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DESIGN OF MECHANICAL TEF HARVESTING MACHINE

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ABSTRACT

Ethiopia use makes use of traditional tef cutter (Mached) manually operated to accomplish the cutting. This method is time and labors consuming, and causes to tef not harvested on time. In order to design of tef harvesting machines, physical and mechanical properties of tef stem must be known. The cutting force for tef stems was measured by designing and fabricating a static and dynamic shear test apparatus and cutting force, cutting energy and power have been evaluated. This research work is focusing on ease of harvesting operation to the small land holders for harvesting of tef in less time and at low cost of equipment, ease of operation.

Keywords: Cutter Cost Of Equipment, Machine To Harvest Tef More Efficiently, Effective Handling, Time Of Operation.

I. BACKGROUND AND JUSTIFICATION

One of the economical cereal crops in Ethiopia is tef. It is indigenous to the country, and is a fundamental part of the culture, tradition, and food security of the people. This crop is gaining international recognition and acceptance, and is a means of foreign currency earning in addition to its value as food and industrial crop at home. Currently, tef is grown on approximately 2.80 million hectares of land which is 27% of the land area under cereal production. Tef accounts for about a quarter of the total cereal production and is highly economical food grain in Ethiopia. Approximately, 6 million households grow tef and it is the dominant cereal crop in 30 of the 83 high-potential agricultural woredas (Bekabil et al., 2011). The grain, after grinding and fermentation of the dough, is used to make a thin flat pan cake called 'injera"(Eleni, 2001).

It is well known that the agriculture sector in Ethiopia in general and the tef harvesting in particular depends very much on man power labor. Manually harvesting Tef is the most common in our regions. It is time-consuming, laborious and ergonomically unjustified. Today is the day of technology. Ethiopia is in the way of growth and transformation. Mechanization must have own contribution for this growth. Design mechanical harvester is unquestionable to solve all problems listed above.

Knowledge of the plant physical and mechanical properties is important for understanding the plant material reaction to cutting forces and deformation. It will also make it easier to find logical solution to improved cutting devise design (Persson, 1987). Cutting is often accomplished by shearing the plant material between a stationary counter shear and a moving knife. Therefore it is necessary to determine the physico-mechanical properties such as diameter, length, shearing and bending stress and energy. Study the shear strength for cutting stems is very valuable for selecting design and Operational parameters of equipments. Studies on the mechanical properties of tef stems seem to be justified the characteristics of lodging strength but also due to the heritability of the mechanical parameters observed by the variety [1].

Studies of cutting energy requirements have been conducted on winter rape [3], hemp [5], pea [6], rice [7], soybean stalks [8], alfalfa and wheat [9], cotton stalks [11], maize stalks [12] and pyrethrum flowers [13]. These studies showed that cutting energy is related to the stem mechanical and physical properties. Furthermore, most cutting experiments were conducted using pendulum type apparatus or shear rig, which may not fully represent the cutting process using reciprocating knives.

Persson (1987) reviewed several studies on the cutting speed and concluded that cutting power is only slightly affected by cutting speed. studied the required shear energy for two varieties of rice and a variety of wheat in cutting speeds of 2.53 and 4.5m/s and edge angle of 20 ^{0}and 40^0 [15].

II. OBJECTIVES

The main objective of this research is to design mechanical cutter to harvest tef stem.

III. LITERATURE REVIEW

3.1 cutting of grains stem

In all cutting process, failure in shear or impact or both is possible when a system of forces act on the material. Before shear failure, the material is invariably first compressed then bend which increases the work required in a cutting operation [2]. O'Dogherty et al (1991) studied the impact cutting behavior of grass and straw stems with sharp and blunt blades. At low cutting speeds of grass stem, about 65% of the energy was utilized in overcoming friction. For straw the frictional component was relatively low (5-10) %and stem kinetic energy was equal about 20% of the total energy input. Tuck et al (1991) studied the performance characteristics of rotary cutting mechanisms when cutting single and groups of grass stems. Results showed that when cutting groups of stems most uncut stems occurred at speeds of 20 m/s and less for blunt blades.

Ghahraeiet al (2008) designed and developed a special cutting system for sweet sorghum harvester. Developed cutting mechanism in this research had a rotary disk with 50 cm diameter and four cutting blade. The stalks cut with the impact inertia forces at the linear velocity of 27 m/s by cutting blade. The stalks cut with the impact inertia forces at the linear velocity of 27 m/s by cutting blade. Harvesting tests in sweet sorghum farm with forward speed of 5km/h and tow series of blade with angles 30° and 45° on stalk were accomplished. Blade with 45° angle accomplished a fine cutting on stalks. Field test of harvester for harvesting of 1 ha had total harvesting time of 45 minute including gathering of harvested stalk without any crushes or uncut stalks. Persson (1993) designed, built and tested a rotary counter shear mower. It consisted of two concentric counter-rotating discs. Results of tests showed that increase of forward speed will improve the cutting performance. Cutting speed with this type of rotors is less than other type of rotary disc cutters. Field experiments on alfalfa showed that the power consumption was less than 1.6 kW/m of cutting width. The rotary counter shear mower worked satisfactory in fine crops, tangled crops and crops mixed with residue.

Bautista et al (2005) designed a rotary cutting reaper for rice. Their purpose was replacing the reciprocating cutter bar assembly with a rotary cutting system borrowed from grass cutters. These rotary cutters require fewer blades and less manufacturing tolerance. From the laboratory studies, the number of blades per disc was set a three; blade tip speed was set as 23- 30 m/s and forward speed ranged from 2.8 t0 3.3 km/h.

3.2. Design Consideration

3.2.1. Design of power transmission

The power transmission systems used in the design of machine are shaft, bearing, rotary knife and clutches.

Design of shaft

A shaft is a rotating machine element that transmits power (Khurmi and Gupta, 2005; Nwaigwe et al, 2012). The design of shaft includes the determination of the correct shaft diameter to ensure satisfactory strength and rigidity while transmitting power under various operating and loading conditions. Design of shaft is based on the maximum shear stress theory. Shafts are usually subjected to torsion, bending, and axial loads. For a solid shaft having little or no axial loading, the diameter of the shaft can be calculated using the equation given by ASME code (ASME, 1995) as:

$$d^3 = \frac{16}{\pi \tau_{max}} \sqrt{(k_b M_b)^2 + (k_t M_t)^2}$$ ………………………………………………………………… ….. E.q.1

where:

d = diameter of the shaft (m),

M_t = tensional moment (Nm),

M_b = bending moment (Nm),

K_b and K_t = combined shock and fatigue factor applied to bending and tensional moment respectively.

Kb = 1.2 to 2.0; Kt= 1.0 to 1.5. τ_{max} = allowable stress (55 MPa for shaft without key way and 40 MPa for shaft with key). For rotating shafts, when load is suddenly applied (minor shock): It must be noted that factor of safety need to be considered in actual design work. The standard sizes of transmission shafts are: 25 mm to 60 mm with 5 mm steps; 60 mm to 110 mm with 10 mm steps; 110 mm to 140 mm with 15 mm steps; and 140 mm to 500 mm with 20 mm steps (Gupta and Khurmi, 2005).

The material used for shafts should have the following properties:

- It should have high strength.
- It should have good mach inability.
- It should have low notch sensitivity factor.
- It should have good heat treatment properties.
- It should have high wear resistant properties.

This shaft transmits power between the source and the machines absorbing power and carry machine parts such as blade, gear and bearing, therefore they are subjected to bending in addition to twisting then stresses due to combined tensional and bending loads. When the shaft is subjected to a twisting moment (or torque) then the diameter of the shaft may be obtained by using the torsion equation.

T= $\frac{\pi}{16} x\tau x d^3$

………………………………………………………………………………………… E.q. 2

Where:

T= Twisting moment (Torque) acting upon the shaft.

τ =Tensional shear stress.

D= Diameter of shaft,

Shafts are usually subjected to torsion, bending, and axial loads. For a solid shaft having little or no axial loading, the diameter of the shaft can be calculated using the equation given by ASME code (ASME, 1995) as:

M=$\frac{\pi}{32} X\sigma_b X d^3$

……………………………………………………………………………………..………E.q.3

Where:

M: Bending moment,

σ_b: Bending Stress

3.2.2 Rotary Knife Design

$F_{cutter} = S_{cutter} \times A_{tef\ stem}$

………………..…………………………………………………………………… E.q.4

Where:

F_{cutter} =Cutting Force, S_{cutter} = Maximum shear stress

$A_{teff\ stem}$ = Cross-sectional area of teff

$$A_{teff} = \frac{\pi d^2}{4}$$

…………………………………………………………………………………………. .E.q.5

3.2.3 Rolling contact bearing selection

The deep groove ball bearings are selected due to their high load carrying capacity and suitability for high running speeds. The load carrying capacity of a ball bearing is related to the size and number of the balls.

3.2.4 Life of a Bearing

The life of an individual ball (or roller) bearing may be defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements.

The rating life of a group of apparently identical ball or roller bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of a group of bearings will complete or exceed before the first evidence of fatigue develops (i.e. Only 10 per cent of a group of bearings fail due to fatigue).

IV. MATERIAL AND METHOD

A pendulum type dynamic tester was fabricated. It shows the different forces acting on the blade edge and pivot point in order to find out the cutting forces in laboratory which enables to assess the designed cutting energy for tef stem diameter and moisture content. The physical parameters like stem diameter, moisture content, etc. of tef stems were calculated through standard methods.

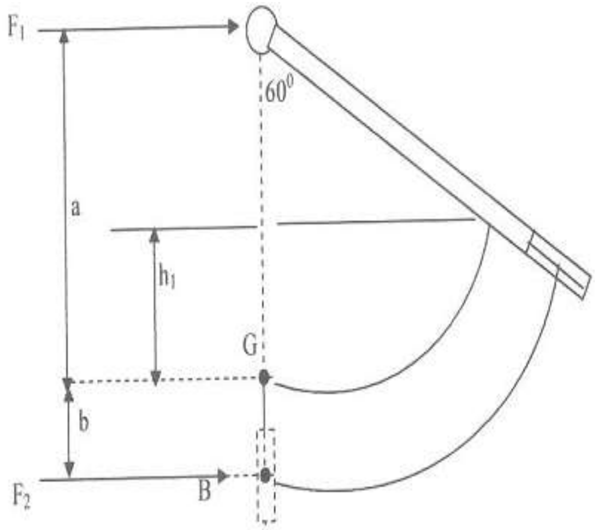

Fig 1. Schematic diagram of pendulum type dynamic tester

Where,

F_1 and F2: Force acting at pivot (A) and at cutting point of blade (B).

h_1- Distance between centre of gravity and centre of gravity of pendulum at Releasing angle.

4.1 Cutting energy

The cutting energy of the stem was determined by the difference between θ_2 and θ_1. Expressions for determining cutting energy requirement and peripheral knife speed were given as stated by Prasad and Gupta (1975). The energy dissipated in cutting a specimen in given formula

$$E = W L (\cos \theta_2 - \cos \theta_1) \quad \text{E.q 6}$$

Where,

E = Energy dissipated, (kgm)

W = Weight of the swinging part, (kg)

L = Distance of centre of gravity of the swinging part from the pivot point of the pendulum, (m)

θ_2= Maximum angle of deflection on the pendulum frame from vertical after cutting the specimen, (deg)

θ_1= Maximum angle of deflection of the pendulum from vertical at the end of free swing, (deg)

θ_s = swinging angle

4.2 Maximum cutting force (N)

$$F_{max} = \frac{2E}{d} \quad \text{E.q. 7}$$

Where,

F_{max} = is maximum cutting force (N)

d= is stalk diameter (m).

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4.3 Determining moment of inertia

Teff stalk like of most cereal has circular and hollow shape, thus its moment of inertia obtained from equation-3 as bellow:

$$I = \frac{3\pi d^3 t}{32} \quad \text{E.q. 8}$$

Where

t is thickness of wall (mm)

d is diameter of stalk (mm).

4.4 Blade velocity

The maximum blade velocity at impact can be determined by nothing the angle of swing between the vertical and rest position. When the pendulum weight W is released through an angle θ,

$$V = \sqrt{2gL(1 - \cos\theta_s} \quad \text{E.q.9}$$

4.5 Moisture content

The moisture content of the tef stem was measured according to standard method. About 500 gm sample of stem was kept in an oven for 24 hours at 105^{0}C. The loss in weight of the sample was recorded and the moisture content in percent was determined as in equation.

$$MC = \frac{W_i X W_d}{Wi} X100 \quad \text{E.q.10}$$

Where,

MC = Moisture content, per cent,

W_i = Initial weight, kg, W_d = Dried weight of sample, kg

4.6. Design Considerations

The tef harvesting machine was designed on the following considerations.

The materials for the construction of the various component parts were selected on the basis of the force that would be acting on them, the work they are expected to perform and the environmental condition in which they would function.

4.7. Description of the Machine

The major components of the tef harvesting machine has the frame contain 2HP gasoline engine, power transmission shaft, bearings and cutting blades.. Figure 2 gives details of designed machine drawing using catia software.

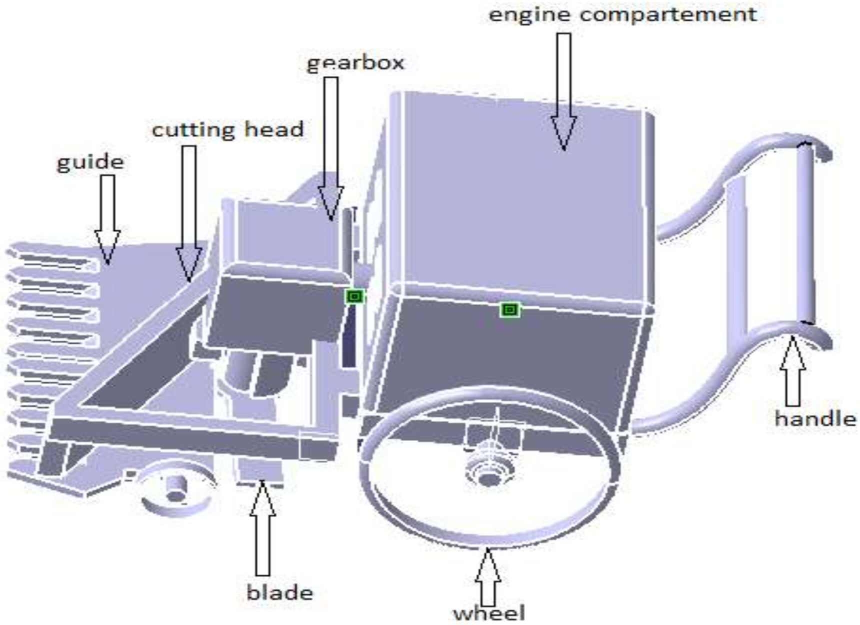

Fig 2. Diagram for Tef harvesting Machine

VI. RESULTS AND DISCUSSION

6.1 Physical properties of teff stem

The physical properties of teff stem is measured and listed on the following table

Table 1.Average of measured values for physical properties of teff stalks

.variety	Thickness of wall (mm)	Diameter of stalk (mm)	height of stalk (m)
Dessie	0.12	1.9	0.78
Tiffany	0.10	1.5	0.73

6.2 mechanical properties of tef stem

Cutting force is calculated and cutting energy is determines.

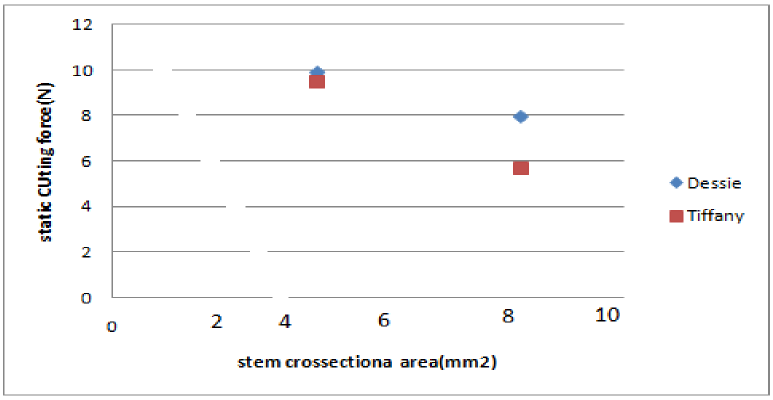

Fig.3 .Effect of stem cross-sectional area on the static cutting force at moisture content of 15% (wet basis).

Effect of stem diameter on cutting energy and force

It showed that the cutting energy and force required for cutting teff stems increased as the diameter of the stem increases.

Effect of moisture content on cutting energy and force

It was observed that the cutting energy and force for tef stems decreases with increases in moisture content. The moisture content has expressed a increasing effect on cutting energy and force. Increasing moisture content leads to decreased cutting energy.

Design of teff stem cutting important parameters

The components of the machine is designed according the formula and summarized according to the table 2

Table 2 Important parameters to be used in the design of a teff harvester

parameter	value	parameter	value
Cutting blade length	46 cm	Width of removable frame	78cm
Number of blade	1	Length of removable frame	110 cm
Rotary speed of cutting disk	431 rpm	power of engine	2hp
Diameter of shaft	40mm		

REFERENCE

[1] Bainer R, Kepner RA, Berger EL (1978) Principles of farm machinery, 3 rd ed. Willey, New York.

[2] Bautista E, Regalado JS, Juliano A, Ishihara S, Monobe H, Ramos J, Molinawe L (2005) The Phil Rice-JICA rotary rice reaper: redesigning a technology for Filipino farmers and manufacturers. Rice is life: scientific perspectives for the 21st century 7: 229-232.

[3] Bekabil Fufa, Befekadu Behute, Rubert Simons and Tareke Berhe, 2011. Strengthening the Tef Value Chain in Ethiopia. Ethiopian Agricultural Transformation Agency (EATA). Addis Ababa, Ethiopia.

[4] Chakraverty A, Mujumdar AS, VijayaRaghavan GS,Ramaswamy HS (2003) Handbook of post-harvest technology cereals, Fruits, Vegetables, Tea and Spices. Marcel Dekker Inc, p 883.

[5] Chancellor WJ (1988) Cutting of biological materials. Handbook of Engineering in Agriculture, Vol 1. CRC prero INC, p 35.

[6]. Dawit Tadesse and Hirut Kebede (1995), Germplasm collection, conservation and characterization of tef. Plant Genetic Resources Centre/Ethiopia. Internal Report. Addis Abeba, Ethiopia.

[7] Doris Piccinin, M.S. R.D., Department of Nutrition and Food Service Contributor(s): Tsegazeab Woldetatios, PhD, Agronomy, Medical Interpreter at Harborview Medical Center Date Last Reviewed: December 14, 2010.

[8] Eleni Zaude, 2001. Market Institutions, Transaction Costs and Social Capital in the Ethiopian Grain Market. International Food Policy Research Institute. Washington, DC. USA.

[9] Ephrem Zeleke Kassa and Dr. Ing Zewdu Abdi.2014. Design and Modification of Appropriate Reel Mechanism to Harvest Tef Crop. International Journal of Research in Mechanical Engineering Volume-2 pp. 15-25.

[10] FAO (Food and Agriculture Organization). 1997. Concept, Selection, Testing and Evaluation of Farm Machinery. FAO Bulletin. No. Document, FAO, Rome.

[11] Ganesh CB, Gunner KH (2007) Low cost mechanical aid for rice harvesting. J Appl Sci. (23):315-318.

[12] Jafarinaeimi, K. Development of measurement system of cutting force and design of cutting system for Atriplex harvester. Unpublished M. S. Thesis. College of Agriculture. Tarbiat Madres University (TMU), (1996).

[13] Koniger R (1953) tentative theory for the cutting of plant stems. Grundlagen der Landtechnik 5: 96-97.

[14] Lawson, O. S. 2004 Crop Processing. Unpublished Lecture Note. Rufus Giwa Polytechnic, Owo, Nigeria.

[15] Michael AM, Ojha TP (1987) Principles of agricultural engineering, Vol 1. New Dehli, ML Jain for Jain Brothers.

[16] O,Dogherty MJ, Gale GE (1991) Laboratory studies of the dynamic behavior of grass, straw and polystyrene tube during high-speed cutting. J Agric Eng Res. 49: 33-57.

[17] Omid ghahraei, m. h. khoshtaghaza and desa bin ahmad(2008) design and development of special cutting system for sweet sorghum harvester. Majlesi Branch, Majlesi New Town, Isfahan, Iran.

[18] Persson S. (1993) Development of a rotary counter shear mower. Trans ASAE. 36(6): 1517-1523.

[19] Pimental, D. (2006). Impacts of Organic Farming on the Efficiency of Energy use in Agriculture.

[20] Seyoum, T. (2007) Grain based Ethiopian traditional common foods and their processing science and technology. Training module for centre of research on grain quality, processing and technology transfer, Haramaya University, Ethiopia.

[21] Sitkey G (1986) Mechanics of agricultural materials. Elsevier science publisher, p 476.