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Virtual Design, Analysis and Development of Single Row Weeder

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ABSTRACT*:* **Delay and negligence in weeding 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 famersby designing new low cost hand operated Weeder using CATIA software. Later the assembly file is imported in ADAMS software to check its functional simulation and determined critical areas by applying Flexible body dynamics concept. Checked the model in ANSYS softwarefor deformation, stresses and strains. Results were compared with both soft wares which are in acceptable limit. Finally validated Virtual Prototype Weeder model is fabricated and tested for field performance. Its cost is Rs 1600/- only and operates at a depth of 25 to 40 mm with field capacity of 0.01 to 0.012 ha/hr. Hence results in reduced weeding cost by 40 percent and labour requirement by 48 percent as compared to hand hoe weeding.**

Keywords: Virtual Prototyping, ADAMS simulation, FEA, Single row Weeder, Manual Draft

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 [1]. 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*, [11].

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* [12] 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 Gunasena and Arceo [10].

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 Rajashekar[9]. 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 weeders

(i) Needs to have built-in adjustability to change the width of working

(ii) Should have some arrangement to avoid mud getting stuck between the teeth/blades

(iii) Needs to be fitted with a guard

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

(v) Should be made all weather-proof and durable.

Table 1: Material Properties.

Young's Modulus	210GPa
Compressive Strength	2.5e+008Pa
Density	7850 kg m^{-3}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	434 J kg^{-1} C^{-1}

Driving Wheel. A 300mm diameter driving wheel were made using MS flat rim. Stiffening rods of 15 mm diameter and 99.48 mm long 4 in numbers were used as spokes on the central hub. The 50 mm long hub was made to suit the 15 mm size round MS rod which is the central axle of the ground wheels.

Weeder Blade. The 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.

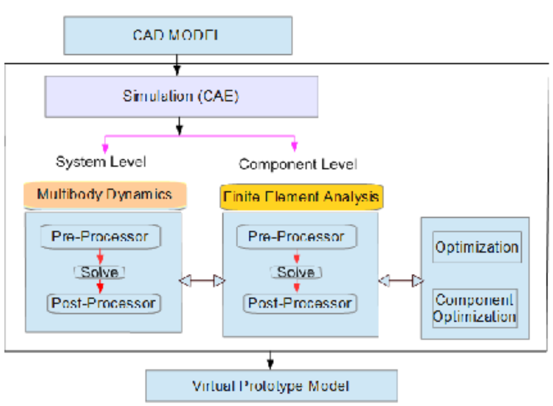

Fig. 1. Virtual Prototype Based Design Approach.

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.

The component parts and assembly drawing of the machine was carried out.

***Soil Parameters*:** The soil properties relevant to the design of weeder were identified as soil type, moisture, bulk density and cone index. The type of soil was sandy black soil were experiment was conducted. 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 2: 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 (0.06) while for a female worker it is consider as 48 Watts (0.048kw) and for child worker as 30watts (0.030 kW).

According to Campbell (1990) the power of useful work done by human being is given by

$$HP = 0.35-0.092 \log t \qquad \dots (1)$$

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

$$\text{Power, } W = \text{push (N) X speed (m/s)/1000, KW} \quad \dots (2)$$

$$\text{Push} = \text{W X 1000/speed (m/s), N} \quad \dots\dots\dots\dots\dots\dots (3)$$

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 known 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. Therefore,

$$P = qV \qquad \dots (4)$$

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

$$Q = p/Fh \text{ N/mm}^3 \qquad \dots (5)$$

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

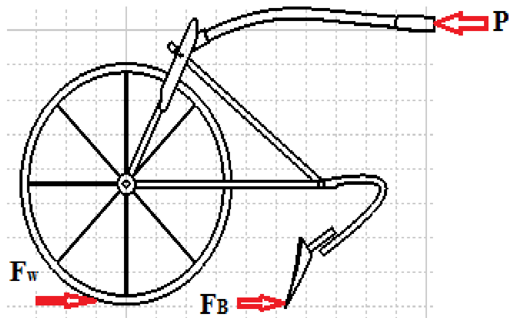

Fig. 2. Forces acting on Model of Weeder.

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

$$Fx = P/\cos\phi \ [\sin(\alpha)+P \tan\phi] \quad ... (6)$$

$$Fz = P/\cos\phi \ [(\cos(\alpha+\phi)-P)] \quad ... (7)$$

A three dimensional model of the new designed weederstructure was designed using CATIA V5. Then checked computational simulation of the bottom was carried out by ANSYS workbench software utilizing the finite element method.

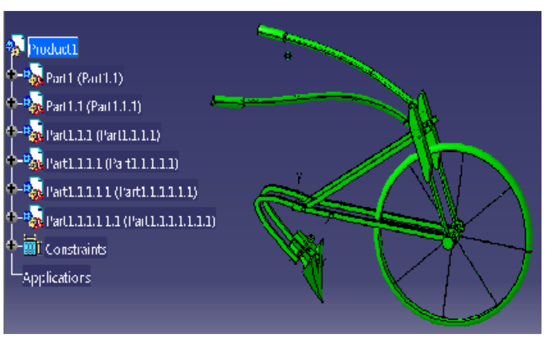

Fig. 3. CATIA Conceptual Model of Weeder.

Simulation of model in an assembly of components and verification of the compatibility of component with fittings and functional groups is performed to assure the correct assimilability and functionality.

Table 3: Mechanical Characteristics of Soil.

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

resistance of the soil. The force p is to be applied in a direction opposite to the resultant R.

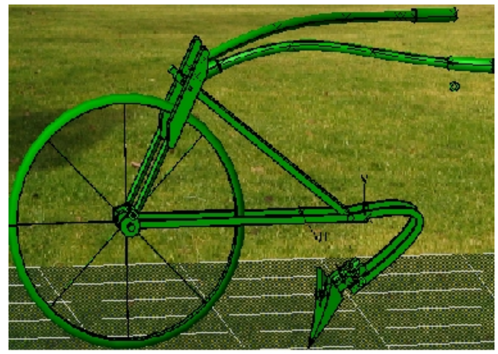

Fig. 4. Weeder Model analysis on soil.

MSC.ADAMS™ Simulation Package is a powerful modelling and simulating environment that lets one build, simulate, refine, and ultimately optimize any mechanical system. Simulations were made using both CATIA and ADAMS helps in better visual inspection of the model and requires changes admitted in model very quickly.

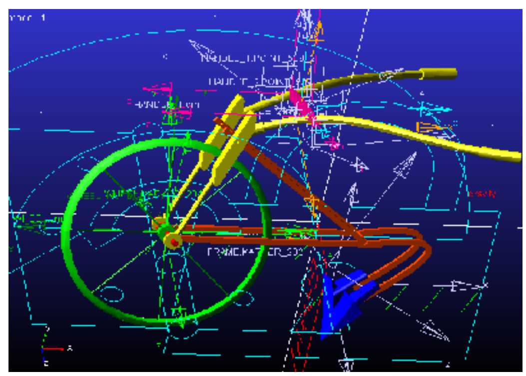

Fig. 5. ADAMS Virtual Model of Weeder.

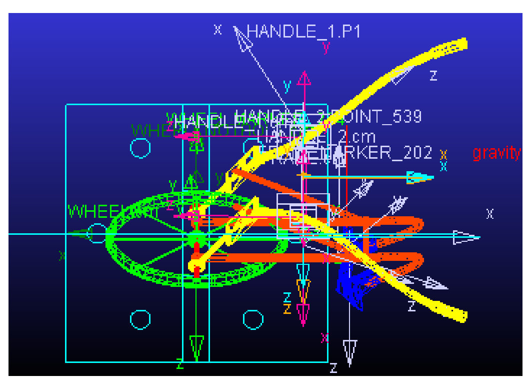

Fig. 6. ADAMS Constraints of Weeder.

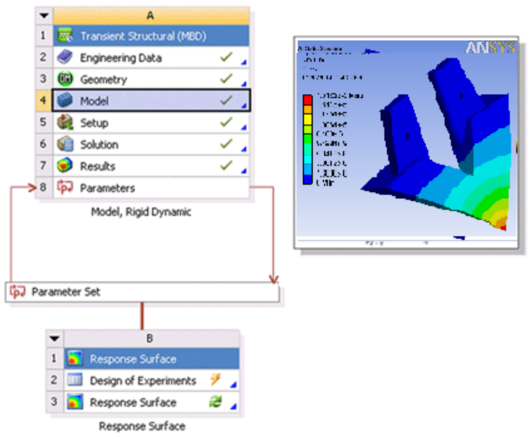

Fig. 7. ANSYSWork Bench Flow Diagram.

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.

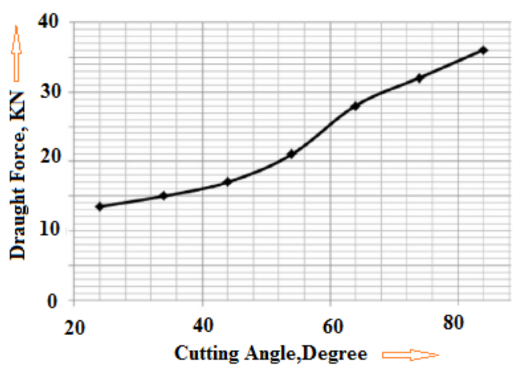

Fig. 8. Effect of the cutting angle on the draught force.

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 × 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 in1m × 1m area was calculated for the types of soil. The average weight of the weeds in 1m x1m area after pass of the weeder through the farm was deducted from the actual weight of the weeds in 1m × 1m area. Thus, functional efficiency was determined from the relation:

$$\text{Functional efficiency} = \frac{(weightsofweedremoved*100)}{Actualweightofweed} \quad .. (9)$$

Fig. 9. Fabricated Model of Weeder.

V. RESULTS AND DISCUSSIONS

The displacement Vector Sum and Von Misses Stress is variation maximum at weeder blade, frame and handle section such as 0.402mm and 2.6704e7Pa 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 thismachine comes to only one third of the corresponding cost by manual laborers. The summarized performance data on the weeder was as follows:

Adjustable weeder blade for different Crops, Age of the crop: 15 to 20 days, Field capacity = 0.01 to 0.012 ha/hr, Depth of operation = 20 to 35 mm, Overall Weeding efficiency = 78 %, Cost of weeder = Rs.1600/- .

VI. CONCLUSION

A single row wheel weeder was conceptually designed first using CATIA and analysed, optimized using ADAMS software.Then validated Virtual Prototype Weeder model is fabricated with locally available material and tested for field performance.Multibody dynamics solutions are supported in the ANSYS Workbench environment, engineers can leverage a fully parametric, persistent modeling environment and a rich set of design exploration tools to optimize their designs for motion, strength and durability requirements.

Its cost is Rs 1600 only and operates at a depth of 25 to 40 mm with field capacity of 0.01 to 0.012 ha/hr. Hence results in reduced weeding cost by 40 percent and labour requirement by 48 percent as compared to hand hoe weeding.For achieving ease of operation and increase in weeding capacity/ha solar powered DC motor is mounted on the base.

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