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Sustainable Design And Manufacture Of A Maize Seed Grading Machine For Small Scale Farmers

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Abstract: ***This paper seeks to present the Design and Manufacture of a Maize Grading machine coupled with a pre-cleaner using Inventor and AutoCAD, for small scale farmers in Zimbabwe. The lack of post-harvest, agro-processing machinery which can clean, grade and pack the grain for market has prompted this design. The aim of the project is to design and manufacture a low cost machine with a capacity of 1500 kg/h which can clean, grade and pack maize grains continuously for small scale farmers to guarantee the small scale farmers (SSF) of good quality grains before taking them to the buyers in Zimbabwe. The design will help the SSF realize their full profits after harvesting. The design consists of a winnowing fan, three grading trays and three packaging outlets. The grains will be graded in accordance to international sizes. The designers applied a special matrix grid to choose the best grading concept (best possible solution) from the three solutions available and applied the knowledge of machine design and strength of materials to optimise individual components. The machine managed to grade the maize into three categories, thus large (13), medium (9) and small (8). Autodesk Inventor 2019 Professional was used to make all the design analyses, and AutoCAD 2018 was used to generate 2D working drawings for conceptualisation as well as to simulate functionality of the design. It was noted that farmers were being short changed when they are selling their produce thereby losing on profits. This design will go a long way in improving the livelihoods of the farmers and reducing time spent with buyers pre-cleaning and sorting maize into different grades.***

Keywords: maize, grades, machine, farmers, design

I. INTRODUCTION

Maize is a crop developed from a plant grown naturally in South America and has become one of the world's largest food grains [1]. Yellow maize is grown all over the world as a feed source for livestock such as poultry, pigs and cattle and white maize is grown as an industrial feed stock to produce starch and alcohol. It is an important food crop in Zimbabwe which earned the country the name "Bread Basket of Africa" and is also a cash crop with ready market both on the formal and informal markets as well as export. Hence its production has become a popular activity in both rural and urban areas of Zimbabwe. The country's maize price is expected to remain at $390 per tonne which is about 30 percent higher than prevailing regional market prices of $290 per tonne. Grain Marketing Board (GMB) has urged farmers to deliver their maize and small grains directly to all its depots throughout the country. The paper will articulate the design of the different components of the machine which include the trays, shafts, the frame, selection of motor, feeding chutes, and the outlet chutes for the different sizes of the grans. Furthermore, the paper will outline the particular gran sizes from the outlet chutes. At the present moment, the SSFs are having challenges in selecting and grading their grains. This is one major challenge as they cannot bargain for higher prices of their produce. The design is going to address the problem of quality since the grains are graded in different categories.

A. PROBLEM BACKGROUND

In Zimbabwe, small scale famers (SSFs) pack their maize into 20 kg bags without sorting the maize seeds into different grades after threshing and pre- cleaning. The Pre-cleaning process is done manually using winnowing or hand picking and sieving methods due to lack of the suitable agro-processing machines. Winnowing and sieving are used to remove chaff while handpicking is used to get rid of undesirable maize (rotten, impurities and deformed grain particles) grains. These processes are long, monotonous poses a health hazard to the SSF in the form of fatigue, resulting in stress, depression and tuberculosis as the farmers do not use any form of personal protective clothing (PPE) to the farmers. The grading process is then done by the GMB and other grain buyers. In this regard, the small scale farmers are short-changed when they sell their produce thereby losing on profits.

B. STATEMENT OF THE PROBLEM

The lack of post-harvest, agro-processing machinery which can clean, grade and pack the grain for market has prompted the design and manufacture of the low cost machine with a capacity of 1500 kg/h which can clean, grade and pack maize grains.

C. AIM OF THE DESIGN

The aim of the project is to design and manufacture a maize seed grading machine that has the capacity of 1500 kg/h for SSFs in Zimbabwe.

D. OBJECTIVES OF THE DESIGN

The objectives of the study are:

- ✓ To design a suitable eccentric drive shaft for proper machine vibration.
- ✓ To design a fan drive shaft for the blower.
- ✓ To design and make the grading tray with three outlet chutes.
- ✓ To design and make two grading sieves to grade the grains into three categories, thus large, medium and small.
- ✓ To design and make the frame to hold and support a load of 9.8 kN.

II. RESEARCH DESIGN

The researchers undertook the Mixed Research Methods (MRM) approach and observations to gather information from the population. MRM is a collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially [2]. Although the MRM approach uses both qualitative and quantitative data collection and analysis, such studies are often marginally mixed in that the types of questions asked and inferences made are either quantitative or qualitative in nature [3]. The MRM approach was considered to be the most appropriate paradigm for this study in the sense that qualitative data collected from the SSF, grain buyers and seed making companies were quantified to justify the need for the maize seed grading machine. The qualitative aspects of the study involved the data collection methods such as interviews and questionnaires.

The researchers designed three different questionnaires, thus for the SSFs (35), grain buyers (20) and the seed making companies (10). Convenience random sampling was used and the response was 98%. Some interviews were conducted and 80% of the SSFs concurred with the grain buyers that there is need for the grading machine.

During the design, the researchers consider all the design stages that include identification of problem, gathering information, generating ideas, modelling, feasibility study, evaluation, decision, and communication [4].

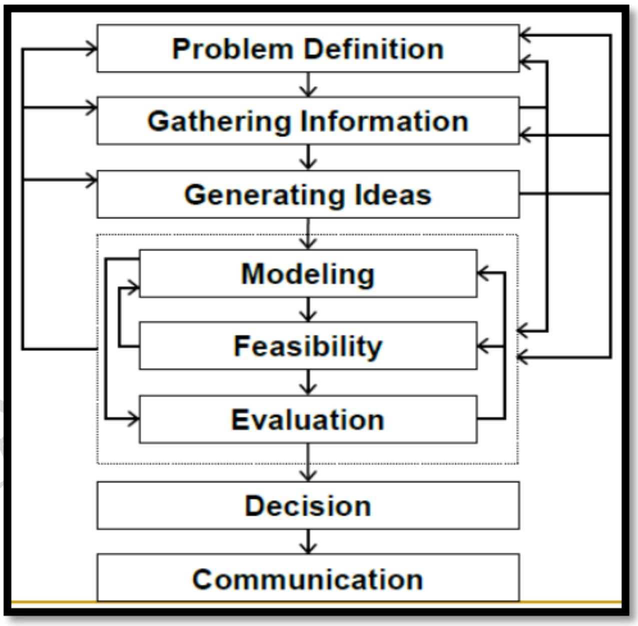

Figure 1: Generic Engineering Design Process [5]

III. SELECTION OF THE POSSIBLE SOLUTION

During the process of designing the machine, the designers considered three possible solutions of different grading mechanisms. The mechanisms include gravity grain screening, revolving cylinder and the vibrating screens. The number of major components for the machines were 7, 8 and 6 respectively. Number of components rating is shown in Table 1 below. In considering these designs, the designers considered the following criteria: operating conditions; design simplicity; number of major components; affordability; maintainability and production process [6]. These parameters were also considered in the grading system concept scoring matrix as shown in Table 12 in order for the designers to come with the best solution [6].

No. of Major Components	Rating
1 – 3	Excellent - 4
4 – 6	Good - 3
7 – 9	Fair - 2
+10	Poor - 1

Table 1: Number of Major Components and Rating

Possible solution A and B in Table 2 were rejected on the basis of the total score while solution C was accepted on the same basis. The total scores were 300, 280 and 360 respectively. The designers went on to further develop possible solution D due to its appropriateness to the operating conditions and optimum number of components.

		Concepts					
		A Gravity Grain Screening		B Revolving Cylinder	*(Ref)	C Vibrating Screen	
Selection Criteria	Weight %	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Operating Conditions	40	4	160	3	120	4	160
No. of Major Components	20	2	40	2	40	3	60
Simplicity in Design	20	2	40	3	60	3	60
Affordability	20	3	60	3	60	4	80
Total Score			300		280		360
Rank			2		3		1
Continue?			No		No		Develop

Table 2: Grading System - Concept Scoring Matrix

IV. DESIGN RESULTS

The design was done using Autodesk Inventor. The material geometric and mechanical properties are shown in Table 3. The extract was taken after the Inventor analysis. The most critical properties being the section area (A), moment if inertia (I_X) and (I_Y), torsional rigidity (J), and torsional section modulus (W_Z).

Geometry Properties	Section Area (A)	378.863 mm^2
	Section Width	40.000 mm
	Section Height	40.000 mm
	Section Centroid (x)	11.619 mm
	Section Centroid (y)	11.619 mm
Mechanical Properties	Moment of Inertia (I_x)	54269.906 mm^4
	Moment of Inertia (I_y)	54269.906 mm^4
	Torsional Rigidity Modulus (J)	3428.404 mm^4
	Section Modulus (W_x)	1912.218 mm^3
	Section Modulus (W_y)	1912.218 mm^3
	Torsional Section Modulus (W_z)	448.939 mm^3
	Reduced Shear Area (A_x)	138.460 mm^2
	Reduced Shear Area (A_y)	138.460 mm^2

Table 3: Material Geometric and Mechanical Properties

A. MACHINE FRAME STRUCTURE

The structure of the machine was loaded on various members with uniformly distributed loads shown in Table 4 and the loads are shown in Figure 2. The load used for the design is the maximum load of the machine 9.8 kN.

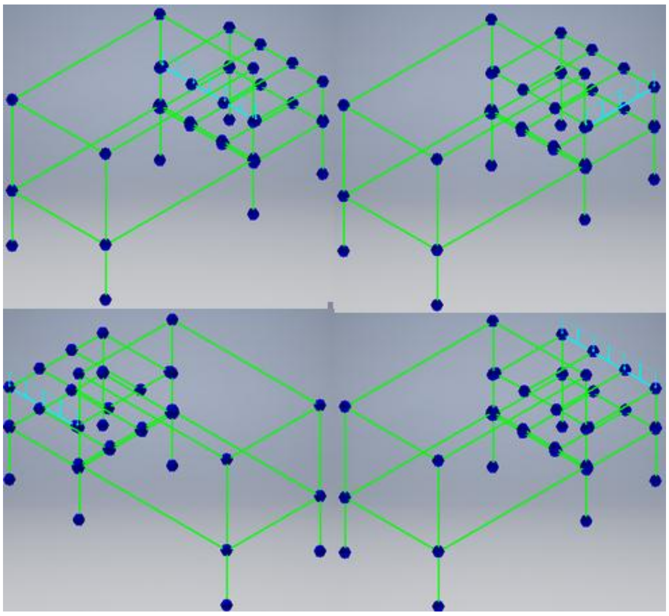

Figure 2: Loaded Parts of the Frame

B. REACTION FORCE AND MOMENT ON CONSTRAINTS

The frame's six upright members were all fixed to the ground as fixed constraints 1 up to 6. The resulting reaction magnitude of each member is shown in Table 4 each with its horizontal and vertical component result. The reaction moment is also shown in the Table 4. The reaction moment magnitudes were 69 kN, 68.9 kN, 76.5 kN, 39.2 kN, 39.7 kN, and 76.3 kN respectively.

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Components (Fx,Fy,Fz)	Magnitude	Components (Mx,My,Mz)
Fixed Constraint:6	6165.706 N	-218.053 N	76238.126 N mm	70301.520 N mm
		-619.264 N		-29494.884 N mm
		6130.652 N		3.702 N mm
Fixed Constraint:4	9478.839 N	-70.467 N	39686.427 N mm	-38598.194 N mm
		205.938 N		-9229.933 N mm
		9476.340 N		-16.850 N mm
Fixed Constraint:3	9479.523 N	69.050 N	39247.139 N mm	-38219.036 N mm
		204.087 N		8924.291 N mm
		9477.075 N		15.434 N mm
Fixed Constraint:5	6165.979 N	217.812 N	76473.135 N mm	70584.244 N mm
		-620.431 N		29427.962 N mm
		6130.817 N		-4.452 N mm
Fixed Constraint:2	4496.062 N	-212.327 N	68787.471 N mm	-63455.882 N mm
		411.710 N		-26553.101 N mm
		4472.134 N		8.710 N mm
Fixed Constraint:1	4495.472 N	213.984 N	69000.127 N mm	-63777.840 N mm
		417.961 N		26332.576 N mm
		4470.882 N		-9.031 N mm

Table 4: Reaction Forces and Moment on Constraints

C. STATIC RESULT SUMMARY

The static result summary of the design frame shows different parameters. The parameters include displacement, forces, moments, normal stresses, shear stresses, and torsional stresses. The most critical values of these are the maximum values. The maximum displacement shown is 6.282 mm; the maximum moment is in the vertical direction and its magnitude is 9.63 kN; maximum moment is in y-direction of value 554 kNmm; normal stress maximum is 289.7 MPa; shear stress value of 132.9 MPa and torsional stress of 3.34 MPa.

Name		Minimum	Maximum
Displacement		0.000 mm	6.282 mm
Forces	Fx	-18395.740 N	18359.764 N
	Fy	-2314.076 N	2313.628 N
	Fz	-1940.774 N	9629.035 N
Moments	Mx	-211007.607 N mm	291090.518 N mm
	My	-631605.911 N mm	553993.433 N mm
	Mz	-1500.828 N mm	1437.837 N mm
Normal Stresses	Smax	-22.823 MPa	286.231 MPa
	Smin	-457.082 MPa	5.029 MPa
	Smax(Mx)	0.000 MPa	110.347 MPa
	Smin(Mx)	-152.227 MPa	0.000 MPa
	Smax(My)	0.000 MPa	289.712 MPa
	Smin(My)	-330.300 MPa	0.000 MPa
	Saxial	-25.416 MPa	5.123 MPa
Shear Stresses	Tx	-132.599 MPa	132.859 MPa
	Ty	-16.710 MPa	16.713 MPa
Torsional Stresses	T	-3.203 MPa	3.343 MPa

Table 5: Static Result Summary

D. DISPLACEMENT AND STRESSES

Table 5 results are confirmed by those Figure 3 design results. The maximum displacement, moment and normal stress are all shown in Figure 3.

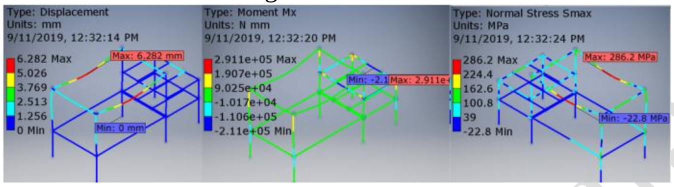

Figure 3: Displacement, Moment and Normal Stresses

Bending Moment and Stresses of the Frame Structure

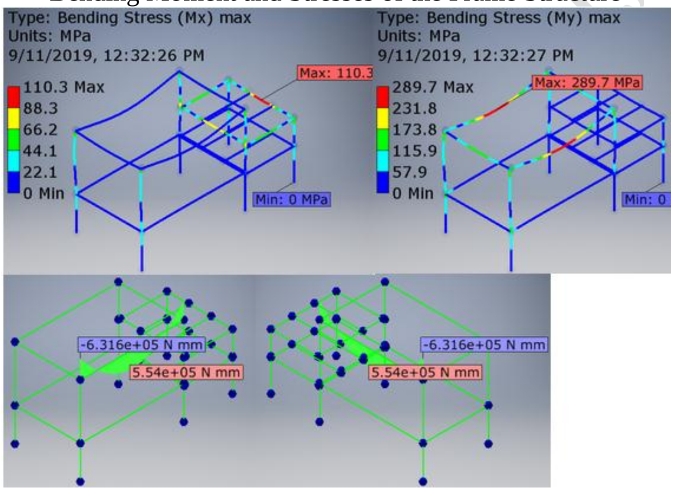

Figure 4: Bending Moment and Bending Stress Diagrams

Figure 4 shows the structure's bending stress and bending moment diagrams of two frame members. The maximum bending stress is 289.7 MPa. The maximum moment for the two members is shown to be acting at the centre of the members.

E. DESIGN PARAMETERS

The designers settled on design concept C (360) which was further developed to detailed design and pictorial design. The pictorial design is shown in Figure 5 below. Table 3 below shows the design parameters of the chosen concept.

DESIGN DESCRIPTION	DESIGN PARAMETERS
Eccentric shaft	Centre distance : 13 mm Diameter : 30mm Diameter of throw : 38mm Eccentric shaft output: 100 – 150rpm
Fan Drive Shaft	Dia. 28mm
Blower	N0. Of blades : 4 Max airflow : 3.5 m/sec
Grading Tray	Large: sieve N0. 13 Medium: Sieve N0.9 Small: Sieve N0. 8
Grading tray inclination angle	3 – 7 degrees
Electric motor speed	2800rpm
Efficiency of electric motor	80 – 90%
V – belt A section	13 mm Mass – 0.099kg/m Max load – 71.6KN

Table 3: Design Parameters of the Chosen Design

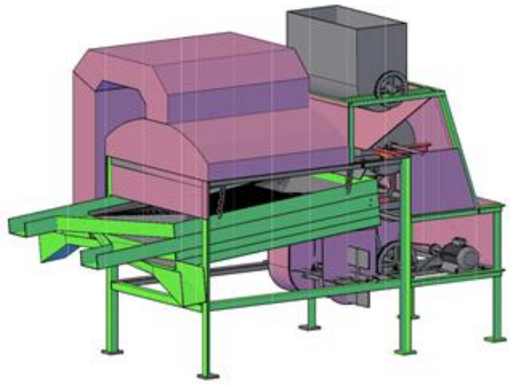

Figure 5: Final Design Maize Grading Machine

V. RESULTS

After optimisation of the major components by Inventor, the 2D drawings for production were produced using AutoCAD as well as 3D drawings for simulation using Inventor. Shown in Figure 2 above is the 3D model of the Pre-Cleaning and Grading machine for small scale farmers in Zimbabwe.

The design consists of the hopper at the top, grading tray, the frame and the drive system which drives the tray and maize pre-cleaning fan. When it was tested, the machine worked to the satisfactory of the stakeholders. It attained the specifications outlined in table 4 below.

Maize Grain Description	Sieve Sizes
Flat Maize Category	Large: 13 Medium: 9 Small: 8
Round Maize Category	Large: 13 Medium: 9 Small: 8

Table 4: Maize Size Description

VII. CONCLUSION

As Zimbabwe implements critical transformative policies such as Transitional Stabilisation Programme (TSP) there is need to invest in critical agro-processing technologies to improve the livelihoods of the SSFs in Zimbabwe [7]. As institutions of higher learning it is our duty to incorporate applied research to solve socio-economic challenges the nation has been going through.

VIII. RECOMMENDATIONS

Institutions of higher learning should:

- ✓ Transform learning, training, research and intellectual excellence to generate agro-processing technologies for farmers.
- ✓ Apply research to generate solutions to socio–economic challenges facing people in the communities to improve their livelihoods.

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