



Virtual Simulation based design of low cost Modified Three row weeder Equipment

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ABSTRACT: Improper and incorrect period intercultivation operation affect the crop yield and the loss in crop yields due to weeds in upland crops varying from 40 to 60 per cent and in many cases cause complete crop failure. Utilization of hand tool technology is one of the major problems of poverty in the rural areas. Hand hoe weeding would find difficult since this tends to perpetuate human drudgery, risk and misery. Efforts were made still on to reduce the drudgery in weeding operation for poor famers by designing new low cost hybrid power Modified three row Weeder using SOLID EDGE software. Later the assembly file is imported in ADAMS software to check its functional virtual simulation and determined critical areas by applying Flexible body dynamics concept. Checked the model in ANSYS software for deformation, stresses and strains. Results were compared with both soft wares which are in acceptable limit. Finally validated Virtual Prototype Modified three row Weeder model is fabricated and tested for field performance. It is mainly used for soil Preparation, Cultivation, Levelling off uneven fields, Inter Row Weeding etc. Its cost is Rs 30,000 only and operates at a depth of 15 to 25 mm with field capacity of 0.15 to 0.24ha/hr. Hence results in reduced weeding cost by 60 percent and labour requirement by 78 percent as compared to hand hoe weeding.

I. INTRODUCTION

Hand weeding is a human-eye controlled operation. It is not very important whether or not the surface is flat and whether or not the plants are in a row; the eye locates the plants and the weeds and controls the operation.

Weed control with animal or tractor-drawn weeder is possible only if the plants are sown in straight and parallel rows, as weeding is done between the rows. In order to obtain favourable results it is important that the field is well-prepared before planting.

Manual weeding requires huge labour force and accounts for about 25 per cent of the total labour requirement which is usually 900 to 1200 man M hours/hectares (Nag and Dutt, 1979). In India, this operation is mostly performed manually with cutlass or hoe that requires high labour input, very tedious and it is a time-consuming process. Moreover, the labour requirement for weeding depends on weed flora, weed intensity, time of weeding, and soil moisture at the time of weeding and efficiency of worker. Often several weeding operation are necessary to keep the crop weed free. Reduction in yield due to weed alone was estimated to be 16 to 42 % depending on crop and location which involves one third of the cost of cultivation (Rangasamy et al, 1993).

Weeding is generally done 15 to 20 days after sowing. The weed should be controlled and eliminated

at their early stage. Depending upon the weed density, 20 to 30 per cent loss in grain yield is quite usual which might increase up to 80 per cent if adequate crop management practice is not observed. Rice and groundnut are very sensitive to weed as reported by Goel, et al (2008). Competition in the early stage of growth and failure to control weeds in the first three weeks after seeding, reduce the yield by 50 per cent (Gunaseena and Arceo, 1981).

In general equipment/machinery fabrication industries, CAD technology has been very widely applied to various fields. But Farm machinery still remains an the primary stage, which based on hand work such as objects, models and drawings and samples to complete the whole process of Farm machinery body design method without using the modern CAD design software tools. At present, foreign farm machinery companies have started to use CAD modern technology, while problems such as not precise enough, long design cycle still exist in domestic agricultural machinery companies.

II. MATERIALS AND METHODS

A. Design considerations of Intercultivator

- Needs to have built-in adjustability to change the width of working
- Should have some arrangement to avoid mud getting stuck between the teeth/blades
- Needs to be fitted with a guard

-Should be simple in design so that it can be manufactured locally and sold at an affordable price

-Should be made all weather-proof and durable.

In the cases of animal-drawn/engine operated, the implement draft & the capacity of the animals/motor to provide the required power will also affect performance, as will ergonomic considerations related to the comfort of the operator.

B. Methods and operations of weeder/Intercultivator

It is an implement for inter cultivation with laterally adjustable tines or discs to work between crop rows. The cultivator stirs the soil, and breaks the clods. The tines fitted on the frame of the cultivator comb the soil deeply in the field. A cultivator performs functions intermediate between those of plough and the harrow. Destruction of weeds is the primary function of a cultivator. The following are a few important functions performed by an intercultivator.

- Interculture the fields.
- Destroy the weeds in the field.
- Aerate the soil for proper growth of crops.
- Conserve moisture by preparing mulch on the surface.
- To sow seeds when it is provided with sowing attachments.
- To prevent surface evaporation and encourage rapid infiltration of rain water into the soil.

C. Modified three row Weeder Blade, Ridger, Bund former

Blade: The Various sizes of blades can be accommodated in a frame, with quick coupling and decoupling.

Ridger: For making ridges in between the rows of crop for moisture conservation in soil and to act as a channel for crop irrigation. It can also be used for creating ridges and furrows.

Bund former: This equipment can be used for making bunds in the fields to facilitate easy surface irrigation. weeder blade was assumed to be a simply supported beam subjected to a uniformly distributed load of 150 N/m. Based on it the thickness sweep of blade, was calculated to be 3mm The two different shapes weeder blades are designed according to need of different soil properties .

III. DESIGN METHODOLOGY

The force required to uproot some weeds determined by using rope was by pulling through a spring balance and the force at the point of weed removal will be recorded. The machine was designed based on the principle of weed stem failure due to shear, and soil or root failure due to impact and abrasion.

The design process can be viewed as an optimization process to find structures, mechanical systems, and structural parts that fulfil certain expectations towards their economy, functionality, and appearance using simulation based design process as shown in block diagram.

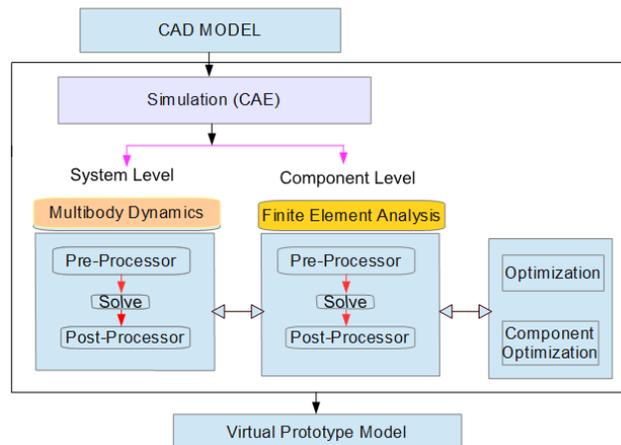


Fig- 1. Virtual Simulation Based Design Approach.

A three dimensional model of the new designed Intercultivator

Structure was designed using SOLID EDGE. Then checked its simulation using ADAMS software and analysis were carried out by ANSYS workbench software using FEM.

The machine design calculations was by the use of first principle of mechanics to determine the force requirement by the frame and the blade, bending

moment, tensional requirement to determine the machine shaft size and other component parts.

Soil Parameters:

When soil-acting mechanical weed-control implements are used, the soil is subjected to cutting or shear forces which cause it to fail and disintegrate. The parameters which influence a soil's resistance to this failure are:

- its cohesion(c)
- internal friction, by the angle of internal friction (α)

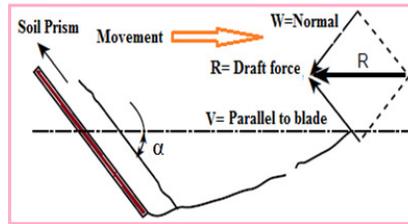


Fig. 2. Forces acting on Blade of Modified three row Weeder.

Micklethwaite, quoted by Ashburner and Sims, expressed the relation between the force required to shear a soil, its cohesion and its angle of internal friction as follows:

$$H_{max} = cA + W \tan\alpha \dots\dots\dots(1)$$

where: H_{max} = maximum shear force

A = area of soil sheared

W = normal loading on the soil

An angle of attack of approximately 15° is ideal to lift and separate the weeds from the soil. For the technical evaluation of any implement with soil acting components, the characteristics of the soil at the time of the test are of importance to enable performance to be compared under different conditions.. Moisture content of soil plays an important role for the growth of the crop hence following Soil resistance and Moisture content of soil are considered as given in table 2.

Table 1: Soil Properties.

| Sl.No. | Type of Soil | Soil Resistance MPa | Optimum moisture content |
|--------|--------------|---------------------|--------------------------|
| 1 | Sandy Soil | 0.21 | 3.5 % |
| 2 | Loamy Soil | 0.34 | 5.8% |

Power Development by the Human Worker:

The average power availability in sustained working from a male agricultural worker is consider as 60Watts while for a female worker it is consider as 48Watts for child worker as 30watts. According to Campbell the power of useful work done by human being is given by

$$HP=0.35-0.092 \log t \dots (2)$$

Where, t=time in minutes

Now, for 3-4 hours continuous work the power development by the operator would be 0.10-0.13 HP say 0.11hp or 0.08KW

We know that

$$\text{Power, } W=\text{push (N) X speed (m/s)/1000, KW} \dots (3)$$

$$\text{Push}=W \times 1000/\text{speed (m/s), N} \dots (4)$$

Resistance of soil to crushing by solid bodies is one of the principal characteristics utilized in evaluating the operating conditions of soil-working machines. Resistance of a soil to load by a solid body is determined by an instrument know as densimeter or density gage.

The bearing strength of the soil during the first phase depends not only on the depth to which the soil is compressed but on the bearing area F (area covered by the densimeter loading shoe) and consequently is proportional to the volume $V=Fh$ of the displaced soil.

$$\text{Therefore, } P=qV \dots\dots\dots (5)$$

where q is the proportionality constant since the force p is measured in newtons and the volume in mm^3 , q has unit of N/ mm^3 the reaction force of the soil measured in newtons when displacing 1 mm^3 soil. This coefficient is known as volumetric deformation coefficient of soil and is obtained from the

$$Q=p/Fh \text{ N/mm}^3 \dots\dots\dots (6)$$

Tractive force applied to the wedge. The tractive force of the wedge is the external force P which is necessary to balance the resultant force R acting on it due to the resistance of the soil. The force p is to be applied in a direction opposite to the resultant R.

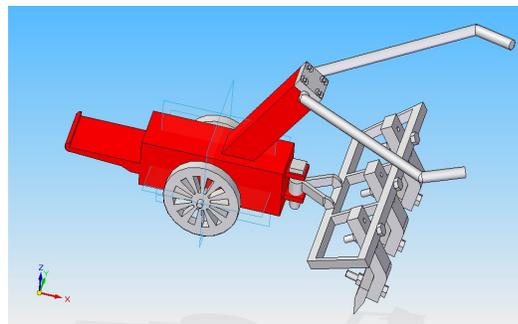


Fig. 3. Solid edge Conceptual 3-D Model of Intercultivator.

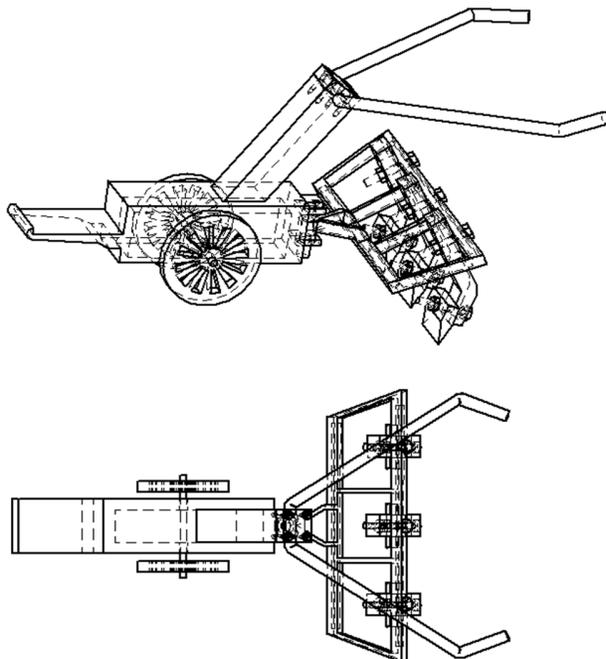


Fig. 4. Solid edge orthographic 2.D Model of Modified three row Weeder.

For a two-forced wedge, where AB is the working face and AC is the rare face, the components of the tractive force of the wedge are

$$P_x = N / \cos \phi [\sin(\alpha) + N \tan \phi] \dots\dots\dots(7)$$

$$P_z = N / \cos \phi [(\cos(\alpha + \phi) - N)] \dots\dots\dots(8)$$

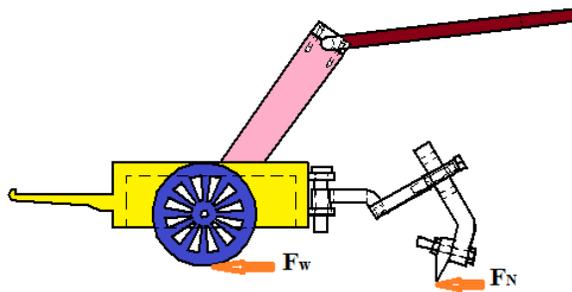


Fig. 5. Forces acting on Model of Modified three row Weeder.

Table 2: Material Properties.

| Sl.No. | Properties | Values |
|--------|---------------|-------------------------|
| 1 | Density | 2000Kg/m ³ |
| 2 | Young Modulus | 4.106N/mm ² |
| 3 | Poisson ratio | 0.3 |
| 4 | Plastic Flow | 160e3 N/mm ² |

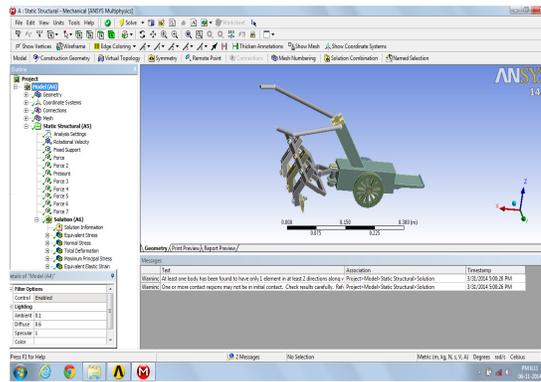


Fig. 6. ANSYS Work Bench Flow Diagram.

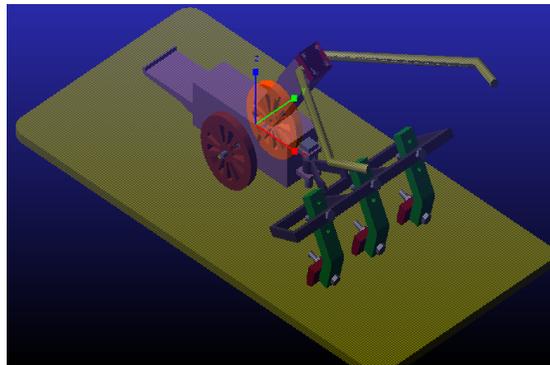


Fig. 7. ADAMS Virtual Prototype Model of Modified three row Weeder.

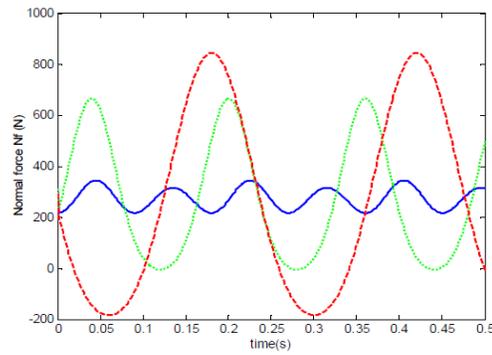


Fig. 8. Normal force on Modified three row Weeder blade with several running speed 1.65km/hr.,(solid line): 2.55km/hr., (dotted): 3.25km/hr., (dash).

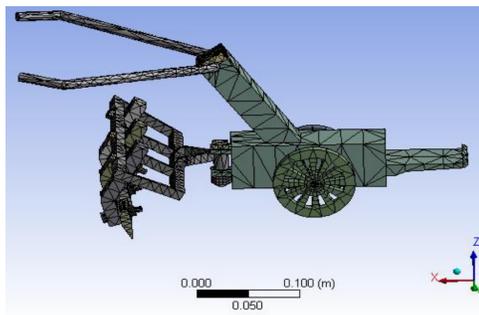


Fig. 9. Meshed Model of Modified three row Weeder.

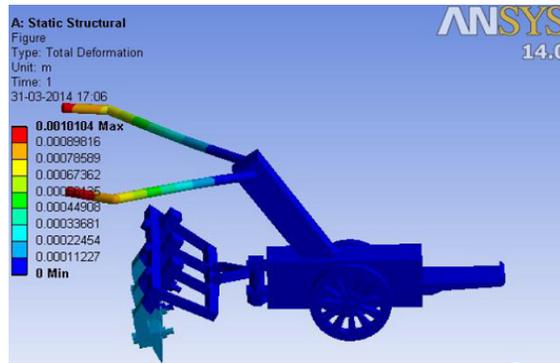


Fig. 10. Modified three row Weeder total deformation analysis.

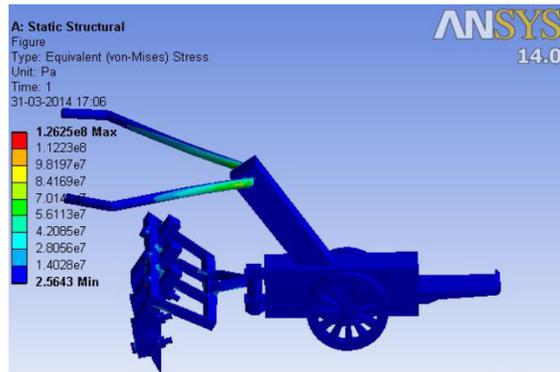


Fig.11. Modified three row Weeder Von-misses stress analysis.

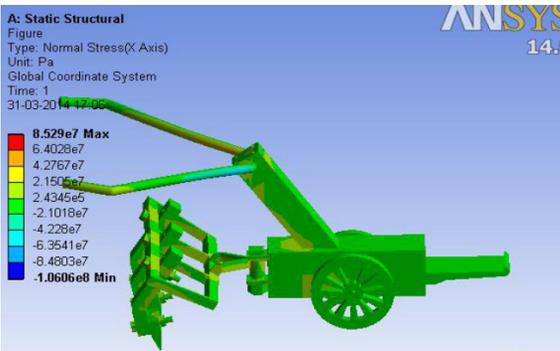


Fig. 12. Modified three row Weeder Normal stress analysis.

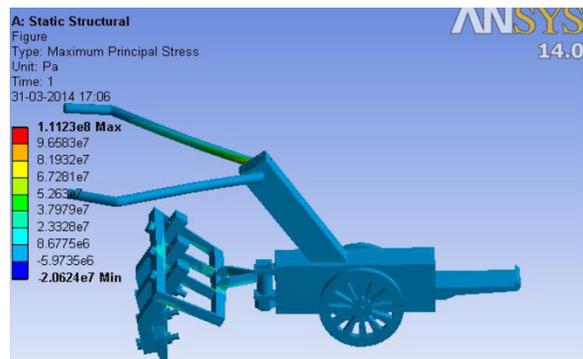


Fig. 13. Modified three row Weeder Principal stress analysis.

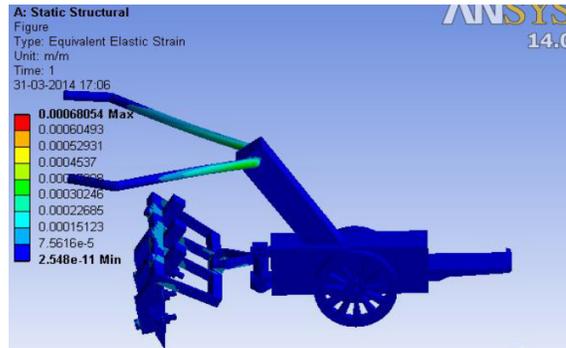


Fig.13. Modified three row Weeder Equivalent Elastic Strain analysis.

Finite element model of the soil tillage process using a mouldboard is established. In order to optimize the design parameters of future mouldboards, the influence of the cutting angles of this tool on the draught force is investigated.

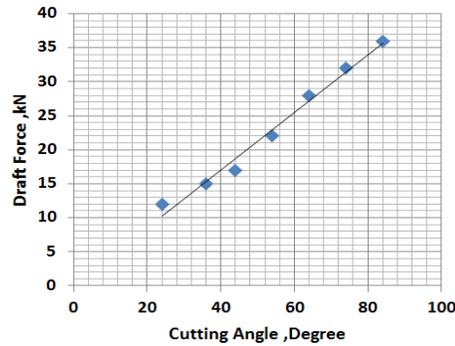


Fig. 14. Effect of the cutting angle on the draught force.

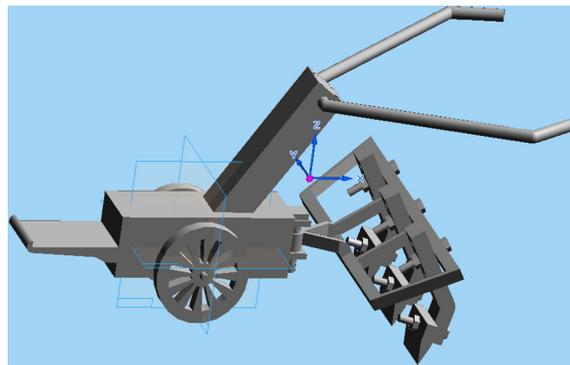


Fig. 15. Validated Model of Modified three row Weeder.

IV. PERFORMANCE EVALUATION

The equipment was evaluated in the field to determine; field capacity, field efficiency, weeding efficiency. Weeding efficiency was determined by removing manually the weeds in 1m x 1m area of the farm, the weeds was weighed and recorded. The process was repeated in five randomly selected locations on the farm. The average weight of the weeds in 1m x 1m area was calculated for the types of soil. The average weight of the weeds in 1m x 1m area after pass of the weeder through the farm was deducted from the actual weight of

the weeds in 1m x 1m area. Thus, functional efficiency was determined from the relation:

$$Functional\ efficiency = \frac{(weights\ of\ weed\ removed * 100)}{Actual\ weight\ of\ weed} \dots\dots (9)$$

V. RESULTS AND DISCUSSIONS

The displacement Vector Sum and Von Misses Stress is variation maximum at Modified three row Weeder blade, frame and handle section such as 0.0112mm and 1.2625e8Pa respectively which are in within safe limit.

Weeding can be done in between standing rows of crops like cotton, tapioca and grape whose row to row spacing is more than 450 mm. More area around 1 ha can be covered in a day using only one or two operators. Cost of weeding by this machine comes to only one third of the corresponding cost by manual labourers. The results show that there is a favourable response to crop growth due to application of subsoil mulch. The moisture profile and soil strength profiles show the favorable results of the mulching operation.

The summarized performance data on the Modified three row Weeder was as follows:

Adjustable weeder blade for different Crops

Age of the crop: 02 to 03 weeks

Field capacity = 0.15 to 0.24 ha/hr

Depth of operation = 15 to 25 mm

Overall Weeding efficiency = 84 per cent

Engine Capacity designed = 3HP

Initial cost of Modified three row Weeder = Rs.30, 000/-

V. CONCLUSION

A low cost hybrid power Modified three row Weeder was conceptually designed first using SOLID EDGE software. And analysed, optimized using ADAMS software. Then validated Virtual Prototype Modified three row Weeder model is fabricated with locally available material and tested for field performance. Suitable for all row crops and soils; provides soil mulch and conserves soil moisture. Intercultivation blades of different width can be fitted to the machine depending on the row to row spacing of the crop. The sweep blade can be raised or lowered so as to have the desired operating depth. Its cost is Rs 30,000 only and operates at a depth of 15 to 25 mm with field capacity of 0.15 to 0.24 ha/hr. Hence results in reduced weeding cost by 60 percent and labour requirement by 78 percent as compared to hand hoe weeding. For achieving ease of operation and increase in weeding capacity/ha animal power or petrol start Kerosene engine and/or solar powered DC motor attachment is mounted on the Modified three row Weeder base frame.

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