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# Design & Development of a Suitable Implement Matching with Low HP Tractor

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Abstract - *Proper matching of implements with tractor and the performance evaluation of the combination is very much important to minimize the expenditure in farming operations. To obtain a suitable implement according to tractor horsepower, implement size plays an important role. An improper matching of tractor-implement combination results in under loading of engine and hence poor efficiency and higher operating costs. Implements that are too large for the horsepower available will cause overload, excessive tire slippage, increase in fuel consumption and unsatisfactory performance in general. Implements that are too small will result in inefficient operations, low production and increased cost. The objective should be to match as effectively as possible the tractor with the implement as some of the small size implements will not utilize all of the tractor horsepower available. With small size tractor, it is necessary to select an implement size that is convenient to use or adequate for the job to be done. This paper aims to describe the design process and development of a suitable size implements to be matched with a low hp Tractor for optimum field performance at minimum operating cost.*

*Key Words: Implements, field capacity, field efficiency, draft, and drawbar*

## 1. INTRODUCTION

A careful approach to matching implements and tractors can increase efficiency and cut costs for farmers. Implement matching involves an attempt to balance the characteristics of a load application unit such as a cultivator and a power unit, which is usually a tractor. The matching process is something, farmers often do sub-consciously but this method can be improved. Any improvements that can be made will substantially affect farm performance. Correct matching of machinery should result in increased efficiency of operations, less operation costs and optimum use of capital on fixed costs (Powell, (2000). A tractor properly matched to an implement provides a "system" that performs at maximum efficiency. Thus correct matching of machinery should results in increased efficiency of operations, less operating costs, and optimum use of capital on fixed costs. When determining an appropriate balance (match) between tractor and an implement, consideration must be given to various factors like area to be covered (ha), working speed (kmph), working hours, estimated field efficiency (percentage), width of machine (working width, m), power requirements for implement to be used (kW) [1].

### 1.1 Effective Field Capacity

The effective field capacity is the actual output achieved by a machine. It is a function of the proportion of the machine width utilized, the travel speed and the amount of time lost in the field during the operation. Time is lost to implement blockages, working areas such as headlands more than once, adjustments, checking and minor repairs and excludes daily servicing requirements such as lubrication but would include the time taken to change points [2].

A practical way of determining field efficiency is to determine the theoretical time required to cover an area and compare this with the actual time taken.

$$Field\ efficiency,\% = \frac{Theoretical\ time}{Operating\ time} \times 100$$

Typical field efficiency values for a range of different operations are listed in Table 1. The higher figures represent operations in larger fields where the number of turns is minimized.

 

Table 1: Typical Field efficiency for a range of operations

| Operation | Field efficiency, % |
|---|---|
| Tillage- Primary and Secondary | 70-85 |
| Planting | 65-85 |
| Harvesting | 60-80 |
| Spraying | 50-70 |

## 1.2 Tractor Drawbar Power

For calculating drawbar power, draft needs to be evaluated at very first. The power required to pull a tillage implement is a function of the travel speed and the "pull" or draft of the implement. This is the power, the tractor must be able to provide at the drawbar. The engine power will be quite a bit higher than this. The draft for a particular type of implement varies a lot depending on soil type, soil condition, depth and speed. Table 2 gives a guide to the draft that could be expected for different implements on a range of soils conditions, soil type, soil moisture, depth of working, ground speed etc. The draft is given in terms of kilograms force per meter width of implement (kgf/m).

Table 2: Approximate draft of tillage implements [3]

| Implements | Primary/ Secondary | Depth, mm | Speed km/h | Soil Conditions | | |
|---|---|---|---|---|---|---|
| | | | | Heavy | Medium | Light |
| Disc Plough | P | 100 | 7 | 800 | 650 | 500 |
| -do- | S | 80 | 8 | 500 | 450 | 350 |
| Chisel Plough | P | 100 | 7 | 700 | 550 | 400 |
| -do- | S | 70 | 8 | 450 | 250 | 150 |
| Cultivator | S | 90 | 8 | 300 | 200 | 150 |
| Scarifier | P | 80 | 8 | 550 | 450 | 350 |
| -do- | S | 100 | 10 | 450 | 350 | 250 |
| Combine Seeder | S | 40 | 8 | 300 | 250 | 150 |

Once the draft and working speed are known, the required drawbar power can be calculated using the following formula:

$$Drawbar\ Power\,(kW) = Draft(kgf\,/\,m) \times Machine\ width\,(m) \times speed\,(kpmh) \div 367$$

When buying a tractor, concentration is required on its quoted PTO power, not its engine power. To calculate the required tractor PTO power from a known drawbar power, power losses associated with wheel slip and rolling resistance have to be taken care off. Reasonable field efficiency for a tillage operation is also necessary to look at the efficiency of the tractor in converting engine power to drawbar power. However, when considering losses from the axle to the drawbar, energy is lost in order to create traction. These losses depend on the tractor type and weight, soil conditions, as well as the load being pulled. Drawbar power is the product of pull and speed; where an infinite number of pull / speed combinations could be used to give the same power. Wheel tractors are designed to operate at higher speeds (greater than 8.0 km/h) and lower drawbar loads [4].

Table 3: Power conversion factors: Drawbar to PTO

| Type of surface | 2WD | FWA | 4WD |
|---|---|---|---|
| Firm surface | 0.72 | 0.77 | 0.78 |
| Tilled surface | 0.67 | 0.73 | 0.75 |
| Soft surface | 0.55 | 0.65 | 0.70 |

Also consideration is needed on tractor loading. Overloading can cause early failure of components; the tractor should not work continuously at over 80% of maximum power.

To calculate PTO power requirements, using only 80% of maximum engine power, the following formula is important [5]:

$$PTO\ Power = \frac{Drawbar\ Power}{conversion\ factor \times 0.8}$$

Table 3 describes some typical tractor efficiencies, which are very much useful for selecting implement and required tractor size [3]

Table 4: Typical Tractor efficiencies

| Tractor type | Rated Crankshaft Power % | PTO Power % | Drawbar Power (Maximum) % | Drawbar Power (Normal) % |
|---|---|---|---|---|
| 2WD | 100 | 85 | 50 | 40-45 |
| 4WD | 100 | 85 | 60 | 50-55 |
| FWA | 100 | 85 | 55 | 45-50 |
| Track | 100 | 85 | 75 | 65-70 |

 

## 2. DESIGN OF SUITABLE IMPLEMENT MATCHING WITH A LOW HP TRACTOR

Considering all the above-discussed matter the following calculation have been carried out for the selection of matching implements for a low HP tractor when engine power is known:

Engine parameters chosen:
Make - Greaves,
Rated Speed = 3000 rpm,
Rated Power = 10.2 hp
Max. Torque = 26 N-m @ 1800-2400 rpm
Available Power = 80% of rated power
= 0.8x10.2
= 8.16 hp
Axle power = transmission efficiency x available power hp
= 0.9x8.16 hp
= 7.34 hp
Tractive efficiency = drawbar power/axle power
Or, drawbar power = (axle power)x(tractive efficiency)
So, drawbar power = 7.34 x 0.6
= 4.4 hp
= 3.24 KW
Assuming operating speed 5.5 km/hr.
Optimum pull = drawbar power/operating speed
= 3240/(5.5 x 1000/3600)
= 2120.7 N

So, Draft=Optimum pull = 2120.7 N~2120 N (Rounded off)

$$Draft = F.i\left[A + B(v) + C(v^2)\right]W.d\,N$$ (ASAE, 1999)

Where, F = dimensionless soil texture adjustment parameter = 0.85
i = 1 for fine, 2 for medium, 3 for coarse
A, B, C = machine specific parameters
v = operating speed km/hr.
W = machine width, m
d = tillage depth, cm
From the ASAE standards, following are the values: (for a cultivator)
F = 0.85,
i = 2,
A = 46
B = 2.8
C = 0
d = 15 cm
v = 5.5 km/hr.
By putting all the values,
Draft = 0.85x2x[46+2.8(5.5)+0x5.52] x Wx15
= 1565.7 x W
To get the total no. of tynes,
Draft = optimum pull
or, 2120 = 1565.7 x W
or, W = 2120/1567.7
= 1.35 m

Assuming spacing between tynes = 12" = 304.8 mm
n, = no. of tynes = 1.35 m/304.8 mm = 5 (approx.)

So for the case of low HP tractor of chosen engine parameters, a cultivator with 5 tynes will be suitable to get optimum performance in field operations.

## 3.0 MODEL CREATION FOR CULTIVATOR

Based on the design calculation and following the ASAE standard, the 3D model of a 5-tine cultivator, which was attached with the small hp tractor later on has been developed as shown in Fig. 1. This cultivator was developed through CAD, using CAD software. Initially the conceptual design was made which using Auto CAD software. After the conceptual design, the detail design and manufacturing design was made. Using high capacity 3D software, 3D CAD model generated for getting the proper visualization of the product to be made through fabrication. This model was then checked for functional analysis to examine whether the product will be capable of carrying the load while the tractor is in field condition. The goal was to minimize the mass of the part while maintaining the same stiffness and strength as an existing cultivator. The 2D CAD model of the designed cultivator has shown in Fig.2 while Fig.3shows the physical prototype of the developed cultivator attached with a Low HP Tractor. Fig 4 describes the laboratory trials particularly weight balancing of the developed cultivator and Fig.5 shows the field trials of the cultivator along with a low hp tractor.

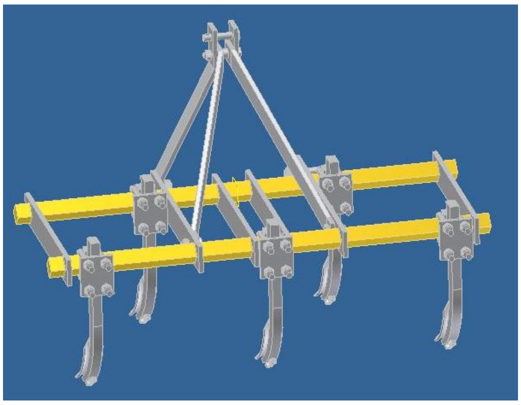

Fig.1: 3D CAD Model of the cultivator

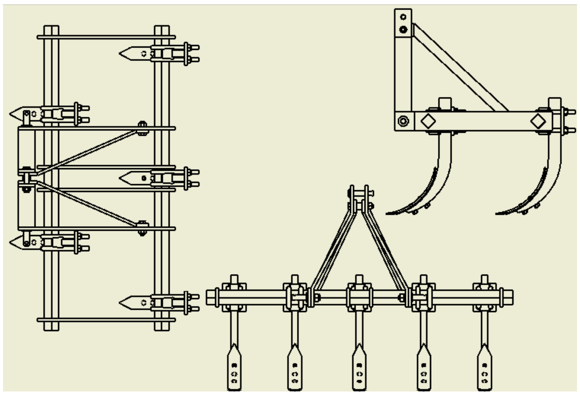

Fig.2: 2D view of the Designed 5-tine Cultivator

Fig.3: Physical prototype of the developed cultivator attached with a Low HP Tractor

Fig.4: Laboratory trial (weight balancing) of the cultivator

Fig.5: Field trial of the cultivator with a Low HP Tractor

Fig.6: Depth of cut measurement during field trial of the cultivator

## 4.0 PERFORMANCE ANALYSIS

The 5-tine cultivator was designed and developed at CMERI and its performance was analyzed in the laboratory and as well as in the field. In the laboratory the cultivator was attached with a low hp tractor which was also developed in CMERI for checking the weight distribution, balancing and proper fitting so as the same should perform well in the field.

For field performance analysis, the cultivator was taken to the field and it was tested to measure the parameters like depth of cut, width of cut, fuel consumption of the tractor etc. The result has been shown in table 5.

 

Table: 5 Data of field performance of the 5-tine cultivator attached with a low hp tractor

| Parameters | Tractor operating speed km/hr | | |
|---|---|---|---|
| | 1.6 | 2.6 | 3.9 |
| Depth of cut (cm) | 150 | 135 | 130 |
| Width of cut (mm) | 980 | 980 | 980 |
| Fuel consumption (l/hr.) | 1.2 | 1.15 | 1.10 |

## 6.0 CONCLUSION

A suitable implement say cultivator was designed and developed at CSIR-Central Mechanical Engineering Research Institute. This implement was designed and developed following the ASAE standard for matching it with a typical low hp tractor. The developed cultivator was evaluated for its performance analysis in the laboratory and as well as in the field. By following the steps outlined in this paper, to carefully select and match the tractor and tillage equipment for particular needs, investment and operating costs of tillage can be minimized. If a step-by-step approach is used when matching power units and implements, it is possible to eliminate the majority of guesswork that is normally employed when a machinery purchase decision has to be made. This approach is simplistic but does allow changes to any of the inputs. Care must be taken not to overestimate either the time available to complete the task or field efficiency.

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