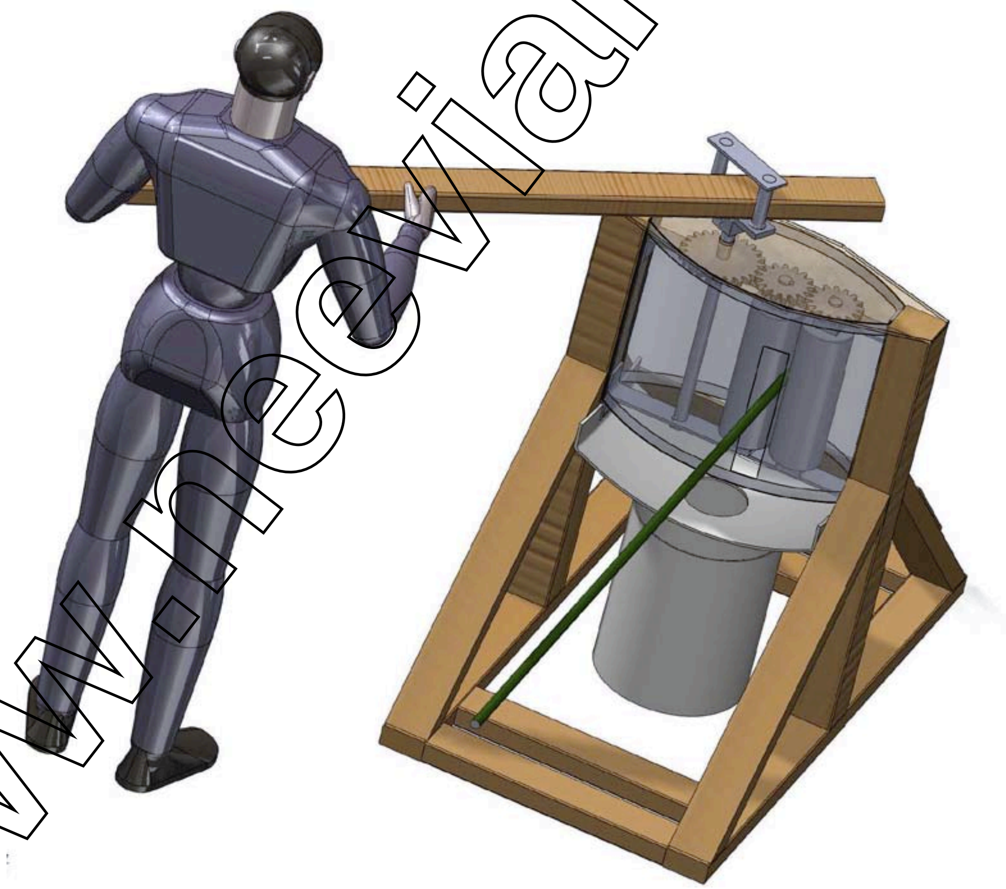
EWB Human-Powered Sorghum Press

Team 20

3/16/2012
ME 189



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I. Executive Summary

This year, we have designed, built, and tested a sorghum press prototype. This is human powered, able to press sorghum efficiently, and manufacturable in Mali.

The human power requirement test shows that the prototype requires only 54N*m (40lb-ft) of torque to operate, which is only 22% of the 240N*m torque a user can achieve with our current design. By making sure a typical user can achieve the needed torque to operate the press, we proved that this prototype can be human powered.

Under the load of 1 stalk of sorghum, the roller denting test shows a deformation of .356mm (.014inch) and the support plate FEA shows a deformation of .071mm (.0028inch). The total deformation with two rollers and the supporting plates is then .78mm which is only 15% of the target roller gap of 5.1mm. Since the total deformation is only 15% of the targeted roller gap, it can be compensated for by designing the gap to be smaller than the targeted roller gap.

The throughput test shows that the current prototype can process 25 centimeters of sugar cane per second (cm/s), which is more than 3 times faster than the old press which has an estimated throughput of 7.62 cm/s. This increase in throughput is expected since our human power test results show that our walk and push way of harnessing human power can harvest 6 times more human power than the hand crank design used in the last press.

To ensure the manufacturability of the design, we made the prototype using only the basic machining tools that are accessible to a Malian machine shop we are in contact with. We have also had 3 gears custom made in Mali by the Malian machinist who owns the shop. By making the prototype use only basic tools and having the gears made in Mali, we have demonstrated that the prototype can be manufactured in Mali.

In the spring quarter, we recommend investigating an alternative gear setup, a stronger frame, and a modular design.

II. Project Summary

2.1 Fall Quarter Status Report

By the end of the fall quarter, analysis, testing, modeling and prototyping teams, specified in Appendix X-1, had all made significant strides in design of the human powered sorghum press. Through the combined work of each of these teams, three main design features were established. These features are as follows:

- Human power efficiently harnessed through a vertical, walk and push press.
- Loose tolerance gears modeled and prototyped to prove effectiveness in spite of poor machining
    - Drawings and prototype sent to Mali for fabrication to prove their manufacturing ability.
- Hollow, thin walled rollers modeled and prototyped to drastically cut cost.

In addition to these key features, a preliminary design for the press was completed, and finite-element analysis was performed on critical components.

Upon completion of our fall quarter design review, input from project coordinator Stephen Laguette and faculty adviser Dave Bothman, led us to the following important design features still to be addressed:

- Safety Features
    - People's body parts must not be able to get caught in any moving parts
    - Machine must have a featuring making it inoperable when not in use (i.e. a lock)
- Roller and Gear Strength
- Roller bearings or bushings.

Moving forward into winter quarter, meeting these considerations was our main priority.

2.2 Winter Status Report

2.2.1 Winter Quarter Objectives

The main goal of the winter quarter was to have a basic final design completed and fully fabricated. This functioning prototype could then be tested. This would in turn allow us to find faults in our design early on and address them to the best of our ability.

2.2.2 Winter Quarter Efforts

Many important accomplishments were finished by the analysis, testing, modeling, and prototyping teams winter quarter. First testing was done to find the force that would be exerted on the rollers, as well as the rollers deformation due to this force. This information allowed the modeling team to properly space the rollers, and finally allowed the prototyping team to build a fully working prototype. The analysis team performed a multitude of calculations on various components to prove their robustness, and testing was performed on the prototype to prove this robustness, as well as find the throughput of the press.

2.2.3 Major Winter Quarter Accomplishments

The following important PTMA items were accomplished winter quarter:

- Built and tested fully-functional prototype (shown in Figure 1)

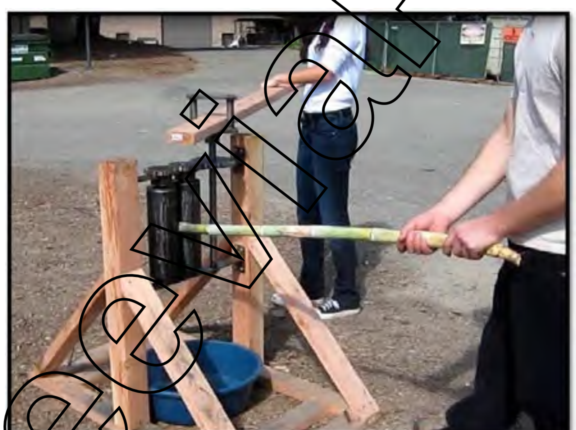

Figure 1. Prototype in action.

- Most complex part of press—gears—were successfully manufactured in Mali by local machinists with available materials (shown in Figure 2)

Figure 2. Malian made gears.

- Human power analysis, how much force can the user exert and how much torque it translates to
- Analysis of roller deformation with 1 stalk and then 8 stalks to find deformation due to denting
- Analysis of support plate to make sure deformation is minimal
- Testing to find maximum load exerted on rollers from stalks
- Testing to find maximum deformation of rollers due to stalk load
- Testing of throughput
- Testing of fatigue effects
- Testing of torque required to operate press with one stalk.

III. Project Background

3.1 Purpose

Our project aims to improve the quality of life for people in a small community in Mali by providing them with an improved sorghum press design. A sorghum press is a device which extracts syrup from the stalks of sweet sorghum plants which are abundant in Mali. This nutritious syrup is then processed to produce sugar. Through this syrup production, business opportunities are created for the villagers of Dissan.

A previous sorghum press design was made for this community by the Engineers without Borders (EWB) Mali team three years ago. After the first prototype was installed and used for a season, it became apparent that this first press required improvement. The current sorghum press is hand cranked and can only pass along one sorghum stalk at a time, making the syrup output slow. Our new design aims to improve the sorghum throughput efficiency of the press.

3.2 Benchmarking

It is important to understand that this project is intended to represent a continuation of the efforts of the EWB sorghum press design team from 2008. At the start of the project, we were given a brief overview of the project history and then given an electronic copy of most of the last team's testing data and design conclusions. The nature and time frame for the project did not allow us time to obtain or build the machine from 2008. Therefore, in order to make efficient progress, we attempted to gather as much information as possible from research of patented designs as well as the data from 2008. The following is a summary of what knowledge was taken from the efforts of the 2008 team.

3.2.1 Background Research

The first step in our design process was to gather as much information as possible regarding sorghum and/or sugar cane presses. Specifically, we wanted to see what people are doing and have done to solve our engineering problem. We found that a human or animal powered sugarcane press is something that has existed for hundreds of years and various designs can be found throughout the developed and undeveloped world. A YouTube and Google search reveals several tried and true designs that are being used in rural and underdeveloped countries.

After investigating several different patented press designs we noticed that there were 3 major design decisions. See works cited for list of patents. These decisions are as follows:

1. Two or three roller press:

Based on the patent information, a three roller press could be slightly easier to operate since the stalk will be broken by the first roller and the crushed by the second. However, it was noted that while a two roller press only requires 2 or 3 gears, a three roller press would require at least 4 gears in order to function properly.

2. Horizontal or vertical orientation:

A horizontal press is usually used in motor or hand crank applications and it has an advantage of easy juice collection. A vertical press is more commonly used in an animal or walk-and-push design. The advantage of a vertical press is that it is very simple and cheap to gain mechanical advantage by using a long lever.

3. Gear vs. Chain vs. Belt drive:

A gear driven press has the advantage of being more robust but it would require more complex manufacturing procedures. Belt and chain driven presses require belts or chains that cannot be manufactured in the village of Dissan and are less robust and require more maintenance than a gear driven press. However, a belt or gear driven press will have more flexibility in the spacing between the rollers.

3.2.2 Sorghum Press Rev. 2008

The design team from 2008 spent a significant amount of their time investigating the properties of sorghum and trying to predict what sorts of forces they could expect in a sorghum press. They started tested a hand-powered 3-roller horizontal sorghum press benchmark with actual sorghum. This year we were unable to obtain sorghum to use for testing so we relied on the conclusions from 2008 that:

- A stalk of sorghum will lose 90% of its juice content when pressed to 5.1 mm
- A single stalk of sorghum will exert no more than 1500 lbs reaction force in response to being pressed to 5.1 mm.

By holding these conclusions from 2008 as true, we were able to save time in defining our design strength requirements and therefore we got a quick start to our design efforts.

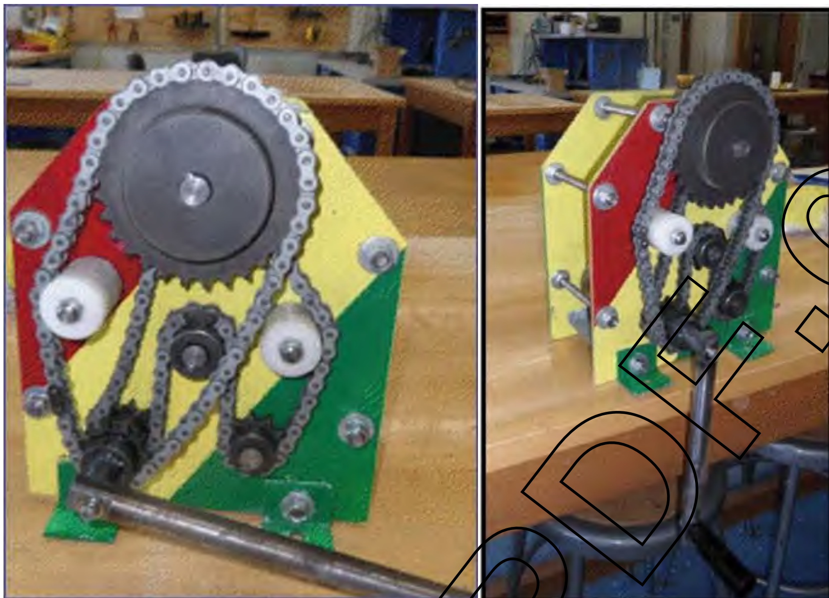

Figure 3. Sorghum press from 2008 team.

As shown in Figure 3 above, the 2008 team's sorghum press was a good representation of a 3-roller horizontally oriented machine. The design featured a 1 foot long lever arm, a 3:1 gear reduction via chain/sprockets to the 4 inch diameter 3 inch long solid steel rollers. The first rollers were spaced 12.42 mm apart and the second rollers were spaced 5.23 mm apart. The limiting factors in this design pertaining to achievable throughput are:

- low maximum achievable input power by hand operation (see TP1 for input power data)
- lack of space for feeding through multiple stalks at once (short 3 inch long rollers)

3.2.3 Benchmarking Conclusions

Based on the data presented to us through our research and through the design efforts from 2008, we concluded that in order achieve a higher throughput we would need to:

- increase input power potential over hand crank designs
- allow for simultaneous feeding of multiple stalks

Furthermore, the testing data from the 2008 team showed that the rollers on our press need to:

- withstand a maximum press force of 1500lbs/stalk
- press individual stalks to a maximum thickness of 5.1cm

3.3 Scope

The end goal of our project is to have a working sorghum press that can be shipped to Mali and used immediately in summer 2012. This press will increase sorghum stalk throughput and therefore production of sweet syrup. We aim to design the press so that it can be fully manufactured in Mali at a low cost. As this press will be an important source of income for the community, our objective is to make it easy and quick to maintain and store in the off-season so that it will last for many years. We will also provide the community with a full drawing and assembly package and illustrated user manual.

3.4 Design Goals

We were given the following design goals from our partner organization Engineers Without Borders, these design goals shaped our technical considerations:

- Human powered
- Presses sorghum
- Have an increased throughput compared to the last design
- Manufacturable in Mali
- Low cost
- Easy to maintain
- Portable

IV. Technical Considerations

4.1 Key Assumptions and Equations

Assumptions: Since the sorghum press is a human powered device, we considered the force a human can exert when designing the prototype. Because the physical ability of the press user cannot be directly measured, the horizontal pushing force of the user was estimated using published values. The maximum force any user can exert is estimated to be 620N (140 lb), while the minimum force any user can exert is estimated to be 160N (36 lb). For detail please see Appendix R-1: Human Factor Research and Analysis.

Equations: We used the following equation to convert the horizontal pushing ability of users into an easily comparable torque value.

$$T=F*L*G \quad \text{(Equation 1)}$$

In Equation 1, T is a torque in Newton-meters, F is a force in Newtons, L is a crank arm length in meters, and G is the gear reduction. In our design L=1.5 and G=1.5, so Equation 1 reduce to the following equation.

$$T = 2.25 * F \quad \text{(Equation 2)}$$

4.2 Critical Performance Parameters

After using the previous sorghum press for two seasons, the community in Mali provided feedback to our contact Scott Lacy. Using this concrete feedback we were able to define our performance requirements with the help of Scott Lacy and our faculty advisor Dave Bothman. As some considerations were vital for the success of our press and others were not, we identified 6 considerations as ‘primary’ and 2 as ‘secondary.’ Table 1 shows our prioritized technical considerations. An extended technical requirements chart, our current Project Completion Requirements, can be found in Appendix X-3.

Table 1. Technical Parameters

Level of Importance	Considerations	Assessment/Value
Primary	1. Human Powered	240 N*m
	2. Presses Sorghum	Crushes to maximum thickness of 5.1 mm
	3. Increased sorghum stalk throughput than last press	>10 cm/sec
	4. Manufacturability	Fully manufacturable in Mali
	5. Low Retail Cost	<$500*
	6. Safety	Safe by subsequently discussed standards
Secondary	6. Ease of Maintenance	Can be disassembled/ assembled/ cleaned in <1 hour with locally available tools
	7. Portability	<890 N

*in the year 2012

4.2 Summaries of Technical Considerations

4.2.1 Human Powered

The Sorghum Press is to be used in Dissan, Mali; a small rural African village. The people of Dissan have very limited access to electricity, making electric power an impractical option. Furthermore, the village does not have enough large working livestock to make animal power a practical option at this time. Because of this, our customer has requested that the press will be human powered by no more than a pair of workers.

4.2.2 Presses Sorghum

The primary function of our product is to extract and collect the juice from sorghum stalks. The background information we collected from the 2008 team concludes that an efficient press will squeeze the sorghum stalks to a maximum thickness of 5.1mm. The new press design will be required to press sorghum stalks of varying diameters down to a thickness of 5.1mm or less. Once inserted in the press, a sorghum stalk should pass through the rotating rollers without any additional assistance.

4.2.3 Increased Throughput

Throughput was the number one concern with the 2008 press design. The 2008 design was used for two seasons in Dissan and this helped the villagers gain enthusiasm about the project. However, the workers feel that a more-rapid press is necessary to justify a significant increase in their sorghum production.

4.2.4 Manufacturability

Our manufacturability requirement was one that seriously influenced the overall design. Our customer has stated that it is the goal of this project to eventually have the sorghum presses manufactured local to where they will be used. The only background information we were given was that the village machinist was extremely capable and creative, however his equipment was limited. We decided to have the more complicated components of our press actually be manufactured in Dissan for us to test the manufacturability of our press.

4.2.5 Low Cost

Cost was another design-driving consideration. We were not given an actual cost limit or goal. Furthermore, it is difficult to quote the cost of something to a foreign-market that we have little understanding of. The goal is to come up with a design that is appealing enough that the villagers feel that pooling together funds for a press would be a worthwhile investment. Because there is no exact number for this, the past team's design was used as a benchmark. Our design should be kept at the same price or lower.

4.2.6 Safety

Safety was not an issue raised by our customers. However, as engineers, it is our ethical obligation to make sure that our design is safe to the people who will use it. The largest safety concern with a human powered press is the presence and accessibility of pinch points. We must make an effort to ensure that potential pinch points are covered or properly labeled. Furthermore, the device must be able to be safely disabled during storage to prevent accidental injury.

4.2.7 Ease of Maintenance

This device is to be used for only a few weeks every year. It is our goal to have a design that can undergo maintenance at the beginning of each duty cycle and then remain maintenance free for the remainder of the year. The design should facilitate cleaning which will most likely be done twice over the sorghum processing period. Further, if the device breaks, parts should be easy to access and replace.

4.2.8 Portability

The device should allow for easy transportation between a sorghum field and a storage locker. The device should be easy to relocate and install in the sorghum field. Setup should take less than 1 hour.

V. Design Considerations

Given the technical parameters defined above, design considerations were derived. We determined the design considerations through close examination of each technical parameter and identified design features that were necessary to meet the technical requirements.

5.1 Design Requirements

5.1.2 Technical Parameter: Human Powered

5.1.2A Various Types of Human Powered Machines

We did a Google research and found that the most common ways to harness human power is biking, walking and cranking.

5.1.2B Minimum Force Required to Operate Machine

Since the sorghum press is to be powered by humans, the device must be designed so that adults of average strength can operate it. Since the force needed to operate the machine is heavily dependent on the length of the crank arm, instead of setting a minimum operating force requirement, we set a minimum operating torque requirement. Minimum operating torque is defined as the minimum torque required to operate the machine. We use the minimum torque instead of maximum torque required for this design consideration since having a minimum torque requirement ensures that a user is able to operate the machine. Thus, the project completion requirement derived from this design consideration is that the device must have a minimum operating torque smaller than a minimum operating torque requirement.

5.1.2C Lever Arm

The lever arm converts linear force exerted by the user into torque. The lever arm affects the force needed to operate the machine and the distance the user need to push press a stalk of sorghum. If the lever arm is too long, the user will be required to walk a long distance to press a unit length of sorghum stalk; on the other hand, if the lever arm is too short, the user will need to exert a large force which might not be possible to achieve. Therefore, we need to design the crank arm to be the right length.

5.1.2D Crank Arm Fixture

The crank arm fixture transmits the torque from the crank arm fixture to the shaft. The most important design consideration for the crank arm fixture is that it is strong enough to transmit the torque with an infinite fatigue life. Also, the amount of material used for the crank arm fixture effects cost, so another design consideration is minimizing the use of material.

5.1.2 Technical Parameter: Press Sorghum (Sorghum Juice Extraction and Collection)

5.1.2A Roller Spacing

In order to properly extract juice many design options had to be considered. First the spacing between the rollers was a key consideration, because according to the previous team's data this is what determined what the percentage of juice could be extracted from the sorghum talks.

5.1.2B Critical Failure Mode of Rollers

Roller failing modes also had to be determined in order to have efficient juice extraction. After consulting faculty, and staff from the Mechanical Engineering department we determined that the critical modes of the rollers under a load which would be deflection and/or denting. Therefore, the roller design had to prove that it could withstand the load exerted by the stalks without deflecting, or denting.

5.1.2C Collection Mechanism

After properly addressing the design considerations for juice extraction we had to determine what a good design collection mechanism would be. After reviewing the previous team's data and prototyping, it was observed that the squeezing of the sorghum would make a mess; therefore it was necessary that the team addressed this issue by innovating the manner by which the juice from the stalks was collected.

5.1.3 Technical Parameter: Increased Throughput

Throughput can be increased in two ways. The first way is to increase the feed rate of a single stalk, and the second way is to increase the number of stalks that can be fed through the machine at one time. We obtained feedback from Mali on their preference between these options and found that they preferred the number of stalks to increase and feed rate remain constant rather than feeding through a single stalk at a faster rate.

5.1.3A Roller Size

The feed rate is directly related to the diameter of the rollers, while the possible number of stalks that can be processed at once is directly related to the length of the rollers. Due to this fact, we decided to redesign the rollers to have similar diameters to the rollers of the old press while increasing their lengths. Our goal then was to decide on the optimal roller length to increase the feed rate.

5.1.3B Ways to Exert Human Power

An increase in number of stalks pressed at once also increases the energy needed to press the stalks. This in turn means that we must design the press to make full use of the human body in putting energy into the system. We determined the possible human power methods to drive our press were hand cranked, biking, or walking and pushing. Our goal then was to find the optimal energy input method to design our crank shaft around.

5.1.4 Technical Parameter: Manufacturability

5.1.4A Mimic Malian Machining and Manufacturing Methods

As previously stated, the overall goal of the project is to have production take place is Mali. Therefore, we needed to consider the manufacturability of the parts that are critical to the function of our press by avoiding tight tolerances and advanced tooling. We have identified the following machines as acceptable for use:

- Mill (and basic tools)
- Lathe (and basic tools)
- Drill Press
- Grinder
- Sander
- Arc/Stick welder
- Band saw
- Hammers, wrenches, files, other various hand tools.

The sorghum press design must not require any unapproved tooling or machines in the manufacturing process.

5.1.4B Minimize Amount of Imported Parts

Our design should not require the villagers to order specialty parts whenever possible. Largely due to this design consideration, our press does not require chains, sprockets, or roller bearings.

5.1.4C Gears vs. Chains

The drive train is the highest-precision part of the sorghum press. Our drive train must allow for as much machining error as possible and must be verified as manufacturable in Mali.

5.1.5 Technical Parameter: Low Cost

5.1.5A Minimize Use of Materials

The easiest way to reduce cost is to reduce the amount of raw material consumed when making a press. We made the following design considerations in order to help reduce material use:

- 2 rollers rather than 3
- Standard geometry pipe for rollers rather than solid steel
- Cosmos strength analysis to reduce over-designing
- Design multiple parts from the same material stock

5.1.5B Use Cheaper Materials

Cheap and plentiful standard geometry metals are used whenever possible. Most metals are inexpensive mild steel. The frame for the machine is made of wood.

5.1.6 Technical Parameter: Safety

5.1.6A Device can be Locked

A key element we had to keep in mind when designing the press was that the press will be operated for a few hours of the day and will be left out in the open. Many of the villagers including children will have access to it during this time. After closely analyzing the environment in which the press will be used, and consulting our customer it became apparent that it would be necessary for us to make sure the press can be locked when the press is not in use.

5.1.6B Safety Guard

Another issue that needed to be addressed was that there are many pinching points in our press. In order to avoid any accidental crushing of appendages it became clear that a shield needed to be designed for the press.

5.1.7 Technical Parameter: Ease of Maintenance

5.1.7A Quick to Clean

The sorghum press must be easy to clean, using no more than water and a rag.

5.1.7B Quick to Assemble/Disassemble

Due to the fact that the press will be stored away at the end of every season, it is necessary that it is easy to assemble. Assembly of the press should take no longer than one hour, and installation should only require basic tools such as a hammer, a screw driver, and a wrench. In a similar manner the disassembly should take no longer than one hour and should also only require the same basic tools

5.1.7C Replacement of Parts

Similarly to assembly and disassembly the tools necessary for the replacing of any parts must be kept at a minimum. We needed to have a design for which the parts could be manufactured in Mali, and replaced by the operators of the press without any additional help.

5.1.8 Technical Parameter: Portability

5.1.8A Detachable from Ground

It was brought to our attention that because the press will be stored away during the off season, the frame must be able to be easily moved. Our design has to be able to be moved from one place to another place without having to be fully disassembled.

5.1.8B Maximum Weight

Since the press will be human powered, operated, and assembled it is important that two average healthy adults can carry the press. We decided that because the press will be manually carried it is necessary that the maximum weight of the press does not exceed 890 N (200 lbs).

5.2 Design History & Evolution

At the end of fall quarter, we had concluded that a walk-and-push vertical design would be a good starting point for our design efforts. An initial CAD model of this concept can be seen in Figure 4.

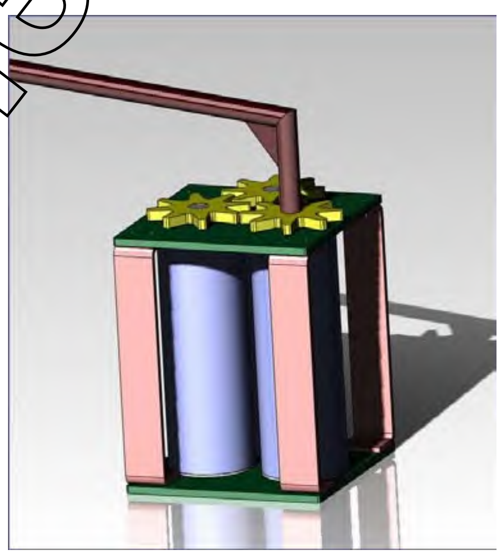

Figure 4. First design attempt.

Once we had a concept model we were able to think about how our technical considerations would be affected by our design. The concept model was a good representative of a human-powered sorghum press with potential for increased throughput. However, we felt that it lacked in cost and manufacturability. Cost and manufacturability drove several of the design considerations previously discussed and lead us to a second working prototype model. This prototype model can be seen in Figure 5.

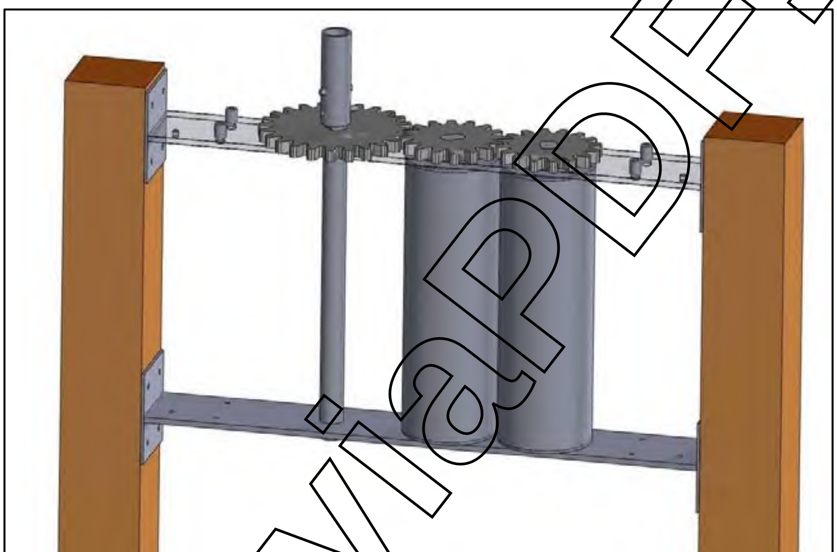

Figure 5. Second design attempt.

The next step in our design efforts was to refine our design for increased safety, portability, and maintenance. Additionally, we decided that we had enough of a working model to begin building the prototype to help us gain intuition regarding the manufacturability and the operator experience for a sorghum press. At the conclusion of our winter quarter efforts (to be discussed in detail in Section VI) we came up with our current proposed design.

5.3 Proposed Design

Our current proposed design, shown in Figure 6, was presented to a panel of independent faculty during the project design review.

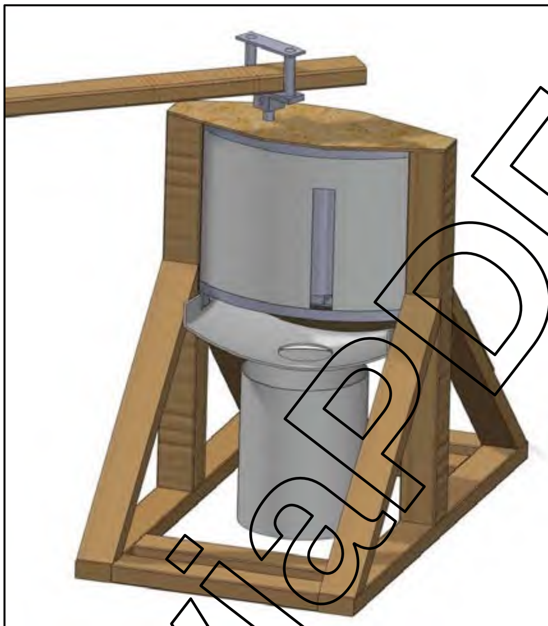

Figure 6. Current design.

Some of the key design features are:

- Vertical axis – We chose to orient the press vertically because this allows simple attachment of a long lever arm to gain mechanical advantage for human power. Our patent reviews concluded that horizontal presses are more common for motor-driven presses while human or animal powered presses are usually oriented vertically.
- Two rollers – Our proposed design features only two rollers in order to reduce cost and increase ease of manufacturability.
- Safety/splash guard – The press is equipped with a guard that encompasses the rollers and gears. This serves to address safety concerns and allow for the easy collection of juice.
- Hollow rollers – Our rollers are made from standard SCH40 steel pipe, this material option is much more readily available and less expensive than the solid-steel rollers from the 2008 press.
- Wooden Frame - By using a simple wooden frame we not only address cost and manufacturability concerns, but we allow for the press to be easily transported and then quickly staked into place.
- 12 inch long rollers – This allows space for multiple stalks of sorghum to be fed through the press at once, thus helping to increase our throughput.

- Replaceable brass bushings – Worn-out bushings is a likely cause of press failure. Our design incorporates a set of bronze sleeve-bushings that can be easily removed for product maintenance.

5.4 Status of Proposed Design

The ‘critical-to-function’ components have been built and tested. Currently, the only manufacturing efforts that remain are building the safety guards and incorporating potential design changes that are discussed in Section 7.2. By the end of Spring quarter, we plan to have completed manufacturing of the proposed sorghum press design.

VI. Results of Main Design Efforts

Overview of Modeling Efforts

Modeling was the backbone of the winter quarter design efforts. A 3D model was made to show the initial design concept. The model served as a basis for precise communication of ideas and as a visual representation of what we expected from our press. Many of the 'critical-to-function' and high-load bearing parts were analyzed and iterated using the Solidworks FEA package. For more detail, see the Analysis section. Once proper form, fit, and strength were established digitally, the model was used as a reference for prototyping an early design. However, before prototyping could be done, there were several design concerns that were addressed simply by modeling and comparing possible solutions. For example, during our fall quarter design presentation there were concerns that the juice from the sorghum could cause possible damage to the bushings. This concern was addressed through sketching and brainstorming ideas, and then constructing a 3D model of our proposed solution to demonstrate feasibility as shown in Figure 7. Furthermore, 3D modeling was used to demonstrate the feasibility of parts such as the safety guard that have not been prototyped.

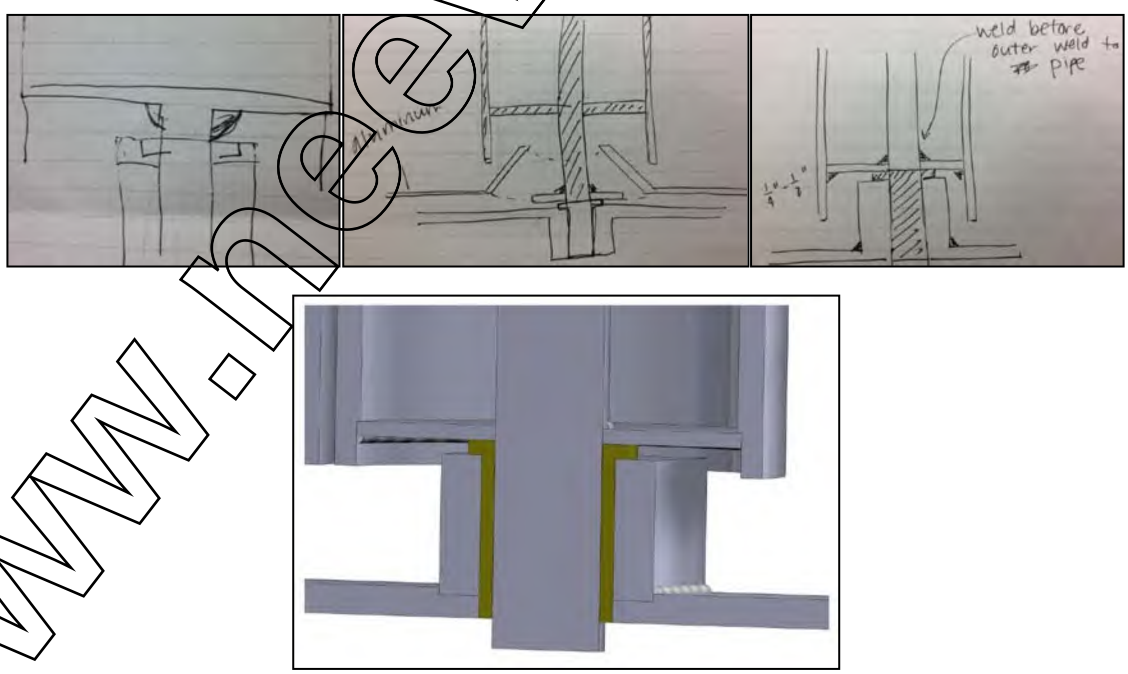

Figure 7. Evolution of design concept for juice avoiding bushings.

Overview of Prototyping Efforts

Prototyping was a huge part of the winter quarter design efforts. We were unable to attain a benchmark human powered press in our budget that closely resembled the vertical, two roller design we were pursuing. This made it critical that we were able to construct a device that we could use to gain intuition about what it is like to build and operate a sorghum mill. When constructing our prototype we tried to do as much as we could to mimic what we knew about Malian machining techniques. We bought and learned how to use a stick welder, and we avoided using precise tolerances and advanced machining techniques. Before our proposed design was presented at the winter quarter design review, we had completed a fully functional prototype. Using the prototype press established that our design:

1. Works as intended.
2. Can be disabled when not in use.
3. Can be maintained/cleaned/assembled quickly and easily using only an end wrench and hammer.
4. Can be easily transported and installed, requiring two people to move and install the press.
5. Can be operated by two people working as a team, one feeding stalks and one operating the lever arm.
6. Can easily achieve feed rates over 11.7 in/sec.
7. Is cheap to manufacture (See Appendix B: Project Budget).

Another significant part of our prototyping efforts was to verify the manufacturability of our press in Mali. In order to do this, we had our most complicated parts, the gears, prototyped in Dissan by the local machinist. We sent the machinist a 3D printed model of our gears and a set of drawings (Appendix D). The gears he made are currently being used on our prototype and are fully functional.

6.1 Minimum Force Needed for Operation

6.1.1 Research

Through research and analysis we found the torque the user can exert with our crank arm design is 240N*m. Therefore, to ensure the user can operate the press, we tested to make sure that the minimum torque needed to operate the machine is smaller than 240N*m. For details, please see Appendix R-1: Human Factor Research and Analysis.

6.1.2 Testing: Torque to Run Machine

Purpose: If the sorghum press is to be human powered, it must be possible for a human to operate it. One condition for this is that the torque required to operate it must be achievable. In order to meet this criterion, the torque required to squish a single stalk of sugarcane must be found.

Procedures: First the sorghum press must be staked into the ground at each corner to prevent it from moving during the test. Next, six samples of sugarcane of diameters 1 ± 0.25in must be obtained. Each of these samples must be fed through the press one at a time. The rollers must be driven directly through a torque gauge, and the resulting torque required to spin the rollers must be recorded for each sample. For more detailed description of test setup and procedures, see Appendix TP5: "Torque Required to Run Press."

Results: With each sample run through the press, the data was tabulated and can be seen in Figure 8.

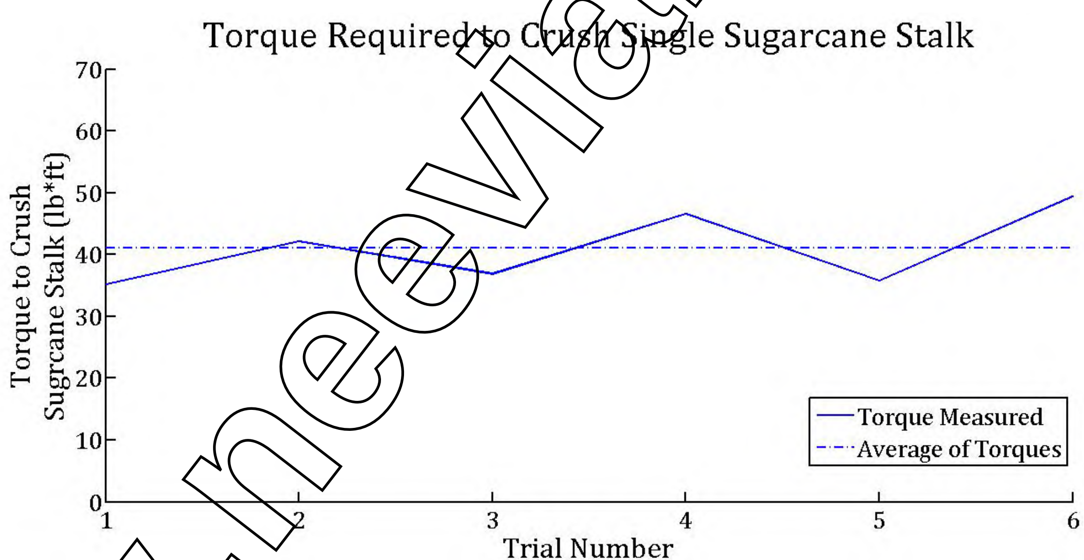

Figure 8. Torque required to crush single sugarcane stalk.

Here it can be seen that the torque required to crush a single 1in diameter sugarcane stalk is 41.0 ± 8 lb*ft. For a more in depth description of data obtained and analysis done, see Appendix TR5: "Torque Required to Run Press."

Conclusion: Any human should be able to exert 41 lb*ft with a lever arm in the range of 5 feet long as this results in a net force of only 8.4lb. This proves that the design of the human powered sorghum press is both sound and effective, and will be very useful to the people of Mali.

6.2 Roller Spacing and Failure Modes

6.2.1 Analysis

6.2.1A Roller Denting

Purpose: Roller spacing is one of our primary design considerations, so we did some finite-element analysis to find the deflection of the rollers. These FEA simulations are to compare the load of 1 sorghum stalk and 8 sorghum stalks. Using this FEA, the stress and deflection due to the loads from the stalks can be found.

Result: For the 1 stalk analysis shown in Figure 9, we found the maximum Von Mises stress to be 102 MPa which corresponds to a safety factor of 2.5. The high safety factor ensures that the roller will not yield nor fail under the load. The maximum deflection is found to be .0018 inch, which is not of concern since the maximum gap between the rollers is .2inches. The deformation can be easily compensated by making the initial gap between rollers smaller than .2 inches.

For the 8 stalks analysis shown in Figure 10, the maximum deflection was found to be 5.8e-4 inches, which is not of concern, since it is minor comparing to the .2 inch target gap. The deflection of the roller can be corrected by placing the roller closer together so that the spacing is less than .2 inches even after the roller deflection.

For information on the problem setup, see Appendix A-3 Roller Denting, 1 Sorghum Stalk, Appendix A-4: Roller Denting, 8 Sorghum Stalk.

FEM:

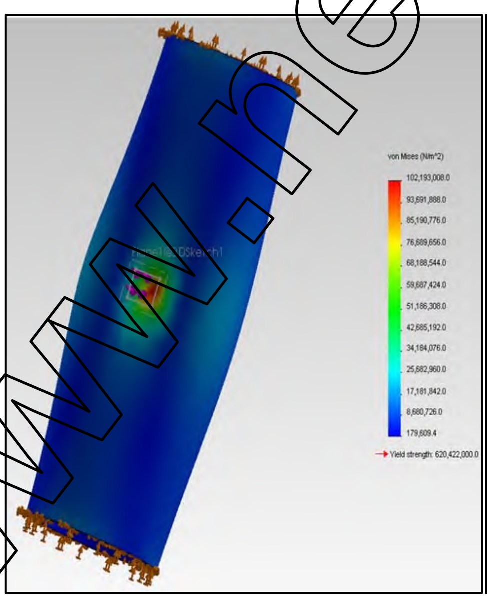

Figure 9. 1 stalk.

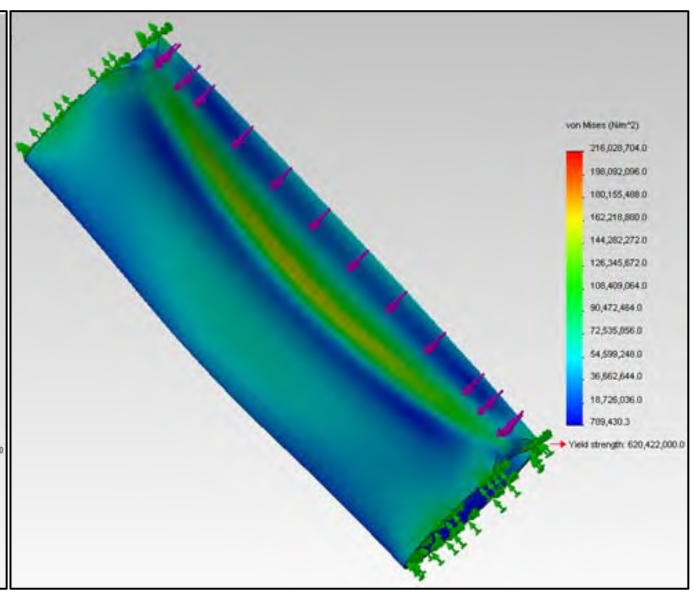

Figure 10. 8 stalks.

6.2.1C Supporting Plate

Purpose: The supporting plate holds the rollers together and is subjected to the force exerted by the sorghum, therefore it is important that the deflection of the supporting plate be taken into consideration so that the gap between rollers does not exceed the maximum gap allowed. We did this FEA to estimates the deformation of the supporting plate.

Result: The maximum Von Mises Stress is found to be 124 MPa, as shown in Figure 11, which corresponds to a factor of safety of N=2. This high factor of safety ensures that the support plate will not fail. The maximum displacement of the shaft hole is .0028 inch which is small compared to the roller gap of .2 inch. This displacement will be compensated by having a smaller roller gap than the targeted gap. Note that the stress caused by the stress concentration of the holes is neglected, since the area will be locally thickened to support the bushing.

FEM:

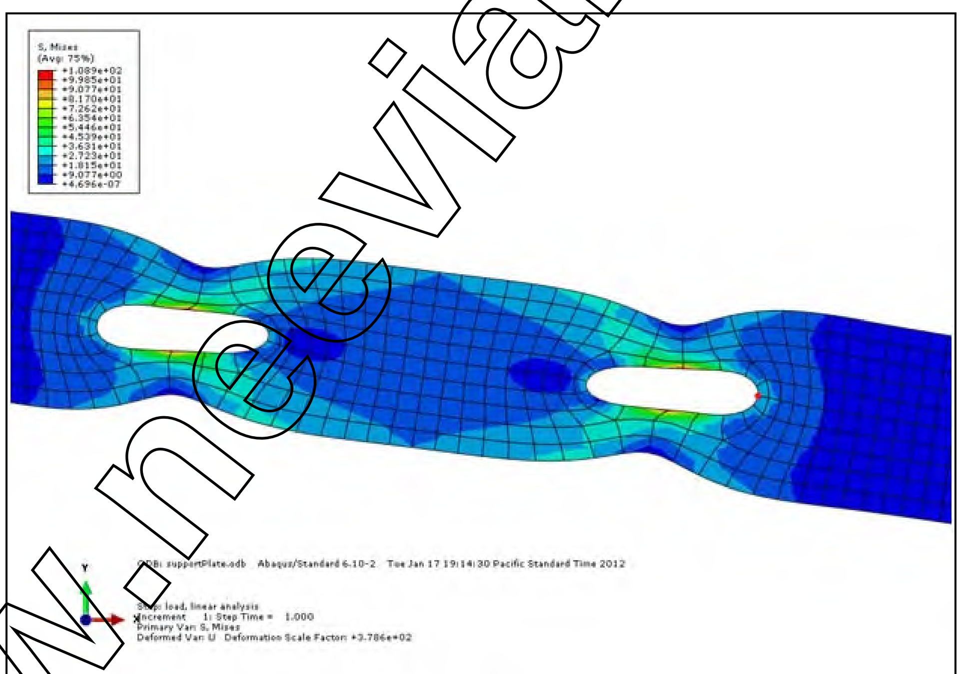

Figure 11. Supporting plate FEA.

For more information on the problem setup, see Appendix A-5: Supporting Plate.

6.2.2 Testing: Three Point Bend Test

Purpose: In order for us to have a robust press design, it must be shown that the loads that will be applied to the rollers by the sorghum stalks will not be enough to cause plastic deformation. In addition, the applied loads must also not cause an elastic deformation large enough to prevent the pressing of the stalks down to a 0.2 inch thickness.

Procedure: Place the roller to be tested into the three point bend test machine. Lower the machine until it is in contact with the roller, then begin to apply force to the roller while measuring resulting displacement. Slowly increase the load up to a force of 1500lb, then backed slowly down to 0lb in order to find the maximum deflection from 1500lb and the plastic deformation it will cause. If the maximum deflection was less than 0.1 inches, the roller should then be reloaded up to the minimum force required to reach a 0.1 inch deformation. The resulting data should be acquired. For more detailed description of test setup and procedures, see TP3, Three Point Bend Test.

Results: First the roller using sch. 5 pipe was placed in the three point bend machine and was exposed to a steadily increasing force from 0 to 1500lb, and then brought back down to 0lb. The current force applied and the resulting displacement were recorded rapidly throughout the duration of the test. The results can be seen in Figure 12.

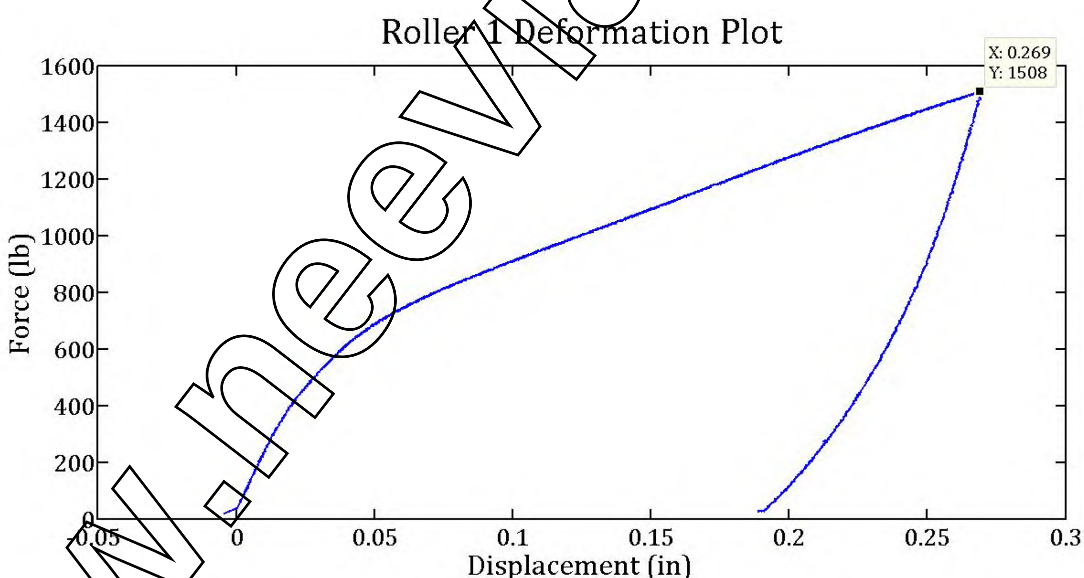

Figure 12. Roller 1 deformation plot.

Here it can be seen that at 1500lb the roller deformed 0.27 inches, and when the load was brought back to 0, there was a resulting plastic deformation of almost 0.2 inches. Another test of the same roller was unnecessary as the 0.1 inch deformation mark occurred long before the needed load of 1500lb. This same procedure was then repeated for the roller using sch. 40 pipe for the walls. The results can be seen in Figure 13.

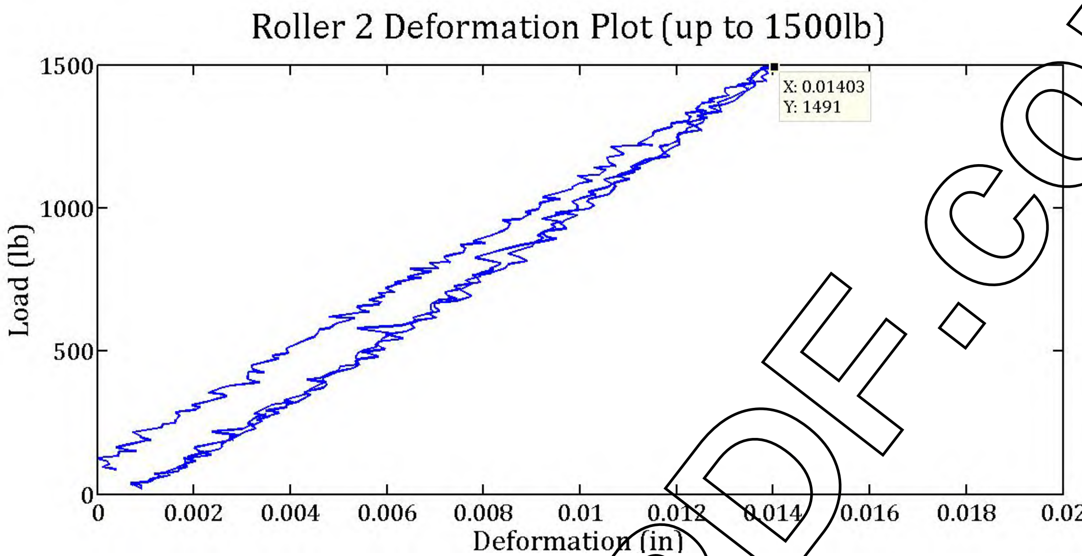

Figure 13. Roller 2 deformation plot (up to 1500 lb).

Here it can be seen that at 1500lb the roller deformed 0.014 inches, and when the load was brought back to 0, the resulting plastic deformation was negligible

The roller was then placed under a steadily increasing load again until the deformation reach 0.1 inches. The resulting data can be seen in Figure 14.

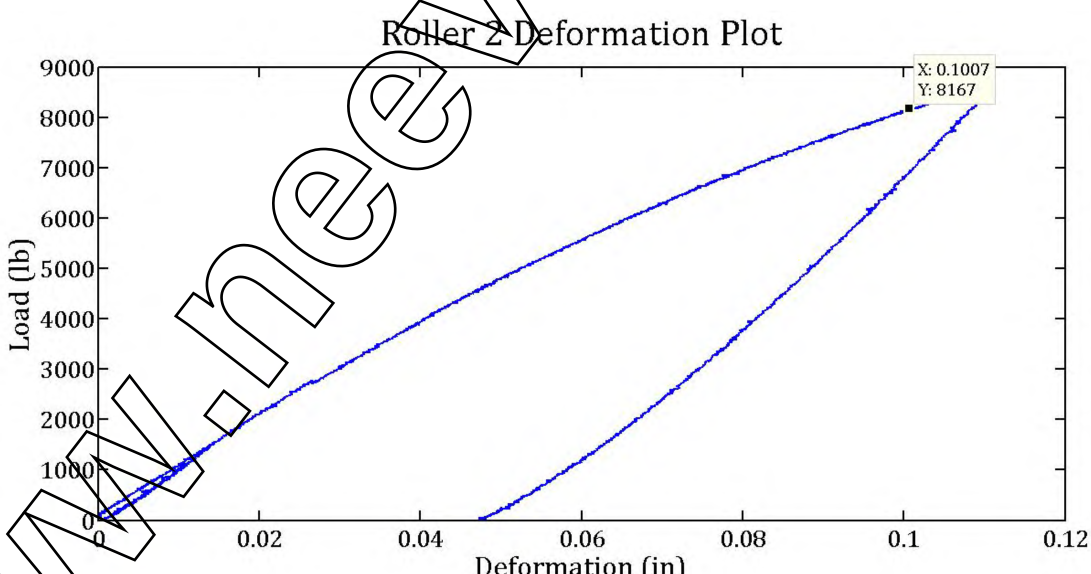

Figure 14. Roller 2 deformation plot (full).

Here it can be seen that the force required to displace the roller 0.1 inches is 8000lb giving the rollers a safety factor of 5.3. For a more in depth description of data obtained and analysis done, see TR3 and TR4.

Conclusion: In order to have a press that extracts 90% of the juice from sorghum stalks, the rollers must press the stalks down to a thickness of 0.2 inches. In order to do this the rollers must not deform beyond this point. In addition to this the rollers must not plastically deform from the load a stalk would exert due to the lack of resources and skilled labor required to maintain the machine if problems occur. These rollers using sch. 40 pipe pass everyone of these specifications and should be acceptable parts for the human powered sorghum press for the people in Mali.

6.3 Increased Throughput

6.3.1 Testing

Purpose: When asked for areas to improve on the past human powered sorghum press, the people of Mali were adamant about improving the throughput rate. The old press given to them processed only one stalk at a time with a feed rate of about three inches per second. In order to address this issues, the rollers were redesigned to accommodate more stalks at once. With this new design, the throughput must be tested at various bundle sizes to see the overall effectiveness of the press.

Procedures: The press should first be staked into the ground at each corner in order to prevent movement during use. Once the press is firmly secured to the ground, one person should begin turning the crank arm at a comfortable speed. The second person should then begin to feed through the rubber rods one at a time until all six have gone through the machine. The time to process all six rods should be recorded, and the same test should be performed two more times. This same procedure should then be repeated for feeding two rods through at a time, three rods through at a time, and six rods through at a time. All times should be tabulated for later Analysis. For more detailed description of test setup and procedures, see TP6, "Sorghum Press Throughput."

Results: The time required to process six rods, each six feet in length, was recorded for bundle sizes of one rod, two rods, three rods, and six rods. Each bundle size was repeated three times, and the results can be seen in Figure 15.

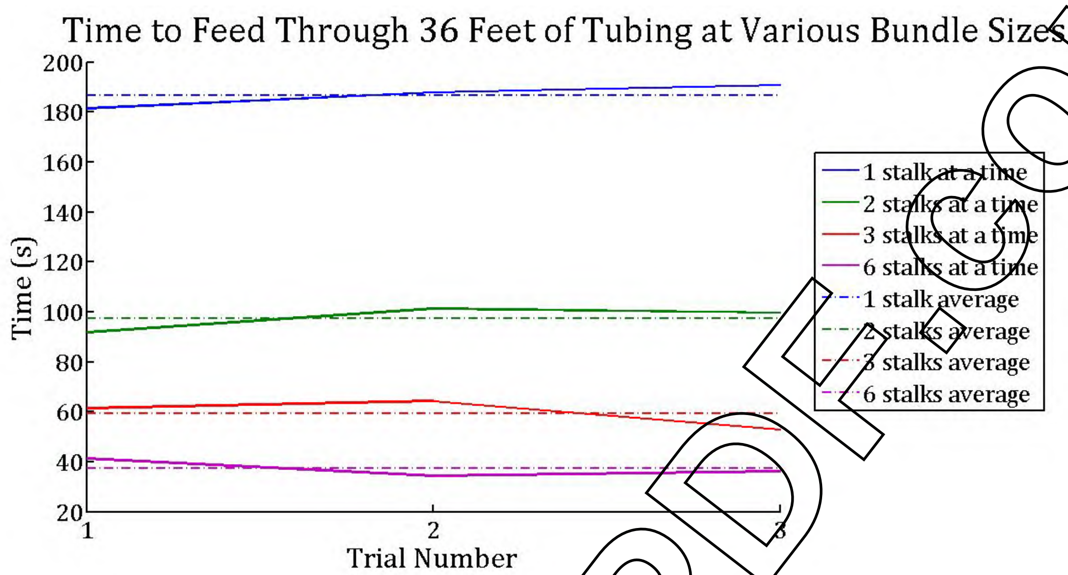

Figure 15. Time to feed through 36 feet of tubing at various bundle sizes.

Here it can be seen that with a bundle of only 1 rod, the average time to feed through all six rods was 187 ± 15s. With a bundle of 2 rods this time dropped to 98 ± 10s. Feeding through a bundle of 3 rods at a time dropped the time to process all rods even further to a total of 60 ± 7s. Finally, with a bundle of all 6 rods at once, the processing time was only 37 ± 4s.

When the feed rate is divided by the number of stalks fed through at once, the feed rate per bundle is found. This data shows that the speed at which each bundle is processed is nearly constant. This relationship can be seen even more clearly in Figure 16.

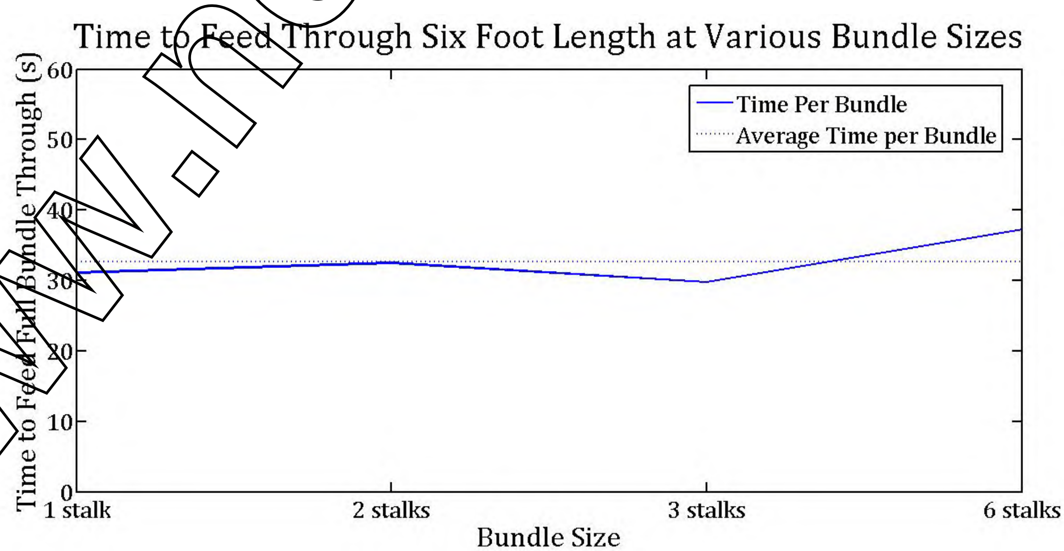

Figure 16. Time to feed through 6' length at various bundle sizes.

Here the time to process each bundle was found by taking the total time for each bundle size, and dividing it by the corresponding number of bundles. The average time per bundle was found to be 33 ± 5s. For a more in depth description of data obtained and analysis done, see TR6 "Sorghum Press Throughput."

Conclusion: Throughput was found to be maximized by feeding through the maximum possible number of stalks at a time up to at least six. The resulting feed rate at a bundle size of six stalks resulted in a processing speed of 11.7 ± 1.2 in/s. This feed rate is approximately four times as fast as the old press which has a feed rate of about 3in/s.

6.4 Efficient Use of Human Power

6.4.1 Testing: Harnessing Human Power

Purpose: In order for us to produce the most efficient human powered sorghum press possible, we must first address the issue of what the most efficient use of human power is. The press is designed to be usable by an average human for an extended period of time in order to squeeze juice out of sorghum stalks. In order for the user to process the sorghum as quickly and efficiently as possible, the transfer of energy must be efficient not only from the machine to the sorghum stalks, but also from the human to the machine.

Procedures: Each of the four test subjects is to perform at whatever he or she feels is a comfortable rate on each of the three workout machines: a hand cranking machine, a biking machine, and an elliptical machine. The power output in watts is recorded off of the display every fifteen seconds for ten minutes. All data for each test is averaged to get an "average person's" power output over a ten minute period. See TP1, Efficiency of Human Power for a more in depth description of test set-up and procedures.

Results: Test results show that hand cranking is by far the least efficient use of human power with test subjects only being able to output 30.7 ± 5 watts of power on average over ten minutes. Walking was found to be by far the most efficient use of human power with test subjects being able to output 179.9 ± 10 watts of power on average over ten minutes. These results can be seen in Figure 17.

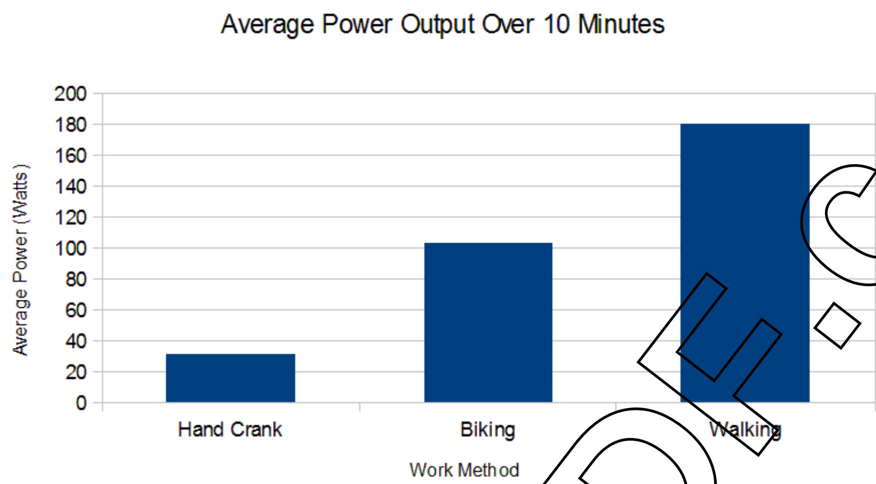

Figure 17. Average power output over 10 minutes.

See Appendix TR1: Efficiency of Human Power, for a more detailed description of data and results obtained.

Conclusion: The purpose of the test was to find the most efficient use of human energy. This goal was indisputably accomplished, as walking while pushing an object was found to have almost doubled the average power output of the next most efficient method. Due to these findings, the human powered sorghum press should utilize a walking method for people to put energy into the system.

6.5 Minimize Use of Materials

6.5.1 Roller Size Analysis

Purpose: If the press is to squeeze the sorghum down to a diameter of .2 inches, the rollers must be able to withstand large loads. In order to determine what roller diameter would work as more stalks were being fed through for a length of .3m (12in) roller the following equitation was use

$$D = 2 \times \sqrt{\frac{PL}{8\pi t\sigma}}.$$

Procedure: This problem was modeled as a beam tapered at both ends, with one load in the middle. Matlab Code was generated to determine the dependence of the roller diameter on the number of stalks being fed through. Figure 18 displays the results.

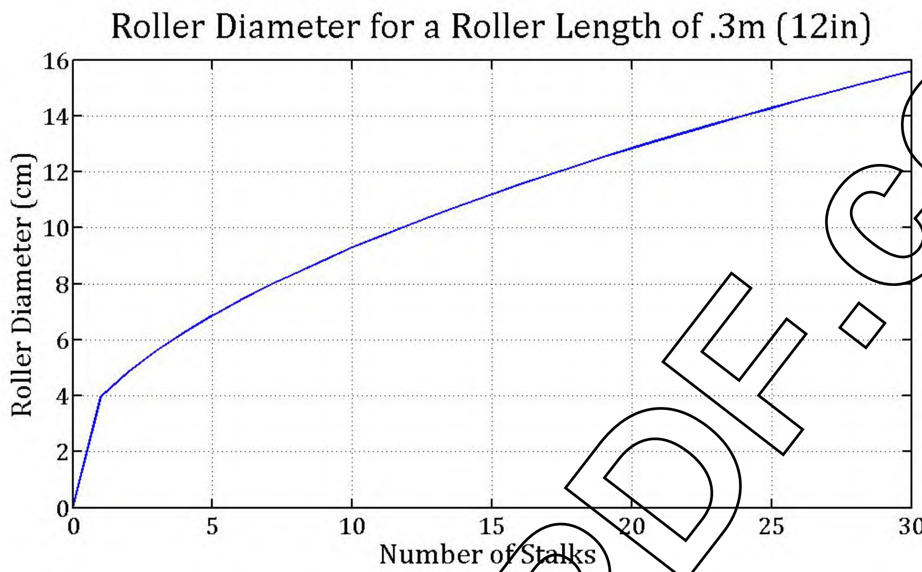

Figure 18. Roller diameter for a roller length of .3 m.

Results: As expected, the roller diameter increases as stalks number increase. From the results, it was noted that roller diameter would not be a critical dimension for the rollers. According to the analysis done, a 16 cm roller would be needed to withstand the equivalent of 30 stalks through at once.

6.5.2 Crank Arm Fixture Analysis

An analysis was done to make sure the crank arm will not fail. For information on the problem setup, see Appendix A-2: Crank Arm, 1 Stalk.

Evolution of crank arm fixture:

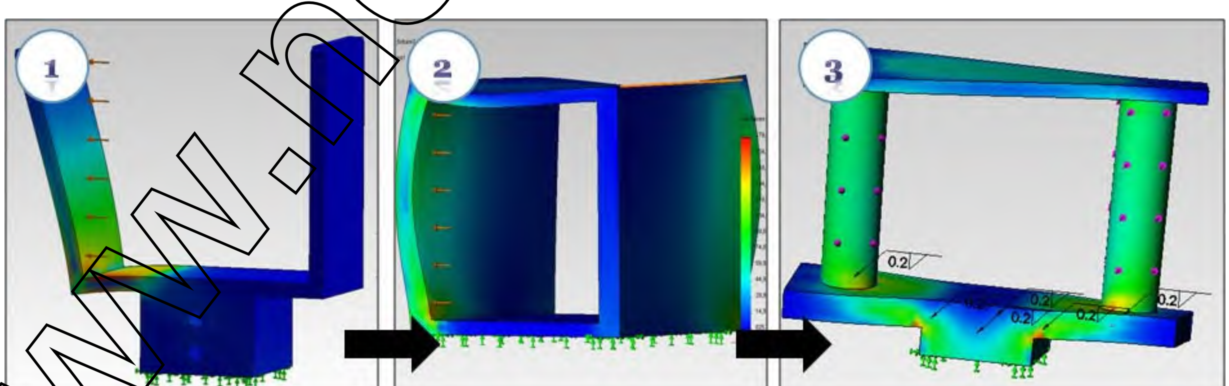

Figure 19. Evolution of crank arm fixture.

Since cost is one of our primary design concerns, we did many design iterations on some parts to lower cost as shown in Figure 19. The first design of the crank arm fixture has a safety factor of N=.11 and an estimated material cost of \$10 (14 in^3).

Due to the low factor of safety, this design will not work. We then came up with the second design. The second design has a safety factor of N=2.23 and an estimated material cost of $29 (40 in^3). This second design has a higher factor of safety. However, due to its high cost, we made a third design in an attempt to make it cheaper. The third design has a safety factor of N=1.5 and an estimated material cost of $16 (22 in^3). This design has a high enough factor of safety to keep it from failing, and also uses material efficiently so that it has a low cost. The material cost is estimated with the Density of steel=.284 lb/in^3 and cost of steel=2.5 $/lb.

6.5.3 Drive Shaft Analysis

To ensure that the shaft can handle the torque, we did an analysis. We found that without the fail safe mechanism, in the event that the machine is jammed and the user pushes it with a force of 140lb, the shaft is likely to yield but not break. However, with the fail safe mechanism installed, given the same situation the dowel pin will break and protect everything else from yielding or breaking. For detail please see Appendix A-1: Drive Shaft Analysis.

6.5.4 Gear Analysis

We have done analysis to make sure that the gears will not fail by fatigue.

For details, please see Appendix A-10: Gear Fatigue.

VII. Results of Additional Design Efforts

7.1 Analysis

7.1.2 Bushings

The bushing is loaded in the radial direction by the force exerted by the shaft. We have done analysis to make sure that the bushing will not fail.

For detail please see Appendix A-6: Bushing analysis.

7.1.2 Bushing Support

The bushing support is the steel block welded to the supporting plate that supports the bushing. The bushing support distributes force along the whole length of the bushing, which lowers the maximum stress on the bushing. Matlab analysis was done to make sure that neither the weld nor the support block will fail. The detailed calculation is available in Appendix A-7: Bushing Support.

7.1.3 Scotch Key

The scotch key transmits the torque from the small gears to their respective shafts. An analysis was done to make sure the gear to shaft scotch key connection will not fail. For details, please see Appendix A-8: Scotch Key Analysis.

7.1.4 Dowel Pin

The dowel pin is used to transmit torque from the crank arm fixture to the driving shaft. A dowel pin analysis was done to ensure that the dowel pin is strong enough to transmit the torque. For details, please see Appendix A-9: Dowel Pin Analysis.

7.2 Testing

7.2.1 Force to Crush Sugar Cane

In order to get the force that a sorghum stalk would exert on the rollers of our press, samples of sugarcane were tested in a compression test machine. These samples were crushed down to 0.2 inches thick, the thickness required to extract 90% of the juice according to research, and the resulting force was measured. This force was divided by the contact area to get pressure, and that pressure was then multiplied by the area that will be in contact with our rollers in order to get the force they would exert. The maximum force these stalks could exert was found to be 1370lb.

In addition, the force required to squish these sugarcane stalks was compared to the past team's data of force to squish sorghum under similar conditions. All data showed that the forces required to squish sugar cane were at least twice as large as the forces required to squish sorghum. For more information on test procedures and results, see TP2 and TR2, "Force to Crush Sugar Cane."

7.2.2 Fatigue Test (Human Powered)

In order prove feasibility of our press lasting at least one full season of sorghum harvesting, a human powered test was run for ten hours at ten revolutions/second, resulting in a total of six thousand revolutions. Test was run with a single rubber rod of similar properties fed through the rollers. After the duration of the test, rollers and gears were inspected for any plastic deformation, and all other parts were checked for breaks. All parts seemed to be in perfect working order, proving feasibility of our design. For more in depth descriptions of test procedures and results, see TP7 and TR7, "Fatigue Test (Human Powered)."

VII. Recommendations and Proposed Efforts

7.1 Proposed Efforts

The primary objective for Spring Quarter, 2012, is to test the final design model with the improvements mentioned in Section 7.2 and to compare against our PCR. In order to assure that a fully working model will be manufactured and tested, our team has selected a set of activities that we felt are critical to perform during spring quarter.

7.1.1 Testing: Fatigue Testing

In order to get definitive proof that the press will last a full sorghum harvest season, the press must be placed under similar conditions to that of a sorghum harvest season. To simulate these conditions, the press will be attached to a 400 W motor and driven continuously for 300 hours at 10 rpm with one o-ring rod fed through in a loop, this results in a total of 180,000 revolutions. 180,000 was found to be the approximate number of revolutions the press would go through in a season given an operation speed of 10 rpm, and operating eight hours a day for one month. After the full number of rotations is completed, the press will be inspected for plastic deformation in the rollers or gears, as well as any other breaking points in the press.

7.1.2 Research

Further research on Malian manufacturability will be done to determine whether their machine shop has knurling capabilities.

7.1.3 Additional Activities

A drawing package along with assembly instructions must be prepared to be sent to the machinist in Mali. Additionally, an instructions manual in both English and French must be made.

7.2 Proposed Improvements to Current Design

7.2.1 Two Gears vs. Three Gears

After testing the prototype, the team came to the conclusion that one of the gears could be removed to further minimize the amount of material being used, as well as the cost of manufacturing the additional gear. The final design will only require two gears with the same gear ratio. This will also minimize the complexity of the design.

7.2.2 Design for Modularity

In order to reduce amount of time and assembly effort while increasing the portability, the final design will be tailored to modularity. The final press will designed in such a way that the metal parts will remain assembled when detached from the frame.

7.3 Deliverable Updates

The Project Design Specification document (Appendix X-2), the Project Completion Requirements (Appendix X-3), and the Project Plan (Appendix X-4) have all been updated in accordance with our changed priority of Performance Requirements and therefore Technical Parameters. An updated Purpose and Scope have also been included.

Works Cited

Hewlett, Allen M. et al., Sugar Cane Mill. US Patent # 2406541 Filed March 28, 1944. Issued Aug. 27, 1946

Powers, D.J., Improved Sugar and Sorghum-Mill. US Patent #96264 Issued Oct 26, 1869.

Withers, Edward A., Improvement in Sorghum Mills US Patent # 192475 Filed March 24, 1877 Issued June 26 1877

Sweet Sorghum Research. University of Nebraska-Lincoln Dept. of Agronomy and Horticulture. http://agronomy.unl.edu/sweetsorghum, 3/4/2011

Kang, Micheal. *Leadership Transitions in the Malawi Water Sector.* Engineers Without Borders Canada. http://www.admittingfailure.com/failure/michael-kang/ 3/4/2012

Kelly, Anderson. *High Tech Water Filter Donation*. Engineers Without Borders Canada. http://www.admittingfailure.com/failure/kelly-anderson/ 3/4/2012

Marc L. Resnick: "An Ergonomic Evaluation of Handle Height and Load in Maximal and Submaximal Cart Pushing", Applied Ergonomics Vol 26 (1995):173-178

Vincent M. Ciriello: "Cart Pushing Capabilities for Males and Females: an Update." Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting (2009): 897-901.

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Andy Weinberg: *Machine Shop Manager/Manufacturing Consultant*
Kirk Fields: *Senior Development Engineer/Testing Consultant*
Scott Lacy: *Primary contact with Mali*
EWB: *Sponsoring Organization*

Appendix

Appendix A-1: Drive Shaft Analysis

Purpose: The driving shaft is the shaft that is connected to the crank arm fixture. The driving shaft is under the torsion load from the crank arm. A analysis was done to finds out what will happen in the event that the machine is stalked and the user pushes with maximum pushing force a human can exert.

Result: The maximum shear stress is found to be 290 MPa which corresponds to a safety factor against maximum shear strength of N=1.03. Disregarding the fail-safe mechanism, in the event that the machine is stalked and the user pushes it with a force of 140lb, the shaft is likely to yield but not break. The low factor of safety is a trade off from cost, since a stronger machine will cost more. This low factor of safety can be tolerated because during proper usage, the machine will not experience such large force. Also when the force exerted by the user is too great, the dowel pin will break and protect the shaft from the excessive force.

Problem Setup: In the calculation, the torque is provided by a 59 in (1.5 m) crank arm with a 140lb force at the end. From the literature review section, 140lb is the maximum horizontal pushing force a regular human male can exert.

1 inch diameter steel shaft
Crank arm length: 59 in (1.5m)
Force exerted by the user: 140 lb

Calculation:

```
Kfs=1
d=1; % inch
Tm=59*140e-3; %59inch * 140 lb
%torsional Shear
taum=Kfs*16*Tm./(pi*d^3); % in Pa
taum=taum*6.895 % in MPa
n=250/taum
```

Appendix A-2: Crank Arm

Problem setup: The crank arm is modeled as a cantilever beam made of 2X4 lumber with a concentrated load of 140 lb at the end. The maximum tensile stress is found to be 15.9MPa which corresponds to a safety factor of N=2.5.

Assume a cantilever beam problem. Force exerted by user = 140 lb. Crank arm length = 1.5 meters. Use 2X4 lumber

Result: Using a 2X4 piece of lumber. Maximum tensile stress=15.9MPa. N=2.5.

Calculation:

```
%Crank Arm Analysis
clear all
clc
l=1.5; %length = 1.5 meters
f=622; %622N = 140lb
%using 2X4 lumber
h=.0889;
b=.04445;
M=l*f % maximum bending moment
I=b*h^3/12;%second moment of area
sigma=M*(h/2)/I; % in pascal
sigma=sigma/1e6 % in MPa
n=40/sigma
% strength of wood = 40Mpa
```

Appendix A-3: Roller Denting, 1 Stalk

Problem Setup: The two rollers are in direct contact with the sorghum being crushed, thus are subjected to the load of from the sorghums. Thus it is important that the roller does not deform so they can press the sorghum stalks flat enough to extract juice efficiently. An FEA was conducted to make sure the roller does not yield and to find the deformation of the roller under the concentrated load of 1 sorghum stalk. The load was modeled as a 1000lb force over a .4inch by .4 inch square half way up the roller.

The design uses 4.5 inch schedule 40 pipe.

The load of 1 sorghum stalk in modeled as 1000 lb of force applied over a .5inch square on the roller.

Appendix A-4: Roller Denting, 8 Stalks

Problem Setup: An FEA was conducted to make sure the roller does not yield and to find the deformation of the roller under the distributed load of 8 sorghum stalks. The load was modeled as 8000lb force distributed on a .4in wid strip running the whole length of the roller.

Result: The maximum stress at the center of the roller is found to be 170MPa, which corresponds to a safety factor of N= 1.5. Again, note that a low factor of safety is tolerated since the force exerted by the sorghum stalk used in this analysis is overestimated. The 8000lb of force is an overestimation because it was calculated assuming the knots of the 8 sorghum stalk lines up exactly. In practice, the knots of the sorghum stalks will not be lined up, and since the not knotted part of sorghum exerts less force, the overall load of the roller will be less than 8000lb.

Appendix A-5: Supporting Plate

Problem Setup: In the FEM, the plate is subjected to concentrated two 4000lb forces in opposite directions. The material is structural steel and the thickness is .25 inch.

Appendix A-6: Bushing Analysis

Purpose: The bushing is loaded in the radial direction by the force exerted by the shaft. Bushing analysis was done to make sure the bushing will not fail.

Result: It is found that the load on the bearing is 3.3ksi which corresponds to a safety factor of 1.7 when compared to the maximum P rating of the bushing. A low factor of safety is tolerated since the force exerted by the sorghum stock used in this analysis is overestimated. The 8000lb of force is an overestimation because it was calculated assuming the knots of the 8 sorghum stock lines up exactly. In practice, the knots of the sorghum stocks will not be lined up, and since the not knotted part of sorghum exerts less force, the overall load of the bushings will be less than 8000lb.

Problem setup and calculation: The analysis was done using the P rating provided by the vendor. The force exerted to the bushing from 8 sorghum stocks is modeled as 4000lb, since each bushing only takes half the total load.

The bushing used is a brass bushing with a bore diameter of 1 inch and a length of 1.5 inches. From McMaster Carr website, their bushing is rated using the following formula. P=bearing load /(shaft diameter * bearing length). The bushing used in this design is rated to 4,500 psi. diameter=1 in. Length= 1.5 in. F=4000 lb when pressing 8 sorghum stocks. P=4000/(1*1.5)=3333. n=1.687

Appendix A-7: Bushing Support

Result: It is found that the maximum stress on the weld is 44MPa which corresponding a safety factor of N= 4.7. The maximum stress on the support block itself is found to be 43.4MPa, which corresponds to a safety factor of N= 2.88. The high safety factors indicate that the part is not going to break.

Problem Setup: The bushing support is modeled as a cantilever beam subjected to a concentrated force at one end. A load of 4000lb was used to model the load exerted by 8 sorghum stocks, since each stock is tested to provide about 1000lb of force and each bushing support only takes on half the load exerted from the sorghum.

Model the force on the supporting block as a concentrated force on the top of the support block. In our design:
b=d=L=2 inch
Weld thickness = h=.2 inch
assume pressing 8 sorghum stocks
F=4000 lb
support block material is structural steel: Yield strength = 250 MPa
Welding material is E6010 electrode: Tensile Strength=410MPa
For calculation, please see Appendix X-1 Bushing Support Code

Calculation:

```
% clc
clear all
h=.2; % in
L=1; %in
F=4000; %lb
%tau total must not exceed 60 ksi
d=1.5;
b=d;
% get tau1
A=1.414*h*(b+d);
tau1=F/A;
%get tau2
M=F*L;
Iu=d^2/6*(3*b+d);
I=.707*h*Iu;
```

```
c=d/2;
tau2=M*c/I;
%vector sum tau1 and tau2
taut=(tau1^2+tau2^2)^.5;
tauKsi=taut*1e-3 % convert taut to ksi
n=30/tauKsi
%%Now lets make sure the beam won't break from bending.
%stress on the beam it should be lower than 36 ksi
clear all
L=1; %in
F=4000; %lb
D=1;
d=1.2;
b=d;
M=L*F;
A=b*d;
r=.5;
I=b*d^3/12-pi*D^4/64;
sig1=F/A;
sig2=M*d/I;
sigtotal=(sig1^2+sig2^2)^.5
sigtotalKsi=sigtotal*1e-3 % convert it to Ksi
```

Appendix A-8: Scotch Key Analysis

Result: The shear stress is found to be 486 MPa which corresponds to a Safety factor of N= 1.5. Note that the low safety factor is tolerated because if the machine is subjected to too great of a load, the scotch key will break instead of any other part. The scotch key can then be replaced easily in the field.

Problem Setup:
Shear strength of dowel pin=719 MPa
Crank arm length = 59 in (1.5 meter)
Dowel pin diameter = 5/16 inch
Dowel pin length = 3/8 inch

Calculation: The scotch key analysis is done using a plane shear model. The area of shear as well as the force exerted on the scotch key are found, then the force was divided by the area to calculate the shear stress.

```
%Scotch key Analysis
clc
clear all
D=5/16 %inch
L=3/8 %inch
A1=1/4*pi*D^2;
F=16/2; % kip
ShearStrength=F/A1*6.895 % in MPa
```

Appendix A-9: Dowel Pin Analysis

Result: The double shear force on the dowel pin is found to be 8260lb which corresponds to a safety factor of N=1.937. High factor of safety indicate that the dowel pin will not break.

Problem Setup: The dowel pin analysis was done by comparing the shear force on the dowel pin to the strength rating for double shear provided by the vendor. Strength rating for double shear is the forced needed to break the dowel pin into 3 pieces. The force on the dowel pin in the analysis is calculated by dividing the torque by the diameter of the shaft, since in our design such calculation provides a force that can be compared to the double shear strength rating.

The 5/16" diameter alloy steel dowel pin is rated to 16,000 lb of double shear. The crank arm is 59 in (1.5 m). The force the user exert is 140 lb

Calculation:

```
torque=59*140
% 59 inch *140 lb
Shear_force=torque
N=16000/Shear_force
```

Appendix A-10 Gear Fatigue

Purpose: Find the safety factor of the gears with respect to endurance limit.

Calculations:

```
clear all
clc
%description: Our human powered sorghum press uses two identical gears.
%Since it is human powered and runs at an low rpm, dynamic effect can be
%neglected.
%material - carbon steel
l=.6; %inch, teeth length
rf=.1; %inch, root radius
d=4; % inch, pitch diameter
N=16; %number of teeth
F=.5; %inch, face width
Sut=58; %Ksi, ultimate tensile stress
t=.5; %inches,
%torque required to press sorghum
T=40e-3 % kip-ft, torque required to press 1 stock of sugar cane
```

```
T=T*12 % convert to kip-inch
stocks=5% number of stocks
T=T*stocks % total torque needed to operate machine
%all equations, tables, figurs comes from Shigley's 9th edition,
%international version
%part a.) find sig = stress on the gear
  %wt, force transmited to gear
    %solve the equation T=d/2*wt
      wt=fsolve(@(wt) T-d/2*wt, 1)
  %stress concentration factor due to root radius
    %from figure A-15-6
      %rf/t=.2
      %estimate D/d=3 since it is a gear
      Kt=1.5
    %from figure 6-20
      q=.75
      Kf=1+q*(Kt-1)%equation 6-32

  %solve for stress using this equation: sig=Kf*6*wt*l/(F*t^2)
      Y=.296; % table 14-2
      P=N/d;
%     sig=Kf*wt*P/(F*Y) %in psi
      sig=Kf*6*wt*l/(F*t^2)
  %lets find Se, fatique strength
    SePrime=.5*Sut; % this is the unmodified fatique strength
    %find Ka Marlin Factor
    a=2.7; % table 6-2
    b=-.265; % table 6-2
    ka=a*Sut^b
    %find Kb, size factor
    de=.808*(F*t)^.5;%using equivalent torating-beam diameter
    %de turns out to be .404 inches, so lets use corresponding size factor equation
    kb=.879*de^(-.107) % equation 6-20
    %find kf
    %lets goodman quiterion
    %since gear teeth undergoes one way bending
    %Use gerber quiterion with one directional bending and Sa=Sm=Sut/2
    %where sig is the applied stress
    %so
```

```
    kf=1.66;
    %lets calculate Se
    Se=ka*kb*kf*SePrime
    %lets calculate the safety factor
    safety_factor=Se/sig
%Anser summary
% When F=.75 inch
% Sig=68.53 KPa
% Se=72.54 KPa
% N=1.0585;
```

Appendix R-1: Human Factor Research

Pushing force from the literature:

A join study of Florida International University and University of Michigan found that the peak static horizontal pushing force for young men is 620N (140lb). Thus we found that the maximum horizontal pushing force of the user of the sorghum press will be no larger than 140lb. Liberty Mutual Research Institute for Safety, Hopkinton, found that the initial force of male subjects pushing a cart is Mean 394N, STD 117N (Mean 88lb, STD 26lb). Using the standard distribution statistic, we found that 3% of all male subject can exert a force over 140lb, assuming the pushing force follows a normal distribution. “Proceedings of the Human Factors and Ergonomics Society Annual Meeting” This maximum pushing result confirms our assumption that the user cannot push harder than 140lb.

Using the same distribution, we found that 97% of healthy human adults can exert at least 36lb of force. Thus we assume that all users can exert more than 36 lb of force.

Minimum Torque Needed to Operate the Press:

The minimum torque required to operate the machine is calculated using the 36lb that all users can exert, 1.5 meter crank arm which we design for, and a Gear reduction of 1.5 using this following equation:

$$T=F*L*G \quad (EQ.1)$$

Appendix B-1: Total Budget

ME189 Team 20- Sorghum Press Budget		
Current Expenses:		
Funding source:	Amount Spent:	Description:
URCA Grant	$750.00	Materials for prototype
EWB	$500.00	Estimated 3D Print cost
Total Current Expenses:		
	$1,250.00	
Estimated Future Expenses:		
EWB	$503.00	Estimated cost - Materials for final model
EWB	$200.00	Estimated cost - Machining tools and expendables
EWB	$350.00	Estimated cost - Testing Equipment
Future Expenses Total:		
	$1,053.00	

Appendix B-2: Retail Cost of Prototype Press

ME189 TEAM 20 Cost Report
LATEST REVISION: 2/16/2012

ITEM	DESCRIPTION	UNIT	QTY BUY	PART #	VENDOR	PRICE/UNIT
1	Low Carbon Steel Bar 1/4"x2"x72"	6ft	1	8910K147	McMaster Carr	$44.16
2	Low Carbon Steel Bar 1/8"x4"x24"	2ft	1	9571K161	McMaster Carr	$35.82
3	Low Carbon Steel Rod 1" Dia. 3 ft length	3ft	1	8920K23	McMaster Carr	$27.68
4	Low Carbon Steel Bar 2"X2"X12"	1ft	1	9143K251	McMaster Carr	$47.47
5	Schedule 40 Steel Tubing 3.5" pipe size	1ft	2	T5312	MetalsDepot	$19.13
6	Alloy 954 Bronze Sleeve Bearing for Shaft Dia 1", 1.5" L	ea	4	2934T27	McMaster Carr	$9.86
7	Low Carbon Steel Rod 5/16" Dia . 3ft length	3ft	1	9120K12	McMaster Carr	$4.68
8	Low Carbon Steel Sheet 1/2"x8"x8"	ea	1	K544K35	McMaster Carr	$50.36
9	Low Carbon Steel Sheet 1/2"x5"x12"	1ft	1	8910K712	McMaster Carr	$39.05
10	Key Stock 5/16" square 1ft length	1ft	1	99374A120	McMaster Carr	$17.66
11	Pine 2x4x8	8ft	6	N/A	Home Depot	$2.38
12	pine 4x4x8	8ft	2	N/A	Home Depot	$4.55
13	Spring Steel Strip .016"x1"x10ft	10ft	1	9075K65	McMaster Carr	$31.20
14	Polypropylene Sheet 1/16"x48"x8'	8ft	1	8742K931	McMaster Carr	$39.73
15	3/32" Stick Electrodes	5lb	1	195792	Home Depot	$15.47
16	#6x2in coarse thread drywall screws	5lb	1	N/A	Home Depot	$21.97
17	1/4x3in coarse thread hex head wood screw	ea	20	N/A	Home Depot	$0.37
18	1/4"x4'x8' Plywood Sheet	ea	1	N/A	Home Depot	$19.97
					NET COST:	$503.70

Appendix X-1: Project Assignments

Name	Assigned Tasks
Kelly Lin (Team Leader)	Analysis
Davide Cordeiro	Modeling, Prototyping
Erika Eskenazi	Prototyping, Document Editor
Marcela Areyano	Analysis
Adam Scott	Testing

Appendix X-3: Updated Project Design Specifications

Product Design Specification
Revision Date: 3/16/2012

Team Leader: Kelly Lin
Team Members: Erika Eskenazi
David Cordeiro
Adam Scott
Marcela Areyano

Product Title: Human-Powered Sorghum Press

A. **Purpose**

Our project aims to improve the quality of life for people in a small community in Mali by providing them with an improved sorghum press design. A sorghum press is a device which extracts syrup from the stalks of sweet sorghum plants which are abundant in Mali. This nutritious syrup is then processed to produce sugar. Through this syrup production, business opportunities are created for the villagers of Dissan.

A previous sorghum press design was made for this community by the Engineers without Borders (EWB) Mali team three years ago. After the first prototype was installed and used for a season, it became apparent that this first press required improvement. The current sorghum press is hand cranked and can only pass along one sorghum stalk at a time, making the syrup output slow. Our new design aims to improve the sorghum throughput efficiency of the press.

The three end goals of this project are as follows:

1. Provide a working model that can be used immediately in Mali.
2. Provide clear mechanical drawings and machining instructions that can be used by the machinists in Mali with the materials and tools they have.
3. Provide an easy-to-follow instructions manual for the community on how to operate and maintain our press.

B. **Features**

We were able to create and prioritize our design features after receiving feedback from the community in Mali on the first sorghum press design. First and foremost, this device must be human powered. Second, the device must press sorghum and extract juice. The device also must be able to be manufactured in Mali relatively cheaply, as the goal of our project is to design a press that Malians can manufacture and use in their own country. All pinch points must either be covered or explicitly drawn attention to as areas to avoid. The press must also be able to be transported relatively easily ensuring storage in the off-season.

After baseline issues were addressed, the design features were determined based on information from the community. The number one request was to increase the number of sorghum stalks that could be fed through the machine so as to maximize output in less time. With this in mind, the press still needs to be operable by people with average strength for a substantial period of time. This is not as important as the previous feature as people in the community could potentially take turns operating the press if the work required is slightly more strenuous. As we intend this press to be used for many years, maintenance must be quick and the parts that need to be changed or cleaned must be easily accessible.

The following are our prioritized design features:

1. The device must be human powered.
2. The device must press sorghum, therefore extracting juice.
3. The device must have increased throughput than the 2008 sorghum press.
4. The device must be able to be manufactured in Mali.
5. The device must be affordable for our intended market.
6. The device must be safe for operators, bystanders, and the community.
7. The device must be quick and easy to maintain.
8. The device must be portable so it can be stored in the off-season.

C. **Competition**

The current competition is too highly priced for most families who live in Mali. Human operated presses are manufactured and sold for around $700. We would like to make a design that can be manufactured in the village where it will be used. As long as it remains less costly for the villagers to make their own press rather than buy from the foreign manufacturers, there will be no market competition.

Website/Seller	www.sugarcanmachine.com	fourbrothersei.com/hand.html	thelotuscafe.com/SugarCane.aspx	Zhen Zhou Whirlston Trade Co.,Ltd
Name	Manual Sugar Cane Juicer	"Boss" Hand Operated Sugar Cane Crusher		Manual Sugar Cane Juicer
Cost	originally $850 on sale for $590 +$75		$695 + $65 shipping	

	shipping			
Weight	82 lbs		65 lbs	37 kg
Material	stainless steel	cast iron except stainless steel rollers	stainless steel	stainless steel
Ships to	only USA		only USA	
Special Features			skin does not have to be removed from stalk before inserted; canes up to 2 inches diameter or less	50 kg/hr (juice?)

D. **Intended Market**

Men and mainly women in the village of Dissan, Mali are the intended users of the sorghum press. They are currently using the first model sorghum press designed by a group from UCSB three years ago and have made requests for improvements. The syrup extracted from sorghum is important to their society as it provides important nutrients.

E. **Performance Requirements**

We are using the testing results and analysis from the previous EWB Sorghum Press team as our primary benchmark. We feel the information and insight we have gained from their documents is sufficient and obtaining a manual sorghum press for ourselves to test would be redundant and not a good use of time or resources as our project aims to improve on the previous design and not to start from square one. We have looked at the mechanical drawings and test results. The most important information we found regarding the design was that it takes on average 9 lbs of force to push a sorghum stalk through the press with a max of around 23 lbs and that the force required to press the sorghum stalk to 0.21 in ranged from 330 lbf to 1200 lbf depending on stalk diameter.

The end goal of this project is to have a working model that can be immediately used by the people of Mali. Not only should a working model be delivered, but mechanical drawings and in depth instructions should be provided as well. The ultimate end goal is not only to produce a single working model for the people of Mali, but also to provide them with the ability to reconstruct their own versions in a cheap and simple way.

To ensure a quality design, the final design must meet these thirteen performance requirements:

1. The torque required to operate the machine must not exceed 240 N*m.
2. The press will crush sorghum to a 5.1 mm thickness.
3. The new press will have a throughput of 10 cm/s.
4. Gears can be manufactured consistently using a template.
5. All joining and fastening achievable with readily available nuts and bolts and stick welder.
6. All materials used in design can be purchased in Mali or are readily available in Mali.
7. The retail cost of the press will not exceed $500.
8. The device will not have accessible pinch points that are not labeled.
9. The device must be able to be cleaned effectively in less than 15 minutes and parts will be able to be changed out in less than 30 minutes.
10. The device will weigh less than 890 N.

F. **Life-cycle**

The sorghum press is intended to be used continuously during the harvest season for sweet sorghum. During the off-season the press will be stored indoors. As part of the user manual, a set of maintenance instructions will be provided. There will be a set maintenance schedule communicating which parts will need to be replaced and after how much time. In this way, the press will have "infinite" life.

G. **Human Factors**

Since this press is designed to be manufactured, maintained, and used by a group of people in a foreign third-world country, the human factor is a large consideration in our design efforts. The most complex problem is for us as designers to gain a working understanding of the way a rural African village society functions. Many questions about the people who will be operating the press and the resources that are available to them will likely remain unanswered due to communication difficulties and time constraints. We have identified a point-of-contact as Scott Lacy. Scott is a cultural anthropologist who has put a lot of time and work into humanitarian projects centered on the particular village in Mali where the press will be used.

As a result of our conversations with Scott and Mr. Bothman we can be sure of a few things about the society in Mali that will pertain to our design:

- The operators of the press will most likely be the women of the village.
- The entire village will likely share one or two presses unless it becomes somehow advantageous for them to have more.
- The local machinist is highly creative and skilled, but his tools and resources are much fewer than those of UCSB's machine shop.

- Mali, like almost everywhere other than the US, uses the SI system of units.
- The villagers are culturally very cautious about offending or displeasing those who are offering help. Therefore it is difficult for us to get any real constructive criticism about the previous press design.
- Village labor is readily available while ordering and obtaining raw materials and parts is not easy or affordable.

In order to minimize safety issues pertaining to assembly, a manual for the assembly must be created. A clear and concise user manual will be developed as well to encourage safe operation of the press. Both manuals will be mostly pictorial to ensure universality and the press itself will have intuitive operation. The mechanical parts that could cause harm to a person will be covered and generally inaccessible unless the press is taken apart to be fixed.

Lastly, the members of our team who are manufacturing the press have learned how to weld and exercise all safety precautions while in the machine shop or test laboratory.

H. Patent

This is a humanitarian project and is not intended for marketing or profit. The end results will be shared and available as an open-source design. Therefore it is important that the design is free of any potential patent infringement. The design is intended for use in rural Mali. However, as an open-source item it should comply with any safety standards required for use and manufacturing in the US. Further investigation will be conducted to find such compliances.

The following patents have been identified for investigation:

Patent number: 544972 Sugar Cane Press. Issued Aug. 20, 1895.

A vertical axis 2 roller gear drive design. The high gear reduction along with the way force is applied (via a walking animal) allows the press to crush hard sugar canes. The down side is that two roller designs (compared with three roller designs) are less efficient in terms of the force needed to press the sugar cane. We will take the vertical axis idea into consideration.

Patent number: 96264 Improved Sugar and Sorghum-Mill. Issued Oct. 26, 1869.

A horizontal axis 3 roller design. The 3 roller design is efficient at extracting sorghum juice, and the gear setup can be used in our design.

Patent number: 31828 Improvement in Sugar Mills. Issued Mar 26, 1861

A horizontal axis 2 roller design that features a feeding bed. It looks like the feeding bed helps the user to feed in the sugarcane stalk by allowing the sugar cane to be placed horizontally in front of the feeding end of the rollers. The feeding bed idea will be considered.

I. Regulations:

Since the sorghum press is a food processing device, all material that will be in contact of food must meet the FDA requirements from *FDA Food Code 2009*# which is summarized below:

Food Contact Surfaces shall meet the following requirements:

- Durable, corrosion-resistant, and nonabsorbent
- Finished to have a smooth, easily cleanable surface
- Resistant to pitting, chipping, crazing, scratching, scoring, distortion, and decomposition
- Galvanized metal may not be used for utensils or food-contact surfaces of equipment that are used in contact with acidic food.

Non-Food Contact Surfaces:

- Non food-contact surfaces of equipment that are exposed to splash, spillage, or other food soiling or that require frequent cleaning shall be constructed of a corrosion-resistant, nonabsorbent, and smooth material.

J. Ethical Discussion

This project aims to raise the standard of living of Malian villagers by allowing them to extract sweet sorghum juice from sorghum. Sorghum juice contains nutrients not found in refined sugar, which will improve the health of the villagers. With the aid of the sorghum press, villagers can grow sorghum as a cash crop, which will raise their income, hence the standard of living.

On the contrary, there are potential problems with having an increased supply of sorghum juice or with providing a press to the village. Sorghum juice can be easily fermented into alcohol, which might increase alcoholism in the village. Also, jealousy might become an issue of contention in the village if only some families are able to afford the press and others are not. However, these risks are offset by the health and economical benefits.

Project Completion Requirements PCR0003

Kelly Lin, David Hunter Cordeiro, Erika Eskenazi, Adam Scott, Marcela Areyano

REV. DATE [3/15/2012]

Requirements				
Specification	**Description**	**Value**	**Verification Method**	**Trials**
1	Minimum torque required to operate the machine.	240 N*m	Test Procedure 5	6
2	Maximum roller gap under normal load.	5.1 mm	Test Procedure 3	1
3	Device can process a length of sorghum stalk per unit time.	10 cm/s	Test Procedure 6	12
4	Gears can be manufactured consistently using a template.	True/False	Achieved through successful manufacturing of gears.	1
5	All joining and fastening achievable with readily available nuts and bolts and stick welder.	True/False	Review of drawing and assembly package and manufactured press.	1
6	All materials used in design can be purchased in Mali or are readily available in Mali.	True/False	Review of mechanical drawings.	1
7	Tolerances must be achievable by manual measuring techniques.	>.01 m	Verification from contact in Mali.	1
8	Performs minimum number of cycles before new parts are needed.	180,000 rotations	Test Procedure 8	1
9	Maximum retail cost of materials.	$500	Review of expenses.	1
10	Can lock moving parts when not in operation to prevent accidental injury.	True/False	Review of press.	1
11	Maximum weight.	890 N	Weigh press.	1

University of California, Santa Barbara
College of Engineering

Mechanical Engineering

ME 189 A,B,C Capstone Mechanical Engineering Design Project
Fall, Winter, and Spring Quarters 2011-12

PROJECT PLAN

Date: 3/16/2012

Project: EWB Sorghum Press

Project #: 20

Team Leader: Kelly Lin

Project Plan Change Log

Change Type	Date	Prepared By (Initial)	Reason for Review/Update
1. Original	11/10/2011	EE	N/A
2. Rev 1	3/16/2011	EE	Engineering Report
3.			
4.			
5.			

TABLE OF CONTENTS

Project Assumptions and Milestones

Project Purpose	Our project aims to improve the quality of life for people in a small community in Mali by providing them with an improved sorghum press design. A sorghum press is a device which extracts syrup from the stalks of sweet sorghum plants which are abundant in Mali. This nutritious syrup is then processed to produce sugar. Through this syrup production, business opportunities are created for the villagers of Dissan. A previous sorghum press design was made for this community by the Engineers without Borders (EWB) Mali team three years ago. After the first prototype was installed and used for a season, it became apparent that this first press required improvement. The current sorghum press is hand cranked and can only pass along one sorghum stalk at a time, making the syrup output slow. Our new design aims to improve the sorghum throughput efficiency of the press.

Project Scope	The end goal of our project is to have a working sorghum press that can be shipped to Mali and used immediately in summer 2012. This press will increase sorghum stalk throughput and therefore production of sweet syrup. We aim to design the press so that it can be fully manufactured in Mali at a low cost. As this press will be an important source of income for the community, our objective is to make it easy and quick to maintain and store in the off-season so that it will last for many years. We will also provide the community with a full drawing and assembly package and illustrated user manual.

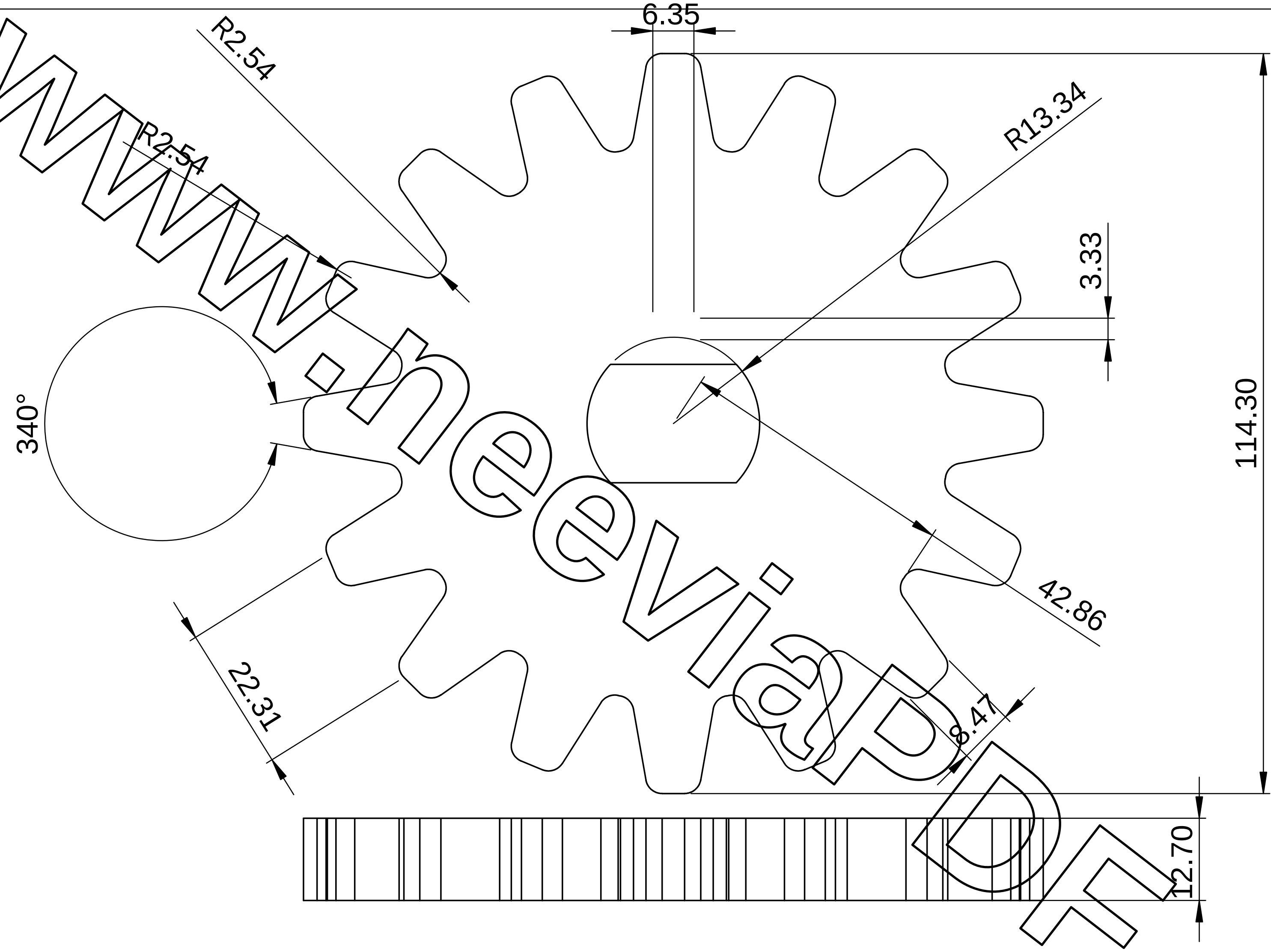
End Project Specifications	The overall goal of this project is to provide a working sorghum press and design that can be used and manufactured by the people of Mali, while meeting the specifications outlined for the ME189 course syllabus. Successful completion of this project can be measured my meeting the following specifications: ŏ A fully functional human-powered sorghum press that: ʓ is capable of pressing more than one stalk of sorghum at once ʓ is manufacturable in Mali ʓ is affordable for the intended market ʓ is safe for operators, bystanders, and the community ʓ can be quickly and easily maintained and cleaned ʓ is portable ŏ A full drawing package ŏ Illustrated assembly, maintenance, and use instructions Additional details can be found in the Product Design Specifcations document.
	We have ensured project completion by identifying and outlining the following sequential course milestones:

<u>Deliverable</u>	<u>Milestone</u>	<u>Completion Date</u>
Course Deliverables	Turn in Engineering Report Document and Complete Uploads to E-binder.	3/16/12
<u>END WINTER QTR.</u>		

Prototyping	Manufacture final design	4/1/12
Course Deliverables	Submit purchase/fabrication requirements.	4/13/12
Course Deliverables	Submit final project completion requirements.	4/27/12
Customer Deliverables	Complete assembly and user instructions.	5/15/12
Modeling	Complete final design engineering drawings and 3D-model.	5/15/12
Prototyping	Complete manufacturing of final design.	5/15/12
Analysis/Testing	Check product performance against outlined specifications.	5/30/12
Course Deliverables	Complete project poster.	6/1/12

Assumptions	• We assume that the materials we think will be available to machinists in Mali will be available. • We assume the machinists in Mali have basic machines and skills and are able to weld. • We assume the men and women operating the sorghum press will have at minimum ñaverageò strength. • We assume the design lab, testing lab, and machine shop will be available to us all year. • We assume we will have a contact in Mali who will answer our questions regarding the project • We assume sorghum can be grown in Mali. • We assume sorghum is not a health hazard when consumed. • We assume there is no alternative more important use of sorghum that will arise besides edible purposes. • We assume the government will not regulate sorghum. • We assume the people of Mali will not gain access to mechanized farming equipment or an alternative effective way to juice sorghum.

Risks	• The project will be jeopardized if the both the URCA and the EWB-UCSB Withdraw their funding. • The materials needed to build the device might not be available in Mali • The project will be jeopardized if no qualified machinists are available in Mali. • The project will be jeopardized if the people in Mali are for some reason not able to operate the press. • The project will be jeopardized if we are not able to make use of the design lab, testing lab, and machine shop. • The project will become much more difficult if our contact in Mali somehow becomes unreachable or unresponsive. • The project will be jeopardized if Mali becomes inhabitable for sorghum stalks due to climate change. • The project will be jeopardized if sorghum juice is deemed harmful to health. • The project will be jeopardized if a better alternative method of using sorghum was discovered. For example, sorghum used as bio fuel or a drug. • The project will be jeopardized if due to political reasons the government starts to regulate the sorghum plant heavily. • The project will be jeopardized if the people of Mali gain access to mechanized farming equipment such as an electric sorghum press.



NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN Millimeters
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

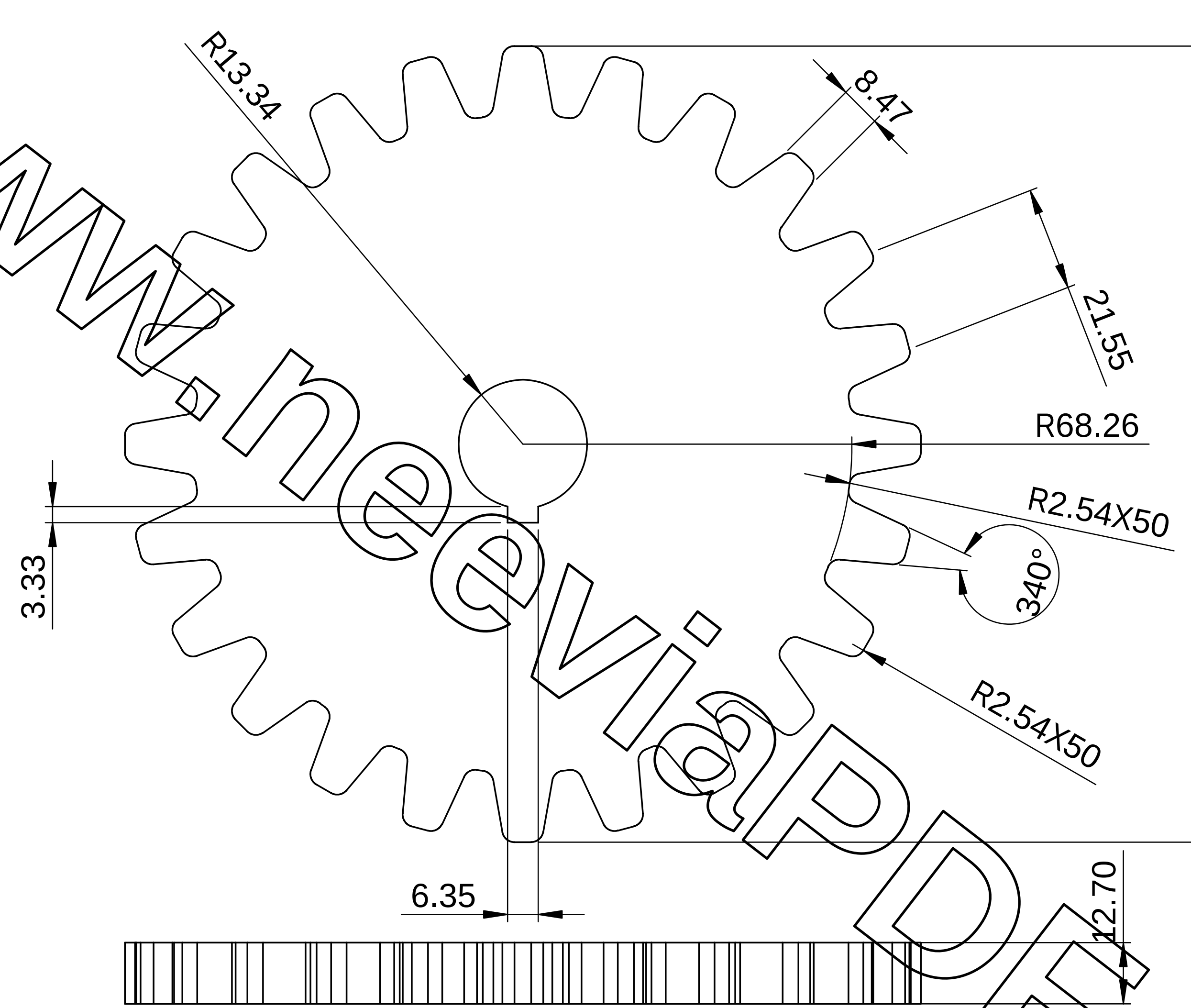
TITLE:

Sm Gear 4P

SIZE **A** | DWG. NO. SM Gear | REV

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
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		MATERIAL Steel	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

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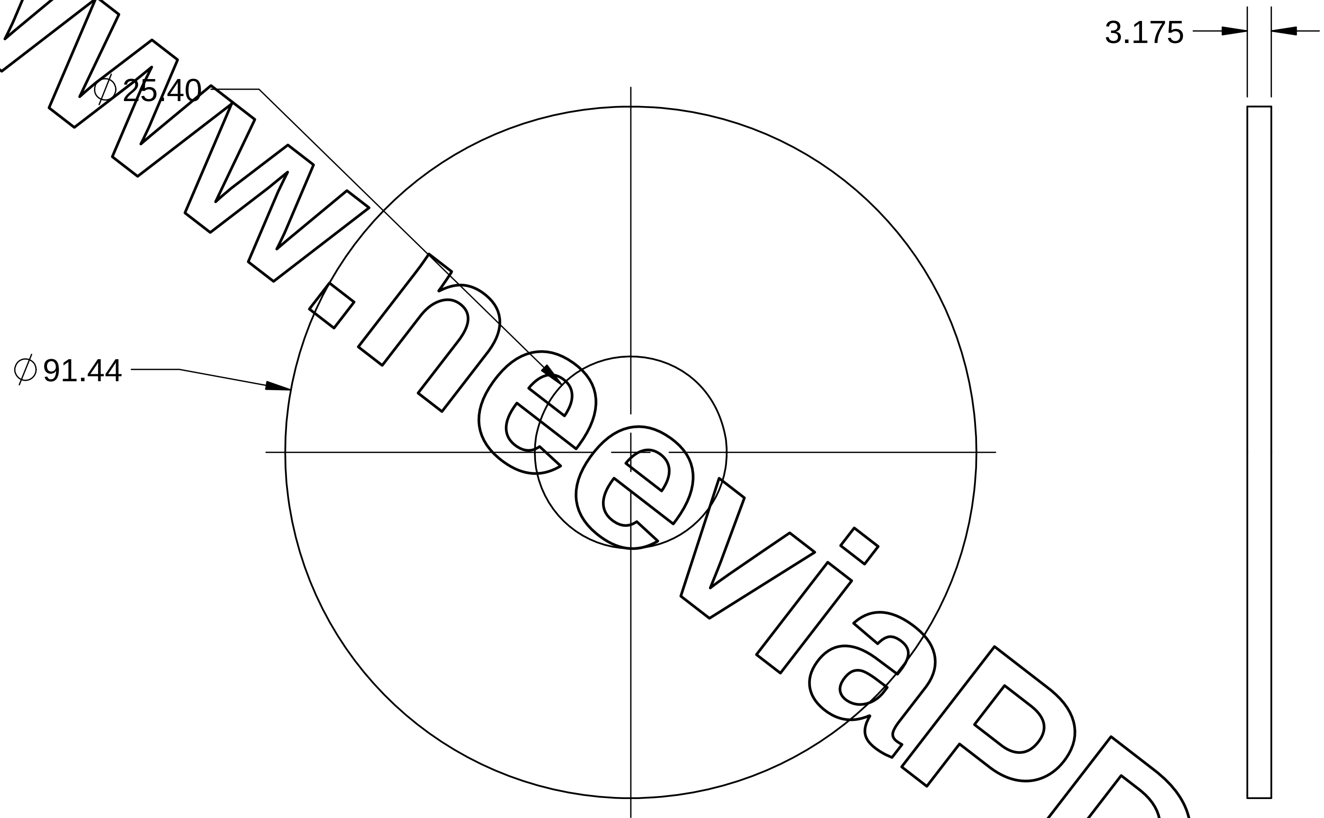

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	MFG APPR.			
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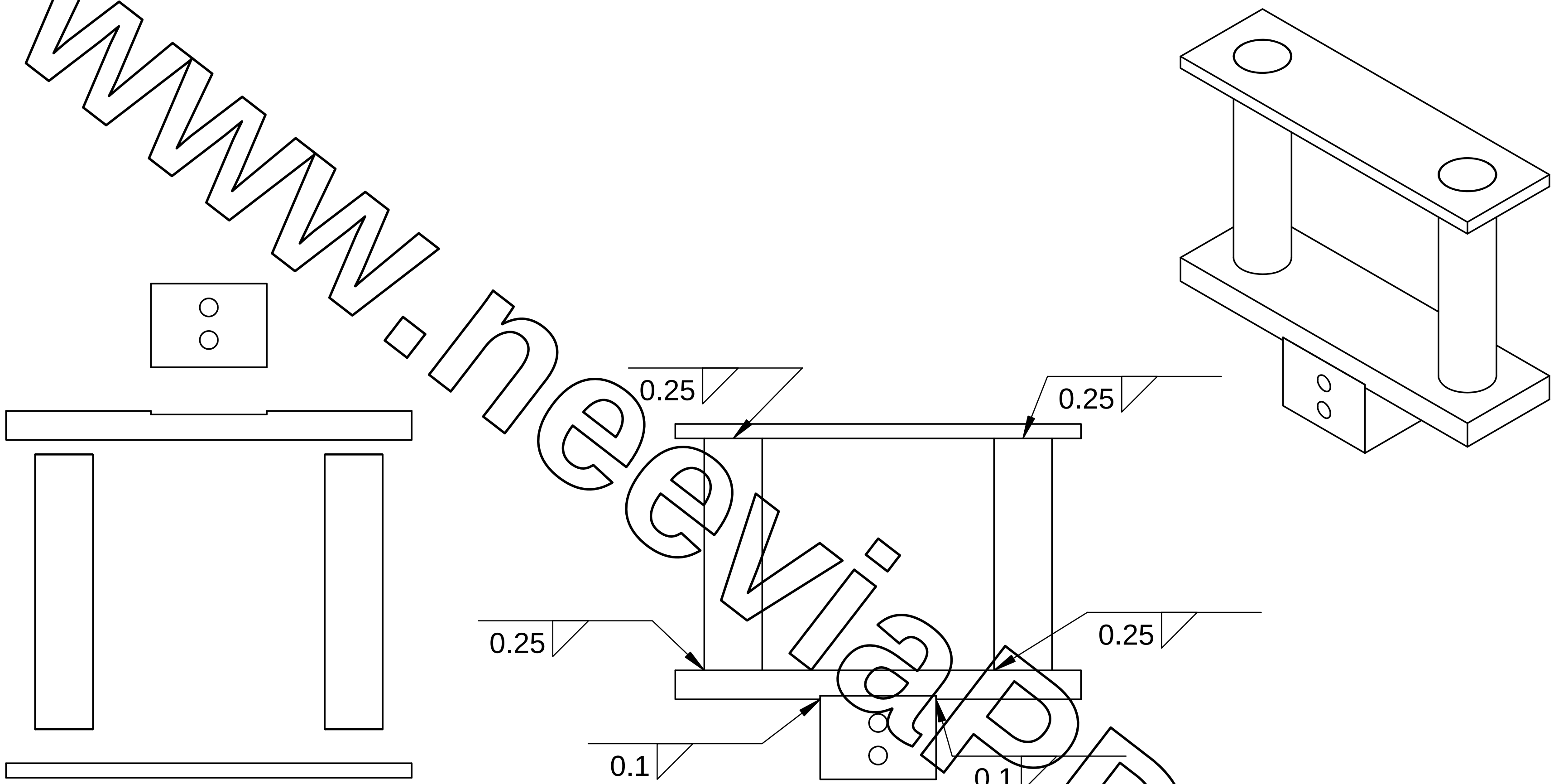

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	MFG APPR.			
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FINISH				
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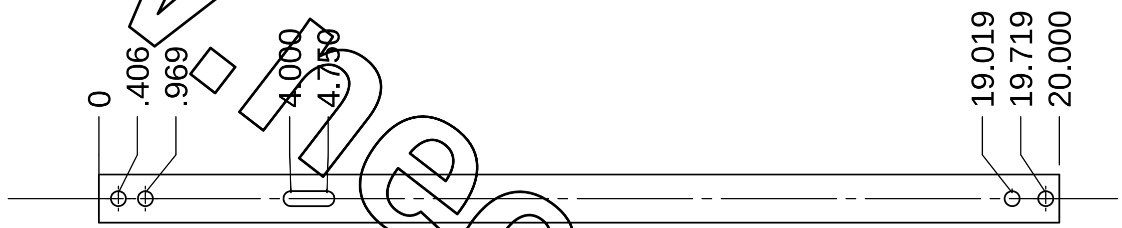

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		MATERIAL
NEXT ASSY	USED ON	FINISH
APPLICATION		DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
A	Drive_Shaft	

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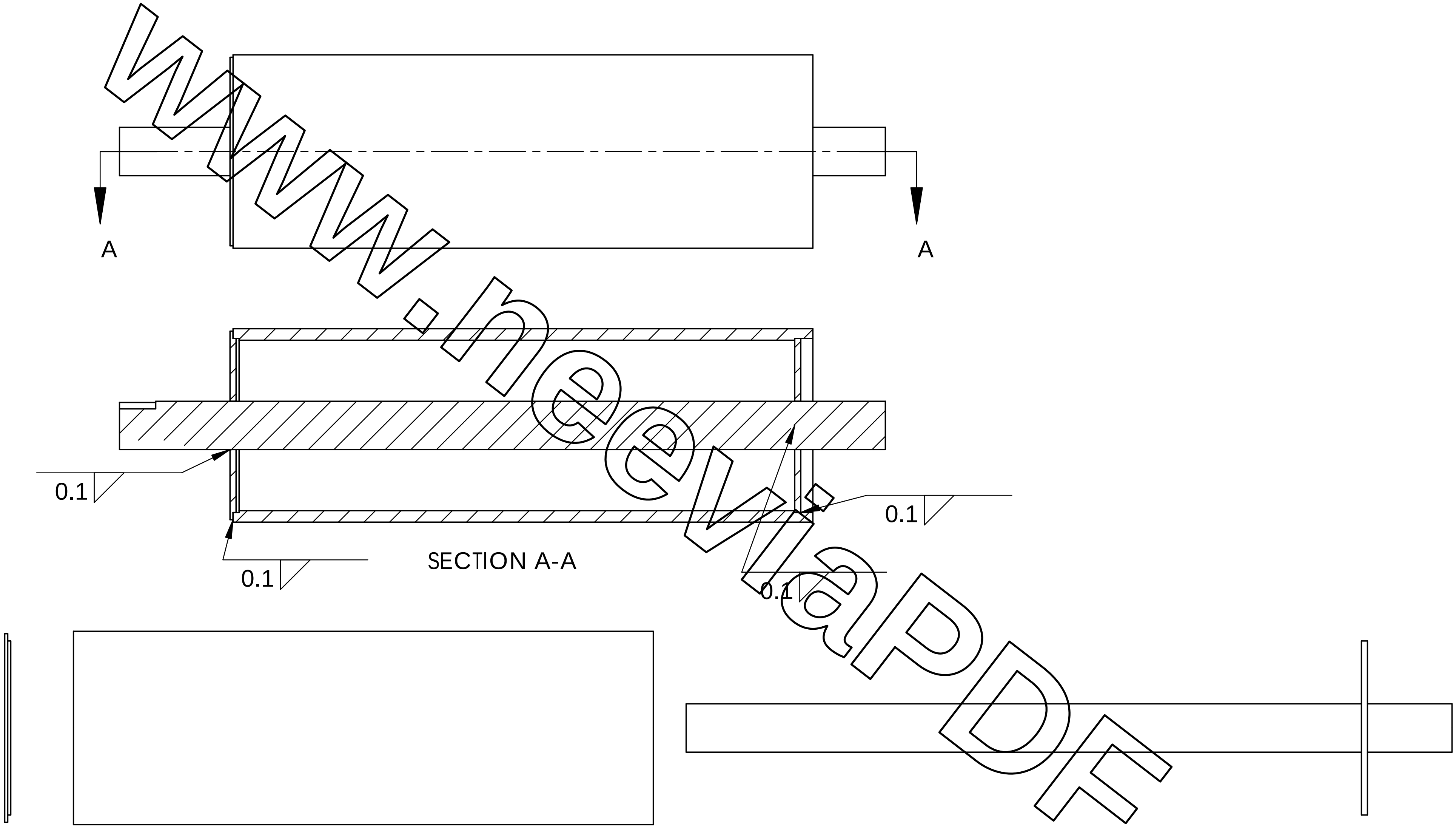

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	MFG APPR.			
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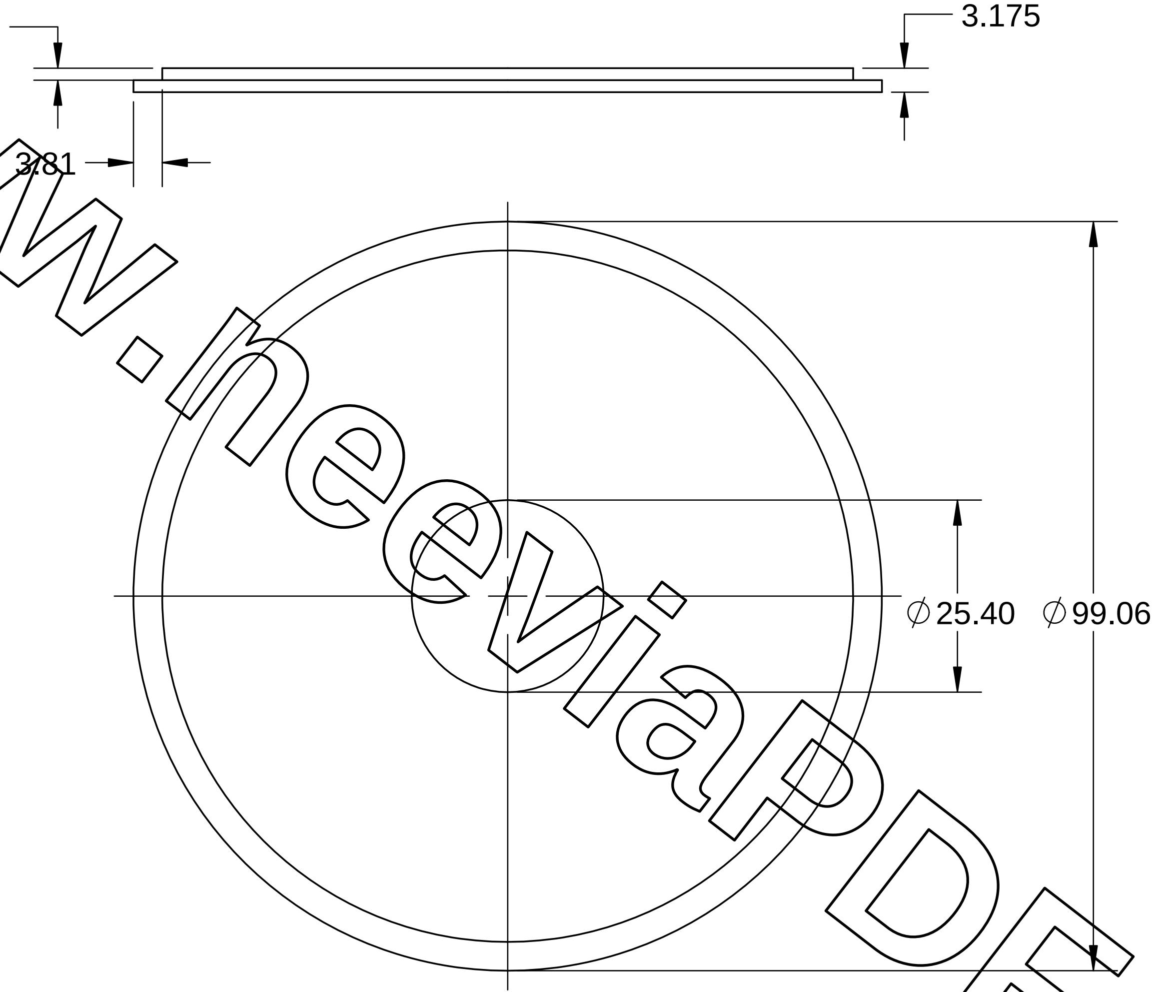
3 2 1



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	MFG APPR.			
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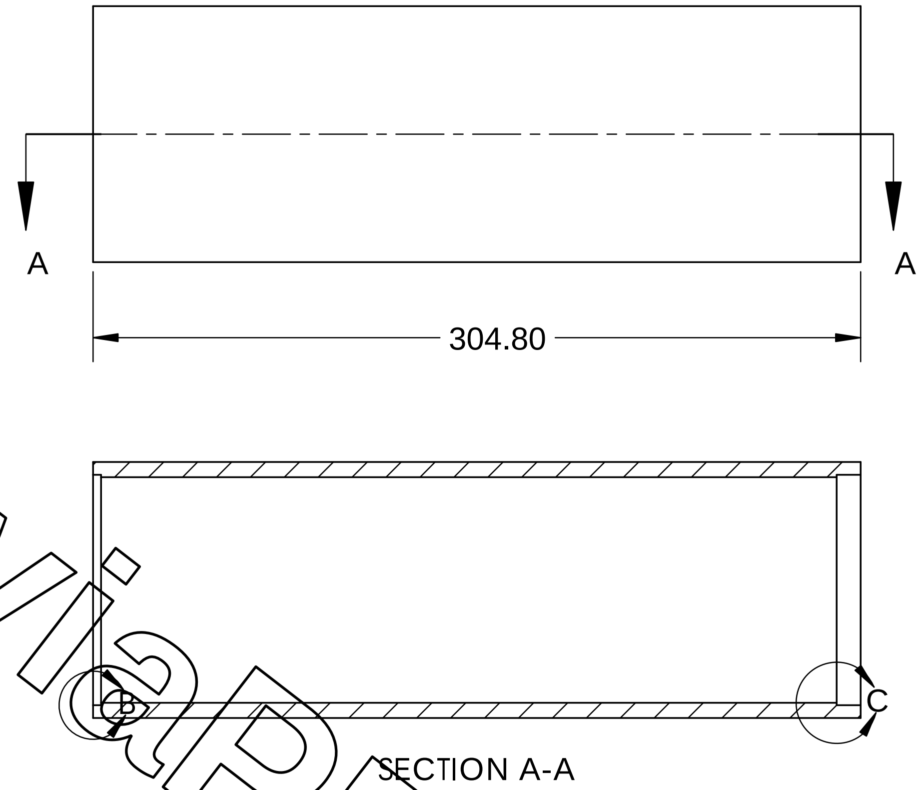

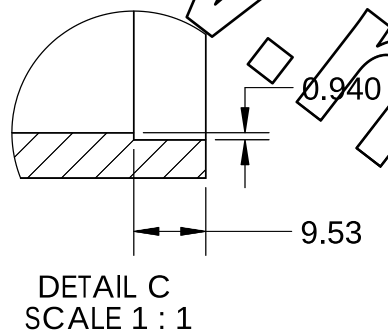

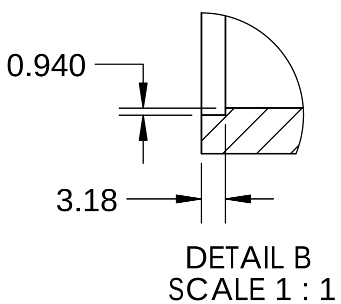

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
SCH 40 STEEL PIPE

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Cordeiro	3/12
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

EWB SORGHUM PRESS

TITLE:

ROLLER TUBE

SIZE A | DWG. NO. | REV A

SCALE: 1:3

3 2 1

Test Procedure – TP1
Efficiency of Human Power Methods

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [11/15/2011]

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1.0 Introduction

In order to produce the most efficient human powered sorghum press possible, the issue must first be addressed of what the most efficient use of human power is.

1.1 Purpose

The following experiment will allow for the testing of three forms of human power: hand powered, leg powered by use of biking motion, and full body powered by use of walking and pushing an object. These tests will in turn allow the tester to definitively show which form of human power is most efficient by showing the power an average person can output for an extended period of time.

1.2 Objectives

This test will allow the tester to find the most efficient way for a human to do work on a crank arm of some form. The test has been broken down into three possible modes for a human to exert work on a system. The first is turning a crank at a steady speed with both hands, the second is turning a pair of pedals attached to a crank shaft with both feet, and the last is performing a walking motion while pushing against an object to be moved.

1.3 Importance

The importance of finding the most efficient use of human power is due to the fact that it directly correlates to the efficiency of the human powered sorghum press. The press is designed to be usable by an average human for an extended period of time in order to squeeze juice out of sorghum stalks. In order to process the sorghum as quickly and efficiently as possible, the transfer of energy must be efficient not only from the machine to the sorghum stalks, but also from the human to the machine.

1.4 Background

Based on previous knowledge and engineering intuition, it is believed that the walking while pushing an object will have the greatest power efficiency, while the hand crank will have the least. This is due to the fact that the hand crank uses some of the weakest muscles in the body, while the walking and pushing allows for the utilization of nearly all the muscles in the body, including most of the strongest muscles found in the legs and torso.

2.0 Reference Documents

No Reference material was used in the formulation and execution of this test.

3.0 Test Configuration

Setup require only a stop watch with minimum resolution of seconds, and the two workout machines, one for hand cranking and biking (shown in figure 1 of appendix), and the other for walking (shown in figure 2 of appendix). Both machines should have displays set to output watts.

3.1 Test Approach

Start with the hand crank machine with the output display set to watts. Have test subject begin to turn hand crank at whatever they feel is a comfortable speed. Record the power output displayed in watts every fifteen seconds, continue for ten minutes before concluding. Repeat this same process with two male and two female test subjects in order to get an accurate "average" reading. After power outputs are recorded every fifteen seconds for ten minutes for all four test subjects, the same processes must be repeated on both the biking machine and the elliptical machine.

3.2 Equipment Needed

Stop watch
Reck MOTOmed hand crank and biking trainer
Precor EFX546i elliptical machine.

3.3 Test Reporting Requirements

Test results are to be tabulated and presented in graphical form. Each test subject can have his or her results graphed over the ten minute interval, and each of these plots can be averaged together to get a theoretical "average person" output. Test anomalies will have insignificant effects on the overall data due to the amount of data collected and averaged. In order to get an average output for an "average person" forty points will be collected from each of the four subjects and averaged together, making any anomalous individual points trivial.

4.0 Test Procedures

The following is a list of procedures to be preformed as well as the expected results for each procedure.

4.1 Human Power Output

Table 1. Human Power Output Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Turn on hand crank machine and set display to output in watts. Have test subject one sit or stand in comfortable position and begin turning crank at comfortable speed,	Machine will display a higher wattage for faster hand cranking	The machine did produce expected trends of wattage output.
2	Record test subject's power output every fifteen seconds for ten minutes	Power output will be somewhat low, results will be fairly steady with some possible drop off at the end due to getting tired.	The power output averaged around thirty watts and was pretty stable.
3	Repeat steps one and two for all test subjects. Tabulate information in table for easy use.	Males should test slightly higher then females with all results being pretty steady.	Males did test slightly higher then females and results were steady.
4	Turn on bike machine and set output display to watts. Have test subject one sit comfortably and begin peddling at a comfortable speed.	Machine will display a higher wattage for faster pedaling speeds.	The machine did produce expected trends of wattage output.
5	Record test subject's power output every fifteen seconds for ten minutes	Power output will be higher then the output from hand cranking. Output will be steady with some possible drop off at the end due to getting tired.	Power output was higher then hand cranking and output was mostly steady with a slight rising trend over time.
6	Repeat steps four and five for all test subjects. Tabulate information in table for easy use.	Males should test slightly higher then females with all results being pretty steady.	Males did test slightly higher then females and results were steady with a slight increasing trend over time.
7	Turn on elliptical machine and set output display to watts. Have test subject one begin walking at a	Machine will display a higher wattage for faster walking speeds.	The machine did produce expected trends of wattage output.

	comfortable speed while pushing against hand rests to simulate pushing object.		
8	Record test subject's power output every fifteen seconds for ten minutes	Power output will be higher then the output from hand cranking or biking. Output will be steady with some possible drop off at the end due to getting tired.	Power output was higher then hand cranking and biking. Output was mostly steady with a slight rising trend over time.
9	Repeat steps seven and eight for all test subjects. Tabulate information in table for easy use.	Males should test slightly higher then females with all results being pretty steady.	Males did test slightly higher then females and results were steady with a slight increasing trend over time.

5.0 Appendix

Figure 1: Reck MOTOmed Handcrank and Biking Trainer


Figure 2: Precor EFX546i Elliptical Machine

TEAM No. [20] – HUMAN POWERED SORGHUM PRESS

Test Report – TR1
Efficiency of Human Power Methods

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [11/18/2011]

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1.0 Introduction

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The following experiment will allow for the testing of three forms of human power: hand powered, leg powered by use of biking motion, and full body powered by use of walking and pushing an object. These tests will in turn allow the tester to definitively show which form of human power is most efficient by showing the power an average person can output for an extended period of time.

1.2 Objectives

This test will allow the tester to find the most efficient way for a human to do work on a crank arm of some form. The test has been broken down into three possible modes for a human to exert work on a system. The first is turning a crank at a steady speed with both hands, the second is turning a pair of pedals attached to a crank shaft with both feet, and the last is performing a walking motion while pushing against an object to be moved.

1.3 Importance

The importance of finding the most efficient use of human power is due to the fact that it directly correlates to the efficiency of the human powered sorghum press. The press is designed to be usable by an average human for an extended period of time in order to squeeze juice out of sorghum stalks. In order to process the sorghum as quickly and efficiently as possible, the transfer of energy must be efficient not only from the machine to the sorghum stalks, but also from the human to the machine.

1.4 Background

Based on previous knowledge and engineering intuition, it is believed that the walking while pushing an object will have the greatest power efficiency, while the hand crank will have the least. This is due to the fact that the hand crank uses some of the weakest muscles in the body, while the walking and pushing allows for the utilization of nearly all the muscles in the body, including most of the strongest muscles found in the legs and torso.

2.0 Reference Documents

See test procedure document.

3.0 Test Procedures

Each of the four test subjects is to perform at whatever he or she feels is a comfortable rate on each of the three workout machines: a hand cranking machine, a biking machine, and an elliptical machine. The power output in watts is recorded off of the display every fifteen seconds for ten minutes. All data for each test is averaged to get an "average person's" power output over a ten minute period. See test procedures document for more in depth instructions on performing test.

4.0 Recorded Data

The first test that was run was with the hand crank machine. Each test subject performed the hand crank test for ten minutes with power output being recorded every fifteen seconds. The results of each test subject were tabulated and graphed as seen in figure 1.

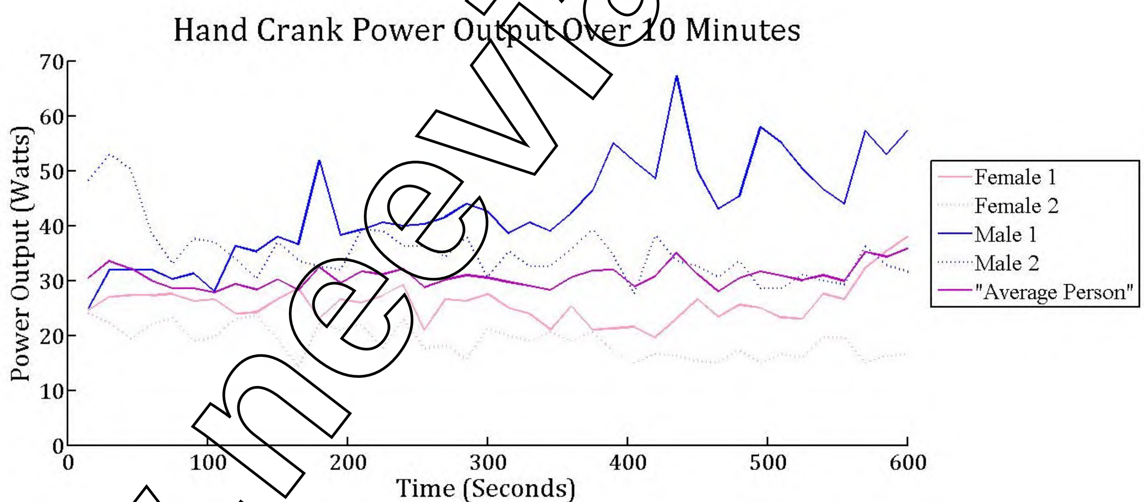

Figure 1: Power Output Over Ten Minutes On Hand Crank Machine

Here each of the blue lines correspond to the male test subjects, and pink correspond to the female test subjects. The thick purple line is the power output of each test subject at that time averaged together. This is representative of what an "average person" could output over a ten minute period. The average output of an "average person" for a hand crank motion was found to be 30.7 ± 5 watts.

The second test that was run was with the biking machine. Each test subject performed the biking test for ten minutes with power output being recorded every fifteen seconds. The results of each test subject were tabulated and graphed as seen in figure 2.

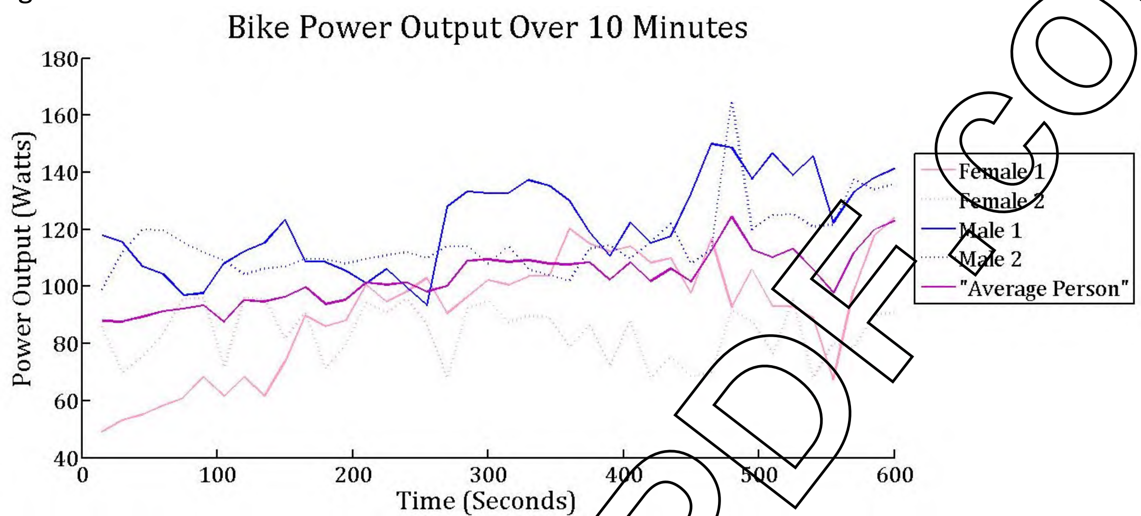

Figure 2: Power Output Over Ten Minutes On Biking Machine

Here each of the blue lines correspond to the male test subjects, and pink correspond to the female test subjects. The thick purple line is the power output of each test subject at that time averaged together. This is representative of what an “average person” could output over a ten minute period. The average output of an “average person” for a biking motion was found to be 103.0 ± 15 watts.

The third test that was run was with the elliptical machine to simulate walking while pushing an object. Each test subject performed the walking test for ten minutes with power output being recorded every fifteen seconds. The results of each test subject were tabulated and graphed as seen in figure 3.

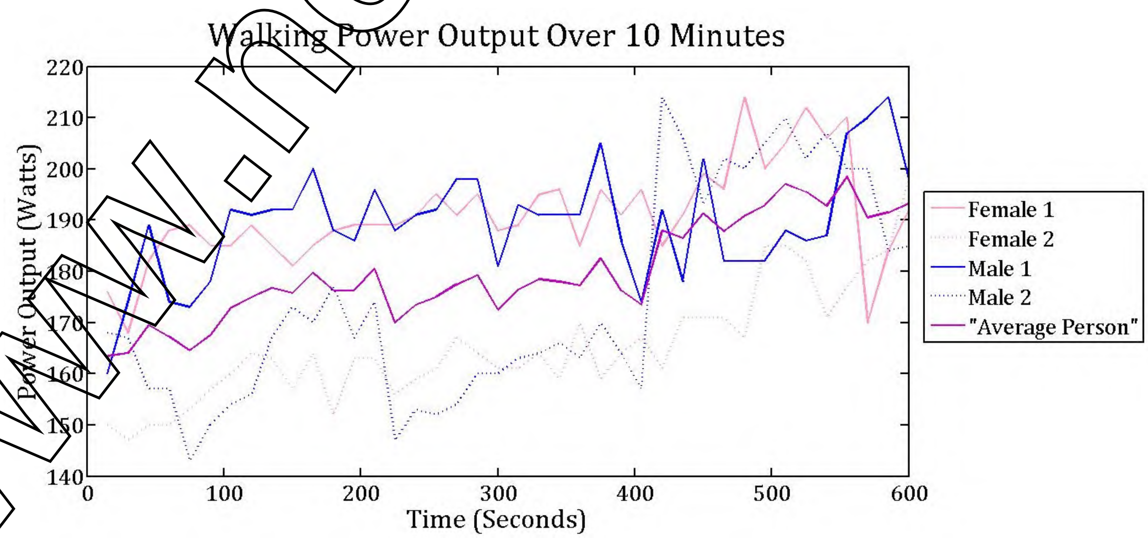

Figure 3: Power Output Over Ten Minutes On Elliptical Machine

Here each of the blue lines correspond to the male test subjects, and pink correspond to the female test subjects. The thick purple line is the power output of each test subject at that time averaged together. This is representative of what an "average person" could output over a ten minute period. The average output of an "average person" for a biking motion was found to be 179.9 ± 10 watts.

For more complete list of test data, see appendix 1

5.0 Test Results

Test results showed that hand cranking was by far the least efficient use of human power with test subjects only being able to output 30.7 ± 5 watts of power on average over ten minutes. Walking was found to be by far the most efficient use of human power with test subjects being able to output 179.9 ± 10 watts of power on average over ten minutes. These results can easily be seen graphically in figure 4.

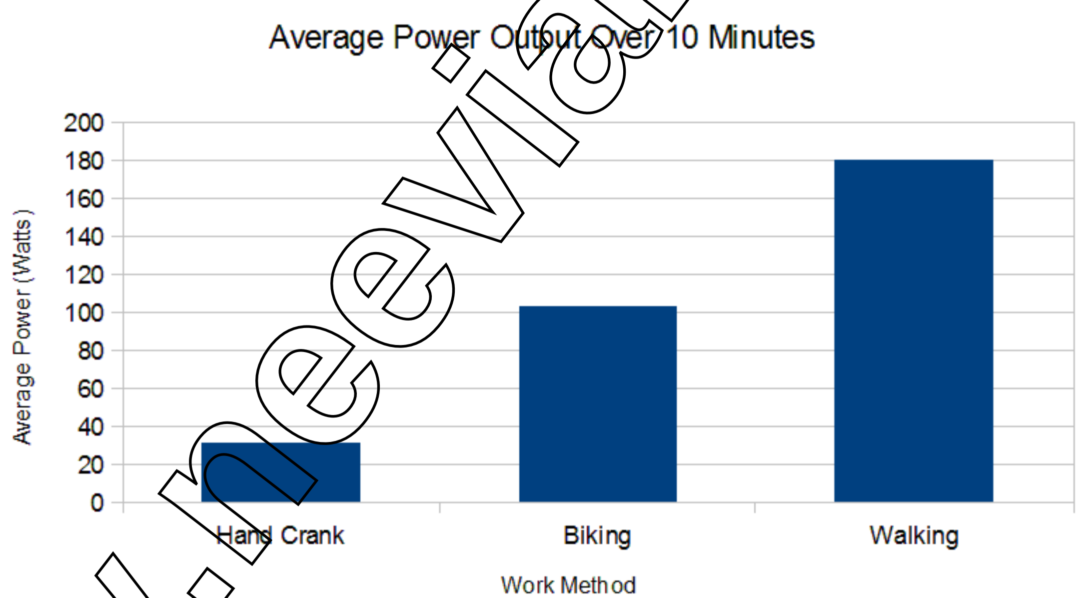

Figure 4: Average Power Outputs of Each Method Over Ten Minutes.

These results are exactly what was expected due to the various muscles being used in each work method. Walking uses the most and strongest muscles, while hand cranking uses the least and weakest muscles, making them theoretically the most and least efficient methods respectively.

6.0 Summary of Test Results

Tests were successful both at following expected trends and at proving the stated hypothesis. Each work method produced fairly steady results throughout the ten minutes, showing that the power output was a reasonable and sustainable value. One slight deviation from the expected trend was that all tests showed spikes in power output of varying degrees in the last minute or so of the test. This is probably due to the fact that the test subjects were aware of how much time was remaining and thus put in more effort at the end. For slightly more accurate results, the subjects should not have been informed of remaining time. These deviations do not have a significant effect on the results however and thus are acceptable.

Results also ranked in the expected order. Hand cranking only uses muscles in your arms to induce work on the system. Not only are these muscles relatively weak, but there are also a limited number of muscles putting work into the system. Hand cranking was expected to be the worst of the methods, and was found to be approximately one third as effective as biking, and one sixth as effective as walking.

Biking has an advantage over hand cranking in that it uses stronger muscles to apply work to the system, however the number of muscles is still limited. Biking ranked second of the three work methods as expected having an average power output of almost three times the power output of hand cranking, and a little more then half of the power output of walking.

Walking while pushing an object was expected to be the best of the methods due to its use of muscles in the arms, legs, and torso. Walking ranked top of all methods by a fair margin as expected, having six times the power output of hand cranking, and almost double the power output of biking.

7.0 Anomalies

Any anomalies in specific data points will be worked out due to the sheer amount of data averaged. Therefor, while there was some significant spikes in the middle of some data samples, these can be ignored due to their insignificant effect on the overall overage.

All tests did show a recognizable increase in power in the last portion of the test. This is probably due to test subjects knowing the remaining time of the test and putting in more effort. This problem could be fixed by not allowing test subjects to know the amount of time remaining in the test. Again however, these trends were not of a significant enough magnitude to have a large impact on the overall results due to the fact that they happened over such a short amount of time. These trends thus can be ignored.

8.0 Conclusion and Recommendations

The purpose of the test was to find the most efficient use of human energy. This goal was indisputably accomplished, as walking while pushing an object was found to have almost double the average power output of the next most efficient method. Due to these findings, The human powered sorghum press should utilize a walking method for people to put work into the system.

9.0 Appendices

9.1 Hand Crank Data

Time (s)	Female 1	Female 2	Male 1	Male 2	"Average Person"
15	24.6	24	25	48.3	30.5
30	27	22.3	32	53	33.6
45	27.3	19.3	32	50.3	32.2
60	27.3	22	32	38.6	30.0
75	27.6	23.3	30.3	33	28.6
90	26.3	19	31.3	37.6	28.6
105	26.6	19.6	28	37	27.8
120	24	23	36.3	34	29.3
135	24.2	23.6	35.3	30.3	28.4
150	26.6	19.3	38	37	30.2
165	28.6	14.3	36.6	33.6	28.3
180	23	22.3	52	32.6	32.5
195	26.6	21	38.3	32	29.5
210	26	22	39.3	39.3	31.7
225	27.3	17.6	40.6	39	31.1
240	29.3	23	40	36.3	32.2
255	21	17.6	40.3	36.3	28.8
270	26.6	18.3	41.6	34.3	30.2
285	26.3	15.6	44	38	31.0
300	27.6	21.3	42.6	30.6	30.5
315	25	20	38.6	35.3	29.7
330	24	19	40.6	32.6	29.1
345	21	20.6	39	32.6	28.3
360	25.3	19	42.3	35.6	30.6
375	21	20.6	46.3	39.3	31.8
390	21.3	17	55	34.6	32.0
405	21.6	15	51.6	27.6	29.0
420	19.6	16.6	48.6	38.3	30.8
435	23	16.3	67.3	33.6	35.1
450	26.6	15.3	50	32.6	31.1
465	23.3	15	43	30.6	28.0
480	25.6	17.3	45.3	33.6	30.5
495	25	15	58	28.6	31.7
510	23.3	16.6	55	28.6	30.9
525	23	16	50.3	31	30.1
540	27.6	19.6	46.6	30	31.0
555	26.6	19.6	44	29.3	29.9
570	32.3	15	57.3	36.2	35.2
585	35.3	16.3	53	32.8	34.4
600	38	16.6	57.3	31.6	35.9

Table 1: Hand Crank Power Output Data Over Ten Minutes

9.2 Biking Data

Time (s)	Female 1	Female 2	Male 1	Male 2	"Average Person"
15	49	85.9	118	99	88.0
30	53.3	69.9	115.6	112	87.7
45	55.2	75.3	107	120	89.4
60	58.3	83.4	104.3	119.6	91.4
75	61	95.7	97	115.3	92.2
90	68.3	95.9	97.6	112	93.5
105	61.6	71.7	108	109	87.6
120	68.3	96.1	112.3	104.2	95.2
135	61.6	95.7	115.3	106.3	94.7
150	73.6	81.5	123.3	107	96.4
165	90	91.0	108.6	109.6	99.8
180	86	71.2	108.6	109.6	93.9
195	88	79.6	105.6	108	95.3
210	100.6	94.4	101	109.6	101.4
225	94.6	90.7	106	111	100.6
240	98.3	95.8	99.6	112	101.4
255	103	86.6	93.3	110	98.2
270	90.6	68.0	128	114	100.2
285	96.3	92.4	133.3	114	109.0
300	102.3	95.0	132.6	108	109.5
315	100.6	87.3	132.6	114	108.6
330	103.6	89.7	137.3	106	109.1
345	103.6	89.3	135.3	104	108.0
360	120.3	78.7	130	102	107.8
375	115	86.6	119	113.3	108.5
390	112.3	72.1	110.6	114.3	102.3
405	114	88.1	122.3	109.6	108.5
420	108.3	67.9	115.3	115.6	101.8
435	110	75.3	117.6	122	106.2
450	97.6	68.4	132.6	108	101.6
465	116.6	69.9	150	113	112.4
480	92.6	91.7	148.6	165	124.5
495	106	87.8	137.6	120	112.9
510	93	76.5	146.6	125	110.3
525	93	95.5	139	125.3	113.2
540	89	68.0	145.6	121	105.9
555	67.3	80.1	122.3	121.6	97.8
570	98.6	78.4	133	137.6	111.9
585	117.6	89.9	138	134	119.9
600	124	90.8	141.3	136	123.0

Table 2: Biking Power Output Data Over Ten Minutes

9.3 Walking Data

Time (s)	Female 1	Female 2	Male 1	Male 2	“Average Person”
15	176	150	160	168	163.5
30	168	147	174	167	164.0
45	182	150	189	157	169.5
60	188	150	174	157	167.3
75	189	153	173	143	164.5
90	185	157	178	150	167.5
105	185	160	192	154	172.8
120	189	164	191	156	175.0
135	185	163	192	167	176.8
150	181	157	192	173	175.8
165	185	164	200	170	179.8
180	188	152	188	177	176.3
195	189	163	186	167	176.3
210	189	163	196	174	180.5
225	189	156	188	147	170.0
240	191	159	191	153	173.5
255	195	161	192	152	175.0
270	191	167	198	154	177.5
285	195	164	198	160	179.3
300	188	161	181	160	172.5
315	189	161	193	163	176.5
330	195	164	191	164	178.5
345	196	159	191	166	178.0
360	185	170	191	163	177.3
375	196	159	205	170	182.5
390	191	164	186	164	176.3
405	196	167	174	157	173.5
420	185	161	192	214	188.0
435	191	171	178	206	186.5
450	199	171	202	193	191.3
465	196	171	182	202	187.8
480	214	167	182	200	190.8
495	200	185	182	205	193.0
510	205	185	188	210	197.0
525	212	182	186	202	195.5
540	206	171	187	207	192.8
555	210	177	207	200	198.5
570	170	182	210	200	190.5
585	184	184	214	184	191.5
600	192	198	198	185	193.3

Table 3: Walking Power Output Data Over Ten Minutes

Test Procedure – TP2
Force to Crush Sugar Cane

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [01/27/2012]

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1.0 Introduction

In order to design a machine that will squeeze the juice out of sorghum stalks, we must first find the pressure required to compress the stalks down to a thickness of about 0.2 inches. This thickness was chosen based on research of the previous team's test results in "SORGHUM JUICE EXTRACTION EXPERIMENT." According to the results of this test, 0.2 inches was found to be the thickness at which 90% of the juice was extracted. Unfortunately sorghum was unobtainable, and sugar cane was therefor used as a substitute

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

There are two main objectives of this test. Both of these objectives require the measurement of pressure required to crush sugar cane stalks down to a thickness of 0.2 inches. The first objective of this test is to show that sugar cane is as difficult, or more difficult to crush then sorghum. This will be done by relating our results to the results of a similar test done by the previous team. The second objective of this test is to get a better understanding of the forces that will be exerted on our press by a single stalk of sorghum or sugar cane, in order to better design the press to resist various forms of failure.

1.3 Importance

This test is important in order to prevent failure in our sorghum press design. This test allows us to find the maximum and average force that will be exerted on our press if sugar cane was fed through. In addition it will prove that sugar cane will produce a greater force on the structure than sorghum would, and therefor all calculations done with sugar cane in mind should also be acceptable for sorghum.

1.4 Background

Based on our experience with and research on sorghum and sugar cane, it is predicted that the pressure to crush a sugar cane stalk should exceed the pressure to crush a sorghum stalk. In addition, this pressure is expected to be on the order of magnitude of hundreds of pounds per square inch.

2.0 Reference Documents

"SORGHUM JUICE EXTRACTION EXPERIMENT," EWB Capstone Team, 2008
"SORGHUM FORCE EXPERIMENT," EWB Capstone Team, 2008

3.0 Test Configuration

Setup requires test samples of sugar cane measuring 2 inches in length with a diameter in the range of 0.5in to 1in. Pictures of such a sample can be seen in figure 1. In addition, a compression testing machine is required that can produce at least 2000lb of force. An example of such a machine can be seen in figure 2.

3.1 Test Approach

Sugar cane of diameter 0.5in to 1in. must be obtained and cut into six 2in. long samples. Three of these samples must contain knots along their length, while the other three must be absent of knots. These samples are to be measured and then placed in plastic bags in order to protect the compression test machine from the juices. The machine is then used to crush the sugar cane down to a thickness of 0.2in as seen in figure 3. The force required to get this displacement is measured as well as the dimensions of the now crushed sample. This force divided by the contact area will result in a desired pressure value.

3.2 Equipment Needed

Sugar cane 0.5-1in in diameter
Compression testing machine
Measuring device with a minimum resolution of 0.125in.

3.3 Test Reporting Requirements

Analysis of test results are unique due to their relation to a previous test. As such data must be analyzed in two ways. Specifically, contact area must be estimated as the length times the diameter in order to compare with the results of the other test. In addition to this analysis, surface area will also be computed by measuring the final area of the squished sugar cane in order to get more accurate results. A sample of squished sugar cane can be seen in figures 4 and 5. This resulting pressure can then be multiplied by an estimated area contact area between the sorghum press and stalks in order to find the force the stalks will exert on the press. By performing the test on three samples, we are able to check to make sure results are steady and therefor more likely accurate.

4.0 Test Procedures

This section lists the step-by-step procedures to be followed for the test.

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Place sample one in plastic bag and place in testing machine. Proceed to crush until a thickness of 0.2in is achieved. Record force measured by test machine	Force will steadily rise until thickness is met and sample is relived of pressure.	Force did increase as expected.
2	Measure area of crushed sampled with tape measure and record	Larger diameter stalks will have a greater final surface area and increased force resulting in a nearly constant pressure between samples	Force to crush stalks did vary with predicted trends.
3	Repeat process for all three samples with and without knots. Record forces required and surface area of resulting sample.	Stalks with knots will require a larger force and pressure	Stalks with knots stalks did follow expected trends.

5.0 Appendix

Figure 1: 2 inch long, 0.75 inch diameter sugar cane sample

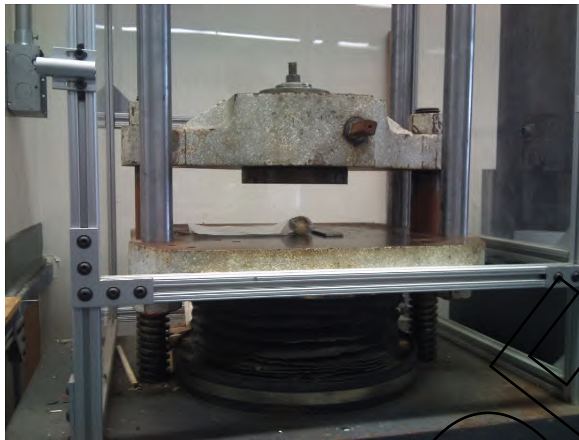
Figure 2: Compression testing machine with sugar cane sample loaded


Figure 3: Sugar cane sample crushed to 0.2in

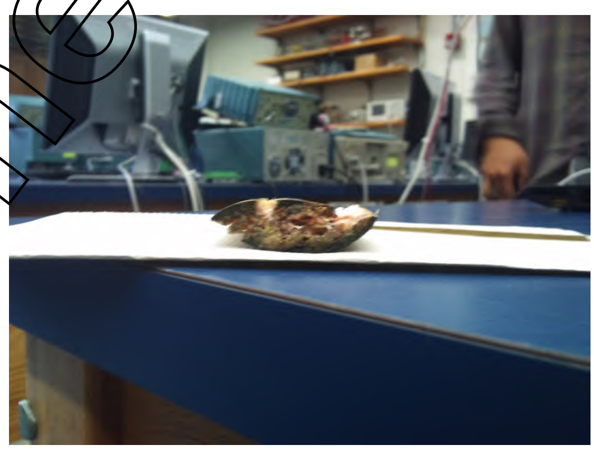
Figure 4: Squished sugar cane sample side view

Figure 5: Squished sugar cane sample top view (contact surface area of test)

TEAM No. 20 – Human Powered Sorghum Press

Test Report – TR2
Force to Crush Sugar Cane

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [01/27/2012]

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1.0 Introduction

In order to design a machine that will squeeze the juice out of sorghum stalks, we must first find the pressure required to compress the stalks down to a thickness of about 0.2 inches. This thickness was chosen based on research of the previous team's test results in "SORGHUM JUICE EXTRACTION EXPERIMENT." According to the results of this test, 0.2 inches was found to be the thickness at which 90% of the juice was extracted. Unfortunately sorghum was unobtainable, and sugar cane was therefor used as a substitute

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The purpose of this document is to provide a detailed description of the lab setup and procedures performed as well as the results obtained in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

There are two main objectives of this test. Both of these objectives require the measurement of pressure required to crush sugar cane stalks down to a thickness of 0.2 inches. The first objective of this test is to show that sugar cane is as difficult, or more difficult to crush then sorghum. This will be done by relating our results to the results of a similar test done by the previous team. The second objective of this test is to get a better understanding of the forces that will be exerted on our press by a single stalk of sorghum or sugar cane, in order to better design the press to resist various forms of failure.

1.3 Importance

This test is important in order to prevent failure in our sorghum press design. This test allows us to find the maximum and average force that will be exerted on our press if sugar cane was fed through. In addition it will prove that sugar cane will produce a greater force on the structure than sorghum would, and therefor all calculations done with sugar cane in mind should also be acceptable for sorghum.

1.4 Background

Based on our experience with and research on sorghum and sugar cane, it is predicted that the pressure to crush a sugar cane stalk should exceed the pressure to crush a sorghum stalk. In addition, this pressure is expected to be on the order of magnitude of hundreds of pounds per square inch.

2.0 Reference Documents

"SORGHUM JUICE EXTRACTION EXPERIMENT," EWB Capstone Team, 2008
"SORGHUM FORCE EXPERIMENT," EWB Capstone Team, 2008

3.0 Test Procedures

Obtain six samples of sugar cane, three with knots and three without. Each of these samples should be two inches long with a diameter falling in the range of half an inch to an inch. These samples should be measured and their lengths and diameters should be recorded. The samples should then be placed in separate plastic bags and placed into the compression test machine one at a time. They should then be loaded until they reach a thickness of 0.2 inches, and the resulting load should be recorded. The sample should then be removed from the machine, and the now flattened sample should have its contact area measured with a tape measure. With this force and contact area, the pressure required to crush the stalk can be calculated.

4.0 Recorded Data

With this procedure repeated for each of the six samples, the following lengths, diameters, forces, and contact areas were measured. These values can be seen in table 1.

No Knot	length (in)	Diameter (in)	Force (lb)	final surface area sq in
1	2	0.75	1350	3.5
2	2	0.875	1600	3.75
3	2	0.5	1200	2.8
Knot				
1	2	0.675	2000	3
2	2	0.75	2350	3.5
3	2	0.75	2400	3.5

Table 1: Measured Values From Tests

All lengths are accurate to within 0.125 inches and all forces are accurate to within 50 lb.

When these results are analyzed to be consistent with the analysis method used in the " SORGHUM FORCE EXPERIMENT," The following results can be seen.

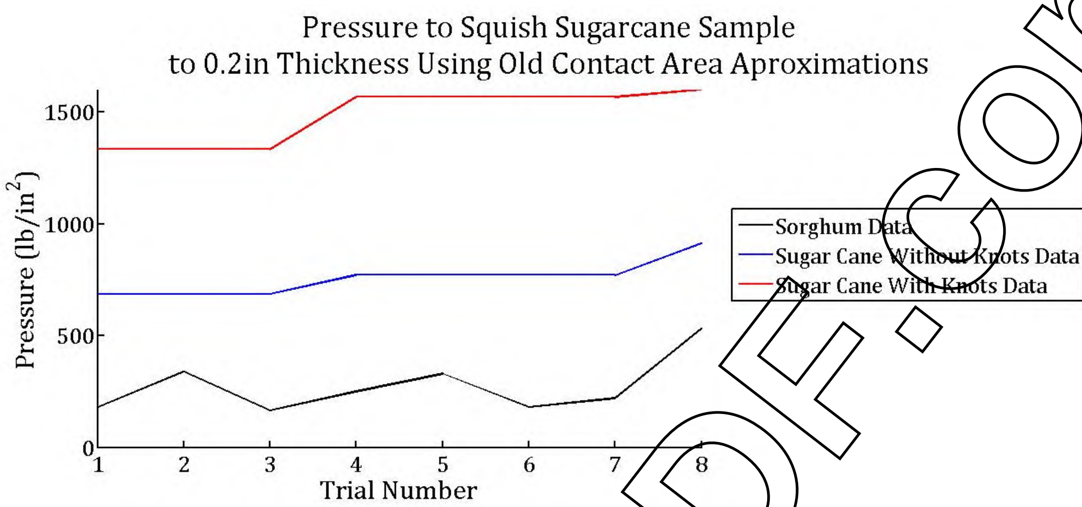

Figure 1: Pressure Required Using Old Area Approximations

Here the black line corresponds to the data from the sorghum test performed by the previous EWB team, while the red and blue lines are the data from sugar cane samples with and without knots. The pressure results here were obtained by taking the force recorded and dividing it by the product of the length and diameter of the stalk. While this area approximation is determined to be ineffective, it must be used in order to compare with values from the " SORGHUM FORCE EXPERIMENT." Here it can be seen that every trial with sugar cane required a higher pressure to crush then the sorghum trials, proving that sugar cane is harder to crush.

In addition to this analysis method, the pressure was also calculated with a better approximation of contact area by measuring the final area of the stalk after it was crushed. Using this approximation, a better estimate of pressure to crush the sugar cane stalks was acquired, and the results can be seen in figure 2.

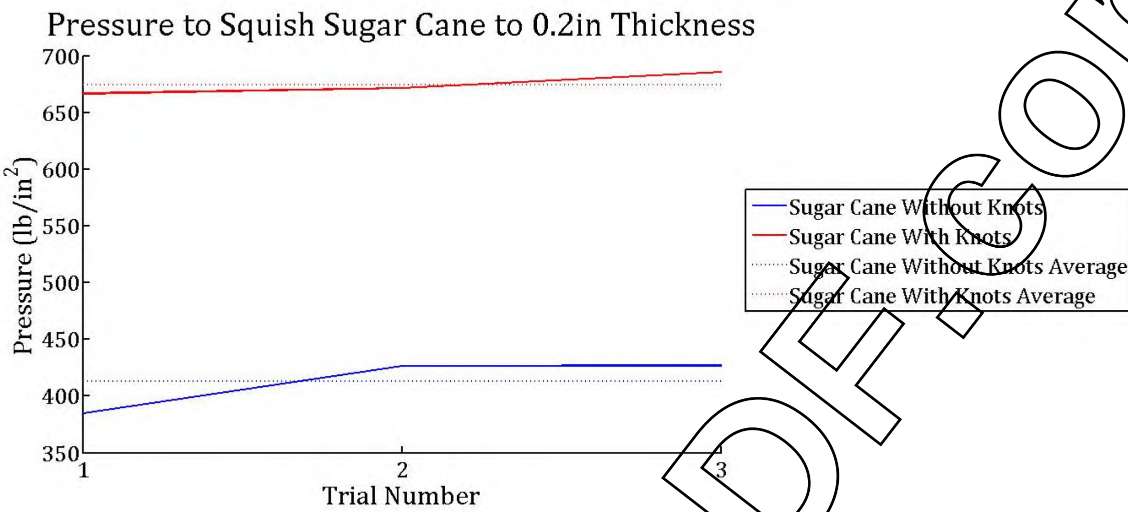

Figure 2: Pressure to Crush Sugar Cane Improved Estimate

Here it can be seen that the average pressure to crush a sugar cane stalk is 413 lb/in^2 with a maximum value of 427 lb/in^2. In places where a knot occurs the average pressure is found to be 675 lb/in^2 with a maximum pressure of 686 lb/in^2.

5.0 Test Results

All results were within expected values in both aspects. Not only were all values of sugar cane higher then all values of sorghum as expected, but pressures were in the range of hundreds of pounds per square inch as expected as well. In addition, sections of sugar cane that contain a knot required much high pressures to crush.

6.0 Summary of Test Results

If the sorghum press is to withstand all potential sorghum stalks, it should be designed to withstand all possible sugar cane stalks. Therefore using the maximum found pressure of 686 lb/in^2, a maximum estimated force on the rollers from each stalk is approximately 1372lb. This was found by using a conservative estimate of 2 in^2 of contact area between the rollers and the stalk.

7.0 Anomalies

All results are within expected ranges, and therefor seem reasonable. No particular outliers were found and all maximum and minimum values were within 5% of the calculated average values.

8.0 Conclusion and Recommendations

Tests were successful and found sugar cane to be stronger then sorghum. Due to this fact, any calculations done with the sugar cane results will also be sufficient for sorghum. In other words, as long as the press is designed to withstand 1372lb per stalk, the press will not break.

Test Procedure – TP3
Three Point Bend Test

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [02/04/2012]

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1.0 Introduction

In order to have a robust press design, it must be shown that the loads that will be applied to the rollers by the sorghum stalks will not be enough to cause plastic deformation. In addition, the applied loads must also not cause an elastic deformation large enough to prevent the pressing of the stalks down to a 0.2 inch thickness.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

This test will prove that the point load force of a sorghum stalk will not cause plastic deformation to the rollers in the form of denting. In addition, it will help support the hand analysis calculations that all bending will remain in the elastic region as well as remaining under a magnitude of 0.1 inches per roller.

1.3 Importance

The sorghum press is designed for a small town in a third world country. Availability of maintenance and materials are minimal, and therefor the press should be designed to last as long as possible. One key feature of this is keeping the rollers from plastically deforming due to the loads caused by the sorghum stalks. The rollers must also be able to maintain a maximum separation of 0.2 inches in order to get the maximum amount of juice from the stalks.

1.4 Background

According to hand analysis, the roller should not deform plastically due to bending moments. Force from sorghum stalks also should not cause a great enough deformation to cause rollers to separate to a greater distance then 0.2 inches. Denting and various other unpredicted modes of failure must be tested for.

2.0 Reference Documents

"Force to Crush Sugar Cane," EWB Capstone Group, 2012

3.0 Test Configuration

Testing requires a three point bend test machine as seen in figure 1. In addition to this, the roller to be tested must also be present. In this case this is a one foot long roller made of sch. 5 pipe and an outer diameter of 4 inches. A picture of the roller already loaded into the testing apparatus can be seen in figure 2.

3.1 Test Approach

Test is simple and all work is done by bend test machine. The roller is to be loaded onto the machine by two supports on its ends. The machine is then lowered until in contact with the roller. Increasing force is then applied to the roller by the machine in the form of a point load in the center. Resulting displacements are measured as the load is applied and released. Roller should be tested both for deformation at 1500lb as found in "Force to Crush Sugar Cane," as well as force required to deform 0.1 inches.

3.2 Equipment Needed

Three point bend test apparatus
Roller to be tested

3.3 Test Reporting Requirements

Bend test machine takes data at a very high sampling rate, causing there to be little average error due to noise. All data points from machine are to be recorded and plotted on a stress strain curve. From this curve the maximum deflection, plastic deformation, and load required for any specific deformation can all be found.

4.0 Test Procedures

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Load Roller onto three point bend test machine	Roller will fit correctly and be ready for testing	Roller fits
2	Apply a ramp force on the roller up to a load of 1500lb, then back to 0	Roller will experience little elastic deformation and no plastic deformation	Roller exhibited large deformations due to unexpected denting
3	Load roller until elastic deformation of 0.1 inches achieved	Roller will require a load greater then 1500lb	Roller passed 0.1 inch deformation before 1500lb

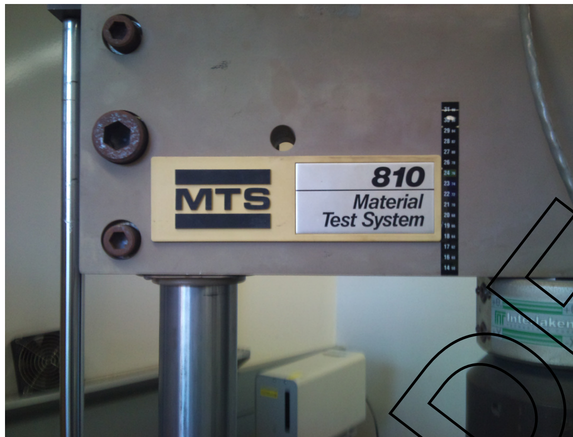

Figure 1: Three point bend test machine


Figure 2: Roller loaded in test apparatus

Test Report – TR3
Three Point Bend Test

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [2/29/2012]

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1.0 Introduction

In order to have a robust press design, it must be shown that the loads that will be applied to the rollers by the sorghum stalks will not be enough to cause plastic deformation. In addition, the applied loads must also not cause an elastic deformation large enough to prevent the pressing of the stalks down to a 0.2 inch thickness.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed as well as the resulting data in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

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This test will prove that the point load force of a sorghum stalk will not cause plastic deformation to the rollers in the form of denting. In addition, it will help support the hand analysis calculations that all bending will remain in the elastic region as well as remaining under a magnitude of 0.1 inches per roller.

1.3 Importance

The sorghum press is designed for a small town in a third world country. Availability of maintenance and materials are minimal, and therefor the press should be designed to last as long as possible. One key feature of this is keeping the rollers from plastically deforming due to the loads caused by the sorghum stalks. The rollers must also be able to maintain a maximum separation of 0.2 inches in order to get the maximum amount of juice from the stalks.

1.4 Background

According to hand analysis, the roller should not deform plastically due to bending moments. Force from sorghum stalks also should not cause a great enough deformation to cause rollers to separate to a greater distance then 0.2 inches. Denting and various other unpredicted modes of failure must be tested for.

2.0 Reference Documents

"Force to Crush Sugar Cane," EWB Capstone Group, 2012
"Three Point Bend Test Procedures," EWB Capstone Group, 2012

3.0 Test Procedures

Place the roller to be tested into the three point bend test machine. Lower the machine until it is in contact with the roller, then begin to apply force to the roller while measuring resulting displacement. The load should be slowly ramped up to a force of 1500lb, then backed slowly down to 0lb in order to find the maximum deflection from 1500lb and the plastic deformation it will cause. If the maximum deflection was less then 0.1 inches, the roller should then be reloaded up to the minimum force required to reach a 0.1 inch deformation. The resulting data should be acquired.

4.0 Recorded Data

First the roller was placed in the three point bend machine and was exposed to a steadily increasing force from 0 to 1500lb, and then brought back down to 0lb. The current force applied and the resulting displacement were recorded rapidly through out the duration of the test. The results can be seen in figure 1.

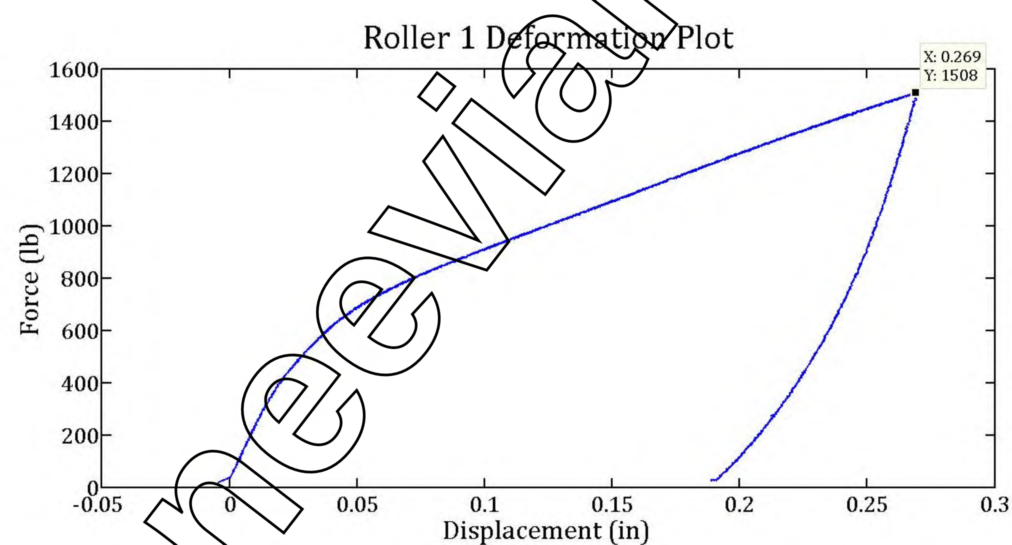

Figure 1: Force Vs Deformation of Roller 1 up to 1500lb

Here it can be seen that at 1500lb the roller deformed 0.27 inches, and when the load was brought back to 0, there was a resulting plastic deformation of almost 0.2 inches.

Another test of the same roller was unnecessary as the 0.1 inch deformation mark occurred long before the needed load of 1500lb.

5.0 Test Results

The stress strain curve follows the basic shape of steel curve as it should. Deformations due to bending were negligible as predicted,. Deformations due to denting however were well above the failure criteria.

6.0 Summary of Test Results

Bending stresses have been proven to not be a problem for the roller, therefore length, outer diameter, and shape are all acceptable. Failure due to denting can be solved by using thicker wall tubing for the walls of the roller.

7.0 Anomalies

Noise is taken care of due to the sheer amount of data taken from the computer. Stress strain curve matches the shape of an expected steel stress strain curve as well. Finally, the plastic deformation was measure with a micrometer to match the deformation in the data, proving lack of calibration error.

8.0 Conclusion and Recommendations

In order to have a press that extracts 90% of the juice from sorghum stalks, the rollers must press the stalks down to a thickness of 0.2 inches. In order to do this the rollers must not deform beyond this point. In addition to this the rollers must not plastically deform from the load a stalk would exert due to the lack of resources and skilled labor required to maintain the machine if problems occur. Therefor a thicker pipe size must be tested in order to find a working design that will satisfy the needs of the people of Mali.

Test Procedure – TP4
Three Point Bend Test

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [02/29/2012]

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1.0 Introduction

In order to have a robust press design, it must be shown that the loads that will be applied to the rollers by the sorghum stalks will not be enough to cause plastic deformation. In addition, the applied loads must also not cause an elastic deformation large enough to prevent the pressing of the stalks down to a 0.2 inch thickness.

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The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

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The sorghum press is designed for a small town in a third world country. Availability of maintenance and materials are minimal, and therefor the press should be designed to last as long as possible. One key feature of this is keeping the rollers from plastically deforming due to the loads caused by the sorghum stalks. The rollers must also be able to maintain a maximum separation of 0.2 inches in order to get the maximum amount of juice from the stalks.

1.4 Background

According to hand analysis, the roller should not deform plastically due to bending moments. Force from sorghum stalks also should not cause a great enough deformation to cause rollers to separate to a greater distance then 0.2 inches. Denting and various other unpredicted modes of failure must be tested for.

2.0 Reference Documents

"Force to Crush Sugar Cane," EWB Capstone Group, 2012

3.0 Test Configuration

Testing requires a three point bend test machine as seen in figure 1. In addition to this, the roller to be tested must also be present. In this case this is a one foot long roller made of sch. 40 pipe and an outer diameter of 4 inches. A picture of the roller already loaded into the testing apparatus can be seen in figure 2.

3.1 Test Approach

Test is simple and all work is done by bend test machine. The roller is to be loaded onto the machine by two supports on its ends. The machine is then lowered until in contact with the roller. Increasing force is then applied to the roller by the machine in the form of a point load in the center. Resulting displacements are measured as the load is applied and released. Roller should be tested both for deformation at 1500lb as found in "Force to Crush Sugar Cane," as well as force required to deform 0.1 inches.

3.2 Equipment Needed

Three point bend test apparatus
Roller to be tested

3.3 Test Reporting Requirements

Bend test machine takes data at a very high sampling rate, causing there to be little average error due to noise. All data points from machine are to be recorded and plotted on a stress strain curve. From this curve the maximum deflection, plastic deformation, and load required for any specific deformation can all be found.

4.0 Test Procedures

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Load Roller onto three point bend test machine	Roller will fit correctly and be ready for testing	Roller fits
2	Apply a ramp force on the roller up to a load of 1500lb, then back to 0	Roller will experience little elastic deformation and no plastic deformation	Roller exhibited minimal elastic deformation and virtually no plastic deformation
3	Load roller until elastic deformation of	Roller will require a load greater then	Roller required much greater then 1500lb

	0.1 inches achieved	1500lb	to deform 0.1 inches.

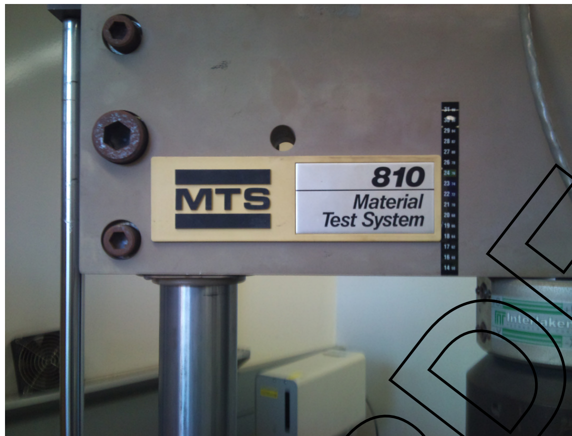

Figure 1: Three point bend test machine

Figure 2: Roller loaded in test apparatus

TEAM No. [20] – HUMAN POWERED SORGHUM PRESS

Test Report – TR4
Three Point Bend Test

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/1/2012]

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In order to have a robust press design, it must be shown that the loads that will be applied to the rollers by the sorghum stalks will not be enough to cause plastic deformation. In addition, the applied loads must also not cause an elastic deformation large enough to prevent the pressing of the stalks down to a 0.2 inch thickness.

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This test will prove that the point load force of a sorghum stalk will not cause plastic deformation to the rollers in the form of denting. In addition, it will help support the hand analysis calculations that all bending will remain in the elastic region as well as remaining under a magnitude of 0.1 inches per roller.

1.3 Importance

The sorghum press is designed for a small town in a third world country. Availability of maintenance and materials are minimal, and therefor the press should be designed to last as long as possible. One key feature of this is keeping the rollers from plastically deforming due to the loads caused by the sorghum stalks. The rollers must also be able to maintain a maximum separation of 0.2 inches in order to get the maximum amount of juice from the stalks.

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According to hand analysis, the roller should not deform plastically due to bending moments. Force from sorghum stalks also should not cause a great enough deformation to cause rollers to separate to a greater distance then 0.2 inches. Denting and various other unpredicted modes of failure must be tested for.

2.0 Reference Documents

“Force to Crush Sugar Cane,” EWB Capstone Group, 2012
“Three Point Bend Test Procedures,” EWB Capstone Group, 2012

3.0 Test Procedures

Place the roller to be tested into the three point bend test machine. Lower the machine until it is in contact with the roller, then begin to apply force to the roller while measuring resulting displacement. The load should be slowly ramped up to a force of 1500lb, then backed slowly down to 0lb in order to find the maximum deflection from 1500lb and the plastic deformation it will cause. If the maximum deflection was less then 0.1 inches, the roller should then be reloaded up to the minimum force required to reach a 0.1 inch deformation. The resulting data should be acquired.

4.0 Recorded Data

First the roller was placed in the three point bend machine and was exposed to a steadily increasing force from 0 to 1500lb, and then brought back down to 0lb. The current force applied and the resulting displacement were recorded rapidly through out the duration of the test. The results can be seen in figure 1.

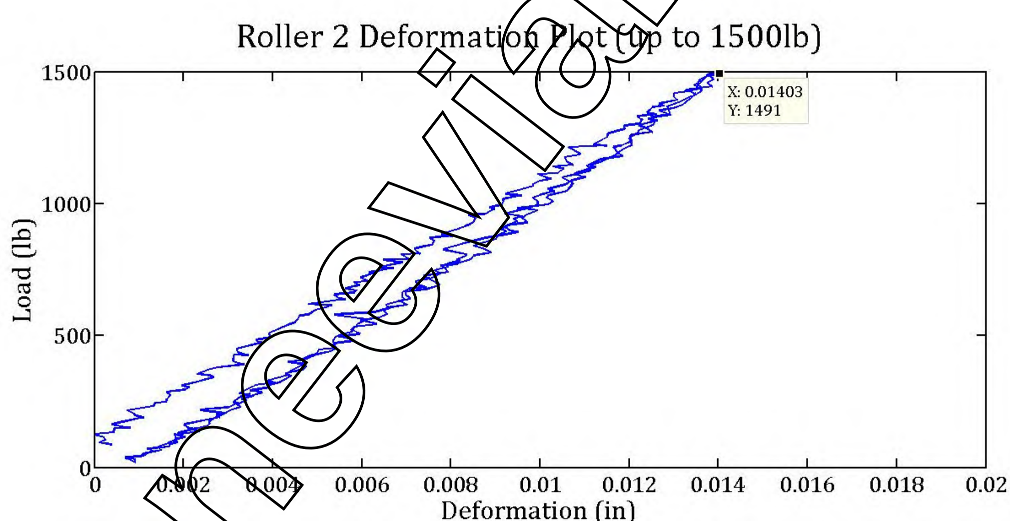

Figure 1: Force Vs Deformation of Roller 2 up to 1500lb

Here it can be seen that at 1500lb the roller deformed 0.014 inches, and when the load was brought back to 0, the resulting plastic deformation was negligible

The roller was then placed under a steadily increasing load again until the deformation reach 0.1 inches. The resulting data can be seen in figure 2.

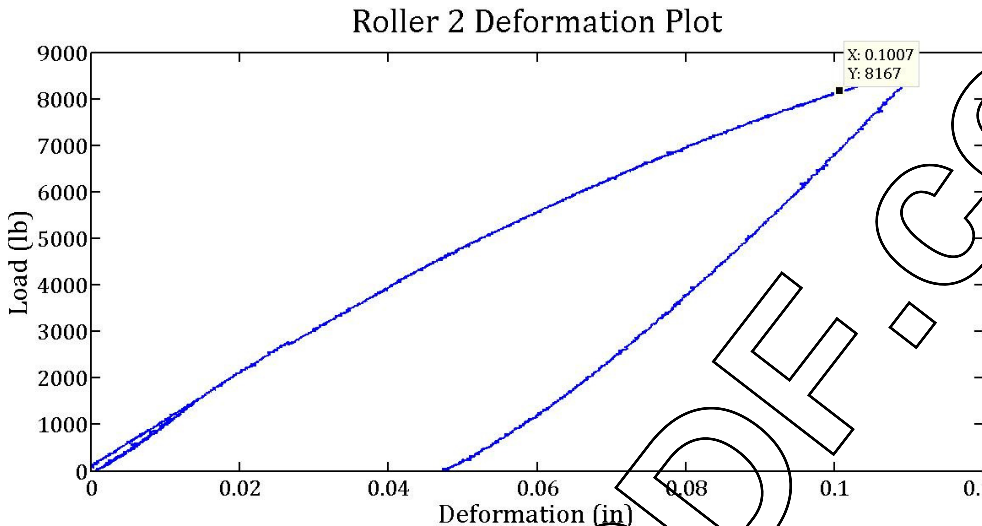

Figure 2: Force Vs Deformation of Roller 2 up to 0.1 Inch Deformation

Here it can be seen that the force required to displace the roller 0.1 inches is 8000lb giving the rollers a safety factor of 5.3.

5.0 Test Results

The stress strain curve follows the basic shape of steel curve as it should. Deformations due to bending were negligible as predicted. Deformations due to denting were also within failure criteria.

6.0 Summary of Test Results

Bending stresses have been proven to not be a problem for the roller, therefore length, outer diameter, and shape are all acceptable. Rollers also now pass the deformation criteria in denting proving the wall thickness is acceptable.

7.0 Anomalies

Noise is taken care of due to the sheer amount of data taken from the computer. Stress strain curve matches the shape of an expected steel stress strain curve as well. Finally, the plastic deformation was measure with a micrometer to match the deformation in the data, proving lack of calibration error.

8.0 Conclusion and Recommendations

In order to have a press that extracts 90% of the juice from sorghum stalks, the rollers must press the stalks down to a thickness of 0.2 inches. In order to do this the rollers must not deform beyond this point. In addition to this the rollers must not plastically deform from the load a stalk would exert due to the lack of resources and skilled labor required to maintain the machine if problems occur. These rollers pass everyone of these specifications and should be acceptable parts for the human powered sorghum press for the people in Mali.

Test Procedure – TP5
Torque Required to Run Press

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/7/2012]

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1.0 Introduction

Test utilizes a torque gauge and various samples of sugar cane in order to test the torque required to crush one stalk of sugar cane.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

The minimum torque required to operate the press must be found. This torque is equal to the torque required to squish a single stalk of sugarcane.

1.3 Importance

If the sorghum press is to be human powered, it must be possible for a human to operate it. One condition for this is that the torque required to operate it must be achievable. In order to meet this criteria, the torque required to squish a single stalk of sugarcane must be found.

1.4 Background

Based on analysis and use of the prototype, squishing a single stalk should not be a problem. The force required to squish a single stalk is not large, and therefor the torque required should not be large.

2.0 Reference Documents

No materials were referenced in the procedures or results of this experiment

3.0 Test Configuration

Test utilizes a torque gauge and various samples of sugar cane in order to test the torque required to crush one stalk of sugar cane. This can be found by placing a sugar cane stalk between the rollers of the press, and driving the rollers manually through the torque gauge in order to get a reading of the required torque. This setup can be seen in figure 1 of the appendix.

3.1 Test Approach

First, the press will be staked to the ground to keep it from moving. Samples of sugarcane will then be fed into press one at a time. The press will be driven directly by the rollers through use of a torque gauge. The torque required to keep the rollers turning while crushing the stalk will then be reorded.

3.2 Equipment Needed

1 Human Powered Sorghum Press
1 Torque Gauge
6 1in diameter sugar cane stalks

3.3 Test Reporting Requirements

Test will comprise of six trials in order to avoid anomalous data. If any data is largely different then the rest, more trials will be performed in order to verify validity of data.

4.0 Test Procedures

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Stake press into ground at each corner to prevent movement during test	Press will remain stationary	Press remained stationary
2	Feed single sugarcane stalk through press. Drive rollers directly through use of torque gauge. Measure resulting torque to turn rollers	Torque required to turn rollers will be relatively small (<100lb*ft)	Torques found to be 35 lb*ft
3	Repeat step two with five more sugarcane samples of diameter 1 ± 0.25in	All torques will be similar to first	Torques ranged from about 30-50 lb*ft

5.0 Appendix

Figure 1: Measuring Torque to Crush Single Sugarcane Stalk

TEAM No. [20] – HUMAN POWERED SORGHUM PRESS

Test Report – TR5
Torque Required to Run Press

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/7/2012]

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1.0 Introduction

Test utilizes a torque gauge and various samples of sugar cane in order to test the torque required to crush one stalk of sugar cane.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed as well as the data obtained in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

The minimum torque required to operate the press must be found. This torque is equal to the torque required to squish a single stalk of sugarcane.

1.3 Importance

If the sorghum press is to be human powered, it must be possible for a human to operate it. One condition for this is that the torque required to operate it must be achievable. In order to meet this criteria, the torque required to squish a single stalk of sugarcane must be found.

1.4 Background

Based on analysis and use of the prototype, squishing a single stalk should not be a problem. The force required to squish a single stalk is not large, and therefor the torque required should not be large.

2.0 Reference Documents

TR5, “Torque Required to Run Press,” EWB Capstone Team 2012

3.0 Test Procedures

First the sorghum press must be staked into the ground at each corner to prevent it from moving during the test. Next, six samples of sugarcane of diameters 1 ± 0.25in must be obtained. Each of these samples must be fed through the press one at a time. The rollers must be driven directly through a torque gauge, and the resulting torque required to spin the rollers must be recorded for each sample.

4.0 Recorded Data

With each sample run through the press, the data was tabulated and can be seen in figure 1. To see the raw data, see table 1 in the appendix.

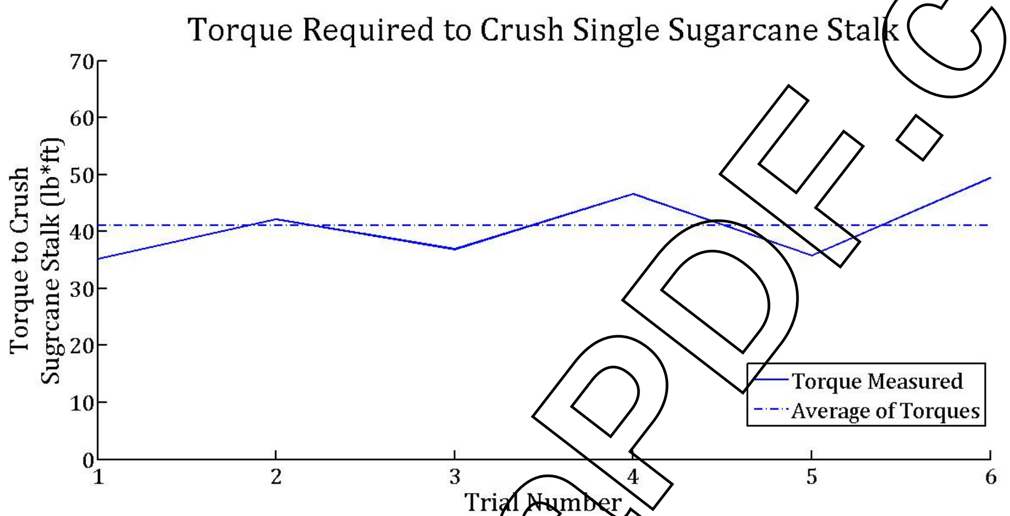

Figure 1: Torque Required to Crush a Single Sugarcane Stalk

Here it can be seen that the torque required to crush a single 1in diameter sugarcane stalk is 41.0 ± 8 lb*ft.

5.0 Test Results

Results were expected to be under 100 lb*ft. Actual results were well within this estimate at 41.0 ± 8 lb*ft. With the lever arm designed to be 4.9 ft (1.5m) long, this results in a required force of 8.4lb. This is well within the abilities of any normal human being.

6.0 Summary of Test Results

With a torque of 41.0 ± 8 lb*ft. And a lever arm that is 4.9 ft (1.5m) long, the force required to feed through a single sugarcane stalk is only 8.4lb. At 6 stalks this number would be only 50lb, a force that should still be achievable by any average human. This torque is equal to 55.6N*m well below the specification of 240 N*m.

7.0 Anomalies

All values were within predicted ranges and no values were far from the average. Using six data points prevented results being based on anomalous data.

8.0 Conclusion and Recommendations

Any human should be able to exert 41 lb*ft with a lever arm in the range of 5 feet long. This proves that the design of the human powered sorghum press is both sound and effective, and will be very useful to the people of Mali.

9.0 Appendix

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Torque (lb*ft)	35.1	42.2	36.9	46.6	35.9	49.4

Table 1: Torque to Crush Sugarcane Stalk Data

Test Procedure – TP6
Sorghum Press Throughput

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/9/2012]

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Definitions

Bundle – Number of rods or stalks fed through machine at once

1.0 Introduction

In order to prove the effectiveness of the design, it must be shown that the throughput of the machine is as great, or greater then the product specification.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

This test is designed in order to determine the possible throughput of the human powered sorghum press at various bundle sizes. Here bundle sizes are defined as the number of stalks fed through the machine at one time.

1.3 Importance

When asked for areas to improve on the past human powered sorghum press, the people of Mali were adamant about improving the throughput rate. The old press given to them processed only one stalk at a time with a feed rate of about three inches per second. In order to address this issues, the rollers were redesigned to accommodate more stalks at once. With this new design, the throughput must be tested at various bundle sizes to see the overall effectiveness of the press.

1.4 Background

By increasing the number of stalks that could be fed through at one time, the throughput is almost guaranteed to increase. Based on various analysis and previous experience with the press in other tests, it is believed that the number of stalks fed through at one time will not have a significant affect on the feed rate. Therefor it is probable that throughput can be maximized by feeding through as many stalks as can be fit at one time.

2.0 Reference Documents

TR5, "Torque Required to Run Press," EWB Capstone Team, 2012

3.0 Test Configuration

Test set-up requires six lengths of six foot long ½ inch o-ring rod as seen in figure 1 of the appendix. These were chosen according to the torque required to feed them through the press. The torque was found to be 40 lb*ft to feed one rod through the press, which closely resembles the average torque required to squish a stalk of sugarcane as seen in test report 5, "Torque Required to Run Press". These six foot lengths will fed through the human powered sorghum press as seen in figure 2 of the appendix.

3.1 Test Approach

Six lengths of ½ inch o-ring rod will be fed through the sorghum press in various bundle sizes, and the time to press all thirty-six feet will be recorded. First the rods will be fed through one at a time until all six have been pressed, the time will be recorded and the test will be repeated three times. The rods will then be fed through two at a time, three at a time, and finally six at a time using the same procedures. All data will be recoded for later analysis.

3.2 Equipment Needed

1 Human Powered Sorghum Press
6 Six foot lengths of ½ inch o-ring rod

3.3 Test Reporting Requirements

In order to account for anomalous data, three trials will be conducted for each bundle size. If one value seems Unusually for from the other two, more trials may be performed to verify results.

4.0 Test Procedures

Table 1. Test 1 Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Stake sorghum press into ground to prevent movement	Press will remain stationary	Press remained stationary.
2	Have one person begin turning crank arm at a comfortable speed while another person feeds through rods one at a time until all six have been processed. Record time.	Time to process all stalks will be longer then other other bundle sizes	Single stalk to longest to feed through.

3	Repeat step 2 three times, recording data for each.	Data will be approximately constant every trial	Data remained constant
4	Repeat steps 2 and 3 feeding through two rods at a time until all six rods have been fed through.	Two rods will feed through faster than one and data will be approximately constant every trial	Trial was faster and data remained constant.
5	Repeat steps 2 and 3 feeding through three rods at a time until all six rods have been fed through.	Three rods will feed through faster than two and data will be approximately constant every trial	Trial was faster and data remained constant.
6	Repeat steps 2 and 3 feeding through six rods at a time.	Six rods will feed through faster than three and data will be approximately constant every trial	Trial was faster and data remained constant.

5.0 Appendix

Figure 1: ½ inch o-ring rod

Figure 2: Rubber Rod Being Fed Through Press

TEAM No. [20] – HUMAN POWERED SORGHUM PRESS

Test Report – TR6
Sorghum Press Throughput

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [03/09/2012]

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Definitions

Bundle – Number of rods or stalks fed through press at one time.

1.0 Introduction

In order to prove the effectiveness of the design, it must be shown that the throughput of the machine is as great, or greater then the product specification.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed as well as the data obtained in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

This test is designed in order to determine the possible throughput of the human powered sorghum press at various bundle sizes. Here bundle sizes are defined as the number of stalks fed through the machine at one time.

1.3 Importance

When asked for areas to improve on the past human powered sorghum press, the people of Mali were adamant about improving the throughput rate. The old press given to them processed only one stalk at a time with a feed rate of about three inches per second. In order to address this issues, the rollers were redesigned to accommodate more stalks at once. With this new design, the throughput must be tested at various bundle sizes to see the overall effectiveness of the press.

1.4 Background

By increasing the number of stalks that could be fed through at one time, the throughput is almost guaranteed to increase. Based on various analysis and previous experience with the press in other tests, it is believed that the number of stalks fed through at one time will not have a significant affect on the feed rate. Therefor it is probable that throughput can be maximized by feeding through as many stalks as can be fit at one time.

2.0 Reference Documents

TR6, "Sorghum Press Throughput," EWB Capstone Team, 2012

3.0 Test Procedures

The press should first be staked into the ground at each corner in order to prevent movement during use. Once the press is firmly secured to the ground, one person should begin turning the crank arm at a comfortable speed. The second person should then begin to feed through the rubber rods one at a time until all six have gone through the machine. The time to process all six rods should be recorded, and the same test should be performed two more times. This same procedure should then be repeated for feeding two rods through at a time, three rods through at a time, and six rods through at a time. All times should be tabulated for later Analysis.

4.0 Recorded Data

The time required to process six rods, each six feet in length, was recorded for bundle sizes of one rod, two rods, three rods, and six rods. Each bundle size was repeated three times, and the results can be seen in figure 1. See table 1 in the appendix for the full set of data.

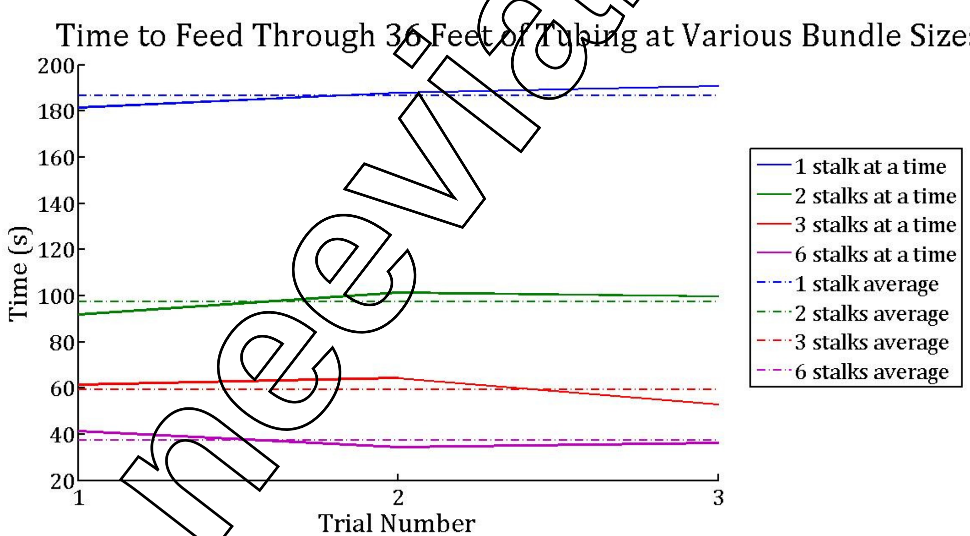

Figure 1: Time to Feed Through 6 Rods at Various Bundle Sizes

Here it can be seen that with a bundle of only 1 rod, the average time to feed through all six rods was 187 ± 15s. With a bundle of 2 rods this time dropped to 98 ± 10s. Feeding through a bundle of 3 rods at a time dropped the time to process all rods even further to a total of 60 ± 7s. Finally, with a bundle of all 6 rods at once, the processing time was only 37 ± 4s.

When these average values are plotted against the bundle size, an interesting trend can be observed. This trend can be seen in figure 2.

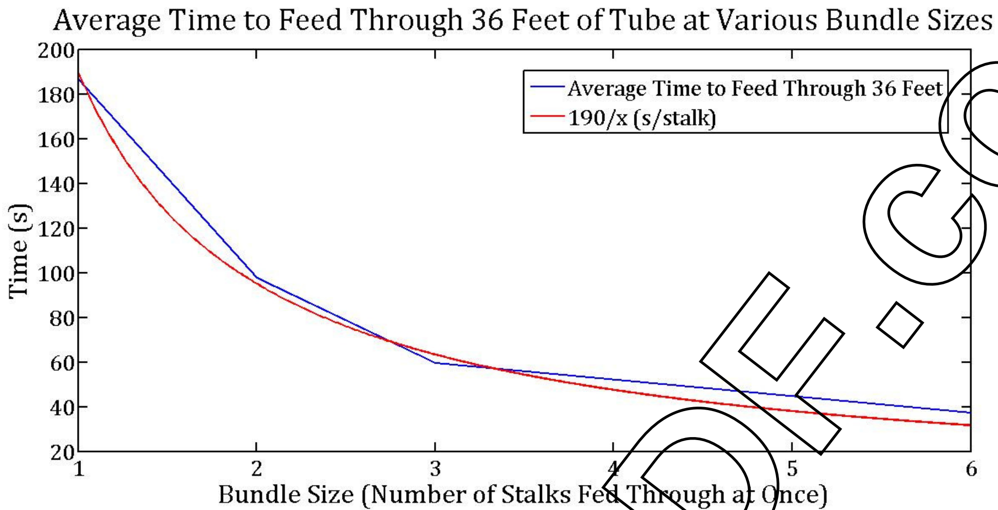

Figure 2: Average Time to Feed Bundles Through

It can be seen that the time required to process the rods can be closely approximated by the function 190/x where x is the number of rods being processed by the machine at one time. This c/x relation where c is a constant, shows that the speed at which each bundle is processed is nearly constant. This relationship can be seen even more clearly in figure 3.

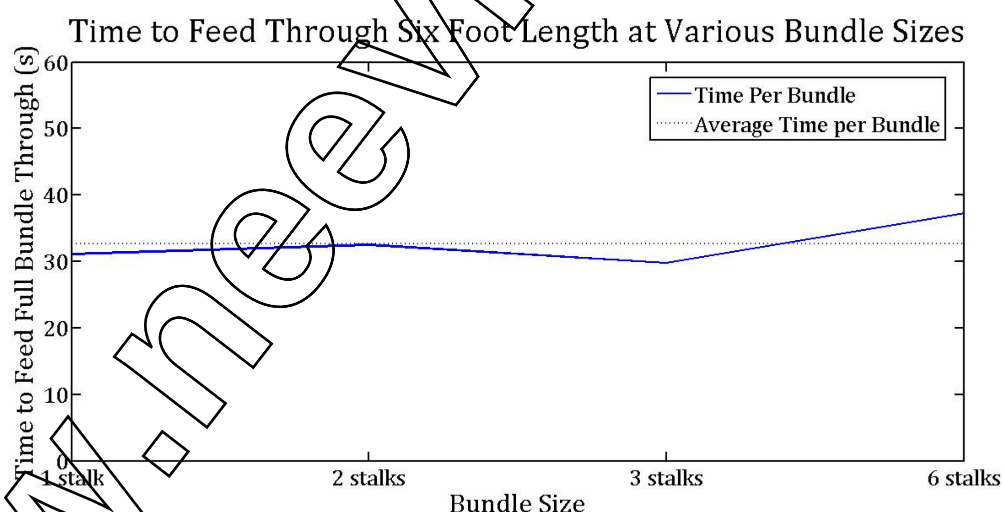

Figure 3: Time to Process each Bundle

Here the time to process each bundle was found by taking the total time for each bundle size, and dividing it by the corresponding number of bundles. The average time per bundle was found to be 33 ± 5s.

5.0 Test Results

Throughput increased as bundle size increased, as expected. It is also interesting to note that processing rate per bundle was nearly constant regardless of bundle size. This is probably due to the fact that although increasing the bundle size does increase the force required and make the press more difficult to use, this increase is minimal. This force also remains low enough to be comfortable even with a bundle size of six.

6.0 Summary of Test Results

It has been proven that throughput can be maximizes by feeding through as many stalks at once as possible into the sorghum press up to a maximum of at least six. Should there be room for more stalks, extrapolation of current data predicts that the throughput can still be further increased by feeding through more then six stalks at a time. With a bundle size of six however, the time to feed through 36 feet was found to be 37 ± 4s, resulting in a feed rate of 11.7 ± 1.2 in/s.

7.0 Anomalies

All data followed expected values and no outliers were found. Sample sizes of three trials per test helped prevent results based on anomalous data.

8.0 Conclusion and Recommendations

Throughput was found to be maximized by feeding through the maximum possible number of stalks at a time up to at least six. The resulting feed rate at a bundle size of six stalks resulted in a processing speed of 11.7 ± 1.2 in/s. This feed rate is approximately four times as fast as the old press which has a feed rate of about 3in/s.

9.0 Appendix

	Trial 1	Trial 2	Trial 3
1 Stalk Bundle	181.4	187.9	190.8
2 Stalk Bundle	91.7	101.3	99.7
3 Stalk Bundle	61.4	64.3	52.8
6 Stalk Bundle	41.4	34.3	36.1

Table 1: Throughput Data (All Values in Seconds)

Test Procedure – TP7
Fatigue Test (Human Powered)

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/12/2012]

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1.0 Introduction

In order to prove the effectiveness of the design and its various components, it must be shown that none of the vital components will fail after prolonged use. In particular, the gears must continue to transmit power, and the rollers must not deform.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

It must be proven that the human powered sorghum press can undergo a minimum of 180,000 cycles without failure. In this case failure can be assessed as plastic deformation of rollers, gears failing to transmit energy through system to rollers, or any other part physically breaking. Due to deadlines, a full 180,000 cycles is impractical, and a lesser test will be performed to show feasibility. In this case feasibility will be proven by testing the press by hand for ten hours at a normal walking speed of ten revolutions per minute, totaling 6000 revolutions.

1.3 Importance

In Mali the press will be used for prolonged periods of time over the course of the sorghum harvesting season. During the length of this season, it is critical that no failures occur with the press. Do to lack of resources and money, fixing the press at all would be a difficult task, however having the press require maintenance during the harvesting season would be detrimental to the harvest. The press must therefor last the number of cycles it would undergo during a harvest season which analysis has found to be approximately 180,000 cycles.

1.4 Background

According to analysis, all components should be under endurance limits and therefor have infinite life. Real life components are not perfect however. The gears specifically were manufactured in Mali and have imperfections due to the lack of manufacturing tools. If any problem were to occur, it is predicted to happen in the gears.

2.0 Reference Documents

No documents were referenced in the formulation or execution of this test.

3.0 Test Configuration

Test setup requires the human powered sorghum press prototype as well as ½ inch o-ring rods to feed through continuously. This first needs to be spliced into a loop and loaded into rollers to apply constant load while press is in use.

3.1 Test Approach

The sorghum press should first be staked into the ground to prevent movement during test. The rubber rod spliced into a loop should then be loaded into the rollers. Testers then proceed to use press continuously for a period of ten hours. Press should then be inspected for any of the previously mentioned failure criteria.

3.2 Equipment Needed

1 Human powered sorghum press prototype
1 ½ inch o-ring rod

3.3 Test Reporting Requirements

Test will be a pass/fail test. If test fails, new parts may be fabricated to try again to test possibility of anomalous faults in parts.

4.0 Test Procedures

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Stake press into ground to prevent moving and load spliced rod between rollers.	Press will remain stationary and feed through rod continuously.	Press remained stationary and rod fed through continuously.
2	Use press continuously at ten revolutions per minute for ten hours	Press will continue to work	Press continued to work
3	Check rollers and gears for failure	No failure will be found	No failure was found

Test Report – TR7
Fatigue Test (Human Powered)

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/12/2012]

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1.0 Introduction

In order to prove the effectiveness of the design and its various components, it must be shown that none of the vital components will fail after prolonged use. In particular, the gears must continue to transmit power, and the rollers must not deform.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

It must be proven that the human powered sorghum press can undergo a minimum of 180,000 cycles without failure. In this case failure can be assessed as plastic deformation of rollers, gears failing to transmit energy through system to rollers, or any other part physically breaking. Due to deadlines, a full 180,000 cycles is impractical, and a lesser test will be performed to show feasibility. In this case feasibility will be proven by testing the press by hand for ten hours at a normal walking speed of ten revolutions per minute, totaling 6000 revolutions.

1.3 Importance

In Mali the press will be used for prolonged periods of time over the course of the sorghum harvesting season. During the length of this season, it is critical that no failures occur with the press. Do to lack of resources and money, fixing the press at all would be a difficult task, however having the press require maintenance during the harvesting season would be detrimental to the harvest. The press must therefor last the number of cycles it would undergo during a harvest season which analysis has found to be approximately 180,000 cycles.

1.4 Background

According to analysis, all components should be under endurance limits and therefor have infinite life. Real life components are not perfect however. The gears specifically were manufactured in Mali and have imperfections due to the lack of manufacturing tools. If any problem were to occur, it is predicted to happen in the gears.

2.0 Reference Documents

TP7, "Fatigue Test (Human Powered)," EWB Capstone Team, 2012

3.0 Test Procedures

The sorghum press should first be staked into the ground to prevent movement during test. The rubber rod spliced into a loop should then be loaded into the rollers. Testers then proceed to use press continuously for a period of ten hours. Press should then be inspected for any of the previously mentioned failure criteria.

4.0 Test Results

The press continued to run without problems for the full ten hours. Afterward the rollers and gears were closely inspected and no noticeable problems were found in either.

5.0 Conclusion and Recommendations

Undergoing 6000 cycles without failure is an important step towards proving the robustness of the design. While it does not yet prove that the design can undergo the same conditions it will face in Mali, it does show feasibility that it can meet these conditions. A test must now be performed using a motor to power the press. This test can be run for a prolonged period of time to meet the full 180,000 cycles and prove the designs ability to withstand fatigue.

Test Procedure – TP8
Fatigue Test (Motor Powered)

Kelly Lin, Erika Eskenazi, Marcela Areyano, David Cordeiro, Adam Scott

REV. DATE [3/12/2012]

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1.0 Introduction

In order to prove the effectiveness of the design and its various components, it must be shown that none of the vital components will fail after prolonged use. In particular, the gears must continue to transmit power, and the rollers must not deform.

1.1 Purpose

The purpose of this document is to provide a detailed description of the lab setup and procedures performed in order to make it reproducible by other engineers or scientists. This in turn allows for the scientific community to both critique the test, and reproduce the test, giving the results greater accreditation.

1.2 Objectives

It must be proven that the human powered sorghum press can undergo a minimum of 180,000 cycles without failure. In this case failure can be assessed as plastic deformation of rollers, gears failing to transmit energy through system to rollers, or any other part physically breaking.

1.3 Importance

In Mali the press will be used for prolonged periods of time over the course of the sorghum harvesting season. During the length of this season, it is critical that no failures occur with the press. Do to lack of resources and money, fixing the press at all would be a difficult task, however having the press require maintenance during the harvesting season would be detrimental to the harvest. The press must therefor last the number of cycles it would undergo during a harvest season which analysis has found to be approximately 180,000 cycles.

1.4 Background

According to analysis, all components should be under endurance limits and therefor have infinite life. Real life components are not perfect however. The gears specifically were manufactured in Mali and have imperfections due to the lack of manufacturing tools. If any problem were to occur, it is predicted to happen in the gears.

2.0 Reference Documents

No documents were referenced in the formulation or execution of this test.

3.0 Test Configuration

Test setup requires the human powered sorghum press prototype as well as ½ inch o-ring rods to feed through continuously. This first needs to be spliced into a loop and loaded into rollers to apply constant load while press is in use. In addition, a 400W electric motor is required to drive the rollers for an extended period of time.

3.1 Test Approach

The sorghum press should first be staked into the ground to prevent movement during test. The rubber rod spliced into a loop should then be loaded into the rollers. Finally, the motor should be attached to the drive shaft and driven at 10 revolutions per minute for 300 hours, resulting in 180,000 revolutions.

3.2 Equipment Needed

1 Human powered sorghum press prototype
1 ½ inch o-ring rod
1 400 electric motor

3.3 Test Reporting Requirements

Test will be a pass/fail test. If test fails, new parts may be fabricated to try again to test possibility of anomalous faults in parts.

4.0 Test Procedures

Table 1. Test Procedures

Step	Procedure	Expected Result	Pass / Fail
1	Stake press into ground to prevent moving and load spliced rod between rollers.	Press will remain stationary and feed through rod continuously.	Press remained stationary and rod fed through continuously.
2	Attach motor to drive shaft and run at 100 rpm for 30 hours	Press will continue to work	Press continued to work
3	Check rollers and gears for failure	No failure will be found	No failure was found