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An emerging method of designing the Flail Mower

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ABSTRACT

In case of cutting of weeds, a system of forces acts upon the material in such a manner as to cause to fail in shear. This shear failure is almost invariably accompanied by some deformation in bending and compression, which increases the amount of work, required for the cutting operation. An impact cutter has a single, high-speed cutting element and relies primarily upon the inertia of the material being cut to furnish the opposing force required for shear. The impact cutting principle is applied in an implement named FLAIL MOWER. The flail mower has knives rotating in vertical planes parallel with the direction of travel. The flail mower includes a cutting member which contains a cutting head named flail knives. The cutting head defines a cutting edge which acts upon material to be comminuted during operation of the rotary impact mechanism. The cutting edge is made wear-resistant by having affixed thereto a plural number of wear-resistant parts made of mild steel metal.

The need for development of effective and economic weed management practices, a research work is carried out in the Designing of a flail mower by an emerging way with the following prime objectives:

- To design cutting mechanism of flail mower
- To develop walking type flail mower
- To evaluate performance of cutting mechanism of walking type flail mower.

1. Introduction

In India, ever since human beings first attempted the cultivation of plants, they have had to fight the invasion by weeds into areas chosen for crops. Some unwanted plants later were found to have virtues not originally suspected and so were removed from the category of weeds and taken under cultivation. But still thousands of land is categorized under pastureland due to lack of cheaper mechanical weed control techniques.

Because, for various reasons, weeds interfere with man's activities, many ways have been developed for suppressing or eliminating them. These methods vary with the nature of the weed itself, the means at hand for disposal, and the relation of the method to the environment. Mechanical weed control, in any event, has become a highly specialized activity employing thousands of trained persons. Universities and agricultural colleges teach courses in mechanical weed control, and industry provides the necessary technology. Governmental workers and private individuals are engaged daily in the practice of mechanical weed control because the growing of food and fiber crops depends on it for current levels of production. The many reasons for controlling weeds become more complex with the increasing development of technology.

An alternative to the more common rotary mower is a Flail mower. Flails do a better job of cutting shrubs and weedy material of the pastureland. The horizontal rotor shaft has many pairs of swinging knives that pulverize vegetation and breakup woody stems. Because the knives are mounted on clevises of flange on rotor shaft, they are free to rebound if they cannot shear some weedy materials on first strike, and thus protect themselves from damage. The vegetation tends to be cut and recut and is scattered uniformly under mower hood. The “V" belt drives the rotor shaft. All these attributes make flails ideal for mowing weeds and general brush clearing operations.

2. Literature Survey

Review of research work carried out by various investigators on various parameters related to mower.

Chancellor (1958) studied the effect of velocity on cutting. It observed that the velocity in the range of 175.26 to 518.26 cm per sec. had no significant effect on force or energy requirement. The energy values at these speeds were of the same magnitude as energy values obtained at a speed of 2.54 cm when all the factors were same.

Dutta, A.C., A.K. Chakravorty and C.P. Gupta (1969) found out the maximum shear stress offered by a crop at a peripheral velocity of knife was higher than 160 m/min.

Nagpal and Aggrawal (1973) while working with energy requirement in a chaff cutter observed that cutting energy vary with moisture content. Energy decrease with increase in moisture content, some observations with cross-sectional area 112.50 cm^2 at 76.5 percent moisture content energy required was 335 kg-cm while it decreased to 328 at 88.5 percent moisture content. Further, at 93.5 percent moisture content it was 288 kg-cm.

Siteki (1986) states that the cutting resistances of younger plants significantly lower than the older plants, also the specific cutting energy increased with the stem diameter.

Mimura, K; Yamada, T (1990) reported a comparative study of the power requirement of down cutting and up cutting flail mowers in Japan. Power required for cutting small diameter (up to 20cm) white oak (Quercus serrata) trees using stirrup shaped cutting blades of the down cutting type was 40 to 50% greater than that for the up cutting type. No difference found between down and up cutting power requirements for brush cutting when tested on bamboo grass (Pleioblastus chino). However, under the same conditions, bamboo grass used 20 to 30% more power than that required for cutting Sasa kurilensis, apparently because the cutting blades clogged with finely cut pieces of bamboo grass, so increasing resistance. Specifications of prime mover and mowers were used and details of tests undertaken in two stands in the Numata National Forest.

Tuck, C.R., O'Dogherty, M.J., Baker, D.E., and Gale, G.E. (1991) evaluated laboratory studies of the effectiveness of rotary cutting mechanisms when cutting single and groups of grass stems were undertaken. The effect of using static stem supports or ledger plates with clearances of up to 5 mm from the cutting blade was investigated. The effectiveness of cutting with single-toothed and plain discs was examined also. The effect of clamping the tops of grass stems was examined for both types of mechanism. A number of mechanism design parameters were investigated and cutting efficacy was assessed by measuring the stubble length of individual stems, together with the number of stems, which were uncut, pulled out of the holder or broken at their base. The critical speed, which is the minimum required for efficient cutting, was also assessed. The use of ledger plates, above and below the cutting blade, resulted in lower critical cutting speeds than for conventional impact cutting when cutting single stems. For groups of stems, however, the critical speeds when using static elements did not differ significantly from those required for impact cutting. Clamping the tops of the stems resulted in very low critical cutting speeds (5 m/s or less). Critical cutting speed was reduced to below 35 m/s by increasing ledger plate length and by utilizing the whole of the blade length during cutting. Lower cutting speeds were also achieved by using a combination of ledger plate and blade angles, which retained stems within the cutting area of the mechanism.

Copland, T. (1993) described briefly the history of rotary shear grass cutting. The principles involved in cutting plant material and the influence of mower knife geometry on cutting are discussed. A project was set up to combine the main advantages of rotary and finger bar mowers, with main objective of reducing energy requirement for mowing, and the developed prototype is described. A mathematical model was used to predict mower-cutting quality and was verified in field tests. It was found that low cutting powers could be achieved, uniform stubble height could be obtained, high spot work rates were possible and machine maintenance was comparable to that of other mowers.

Komarizade, M, H. (2002) studied on energy requirement of hay mowers. In order to evaluate energy consumption of hay mowers, performance of four types of mowers including self-propelled cutter bar mower (binder mower), Integral cutter bar mower, disc mower and drum type mower were studied. The main components of the consumed energy were the machine, fuel and labour energies. Results showed that disc mower with 455.76 Mj/ha and binder mower with 120.86 Mj/ha consumed the highest and lowest rates of energy, respectively. Although there were no significant differences between the tractor mounted mowers, the drum type mower with 422.73 Mj/ha and binder mower with 120.86 Mj/ha consumed the highest and lowest rates of energy, respectively. Although there were no significant differences between the tractors mounted mowers, the drum type mower with 422.73 Mj/ha appeared to have the lowest consumption in comparison with the two other types. Fuel energy showed to have the highest amount among other items of energy; this included 83.4 to 88.5% total energy used by tractor-mounted mowers. Machine energy consumption was directly affected by effective field time. For example among the tractor mounted mowers, the cutter bar mower in spite of its lowest weight had the highest machine energy consumption due to its poor field capacity, likewise, the drum type mower with the highest weight, showed the lowest consumption due to its higher field capacity. Machine energy came out to be between 10.87 and 15.5% total energy for tractor mowers. The measured labour energy appeared to be very low in comparison with the other part of energies. Total energy consumed per hectare per one meter of operating width was 86.32 Mj for binder mower, 187.88 Mj (the lowest) and 284.85 Mj (the highest) for drum type and rotary disc type, respectively.

Erokhin, M.N; Belov, M.I; Sudnik, Yu.A a (2003) carried out theoretical studies on rotary cutting units as found in forage-harvesters and self-propelled or trailed mowers (i.e. with vertical axis of rotation and intended for mowing tall grass). A test rig was developed (layout illustrated) for high-speed cutting, and results are shown in graphs and compared with the theoretical findings. The results indicate that the regime of work of rotary cutters must be capable of being regulated. And the most convenient way of achieving this is by changing the advance speed v, according to the law **v = cR** omega, where R is distance from axis of rotation of the rotor to the furthest part of the blade; omega is angular velocity of rotor (in rad/s); and c is v/R omega..

Purwantana, B; Horio, H; Shoji, K; Kawamura, T (2003) studied a flail-type rotary cultivator is efficacious for swampy land preparation, grass cutting and topsoil treatment. The cutting characteristics of the cultivator were studied in the laboratory to determine the energy requirement for cutting grass stems. The cutting speed was significantly effective in the cutting process. The specific energy required decreased by approximately 58% when the cutting speed increased from 10 to 25 m/second. Effective cutting was achieved at cutting speeds of over 20 m/second. The bent angle of the knife did not significantly affect the specific cutting energy, although less energy was required at bent angles between 90 and 102 degrees. The specific energy required was less when the grass stems inclined towards the machine and when cutting a single stem rather than a bunch of stems. The effect of the number of stems in a bunch on the specific energy decreased as the cutting speed increased.

Patnaik (1982) stated that the power requirement increased with increase of rotor speed. He further concluded that the power requirement decrease with the increase of forward speed.

Ambujam *et al* (1984) designed and developed a rotary paddy weeder powered by a knapsack type 1 KW spark ignition engine. The machine had an operational depth of 70mm with 80 per cent weeding efficiency. The effective field capacity of the machine was 0.022 ha/hr. The average fuel consumption was 0.86 lit/hr.

Singh, R.D. and Ingle, G.S.(1987) studies were conducted on a straight rotary tiller tine to evaluate specific energy requirement during operation under laboratory conditions and a mathematical modes was developed to predict the specific energy requirement in up cut and down cut modes. Input values were 0.05, 0.075, 0.1 & 0.125m depth of operation, 0.093, 0.143, 0.217 and 0.385m/s linear speeds and 148, 212, 328 and 432 rpm rotor speeds. Specific energy found to increase linearly with the increase of the speed of rotovator and to decrease with the increase of linear speed of the machine.

Fawoll (1988) evaluated three models of shoulder suspended, hand guided rotary power weeders in comparison with hand slashing of weeks. The power weeders were operated by 1.86, 1.49 and 1.12 KW gasoline engines. The carrying weights of threes machines ranged from 5.4 to 10 kg with overall lengths of 1600 to 1700 mm. A rigid shaft rotating in a pipe shield by a centrifugal clutch transmitted power from the engine to a saw type rotary cutter. Out of three models the 1.49 KW machine had better performance in terms of both field capacity and weeding cost.

Guzel, et.al.(1990) studied the properties of rotary cutter for cotton i.e. peripheral velocity, impact energy, free cutting curves, cutting points and cutting forces in laboratory and under field conditions. Energy consumption of the blade was 240 to 289kg-m and power requirement was 1.74hp at 540rpm. Maximum and minimum blade velocities were 46.97 to 51.87 and 33.64 to 36.52m/s resp.

Rotz and Mutitar (1992) worked on rotary power requirement for harvesting and handling equipment. A model and parameters were developed for predicting average rotary power requirements for 32 major harvesting and handling machines. Typical power requirement parameters were determined along with an expected range of variation due to differences in machine design, machine condition and crop characteristics.

Victor and Verma (2003) studied on power operated rotary weeder for wetland paddy. He concluded that, the introduction of efficient weeding aids and equipments for weed control seems highly necessary to minimize time consumption, labour requirement and cost. As consequence, a prototype power operated rotary weeder for weeding in wetland rice cultivation was designed, developed. A 0.5 HP petrol driven engine was used for power weeder with a reduction gearbox. The power transmission from engine to traction wheel and to the cutting unit was provided by means of a belt, pulley and chain, sprocket. For cutting the 4 L-shaped standard blades were used on the hub, and in turn fitted on rotary shaft. Two big traction wheels were used to make the operation smooth. A gauge wheel was provided for depth adjustment of the cutting unit. With 200 mm spacing, the field capacity of the machine varied between 0.04-0.06 ha/h with field efficiency of 71%. The weeding efficiency of the machine was 90.5%.

Celik, A (2006) concluded that the engine power should be at least 25% greater than the power required by the mower, to overcome changes of forward speed, forage density and ground topography conditions in the field.

3. Design Considerations

The principle of working of the flail mower is to cut the weed by swinging action of the flail knives above the ground surface without damaging the flail knives when it strikes an immovable object such as rock, stone or the like. The cutting of weeds takes place due to impact and shearing action.

Until now, no work has been done on diesel engine mounted flail mower. Following are the various parts of flail mower to be designed carefully.

4. Cutting Unit

The “Y” shaped cutting edge has been sharpened for easy cutting and fixed at an optimum angle of inclination of 120^0 to its vertical axis. The cutting blade has also been used as an inclined plane to perform cutting the weeds efficiently. Design aspect of cutting unit consists of following considerations.

Design of flail knives

In order to cut the weeds, the peripheral speed of flail knives is calculated by the formula,

$$V_k = \frac{S \times n}{30}$$

Where,
V_k = flail knife speed, m/s
S = Length of stroke, m
n = rotor speed, rpm

Calculations for peripheral speed of flail knives

The peripheral speed of flail knives is calculated by the formula,

$$\mathbf{V_k = \frac{S \times n}{30}}$$

Where,
V_k = flail knife speed, m/s
S = Length of stroke, m = 584mm
n = rotor speed, rpm = 1500rpm

Therefore,

$$V_k = = \frac{584 \times 1500}{1000 \times 30}$$

V_k = 1752 m/min
V_k = 29.2 m/s

Design of Byte length

The byte length for the Flail knives was calculated as follows.

Byte length, mm =

$$\mathbf{\frac{V_k \times \pi \times D}{V_m}}$$

Where,
V_k = Speed of flail knives, m/s
D = Outer diameter of the flange, mm
V_m = revolutions of the rotor shaft, rpm

Determination of Byte length

The byte length for the Flail knives was calculated as follows.

Byte length, mm = $$\frac{V_k \times \pi \times D}{V_m}$$

Where,
V_k = Speed of flail knives, m/s
D = Outer diameter of the flange, mm
V_m = revolutions of the rotor shaft, rpm

$$\text{Byte length} = \frac{29.2 \times 3.142 \times 152}{1500}$$

Byte length = 9.29 mm = 10 mm

Determination of number of blades

The number of blades was calculated by using the expression.

$$Z = \frac{2 \times \pi \times h}{S \times \lambda - 2A}$$

Where,
Z = number of blades
h = maximum depth of operation, m
S = byte length, m
A = blade thickness, m
λ = speed rate $\Rightarrow \lambda = \frac{V_c}{V_t}$ V_k
V_k = cutting speed, m/s
V_t = forward speed, m/s

Determination of number of blades

The number of blades was calculated by using the expression.

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S = byte length, m
A = blade thickness, m
λ = speed rate $\Rightarrow \lambda = \frac{V_c}{V_t}$ $\underline{V_k}$
V_k = cutting speed, m/s
V_t = forward speed, m/s

Speed rate,

$$\lambda = \frac{V_k}{V_t}$$

= 29.2 / 26.1

λ = 1.118

Therefore,

$$Z = \frac{2 \times \pi \times h}{S \times \lambda - 2A}$$

Z = 53.94

$$Z = \frac{2 \times 3.142 \times 0.01}{0.01 \times 1.118 - 2 \times 0.005}$$

Z = 54

Power requirement for cutting

The horsepower required to cut the weed can be found out with the help of formula,

$$H_p = \frac{F_t \times V_k}{75}$$

Where,
F_t = tangential force, m/s
V_k = peripheral speed of flail knife, m/sec.

5. Measurement of cutting unit

A)
Flail knife Specifications

Width, mm	30
Thickness, mm	5
Height, mm	130
Angle of inclination, ^{0}	120^0
Bite length, mm	10
Total number of flail knives	54
Weight of each flail knife, gm	350
Total weight of flail knives, gm	18900
Number of flail knives on each flange, pairs	3
Spacing between two flail knives of a single pair, mm	10
Overlapping distance of each pair, mm	100
Stroke length of flail knife, mm	584
Radial height of flail knife, mm	186
Circumference made by flail knives, mm	1169
Flail knife speed, m/s	29.2
Effective cutting width of pair of flail knives, mm	110
Overall cutting width by flail knives, mm	990
Mean cutting height of weeds, Mm	12.67

B) Flange Dimensions

Outer diameter, mm	152
Inner diameter, mm	62
Thickness, mm	10
Total number of flange on rotor shaft	9
Weight of each flange, gm	1100
Total weight of flange, gm	9900
Spacing between each flange, mm	100
Distance between outer radius and inner radius, mm	45
Circumference of flange, mm	478
Distance of flail knives on circumference of flange, mm	159
Angle between mounting of flail knives, ^{0}	120
Diameter of hole on flange, mm	10
Radial distance of hole from axis, mm	66

C) Self-locking nut and bolt

Standard diameter of nut, mm	10
Standard length of nut, mm	31.75
Type of bolt thread	Fine thread
Type of bolt shape	Hexagonal type

D) Rotor shaft

Hollow rotor shaft specifications	
Outer diameter, mm	62
Inner diameter, mm	59

Thickness of shaft, mm	3
Length of rotor shaft, mm	1000
Solid shaft specifications	
Diameter of connector solid shaft, mm	32
Length of each connector solid shaft, mm	70
Diameter of transmission solid shaft, mm	25
Length of transmission solid shaft, mm	755

6. Selection of material

Design of machine was carried out and the material required for its fabrication was used as per the availability in the market. The available material was used as per the requirements, concerning the function, stressing and the life of the component. In order to reduce the cost of manufacturing, the material used was not so expensive.

Mild Steel

Mild steel is known as soft metal, having less than 0.25% of carbon, able to withstand with the loads that will occur against machine elements, its lower cost, easy availability, it is mostly used in order to reduce the cost of agricultural machines. Hence, for the fabrication of the machine, mild steel was used.

7. Results and discussion

The design of flail mower and its performance analysis is presented. The performance of the flail mower under different field conditions such as height of weeds, intensity of weeds, cutting height of weeds and speed of operation are discussed.

Working of flail mower

The 6hp Lombardini diesel engine started by recoiling the rope manually. When the engine starts, the power is transmitted from the engine pulley ‘A’ to the parallel pulley ‘B’ through v-belt when engage–disengage lever is move down. The power from pulley ‘B’ receives the pulley ‘C’ being both mounted on same shaft and it transmits the power further to pulley ‘D’ and pulley ‘E’ those were mounted on the same shaft as shown in Fig.5.1. The pulley ‘E’ transmits the power to pulley ‘F’ through v-belt. The pulley ‘F’ rotates the rotor shaft along the direction of travel. When the rotor shaft rotates, the flail knives mounted on flanges also rotates with respect to rotor shaft and cutting of weeds takes place. The weeds having height more than 180mm were also cuts efficiently.

Effect of height of weeds on speed of operation

The effect of height of weeds on speed of operation is presented in Fig.5.1. From the Fig.5.1, it is seen that as the height of weeds is increases, the speed of operation decreases. There is decrease in speed of operation from 1.548km/hr to 1.340km/hr when the height of weeds increases from 179mm to 244mm resp.

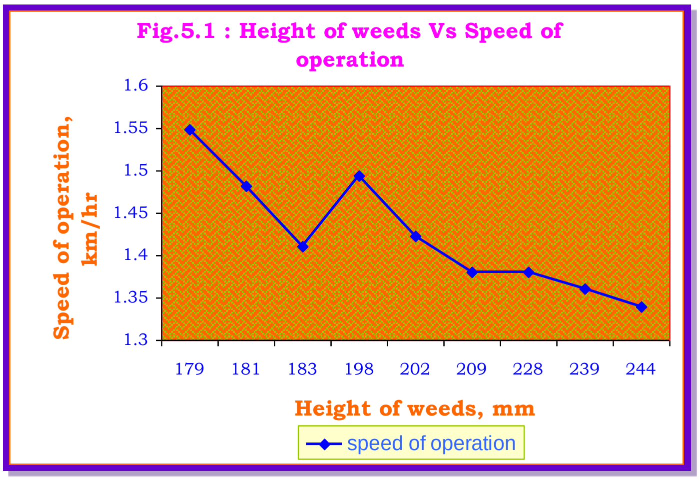
Fig.5.1 : Height of weeds Vs Speed of operation

8. Conclusion

1) The flail mower is able to cut weeds of height from 25 to 220mm above ground level at a cutting height of 10mm to 25mm resp.
2) It is able to cut a wide variety of weeds from thin-dense portion to thick-dense portion, tough stalks, cleanly and without choking.
3) The cutting parts of the mower were protected from rocks, stones etc. and are capable of cutting through occasional mounds of soil without damage.
4) The forward speed of the machine is comparatively higher than the speed of operator.

References

1. Chancellor, W.J. (1958). Energy requirement for cutting forage Agricultural Engineering. A.S.A.E. 30(10) pp. 633-636.
2. Chattopadhyay, P.S. and Pandey, K.P. (2001). Journal of Agricultural Engineering Research, Volume 78, Issue 3, March 2001, pp. 245-252.
3. Copland, T. (1993). Developments in cutting of grass. Journal of Agricultural Engineering Research, Volume 48, Issue 2, pp 38-41.
4. Dutta, A.C., A.K. Chakravorty and C.P. Gupta (1969). Dynamic
5. Shear Stress for different forage crops. The harvester, I.I.T.Kharagpur 111(2) pp.99-103. Ambujam, A.K., Arasu. P, Berty Edwin and S. Chandra Mouli (1984) Design and development of power driven rotary paddy weeder. Unpublished B.E (Ag) project work, Tamilnadu Agricultural University, Coimbatore.
6. ASAE. 2004b. ASAE Standard S472. Terminology for forage harvesters and forage harvesting, In ASAE Standards 2004, 337-340. St. Joseph, MI: ASABE.
7. Celik, A. (2001). Present Situation of Agricultural Mechanization inTurkey. Country Report for Group Training Course on Farm machinery Design. Japan International Cooperation Agency, TBIC, JR, 01-203, Tsukuba, Japan.
8. Erokhin, M.N; Belov, M.I; Sudnik, Yu.A a (2003). Model and experimental study of a rotary cutting unit. Traktory-i-sel’-skokhozyaistvennye-Mashiny. Volume 12, pp.31-34.
9. Fawoll Laurence. O., (1986). Maintenance of tree crop plantations using portable motorized rotary weeder. Agric. Mech. in Asia, Africa and Latin America.
10. Fanigliulo, R; Vassalini, G; Fedrizzi, M (2003). Choice and use of self-propelled mowers : evaluation of performance in operation. Mondo-Macchina Volume 12, Issue 2,pp. 50- 54.

11. Handler, F. (1994) Implements for maintaining fallow grassland. Forde rungsdienst. Volume 42, Issue 7, pp.206,208,210-212.
12. Khadem, S-M-R (1996). Feasibility study manufacturing and test of dual purpose reaper-mounted mower. Journal of Agricultural Sciences Islamic Azad University. Volume 2, Issue 5/6, pp. 61-74.
13. Kogut, S. (1994). Influence of the slope angle of the field on the effective efficiency of selected machines for green crop and grain harvesting. Volume 415, pp.97-104.
14. Komarizade, M, H. (2002). Energy requirements of hay mowers. Proceedings of Eighth International Congress on Mechanization and Energy in Agriculture, Kusadas, Turkey.15-17 October 2002.pp.235-239.
15. Loo, L-van (1997). Experience of users of rotary mowers in Germany. Land bouwmechanisatie. Volume 48, Issue 4, pp.20-21.
16. McRandal and McNulty. 1980. Mechanical and physical properties of grasses. Trans. ASAE, 23: 816-821.
17. Mimura, K; Yamada, T (1990). Brush cutting performance of the forest shredder with flail-type cutters. Journal of the Japanese Forestry Society. Volume 72, Issue 6, pp.513-519.