International Journal of Advanced Research and Review

www.ijarr.in

DEVELOPMENT OF HYDRAULIC OPERATED TRACTOR MOUNTED HAY RAKE CUM LOADER

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ABSTRACT

There are many equipments for transportation of goodsavailable for on road transportation for commercial purposes. But for on-farm transportation of agricultural goods, there are only limited options which include ox carts, donkeys and camels etc. The manual transportation of loads is also present in villages. The conventional practises for transportation of agricultural goods involves drudgery to both animals and humans as compared to modernized methods of transportation.Tractor trolley is the modern day device in agricultural sector available for transportation of agricultural goods. But generally tractor trolleys have larger space requirement and are highly expensive which is not affordable by every section of the farmer's society. Therefore, hydraulic operated hay rake cum loader was developed which has loading capacity of 500 Kg. The paper focusses on the structural properties of the device viz bending moment, moment of inertia, section modulus, bending stress, modulus of elasticity and deflection. The cost economics of the device is also evaluated. The payback period and benefit-cost ratio was found as 3 years and 1.732 respectively.The main aim of the study is to develop low cost transportation device with low manpower requirement and affordable by every section of the farmers society.

1) INTRODUCTION

In rural India, the agricultural produce are primarily transported manually. Also, for carrying the agricultural implements and livelihoods trolley is incorporated attached to the tractor. The tractor trolley is suitable for on road transportation of agricultural produce, livelihoods and implements. But for transportation within the territory of agricultural fields and farmers place is not suitable. As its large size occupy more space, uncertainty in availability and is also costly. The movement of agricultural produce in villages mostly done manually by hiring locallabourers requiring high manpower. In addition conventional practices causes wastage of time and labour while loading/unloading of mass and their transportation along with drudgery to both animals and human.

For on-road transportation of agricultural produce and implements, the major categories of transport equipment used are namely conveyors (equipment used to move materials over a fixed path between specific points), cranes (equipment used to move materials over variable paths within a restricted area), industrial trucks (equipment used to move materials over variable paths, with no restrictions on the area covered by the movement.) and no equipment (materials transported manually using no equipment). (Anon., 1999)

Similarly, the conventional practices of goods transportation is performed using donkey, ox carts, camels and also manually.

The disadvantages of conventional practices are:-

1) Wastage of time and labour while loading/unloading of mass and their transportation.

2) Use of the conventional practices require animals and manpower which leads to increase of cost.
3) These practices involve drudgery to both animals and human.

The advantages of mechanized loading/unloading include saving of time, labour and drudgery involved. Also the mechanized means increases the transportation efficiency and easiness while loading/unloading of mass.

The following objectives are considered for the development of the device:

1. To develop the hydraulic operated hay rake cumloader.
2. To analyse the economics of the developed device.

2) REVIEW OF LITERATURE

Karaoglu and Kuralay (2002) conducted stress analysis of a truck chassis with riveted joints which was performed by using FEM. They concluded that increasing the connection plate thickness reduced stresses in the connection plate. And when the length of the connection plate was increased, stresses in both side member and connection plate decreased. The author suggested that if the change of the side member thickness using local plates could not be achieved then choosing an optimum connection plate length seemed to be practical solutions for decreasing the stress values.

Raval*et al*. (2010) developed Tractor operated hay rake cum loader which was suitable for handling different types of crops hay. It reduced operational and collection time and cost. The labour saving cost wasabout 40% to 50%. Therefore, it was found beneficial to farmers, local artisans and manufacturers.

Bajwa*et al.* (2013) studied the static load analysis of TATA super ace chassis. They found that automotive chassis can be considered as the backbone of any vehicle. The research provided an insight into the design and analysis of the chassis

Patil*et al.* (2013) conducted a study on stress analysis of a ladder type low loader truck chassis structure consisting of C-beams design for application of 7.5 tonne by using FEM. Numerical results showed that if the thickness change was not possible, changing the position of cross member would be a good alternative. The computed results were then compared to analytical calculation, where it was found that the maximum deflection agreed well with theoretical approximation but varies on the magnitude aspect.

Tayade and Patil (2015) conducted research to redesign a modified chassis for tractor trolley by keeping the material and dimension similar and using ‘I’ cross section area instead of ‘C’ resulted in more safer stresses than ‘C’ and the material used was mild steel.The experimentation was performed on universal testing machine by keeping the load vs. deformation. The author found that the newly designed “I” section chassis reduced deformation as compared to the existing “C” section chassis and more stresses were obtained in new suggested design. The author observed increase in the factor of safety in the new suggested design.

Badhe and Firake (2016) described modelling and analysis of existing “C” section of mini tractor trolley chassis. The automobile was divided into two parts body and chassis. The chassis was basic structure of a vehicle. It contained all the engine parts and power systems but frame was the main portion of chassis. Its principle function was to safely carry the maximum load for all designed operating conditions. In the paper, the dimensions of an existing “C” section chassis of mini tractor trolley was taken for modelling and analysis.

Weight reduction was found the main issue in automobile industries. The research was aimed to redesign a modified chassis for tractor trolley. The authors concluded that "I" section chassis reduced 36% of weight reduction as compared to the existing "C" section chassis and also more safer stresses were obtained in the new suggested design. The reduction in weight showed that the raw material required for manufacturing of the chassis was reduced. And as raw material was reduced, the reduction in cost was also achieved.

3) MATERIALS AND METHODS

3.1 Design of hydraulic operated hay rake cum loader

Considering the sweep rake as a cantilever beam with a uniformly distributed load, the bending moment and the moment of inertia were calculated [Bansal(2009)] as follows:-

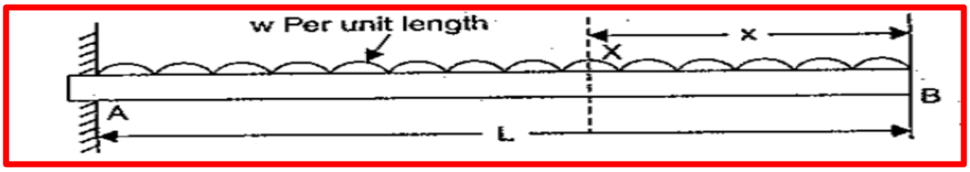


Fig 3.1: Load distribution on sweep rake

Taking a section X at a distance of x from the free end B.

a) Calculation of bending moment:

Let, $B.M_X$ = Bending Moment at X.

L = effective length of sweep rake = 0.85 × length of sweep rake. (Anon., 2013b)

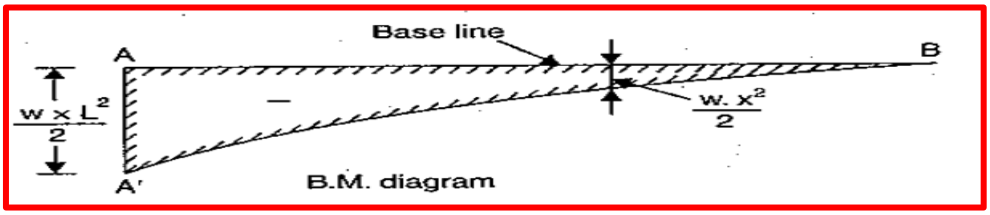


Fig 3.2: Bending moment diagram for sweep rake

As we already know that the uniformly distributed load over a section was converted into point load acting at the C.G of the section.

The bending moment at the section X is given by:-

$B.M_X$ = -(Total load on right portion) × (Distance of C.G of right portion from X)

= - (w .x) . (x/2)

= - w .x . (x/2)

= - $(w.x^2)/2$

At B, x = 0 hence $B.M_X = 0$

At B, x = L hence $B.M_X = - w.\frac{L^2}{2}$ (Anon. 2013a)

b) Moment of inertia of a Sweep Rake:

Considering a square cross-section of the sweep rake.
(Anon., 2018)

Cross-sectional area of sweep rake, $A = a^2 - (a_1)^2$

Moment of Inertia of sweep rake, $I = \frac{a^4 - a_1^4}{12}$

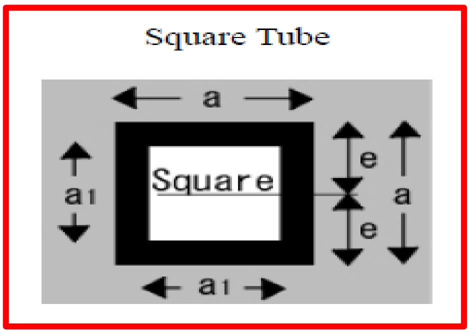


Fig 3.3: Square cross-section of a sweep rake

c) Section modulus of sweep rake, Z:

(Anon., 2018)
$Z = I/e = \frac{a^4 - a_1^4}{6a}$

d) Bending stress of sweep rake, σ:
Referring to Bansal (2009), we know that
B.M = σ × Z

e) Modulus of elasticity, E:
According to "Strength of Materials" by Bansal (2009),the bending equation was used as follows:-

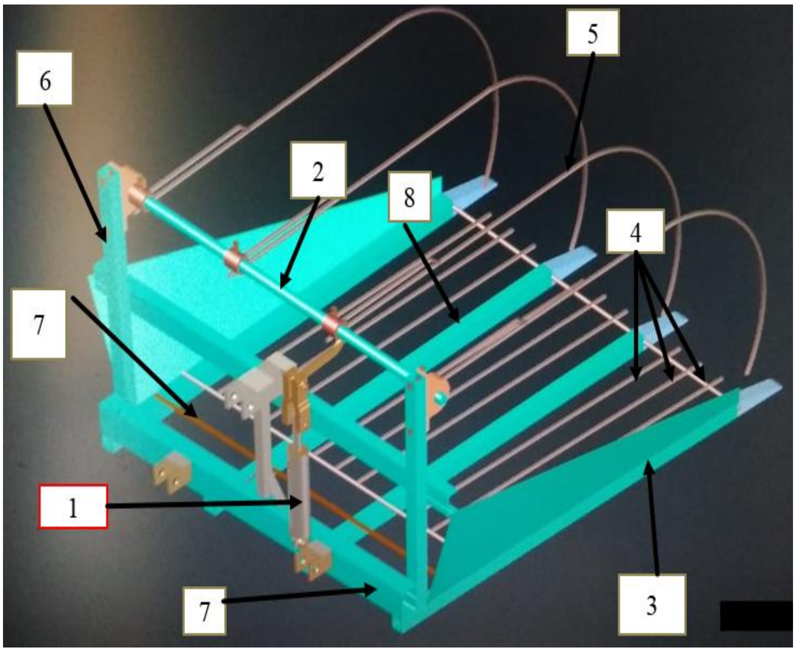
$\frac{B.M}{I} = \frac{\sigma}{e} = \frac{E}{R}$
$\Rightarrow \frac{B.M}{I} = \frac{E}{R}$
⇒ E = (B.M × R) / I

Where, B.M = Bending moment (N.mm)
I = Moment of inertia (mm^4)
σ = Bending stress in the forklift rod(N/mm^2)
e = Extreme point (mm) = a/2
E = Young's modulus (N/mm^2)
R = Radius of gyration (mm) = √I/A $= \sqrt{\frac{a^2 + a_1^2}{12}}$

f) Deflection in the sweep rake, D:
As per Blakeley (1903), the deflection of the sweep rake was calculated as:-

Deflection, D (mm) = $wL^3/8EI$

3.2 Components of hydraulic operated hay rake cum loader



1.	**Hydraulic cylinder**
2.	**Lever shaft**
3.	**Side Support**
4.	**Bracing rod**
5.	**Holding rakes**
6.	**Stand post**
7.	**Bracing flat**
8.	**Sweep rake**

Fig 3.4: Different components of the developed device

a) Sweep rake

Four number of sweep rakes made of double angle section (50X50X6 mm and 1690 mm length) were spaced at 480 mm centre to centre distance, covering of a floor area of about 1690X1560 mm. The end of sweep rakes was made tapered with an angle 20˚ to the horizontal. Sweep rake was the part where the hay was to be loaded. The hay was to be spaced on the sweep rake.

b) Bracing flat

Bracing flat (size of 25 × 5 mm size and1560 mm length) were spaced at 410 mm centre to centre distance to hold the bracing rod in proper position.

c) Bracing rod

Three number of bracing rod (each of diameter 15 mm size and 1385 mm length) were spaced at 480 mm centre to centre distance to hold the sweep rake in proper position. The sweep rake and bracing rodjointly provided a platform for resting the loaded material.

d) Cross hollow tie

Cross hollow tie section made with a double channel section (70 × 5 mm size and 1560 mm length). The assembly of sweep rake was welded with the cross hollow tie.

e) Holding rake

Four number of holding rake rods (each of 15 mm diameter and 2064 mm length diagonal) welded on lever shaft. The lever shaft can be swinged (0-30^{o}) with the help of hydraulic cylinder so the loaded hay do not get loosen during transportation.

f) Stand post

The hollow stand post height (830 mm spaced at 1560 mm distance) made of angle section (50 × 50 × 6 mm) with the facility to provide appropriate height.

g) Lever shaft

A lever shaft wasmade of MS round bar (30 mm diameter) supported on the stand post equipped with pedestal bearings at the two ends.The bearings provided trouble free movement of holding rakes.

h) Hydraulic cylinder

The up and down movement of holding rakes, hydraulic cylinder was provided and welded with the lever shaft. As the holding rakes were welded to the lever shaft, the movement of holding rakes was controlled by the hydraulic cylinder. The arrangement of hydraulic cylinder helps in reducing one labour to operate the holding rakes while loading and unloading**.** The bore, stroke and piston diameter of the hydraulic cylinder was 67 mm, 150 mm and 30 mm respectively.

i) Side support

The side support made of MS sheets (gauge 4) were provide at the two sides of the developed device along the length of the device. These side support help in preventing the losses during loading, unloading and transportation. These ensures safe transportation of the loading material.

Fig 3.5: Different views of developed hydraulic operated hay rake cum loader

3.3 Cost economics:

3.31Fixed Cost

Fixed costs of a machine include depreciation, costs of interest, taxes, insurance and shelter. Depreciation was usually the largest component of machine total costs. It measures the amount, by which the value of a machine decreases in time, whether it was used or not (Hunt, 2001).There are several methods of calculating depreciation. The most common methods are straight line method, declining balance depreciation and detrimental depreciation (Witney, 1988).

A. Depreciation

It means a loss in the value of a machine owning to time and use. Often, it was the largest of all costs. Machine depreciate, or have a loss of value, for several reasons, viz. age of machine, wear and tear of machine and obsolescence.

a) Straight Line Method :

In the straight-line depreciation method, an equal reduction of value was used for each year the machine was owned. This method can always be used to estimate costs on a specific period of time, period of time, provided the proper salvage value was used for the age of the machine. Use of tractor and other implement was considered as 1100 and 300 h respectively. The annual depreciation value can be calculated from the following expression.

$$D = \frac{P-S}{L*H}$$

Where,

D= average annual depreciation, ₹/h

P= purchase price, ₹

S= salvage value, taken as the purchase price, ₹

L= life of machine, years

H= annual use of machine, h

B. Interest on Investment

In the agricultural machinery management interest was the secondary largest item of expanses. The interest was calculated on the average value of the machine.

$$I = \frac{P+S}{2} \times \frac{i}{100}$$

Where,

I= interest on investment, ₹

P= purchase price, ₹

S= salvage value, taken as the purchase price, ₹

i= rate of interest

C. Taxes, housing, and insurance = 2 % of initial investment

3.32Variable Cost

The variable costs of a machine as it name suggests vary with its use and they are expressed as costs per area worked or hour of operation. They are divided into maintenance and repair costs, Electricity charges and Labour charges (Witney, 1988).

Fixed and variable costs give the overall costs of operation of a machine. Labour charges must be added depending on labour requirements of particular operation. The average labour costs include National insurance contribution, employer’s liability, overtime and benefits.

These costs depend on how much it was used. Variable costs includes,

1. Repair and Maintenance cost = 5 % of purchase price
2. Labour charges: ₹500 per person

The straight line method assumes equal reduction in the value of machine every year. Use of implement was considered as 500h.

3.33Payback period

The payback period of hydraulic operated hayrake cum loader in in years has been worked out on the relationship of annual use of working hours, total benefits, total cost,, net benefits and initial investment of the device. The payback period is expressed by the relation given below:

$$\text{Payback period} = \frac{\text{Initial Investment}}{\text{Average net annual benefit}}$$

Where,

Custom fee, ₹/h = (Cost of operation + 25% overhead charge) + 25% profit over newcost

Average net benefit (₹) = (Custom fee, ₹/h – Total operating cost, ₹/h) ×Annual utility

3.34Benefit: Cost ratio

The benefit: cost ratio was calculated by using the following formula:

$$B: C = \frac{\text{Total benefit}}{\text{Total cost of investment}}$$

Where,

Total benefit = Average annual net benefit, ₹/h × Life of machine (L) in years

Total cost of investment = Initial cost of machine

4) RESULTS AND DISCUSSIONS

Mathematical calculations for the selection of MS angle iron for sweep rakes:

Total number of sweep rakes = 4

Length of the sweep rake = 1.98 m

Effective/actual length of sweep rake = 0.85 ×1.98 = 1.69 m

Total load to be carried by the device = 500 kg = 500 × 10 = 5000 N

Load carried by single sweep rake, q = (5000/4)/1690 = 0.74 N/mm

The selection of angle iron for sweep rakes was done by comparing the structural properties of mild steel given below:

Table 4.1: Structural properties of sweep rake

Size	Inertia, I (mm^4)	Section Modulus, Z (mm^3)	B.M (N.mm)	Bending Stress, σ (N/mm^2)	Elasticity Modulus, E ($N.mm^2$)	Deflection, D (mm)
25*25*5	28333	2266	-1098500	484	326	50
30*30*5	54166	3611	-1098500	304	211	40
35*35*5	92500	5285	-1098500	207	147	34
40*40*6	162112	8105	-1098500	135	95	29
45*45*6	242892	10795	-1098500	101	72	26
50*50*6	347072	13882	-1098500	79	57	23

The Table 1.1 indicated that the angle iron of size50*50*6 showed the minimum deflection and bending stress. Therefore, 50*50*6 size MS angle iron was selected for sweep rakes.

Table 4.2:Cost economics of developed hydraulic operated hay rake cum loader

Fixed cost			Variable cost		
John Deere tractor 5104		Hydraulic operated hay rake cum loader	John Deere tractor 5104		Hydraulic operated hay rake cum loader
Initial cost, P	₹ 625000	₹ 35000	Fuel cost	₹ 326.28	
Depreciation	₹ 56.25/h	₹ 12.6/yr	Lubricant cost	₹ 97.88	
Interest, I	₹ 41.25/yr	₹ 4.62/yr	Wages	₹ 62.5/h	₹ 125/h
Housing cost	₹ 6.25/yr	₹ 0.7/yr	Repair and maintenance cost	₹ 62.5/h	₹ 3.5/h
Tax cost	₹ 6.25/yr	₹ 0.7/yr			
Insurance cost	₹ 6.25/yr	₹ 0.7/yr			
Total fixed cost	₹116.25/h	₹ 19.32/h	Total variable cost	₹ 549.16/h	₹ 128.5/h

Total cost of tractor operation = Total fixed cost + Variable cost
=₹ (116.25 + 549.16) = ₹ 665.41/h
Total cost of operation of the device = ₹ (19.32 + 128.5)
= ₹ 147.82/h
Total cost of operation of developed device with tractor = ₹ (665.41+ 147.82)
= ₹ 813.23/h

Table 4.3 Payback period and Benefit cost ratio

Initial cost	660000	Benefit cost ratio	
Custom fee, ₹/h	1270.67	Total benefit, ₹	1143600
Average annual benefit, ₹	228720	B:C ratio	1.732
Payback period, yr	2.88		

CONCLUSION

The hydraulic operated hay rake cum loader has been successfully developed having with actual loading capacity equal to 500 kg.The payback period and benefit-cost ratio was found as 3 years and 1.732 respectively.

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