Computer Aided Design Optimization of Flexible Cultivator

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Abstract: The process of tillage tool operation for soil bed preparation or inter-cultivation by tillage tool-soil interface using a sweep type cultivator is designed by using CAD software. This design is tested for various field conditions to obtain the safe tolerance and the flexibility in terms of adjustable arrangements.The distance between tines for row spacing, types of tines such as C, L, S and the five types of shovels can be applied together with 24 types of combination. The Flexible tillage tool (FTT) is fabricated and the field performance is taken in the various crop patterns .It is most usefull in obtaining high weed removal efficiency. The maximum and minimum width of cut were observed as 18 cm and 8 cm where as the depth of cut were determined as 17 cm and 8 cm. The speed of operation, field capacity, field efficiency were 4.2 km/hr, 0.42 ha/hr, 78%, respectively. The theoretical field capacity and draft force were determined as 0.33 ha/hr and 6.5 kN respectively.The cost of operation was estimated Rs 597.6/ ha (€9.41868/ha). The Computer aided design was created and tested with actual field condition parameters and found a maximum von misses stress noted 138 N/mm$^{2.}$

Key words: Flexible tillage tool, sweep cultivator, CAD/CAM, structural analysis, weed removal efficiency

INTRODUCTION

Tillage Tools

Tillage tools are direct energy in to the soil to cause some desired effect such as cutting, breaking, inversion or movement of soil. Soil is transferred from an initial condition to a different final condition by this process. Seedbed preparation greatly contributes towards the overall cost of farm operations, employing that significant savings are possible through optimized design and development of tillage machinery.

Primary and secondary soil manipulation is the basic operation required for cultivation of any kind of crop. Soil manipulating tools should withstand adverse field conditions, such as the presence of a hardpan, small rocky formations stumps stable during soil engagement without failure.

Soil working tools such as mould board ploughs, disc ploughs and ridger has long been accepted and successfully used by farmers under average field conditions. The duck foot sweep is another kind of soil engaging tool that is popular amongst farmers for secondary field operations because of its large wing width, which causes better coverage of soil manipulation between two furrows.

Flexible cultivator

The Concept of flexibility by flexible tillage tool operations influencing factors and definiations of these factors are given as follows. In Figure 1, proposed flexible cultivator model was shown.
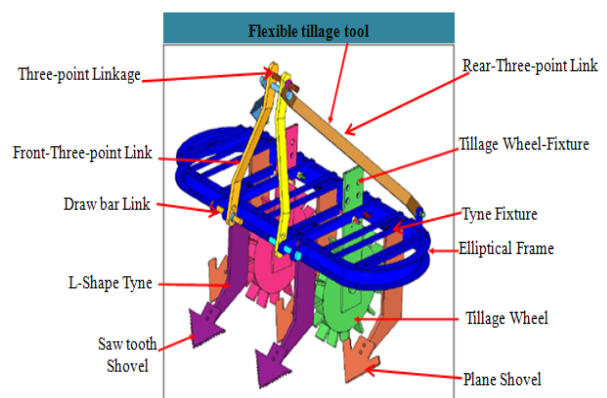

Figure 1. Proposed model for flexible cultivator

Distance between tines as required according to row crop spacing.

Types of tines used as shank for different shovels by different angles.

Types of shovels used as soil utting tool geometry for soil bed preparation and weed control.

It is a cultivator in which different part can be assembled with custom requirements of tool services during tillage operation. The elliptical frame with holes specifying the distances between the tines to be arranged according the crops. C, L and S types of tines can be attached to elliptical frames.

The use of straight blades in mechanical weeder and evaluated in black cotton soils. The draft force per unit working with (D_u) was minimum for the rake angle of 22.01^0, the blade width of 15 to 40 mm may be selected with the thickness of 2 to 5 mm and the blade sharpness angle of 15^0 and below may be used (Biswas, 1993). The shovels such as triangular, triangular with saw tooth, triangular with step tooth, reversible and blade harrow with saw tooth like different geometry are the main highlights of this thesis work.

Objectives of project work are given as below:

- To fabricate the flexible tillage tool cultivator with:
  - Distance spacing row crop pattern,
  - Different types of tines such as S, C and L,
  - Different types of shovel such as plane, saw tooth, step tooth, reversible, and blade harrow.
- Testing and evaluation of flexible cultivator by18.5 and 45 Hp tractors.
- Computer aided modeling& testing by CAD-Software.

MATERIALS and METHODS

The field test tool variables included rake angle to the horizontal of 12.5, 17.5 and 22.5°, working depths of 70, 110 and 150 mm and forward velocity of 1.08, 1.55 and 2.08 m/s. The draft force in different trials varied from 42 to 202.5 daN.

Field Site

The field testing and performance of Flexible tillage tool cultivator is done at C.A.E.&T.,

Marathwada Agriculture University Parbhani(M.S.) during winter 2010. The field site located at 107°North 19.7° east. The soil of the field is black cotton soils.Clay 0.4-0.56kg/cm^2,Slit0.35-0.556kg/cm^2 soil sand 0.2 and loam sand 0.356kg/cm^2

Design of flexible tillage tool cultivator

The design consideration and solutions for systems to measure the forces, displacements and angular position of soil-engaging implements where variation in-both soil shear strength and surface elevation occur are described (Godwin, 1987). Cultivator consist the following main part are hitch arrangement, tine, shovel, leveler, toothed Wheel and tine fixture. Specifications of components for flexible cultivator were given in the Figure 2.

General conditions for field tests

Instrumentation

The reliability of testing data to a great extent depends upon the accuracy of instrumentations. The measuring instruments should have accuracy as specified as below:

Time (s):   ±0.2
Distance: ±0.5%
Force (kgf):   ±2.0%
Mass(kg):   ±0.5%
Rotational speed (rpm): ±0.5%

Selection of test plot

Tillage machinery gives best performance in rectangular fields. The test field should be rectangular with side lengths ratio of 2:1 as for as possible. If the field is irregular then a rectangular test plot should be marked for conducting the test. The other portion of the field could be used for initial setting up and adjustment of the equipment.

Field operational pattern

The field capacity and field efficiency of an implement are affected by field operational pattern which is closely related to the size and shape of the field, the kind and size of implement. The field operational pattern common field operational patterns for rectangular fields are: continuous, circuitous, headland, alternation, overlapping etc.

No:	Components			Specification			Weight (kg/ unit)
				Width (cm)	Length (cm)	Thickness (mm)	
1	Frame			45	121	5	23
2	Tyne Fixture			4	44	0.9	7
3	L shape Tyne			10	45	17.8	6.120
4	C type tine			4.6	45	16.5	4.11
5	Shovel	Plane		15	16.5	7	0.75
		Step Tooth		15	20	7	0.82
		Saw tooth		15	16.5	7	0.61
		Reversible		5	30	5	0.80
		Blade harrow		5	42.5	5	1.85
6	Tillage wheel	Tooth		2	2	6	0.2
		Plate		7.7	46.5	13.5	3.380
7	Nuts and bolts of the frame			-	-	-	0.08
8	Nuts and bolts of the frame			-	-	-	0.2

Figure 2. Component specifications of the flexible cultivator

Speed of operation

The speed of operation will be calculated from the time required for the machine to travel the distance of 20 m between the assumed lines connecting two pole of opposite side. The easily visible point of the machine should be selected for measuring the time.

Duration of test

The test sample should be operated under different soil and surface conditions for a minimum period of 50 ha to establish bits performance. Each test should be of minimum 3 hours. However, for exhaustive testing to establish soundness of construction and durability, minimum testing of 200 hrs is recommended.

Field parameters

There are various parameters to define soil characteristics and surface conditions of the test plot as specified below is observed and recorded.
1) Location of test plot; 2) size of test plot; 3) last crop grown; 4) detail of previous tillage operation, 5) topography of field; 6) soil parameters; 7) bulk density of soil; 8) cone index of soil. For 1 to 5 see (Gill and Vanden Berg, 1996)

The soil parameters influencing mechanical weeding of cotton were identified and measured. The soil properties relevant to the design of tool for weeding were identified as soil type, moisture, bulk density and cone index. The manners of measurement and characterization of these properties are discussed in the following sections.

Soil type: The type of soil affects on the implements and draft required to it. The type of soil was black cotton soil were experiment was conducted.

Soil moisture: The Moisture content of soil plays an important role for the growth of the crop and optimum soil moisture is needed at the time of weeding to minimize the field losses and energy input. Experiments were conducted at two moisture levels i.e. 8.90 and 17.45%, since these are optimum for weeding .The soil moisture for different soils given in (Spoor, 1969.)

Soil units draft: The unit draft of the different soils, which is responsible for the performance of the implement. The soil units draft for different soil is given in Zhang and Khuswala (1996).

Bulk density: Bulk density of the soil is a measure of compaction of soil condition influencing the tool parameters. Hence it was measured to define the soil condition. The bulk density of the testing fields is 1.3 gm/cc.

Cone Index: Cone index is measure of penetration resistance of the soil, hence it is necessary to define the soil condition. The cone index of the field is 0.7 kg/cm^2.

Properties of materials

The properties of the constructional materials are taken from standards (Biswas, 1993) and the design data (Krutz et al., 1984). The system of equations of forces acting on trailed plough was established, and

the solution was found by the use of computer-aided analysis.

In light of the equation, the influence of different values of parameters on the forces was forecast (Yibin et al., 2004.)

Field tests for the performance of flexible cultivator
- Rate of work:
  - Width of cut
  - Effective field capacity
  - Field efficiency
- Quality of work:
  - Depth of cut
  - Soil inversion
  - Soil pulverization
- Draft measurement
- Fuel consumption

Rate of work

Width of cut: For determining width of cut average of 5 runs should be taken. The measurement of composite width should be taken at minimum 5 equidistant places in the direction of travel and average working width should be determined. The width of cuts for different shovels shown in Table 1, it shows the performance of the shovels combinations with 'L' shape tine (Table 1 and Figure 3a).

Effective field capacity: The actual field capacity is calculated by the formula as follows:

$$E_e = A/(T_p + T_n) \qquad (1)$$

Where;
E_e: effective field capacity (ha/h),
A: area covered (ha),
T_p: productive time (h),
T_n: non productive time (h).

Field efficiency: The field efficiency is the ratio of the effective field- capacity to the theoretical field capacity expressed as percentage. The field efficiency is determined by, the known theoretical field capacity.

$$FC_{Th} = \frac{W_{th} * N_{op} * 36}{10000} \qquad (2)$$

$$FE = \frac{FC_{Effective}}{FC_{Th}} * 100 \qquad (3)$$

Where;
FC_{Th} : theoritical field capacity,

W_{th}: theoritical width of implement (cm),
N_{op}: speed of Operation (m/s).

The field efficiency for the tillage operations with different tillage tools ranges between 75-90%.

Quality of work

Depth of cut: The vertical distance between furrow sole and ground levels is referred as depth of cut. For accurate depth should be measured at minimum 10 places and its average taken. The depth of cuts for combinations of shovels are given in the Table 1.

Table 1. Width of cut and depth of cut for 'L' and 'C' tine

No:	Combinations of shovels	Avarage width of cut in cm/shovel	Avarage depth of cut in cm	
			'L'	'C'
1	3 S1-2 S2	17.0	12.0	10.0
2	5 S1	18.0	13.0	10.0
3	3 S3-2 S1	15.0	11.5	9.0
4	3 S1-1 S4	18.0	9.5	9.5
5	3 S3-2 S2	15.5	10.0	9.0
6	3 S3-1 S4	18.0	8.0	7.5

Soil inversion: A soil inversion (SI) is the process through which the furrow slice is inverted. Soil inversion is calculated using below equation.

$$SI = \frac{W_b - W_a}{W_b} * 100 \qquad (4)$$

Where,
W_b: number of weeds before operation on fixed area,
W_a: number of weeds after operation on the same area (see Table 2 and Figure 3b).

Table 2. Soil inversions for 'L' &'C' tine

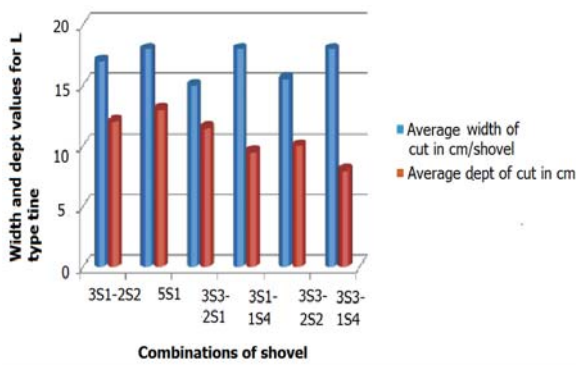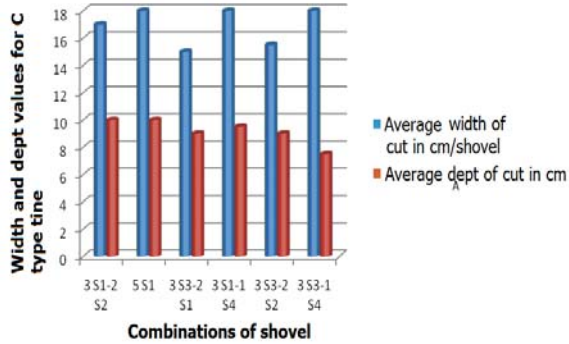| No:	Shovels combina-tions	No.of weeds before operation (W_b)		No. of weeds after operation (W_a)		Soil inversion	
		L	'C'	L	'C'	L	'C'
1	3 S1-2 S2	24	25	6	8	0.75	0.68
2	5 S1	20	21	4	6	0.80	0.71
3	3 S3-2 S1	22	23	6	7	0.72	0.69
4	3 S1-1 S4	40	42	5	8	0.87	0.80
5	3 S3-2 S2	37	39	8	11	0.78	0.71
6	3 S3-1 S4	35	40	6	6	0.83	0.85

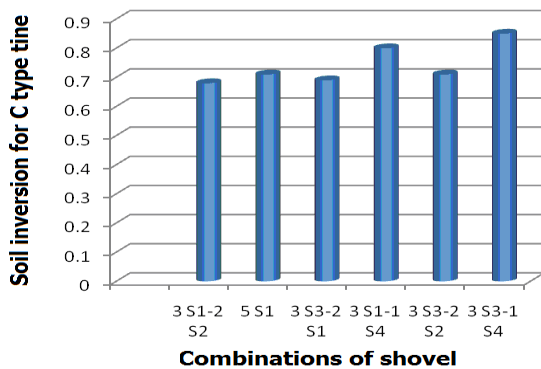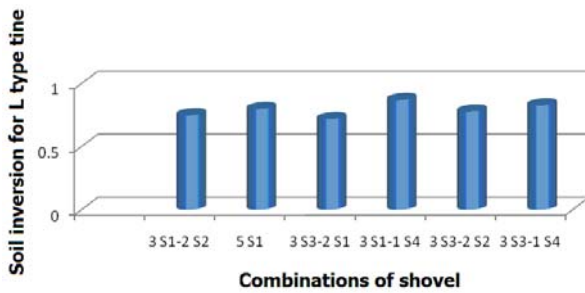Figure 3a. Average width and depth of cut for 'L' and 'C' tine

Figure 3b. Soil inversion for 'L' & 'C' tine

Table 3. Flexible Combinations

No:	Tine	Type of tine used	Types of shovels used	Combinations
1		5T1	3 S1-2 S2	5T1-3 S1-2 S2
2		5T1	5 S1	5T1-5 S1
3		5T1	3 S3-2 S1	5T1-3 S3-2 S1
4	'L'	5T1	3 S1-1 S4	5T1-3 S1-1 S4
5		5T1	3 S3-2 S2	5T1-3 S3-2 S2
6		5T1	3 S3-1 S4	5T1-3 S3-1 S4
7		5T2	3 S1-2 S2	5T2-3 S1-2 S2
8		5T2	5 S1	5T2-5 S1
9		5T2	3 S3-2 S1	5T2-3 S3-2 S1
10	'C'	5T2	3 S1-1 S4	5T2-3 S1-1 S4
11		5T2	3 S3-2 S2	5T2-3 S3-2 S2
12		5T2	3 S3-1 S4	5T2-3 S3-1 S4
13		2T1-3T2	3 S3-1 S4	2T1-3T2-3 S3-1 S4
14		2T1-3T2	3 S1-2 S2	2T1-3T2-3 S1-2 S2
15	'L'	2T1-3T2	5 S1	2T1-3T2-5 S1
16	&	2T1-3T2	3 S3-2 S1	2T1-3T2-3 S3-2 S1
17	'C'	2T1-3T2	3 S1-1 S4	2T1-3T2-3 S1-1 S4
18		2T1-3T2	3 S3-2 S2	2T1-3T2-3 S3-2 S2
19		2T2-3T1	3 S1-2 S2	2T2-3T13 S1-2 S2
20		2T2-3T1	5 S1	2T2-3T1-5 S1
21		2T2-3T1	3 S3-2 S1	2T2-3T1-3 S3-2 S1
22		2T2-3T1	3 S1-1 S4	2T2-3T1-3 S1-1 S4
23		2T2-3T1	3 S3-2 S2	2T2-3T1-3 S3-2 S2
24		2T2-3T1	3 S3-1 S4	2T2-3T1-3 S3-1 S4

Soil pulverization: Soil pulverization is the process of breaking of soil into small aggregates resulting from the action of tillage forces. The mean mass diameter (NMD) of the soil aggregates is considered as index of soil pulverization.

Draft measurement

The tillage forces were similar in magnitude for two types of soils viz. clay loam and sandy loam however the wear rate was increased by 40 to 50 per cent in the sandy loam soil (Fielke et al., 1993). Draft can be measured by the dynamometer. Draft power requirement for the implement can be calculated by following formula:

Power (ps)=(Draft (kgf)*$N_{operational}$)/75   (5)

The flexibility counts with 24 possible combinations and views from testing of flexible cultivar are given in Table 3 and Figure 4.

Figure 4. Flexible cultivator for 45 Hp and 18 Hp tractors testing

RESULTS and DISCUSSION

The FTT introduces following features:

1. Cultivator has aesthetics look, uniform homogeneous structure ease for transport. It was used with different crop spacing because of adjusting holes on elliptical frame. Weight reduces due to elliptical shape of frame.
2. Tines can be adjustable by distance between subsequent tines, different type of shovels.
3. Shovels with tine combination can be made according to crop pattern. Step tooth triangular shovels have high weed removal efficiency.
4. Wheel used for breaking clods, smooth tillage operation, easy transport.

The flexibility counts with 24 possible combinations as mentioned in the Table 3: flexible combinations by field experiments, follows were obtained:

- Maximum and minimum width of cut were found as 18 cm and 8cm, respectively.
- Maximum and minimum of cut were found as 17cm and 8cm, respectively.
- Speed of operation was found as 4.2 km/hr.
- Theoretical Field capacity was found as 0.42 ha/hr.
- Field efficiency was found as 78 %.
- Field capacity was found as 0.33 ha/hr.
- Theoretical draft force was found as 6.5 kN.

The following are the observations:

- The draft force increased with increasing rake angles, forward velocity and working depth.
- The soil inversion is increased with the width of the shovels.
- The depth of the cut is more in the step tooth shovels.
- The width of cut is more in the blade harrow shovels.

The computer aided design testing resulted with No strain in the entire assembly sections (Yibin et al., 2004). The maximum Vonmisses stresses up to 18 kN forceses tested by CAD-Software and it is observed that the structure of Flexible Cultivator lie within the safe limit see in Figure 5 the CAD-analysis cycle for Flexible tillage tool system (Ansys Inc, Structural Guide, 2004).

FUTURE SCOPE

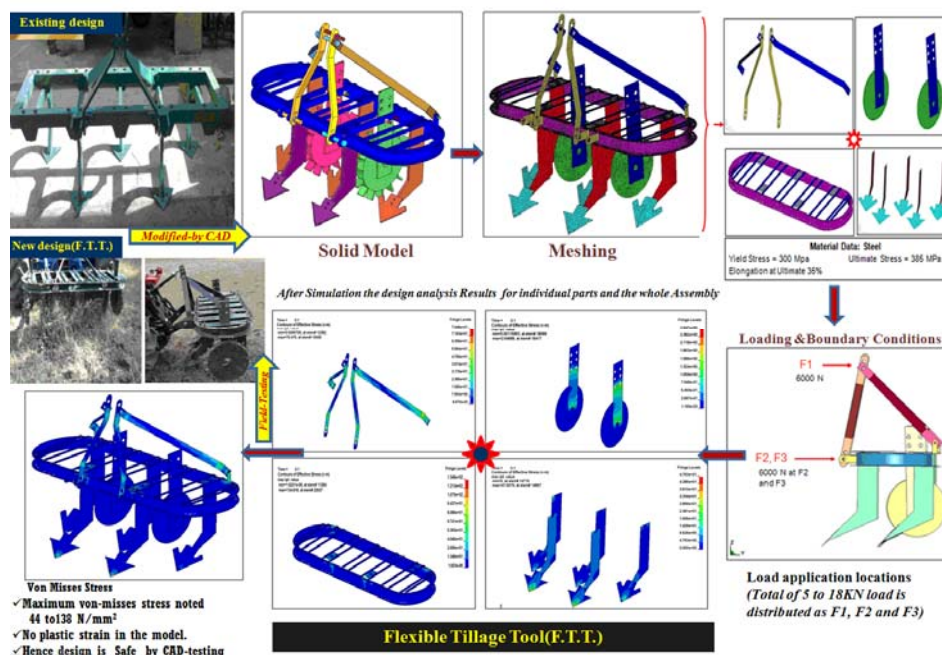The future scope for this tillage implement as below:

Figure 5. CAD-Analysis cycle for flexible tillage tool: cultivator

1. The flexible cultivator with different combinations can be combined with seed cum fertilizer operation.
2. The turmeric digger blade can be used in place of triangular blade for turmeric harvesting operation.
3. The whole assembly can be fixed by Pin-sockets so that assembling time can be minimized
4. Flexible tillage tool can be also used by animal power.

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