX- Draft of Left Scoop

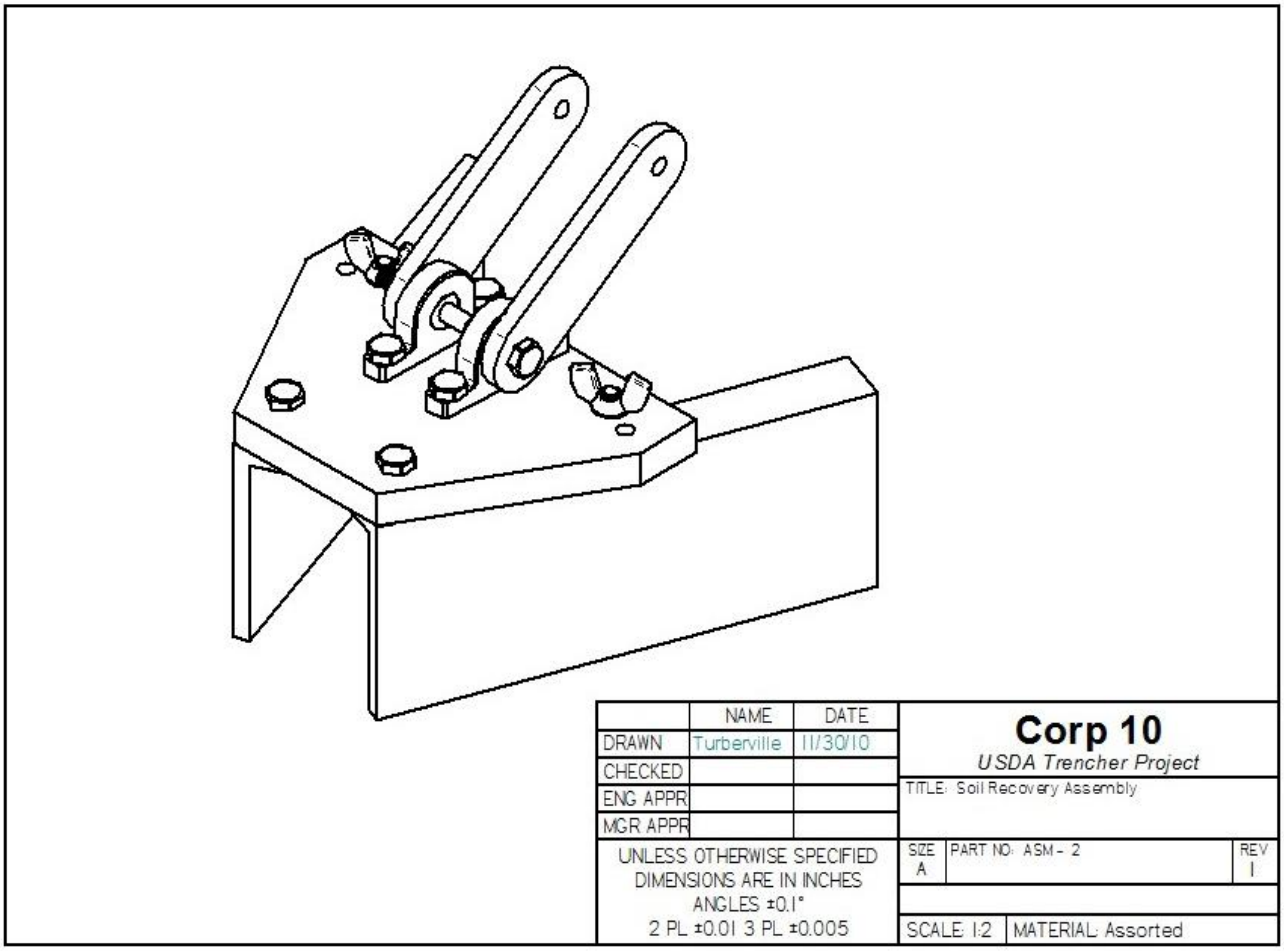


Figure XX- Soil Recovery Assembly

Project Management:

The project management structure is based on the strengths of the individual team members. As is such, there is some overlap within the structure, and the completion of a task is rarely performed by one member. The project manager for Corp_10 is Patrick Smyth, who also performs the majority of the systems engineering. The budgeting for the project is performed in coordination with the USDA, which handles ordering of parts and materials based on the needs of the project. Thus far, the project has had no budgetary limits, although care is taken in design to keep costs as low as possible.

For the upcoming semester, the focus of the group will be on fabrication and validation of parts, components, and systems. It is expected that most of the parts will be fabricated in the USDA's machine shop by the group, under the advisement of Dr. Tom Way and Marlon Siegford. Additionally, the interfaces will be checked in accordance with the systems engineering process. Deliverables for next semester are expected to include fabricated parts, and verification of parts and components.

The project is managed by using a series of milestones, presented in a Gantt chart. Due to size constraints, the Gantt chart is available in Appendix D.

Conclusions:

Throughout the project, the desire of Corp_10 has been to effectively complete the mission objectives while utilizing the simplest design possible. This is due to the nature of the project. The end user for the implement, the farmer, does not need or desire an overly complicated piece of machinery. Rather, the user requires a device that will perform reliably in all circumstances, while needing little maintenance and keeping costs down. This mentality has provided the group a chance to experience practical engineering.

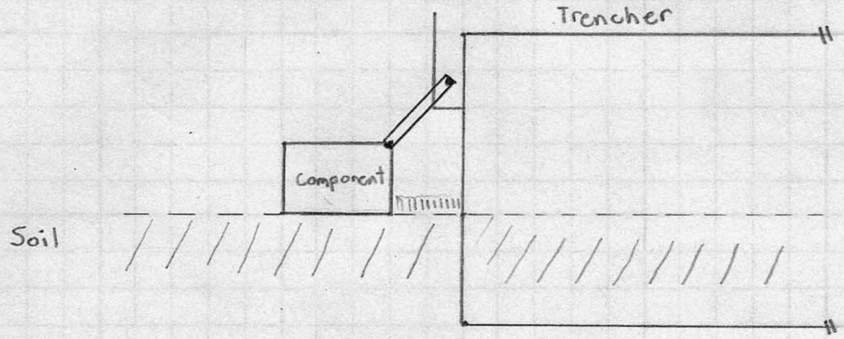
Using the structured evaluation, deductive reasoning, and our sponsor's input, it was decided to pursue an angled bend design for the trencher walls. This will eliminate pinching in the walls, which previously caused poultry litter backup. Based on the results of the force testing performed at the USDA, and the ANSYS analysis of the trencher walls, an appropriate thickness was chosen for the walls. This thickness is 0.25 inches, which provides the optimal combination of strength and weight, and will meet or exceed all of the requirements set forth. The detailed design work continued in determining the angle of bend in the walls, where a design was chosen to be easy to fabricate, while meeting the desired goals for the poultry litter application process.

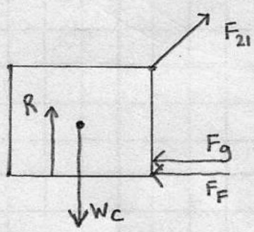
For the soil recovery device, it was decided to use a two bar linkage system that will ride behind the trencher, but in front of the press-wheel system. The simple design will augment the effectiveness of the press-wheels and meet the requirements set forth. The group has spent the majority of its time performing detailed design of the soil recovery device. A wooden prototype was fabricated to serve as a proof of concept, and to help in sizing the components and parts. From that, and with the use of Solid Edge modeling, parts have been sized and drafted, and the interfaces have been checked appropriately.

Overall, the project appears to be on-schedule for completion by the culmination of the spring semester of 2011. Our corporate sponsor has been instrumental in ensuring this is a learning experience for the group, and each member of Corp_10 has been able to further their engineering knowledge thus far. The expectation is that this will continue as the project progresses into the fabrication stage.

Appendix A:

Appendix B: Analysis





$$\Sigma F = ma$$

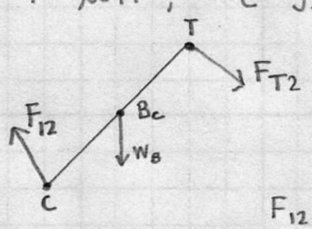
$$\Sigma F_y = 0 \rightarrow R + F_{21y} - W_c = 0$$

$$\Sigma F_x = ma_x \qquad F_{21x} - F_g - F_F = m_c a_x$$

$F_g = \rho_{soil} V_{soil}$ [lbf]

$V_{soil} = h_s \times w_s \times d_s$ [in³]

$F_F = \mu R$, $W_C = \rho_{steel} V_{steel}$ [lbf] $m_c = \frac{W_c}{g}$ [lbm]



$$\Sigma F = ma$$

$$\Sigma F_y = 0 \qquad F_{12y} + W_B + F_{T2y} = 0$$

$$F_{12} = -F_{21} \qquad \Sigma F_x = m_b a \qquad F_{12x} + F_{T2x} = m_b a$$

$W_b = \rho_{steel} V_{steel,b}$ [lbf]

$$\Sigma M_c = 0$$

$$\Sigma M = (r_{B_cC} \times F_{12}) + (r_{B_cT} \times F_{T2}) = 0$$

Assume $R = 0$ for min W_c , 5 equ's , 5 unknowns

$Q_{Pivot} = \sqrt{F_{T2x}^2 + F_{T2y}^2}$ Maximum shear in the pivot

```
% Senior Design
% Force on the soil recovery device
% Corp_10

clear all
close all
clc

% Knowns
g = 32.2; % f/s^2
p_steel = 0.284; % lb/in^3 (Structural Steel A36, Hibbeler- Back Cover)
p_soil = 110/(12^3); % lb/in^3 (http://www.concrete-
catalog.com/soil_compaction.html)
V_soil = 5*1.75*4; % in^3 max displaced by trencher
u = 0.3;

Fsoil = [-V_soil*p_soil,0,0]; % lbs

% Wcs = 12.5;
acx = .88; % ft/s^2 0-3mph in 5 seconds
syms Rgs F21xs F21ys FT2xs FT2ys Wcs real

ac = [acx,0,0];
F21 = [F21xs,F21ys,0];
Wc = [0,-Wcs,0];
FT2 = [FT2xs, FT2ys,0];
R = [0,0,0]; % Assume min weight when ground doesn't provide any reaction
Ff = [-u*R(2),0,0];
m1 = -Wc(2)/g;

equ = Wc + R + F21 + Ff + Fsoil - m1*ac;
equ1 = equ(1);
equ2 = equ(2);

rT = [0,0,0];
rM = [-1.5,-5,0];
rC2 = (rT + rM)/2;
rC2T = rT-rC2;
rC2M = rM-rC2;
rTM = rM-rT;
V_2 = hypot(rTM(1),rTM(2))*1.5*.25*2; % Volume of Steel in linkage (quarter
inch, by 1.5 inches)
m2 = V_2*p_steel;
G2 = [0,-m2,0];

% Linkage

equ_B = -F21 + FT2 + G2 - m2*ac;

equ3 = equ_B(1);
equ4 = equ_B(2);

equ5z = cross(rC2T,FT2) + cross(rC2M,-F21);
equ5 = equ5z(3);
```

```
sol = solve(equ1,equ2,equ3,equ4,equ5);
F21x = eval(sol.F21xs);
F21y = eval(sol.F21ys);
FT2x = eval(sol.FT2xs);
FT2y = eval(sol.FT2ys);
WC = eval(sol.Wcs);

F21 = [F21x, F21y, 0]
FT2 = [FT2x, FT2y, 0]
WC = [0,WC,0]

Q1 = hypot(F21x,F21y)
Q2 = hypot(FT2x,FT2y)
```

Appendix C:

Appendix D: Gantt Chart