Consultancy report for MOST 27th July 2015

MST-REP-002-01

Thresher Prototype No.1 Design Dossier

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1. Introduction

The eclectic and diesel Domasso threshers acquired by MOST to initiate the project, while slightly different from each other, have provided a quantifiable starting point to the design of the MOST thresher. Figure 1 shows the Domasso threshers in their assembled state to be used on Soya (i.e. without the sunflower attachment used on the diesel thresher). The reverse engineering and initial design work has focused on establishing the current state of the threshers, establishing a baseline design basis when the two threshers differ, establishing best practise around design for manufacture and assembly and addressing some of the improvements that these initial thresher suggest are required.

Figure 1 - Domasso electric thresher (left) and diesel thresher (right)

Figure 2 shows the general assembly of the MOST Thresher Prototype No.1, which retains the layout, mechanism, and overall design intent of the Domasso design. This means that in compliance with the statement of requirements (MST-SOR-001-01) the proposed basic layout is the same, with a threshing chamber set consisting of five stationary threshing blades and four rotating threshing blades with hooks, the lid of the chamber is removable, the input for material to thresh being on one side (at 0 degrees) the chaff ejected on the other side (180 degrees). The lower half of the chamber consists of a series of holes to filter the threshed output into a chute to collect the into a bucket and the entire assembly is assembled from readily available materials and using readily available manufacturing techniques.
This design dossier will detail the reverse engineering and benchmarking process alongside the design and manufacture process for the MOST No.1 thresher. Full manufacturing drawings are available and some of them are included here when required. Much of the detail of this report features photos of the original threshers along side the Computer Aided Design (CAD) images of the MOST design to explain design decisions.

1.1. CAD Note
The design work has all been produced using the Autodesk Fusion 360 CAD package. This has been used as it is available for download (http://www.autodesk.com/products/fusion-360/overview) and use either for free or at a low cost and will run on a variety of computers (including PCs and Macs) meaning that once the project is complete, all of the source files will be available for other people to use, refine, develop etc. which aligns with the intention to make the MOST thresher an open source design which can be improved in Malawi.

1.2. Materials and Operations
The design uses:
- 40mm x 40mm steel angle
- 2mm sheet steel
- 8mm thick plate / bar
- 8-10mm diameter rebar
- 20mm diameter bar

The operations required are:
  - Welding
  - Sheet metal bending
  - Cutting plate, sheet, bar
  - General assembly (nuts, bolts, aligning things etc.)

A lot of time has been put into ensuring that this design is manufacturable in Malawi using non-specialist equipment, this also means that the finished thresher will be able to be repaired in Malawi using the same level of equipment if the need arises.

Full part drawings are available and provided to the prototype manufacturer and following refinement and design freeze to all interested parties and in hard and soft copy to MOST for dissemination and future use.
2. General Assembly

Figure 3 - General assembly drawing - NOT TO SCALE
3. Design Process

3.1. Threshing mechanism

The starting point for the thresher reverse engineering and the key to the whole machine is the threshing chamber and the mechanism for carrying out the threshing activity. The threshing chamber consists of a rotating element (the rotor) and a stationary element (the stator) to carry out the threshing; the rotating element consists of four sets of five blades, orientated at 90° to each other which is driven at one end from the power input (electric or diesel) while the stationary element of the threshing mechanism consists of five sets of six blades mounted into the threshing chamber and arranged equally around approximately 180° of the chamber base.

Figure 4 shows the rotor of the Domasso threshing mechanism removed from the machine, Figure 5 shows the stator, along with the mesh through which the threshed material falls and Figure 6 shows the interface between the rotor and the stator at the material input (also showing some of the variance in the manufacture).
There is some difference in terms of the dimensions, spacing and alignment of the relevant parts of the threshing mechanism across the two machines, so the reverse engineering process defined the relevant spacing and orientation of the blades based on the two machines available and the conversations and inspection of the original Domasso machine in Mponela. Figure 7 shows a CAD image of the rotating and stationary elements with the other parts of the machine hidden to aid the view. Figure 8 shows the interaction between the two sets of blades and the dimensions defined during the reverse engineering phase.
The blades are manufactured from 38mm by 6mm flat steel bar with rebar used for the hook on the rotor blades. Drawings of each component will be provided to the manufacturer and refined during the prototype manufacture. The work in progress (WIP) assembly drawing of the rotor is shown in Figure 9 with some relevant dimensions included and a WIP stator blade assembly drawing is shown in Figure 10. These parts are the starting point for the design and assembly of the entire machine, ensuring that the rotor is accurate and straight will make the rest of the build more straightforward.
Figure 10 - Stator blade assembly drawing - NOT TO SCALE
Note: The rotor assembly alone consists of 47 parts, across six different part numbers; each part number has its own manufacturing drawing and where appropriate sub level assembly drawings are used to aid manufacture of the assemblies shown. These drawings are not all included in this report, these drawings will all be provided to the prototype manufacturer and refined during the manufacture process.

3.2. Bearings

The Domasso threshers utilised basic bearing units which are designed to cope with a small amount of axial misalignment, this standard will be utilised going forward as it avoids the need for very tight tolerances in the manufacturing process and is also a readily available design. Self-aligning ball bearings or toroidal roller bearings in a casing with a grease port are suitable for this application and are readily available in manufacturing areas in Malawi.

3.3. Bearing Support Frame

The frame, which supports the bearings, defines the datum for the rest of the assembly; between the two Domasso threshers there were two styles of bearing support, shown in Figure 11, each of which has benefits for usage in the thresher. The electric thresher features a slightly lowered bearing mounting plate compared to the level of the join between the threshing chamber lid and base bringing the centre of the rotor axle to the centre level of the threshing chamber; whereas the diesel thresher use a flat mount below the centreline of the rotor axle. The style used on the diesel thresher has been chosen for the MOST thresher as by using a single flat bar to support the bearing there is fewer manufacturing steps which leads to an inherently more accurate and stronger frame.

Figure 11 - Domasso bearing mounting, Electric (Left) and Diesel (Right)
Figure 12 shows a CAD image for the MOST thresher support frame, this features the bearings supported on a flat mount as in the Domasso diesel thresher but with an increased height on the short edges to assist in the orientation of the stator blades, this is discussed below.

![Figure 12 - CAD image of the bearing support frame](image)

### 3.4. Stator Blade Position

The position of the stator blades at each side of the lower threshing chamber (i.e. by the feed and by the exit) are angled slightly upwards on the Domasso threshers and are not welded directly to the frame of the bearing support. The leaves a void behind the stator base plate, which gets filled with chaff, and can lead to material wedging in the thresher Figure 13 highlights this void and the chaff behind it.

In the Domasso thresher these stator blades are angled up slightly due to the manner in which the stator blades are fixed into the threshing chamber. For the MOST thresher the stator blades on each side of the chamber are welded directly to the bearing support frame and the relative motion of rotor and stator is roughly the same as on the Domasso thresher but with a more repeatable (manufacturable) method of achieving this, the method of assembly also avoids the void behind the stator base bar which can clog with chaff.
Figure 13 - Stator base bar void filled with chaff

Figure 14 - Domasso thresher showing top two stator blades

Figure 15 - MOST thresher showing top two stator blades

Figure 14 and Figure 15 show the slight difference between the diesel Domasso and the MOST threshers with respect to the orientation of the first stator blade.
3.5. Filter

The 10mm diameter filter/mesh in the bottom of the threshing chamber appears to be ideally sized and has been refined over the last few prototypes manufactured by Domasso so the same 10mm hole spacing on a 20mm grid will be continued with the MOST thresher, however there will not be a space between the filter and the stator blades bases to avoid the build up of chaff shown in Figure 16 below.

![Figure 16 - Stator bar base void filled with chaff](image)

The stator blades will be welded on their ends to tube curved to the required profile and then welded on the long flat sides to the filter, Figure 17 below shows a CAD image of curved plate, stator blades and the curved tubes, the semi-circular sides of the threshing chamber base will then be welded along the join to avoid sharp edges and gaps. Note: Due to graphic constraints the holes in the mesh are not shown in this image.
3.6. Lid

The top half of the threshing chamber is removable; the Domasso threshers utilised a hinge mechanism to pivot the lid up but this is deemed unnecessary and introduces a weak point to the design. By removing the hinge and retaining the lid via a series of bolts the thresher can be opened relatively simply for cleaning and maintenance without specialist tools, to improve safety the threshing input has been modified from a simple open slot to a closed chute, the exit has been retained in the same design as the Domasso thresher. Figure 18 shows the Domasso thresher lid and Figure 19 shows the CAD image of the MOST thresher lid featuring the extended input chute.
3.7. Frame

The threshing chamber is supported on a straightforward frame manufactured from steel angle section, this is the same method used on the Domasso threshers, is simple and strong and the frame can be adjusted easily if the desired size of steel is not available. For the prototype a full back plate of sheet steel is included to shield the motor from the working side of the thresher to reduce the chance of accidents the frame is shown below in Figure 20.
4. Power Input

4.1. Diesel/Petrol
The first prototype will be manufactured to use the Domasso diesel as an input while research into motor availability in Malawi continues. The design of the threshing chamber, and power input will remain the same with the option to modify the pulley sizes if required by a different power supply. The current diesel works and is of a relatively robust design; however it is heavy (60kg), which causes transportation issues, hard to get started (a barrier to being an accessible machine) and is more powerful than required (7hp; 2hp should suffice). The aim is to source 2hp petrol or diesel engine, which will be mounted on a separate, damped extension to the thresher in much the same layout as the current Domasso diesel layout and be flexible depending on local availability of motors.

4.2. Human Powered
More work is required around the human powered option; a human is able to output less than 0.1kw vs the 1.5kw requirement to power the thresher and significant complexity is added by incorporating a gearbox. Once the first prototype has been manufactured research into the inclusion of a human powered put to the drive shaft will be prototyped. To sustain 8-12 hours of activity at a sufficient power to thresh in line with the motor power option will be a tough challenge but adapting the drive system to allow temporary input of human power may be more suitable.

5. Construction Points
There are several places on the Domasso threshers, which collect chaff, which can lead to added friction and wear on the components, lower throughput of material and potentially damage to parts. To minimise this, and to increase safety all joints and seems on the MOST thresher will be welded to seal them avoiding areas for chaff to collect and reducing the number of sharp (dangerous) edges.

The motor will be removable from the main stand of the thresher to aid breakdown and transport, and as discussed above the power input can be addressed separately from the threshing capability as long as the requirement to keep the power input aligned to avoid unnecessary wear on the belt.
6. Assembly Points

Sensible length bolts will be used where bolted connections are used, avoiding the long bolts of the Domasso thresher, guarding will be used over the belt drive section in conjunction with the power input and the changes to the input area will all make the prototype safer than the Domasso threshers.

Where fasteners are used they will be of a standard sizes and as few different sizes will be used as possible.

7. Prototype Manufacture

The prototype manufacture will be carried out using the production drawings created as part of this design process, there will be parts which do not quite work in real life and some parts which are less practical to manufacture than anticipated so the manufacture process will be supervised and feedback from the people doing the manufacture will be incorporated into the revisions for the second prototype.

No specialist equipment will be required for the manufacture of the thresher and If during the prototype manufacture the design requires equipment which is not readily accessibly the design will be modified for simplicity and documented for he second prototype.

8. Other Documentation

Prior to the start of manufacture a full set of manufacturing drawings will be provided to the manufacturer and refined to reflect the actually manufactured prototype No.1 following the completion of the build, a bill of materials will be produced in the same manner and a cost model. Following the manufacture of the first prototype will be carried out in conjunction with the manufacture and a bill of process produced for prototype No. 2 manufacture.