DESIGN AND DEVELOPMENT OF A PUSH–PULL MECHANICAL WEEPER FOR FARMERS’ USE

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Abstract

Weed plant competes with crop plant for soil nutrients, moisture, light and space, thereby reducing the production and increasing cost of maintaining the farm. Many methods of weed control (Mechanical, chemical, cultural, biological) have been tried with varied degrees of success but our traditional farmers cannot adapt them due to their finance, skill, knowledge involved and the land holding system. A push-pull type of mechanical manual weeder was designed and fabricated bearing in mind basic engineering principles with other field requirement using locally available materials. The weeder consists of main frame / handle, soil cutter (wedge), spikes, wheel bearing, bicycle chain and sprockets. The weeder is quite simple, effective and the result is immediately observed. Tests result shows a weeding index (e) of 74.53% efficiency of cutting blades 88% and field capacity of 0.02 ha/hr. Small scale farmers can take advantage of the improved weeder to control weeds on their farms.

Weed control is one of the most important aspects in the present day agriculture. Among the control methods are mechanical, chemical, biological and cultural (Biswas, 1984). The mechanical control of weeds is most widely used. It is the simplest method of weed control being followed by man since agriculture came into practice. The chemical method involves scientific knowledge on the subject and the health hazards involved scares some of our traditional farmers coupled with the cost. (Shiru 1991).

There are many mechanical manual weeder such as the one produced by National Centre for Agricultural Mechanization (NCAM). These have the problem of weight and lack of weed shacker (NCAM, 1989). Also, the John Holt Agricultural Engineering Weeder has the problem of weight and rolling resistance during operation. There are some imported weeders from England (Chillington, Forge Edward Elwell Ltd, wednesbury and Bull dog tools Manchester) Holland and Germany (FAO, 1994). These have generally not been accepted by the farmers due to cost, soil condition i.e. sticky, stony, presence of roots and their foreign design features that did not consider the distinct farming system in Nigeria (Sule, 1993). It is in this regard that a push–pull type of mechanical weeder was designed and fabricated. The manual weeder uses the common features of the bicycle chain drive, puts into the consideration Nigerian farming system and soil conditions. The weeder is affordable and can be maintained by the average Nigerian farmer.

Materials and Method

The push-pull type manual weeder puts into consideration the basic engineering principles and the properties of the soil where the cutter (wedge) will operate. The maximum power output from man combined with functional requirements and cost are combined to achieve the designed objectives. The designs parameters were established after reviewing some literatures and employing the assessed engineering properties of soil on which destruction of weeds will take place. Power transfer device is bicycle chain and sprockets which our traditional farmers are familiar with in terms of use, adjustments, repairs and maintenance.

Power Source and Transfer Calculation/Design

The source of power is manual and from design consideration, a man can walk 1.1m/s (normal walking). This implies that if he is to exert a force (push an object). The speed will be lower than 1.1m/s. An average speed of 0.50m/s was assumed for the weeder operation. A healthy human can develop 0.08kw and more but this of course, varies with the environmental conditions and type of food intake (kaul, Egbo and Onazi 1985). An average power of 65w was assumed (1hp=746watts). A drive wheel diameter of 300mm (0.30m) was assumed (PSG 1995).

Recall that:
Deformation of Soil / Weed with Cutter (Wedge) Actions

Soil/weed may be deformed in a variety of ways when it is worked by a simple cutter. The nature of deformation depends upon the physical and mechanical properties of the soil and angle α subtended by the working force on a horizontal plane (fig 1a)

Phase 1. From fig 1, the working force crushes the soil particles a, b ------- and so on in contact with the surface of the weed cutter, slide over the working face and are forced into the adjacent surroundings. When the weed cutter moves from position I to position II, particles a move to a', b move to position b' and so on. The shift in the intercept aa' and bb' are governed by the displacement of the soil since aa' is greater than bb', bearing stress at point b'. The extent to which soil is crushed by the cutter depends upon its shearing resistance as indicated in the formula

\[ T = C + r \tan \theta \]

\[ T = \text{shearing stress at soil failure} \]

(2) keepner . et al, (1980)
Phase 2. Breaking of the soil weeds begins with the appearance of fissures and fractures or the tearing of the soil layer, as a result of which prism shapes block are formed. The direction of the fissures relate to the row characterized by angle $\Theta$. $\Theta$ may vary widely and depends upon the properties of the soil [fig 1a]. Rigid body soil on soil friction is usually assumed to follow the law for simple friction given by

$$\mu = \frac{F}{N} \tan \psi$$  \hspace{1cm} (3)

Where

- $\mu =$ Coefficient of friction soil on soil
- $F =$ Friction force tangent to the surface
- $N =$ Normal force (perpendicular to the surface)
- $\psi =$ friction angle

The tractive force applied to the cutter is the extent force $P$ which is necessary to balance the resultant force $R$ acting on it due to resistance of the soil. For a simple wedge based equilibrium condition of the forces acting on it, the horizontal component $P_x$ of the tractive force, that is the force causing displacement is obtained as $\text{fig 1c}$

$$P_x = N \sin \alpha + N \tan \Theta \cos \alpha - \frac{N}{\cos \Theta} \sin (\alpha + \Theta)$$  \hspace{1cm} (4)

$$P_z = N \cos \alpha - N \tan \Theta \sin \alpha - \tan \alpha \frac{N}{\cos \Theta}$$  \hspace{1cm} (5)

**Powered Requirement**

Power requirement $P$

$$P = FV$$  \hspace{1cm} (6)  \hspace{1cm} (Bound, 1994)

Where

- $F =$ Velocity of operation
- $F =$ mass x acceleration due to gravity

$M = 9$kg measured using spring balance $j$

$\varepsilon = 9.81$! ($f = 9 \times 9.81 = 81.9$ N

$\nu = 0.23$m/s (calculated)

$$P = 81.9 \times 0.23 = 18.84$w  \hspace{1cm} (from equation 6)

The least power required to operate the push-pull weeder is 18.84 watts.

65 watts was used for the design from field experiment and calculation. Therefore, human power can effectively operate the machine.

**Torque**

The torque is calculated from

$$P = TW$$  \hspace{1cm} (7)  \hspace{1cm} (Hall, et al 1998)

$T = \frac{p}{n}$

Recall that $w = \frac{2\pi n}{60}$  \hspace{1cm} (8)

$n = 32, p = 65w$

The torque was calculated to be 19.4Nm

**Determination of Shaft Diameter**

The shaft diameter was determine by using the equation

$$d = \sqrt[3]{\frac{3}{5.1} \left[\left(C_m M\right)^2 + \left(C_T T\right)^2\right]}$$  \hspace{1cm} (9)  \hspace{1cm} (Reshestov, 1985)
T max = Allowable shares stress for mild steel.
The diameter is 11.05 but for safety precaution 15mm diameter was used.

**Tensile Force on Chain**

Velocity of chain \( V = \frac{P \times N \times R \times \text{Rpm}}{376} \) (10) (Baljit, 2000)

\( P = \) chain in pitch (measured) \( 0.635 \)
\( \text{Rpm} = \) number of rev/min = 32
\( N = \) Number of teeth = 44 (counted on sprocket)
\( V = \) is calculated to be 2.38 ml/s

**Power Rating of Chain (\( P_r \))**

\( P_r = \frac{p_m}{C_2 \times C_3} \) (11) Reshetov (1988)

\( P_m = \) prime mover power in kw, \( c_2 c_3 \) obtained from table.
\( P_r = 0.15 \text{kw}. \) This was used to select the chain

**The Circumferential Force (\( F_u \))**

\( F_u = 102 \frac{p}{V} \) (12)

\( F_u = 2.79 \text{ N}, \)

**The Centrifugal Force (\( F_c \))**

\( F_c = \frac{W V^2}{9.81} \) (13)

\( F_c = 0.548\text{N} \)

**The Total Tensile Force on the Chain (\( F_t \))**

\( F_t = F_u + F_c \) (14)

Calculated to be 3.338N

**Factor of Safety Against Breakage**

The following condition must be satisfied

For static factor (\( S_{st} \)) (Bond, 1944)

\( S_{st} = \frac{F_u}{F_t} \geq 7 \) (15)

For dynamic factor (\( S_{dyn} \))

\( S_{dyn} = \frac{F_b}{F_t \times Y} \geq 5 \) (16)

\( F_b = \) breaking load obtained from table, \( Y = \) conversion factor obtain from table.
\( S_{st} \) is 680 and is greater than 7 \( S_{dyn} \) is 450 and is greater than 5 both static and dynamic forces can not cause breakage on the chain since the condition are satisfied.

**Wearing of the Components**

The bearing pressure \( P_b \) on the link is given by

\( P_b = \frac{F_t}{A} \) (17)

\( F_t = 3.38 \) obtained earlier

\( A = \) area (from table \( 0.67\text{cm}^2 \)

\( P_b = 4.98 \text{n/ cm}^2 \)
The Allowable Bearing Pressure $p_{bp}$ is given by
\[ P_{bp} = P_0 C_1 C_2 \quad (18) \]

\( P_0 \) = obtain from table (242)
\( C_1, C_2 \) correction factors from table 0.3, 0.72
\( P_{bp} \) is calculated to be 52.3N / cm²

The condition to be satisfied is that
\[ P_b < P_{bp} \quad (19) \]

**Bearing Life Calculation**

The bearing life in hour \((L_h)\) is given by
\[ L(h) = \frac{1,000,000}{60n} \left( \frac{C}{P} \right)^{1/2} \quad (20) \quad (ACME, 1987) \]

Ball Bearing number 6002, 62002, 6302 can serve with 15mm diameter shaft.

\( C, k \) constant obtain from tables
\( P = x F_r + Y F_q \) \( x, y \) are constant obtain from table
\( P \) is calculated to be 77.61kN

From equation (20)
\[ L(h) = 8.66 \times 10^7 \]

The value is greater than 3,000 hours so the bearing can serve.

**Chain Length Determination**

Chain length in pitches \((C_{lp})\)
\[ C_{lp} = \frac{m + 2c + s}{2} \quad \left( \frac{c}{P} \right)^{1/2} \quad (21) \]

\( C_{lm} = C_{lp} \times \) Chain Pitch

The chain length was determined to be 1.5m

**Handle Height**

The height was based on the fact that for proper and effective operation, the arm must be at 90° to the elbow and must not exceed angle of inclination of 45° (Adekoye, 1999). There are provisions for adjustment to accommodate larger user since human beings have variation in biodata. (Mc Cormick and Sanders 1982)

**Fabrication of Push-Pull Weeder**

The components of the designed weeder were fabricated using locally available materials. The fabricated components had been assembled and some preliminary performance tests were carried out on the machine (fig 1& 2). The weeder operates by pushing and pulling when force is applied through the handle, cutting blade enters into the soil thereby, cutting the weeds from their roots and the weed spikes removes the weeds off the soil exposing them to the sun. The whole component is supported by wheel fixed with bearing to reduce friction. This is to ease pushing and pulling by the operator in the required direction.

**Conclusion and Recommendation**

Field tests were conducted on Okoro and maize crops planted in rows with inter row spacing of 30cm to ascertain its performance and hence, facilitate necessary modification that would lead to perfection (fig 3). The suitability of the weeder to cut the weeds from the roots was achieved by the sharp vee shaped cutter that penetrate into the soil as a result of the force applied through the handle, though weed spikes left some weeds unturned. Result shows a weeding index \((e)\) of 74.53%, efficiency of cutting blade 88% and field capacity of 0.02 ha/hr.

To enhance the performance of the weeder, it is recommended that the weed spikes be spirally welded or inclined between (30 and 40)° to the direction of movement to improve the exposure of the weed to the sun.
**NOTE:**

All dimensions in millimeter

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**KEY**

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<th>Description</th>
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<td>A</td>
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<td>B</td>
<td>WEED SPIKES</td>
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<td>C</td>
<td>SOIL CUTTER</td>
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<td>D</td>
<td>LAND WHEEL</td>
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Fig. 1  **SHOWING THE PLAN AND ELEVATION OF THE WEEDE**
Fig (2) Assembly Drawing Of Push–Pull Weeder
Testing of Fabricated Weeder
Fig 3 Showing the Weeder in Operation

References


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Design And Development Of A Push–Pull Mechanical Weeder For Farmers’ Use

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