Utilization of Tractor Power using Front Three Point Linkage

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Abstract. With a higher HP tractor it is difficult to take the maximum use of tractor power. Front three-point linkage has been found profitable with these tractors due to higher power requirement and also due to multiple operations in single pass. The importance of this study is to check its feasibility under Indian field conditions. Front three-point linkage are designed and fabricated according to Category II hitch requirements. Hydraulic cylinders are designed to provide hydraulic power to the front linkages. Selection of hydraulic hoses is done according to the requirements and availability. Mechanical front-wheel drive tractor is selected for the test. Laboratory test is carried out to evaluate its lifting performance. Field performance is also done to check its profitability. A field is prepared using cultivator in front and harrow in rear and the performance are calculated.

Keywords: Front three-point linkages, three-point hitch, Front linkages and front wheel drive tractor.

1. Introduction
The increased mechanization in Indian agriculture plays an important role in improved production of agricultural products to market allowing our country to export food products and make revenue for the better economic growth. The country has now become not only self-sufficient but also a net exporter of food grains. Total production of food grain became 230 Mt in 2008-09 which was only 198 Mt in 2004-05 [1]. Better irrigation and crops yield has paid a way for the higher agriculture product production. Farm mechanization has increased the agricultural production to meet our requirement [2]. Number of tractors increased to 2,749,000 in 2006 which was 1,540,000 in 1994. Use of tractors has witnessed an increase of more than 78% since 1994 [3]. There are more 13,500 tractors per millions of hectares. Not only has the use of tractor also the use of Farm Machinery equipment has been increased in the last decade.

Number of reapers has increased to 11,595,000 in 2006 which was 2,782,000 in 1994 with an increase rate of about 315% [4]. With the increase in mechanization in agricultural sector the use of tractor has also increased the farm power availability. The tractor is the major energy consumer in the form of diesel and lubricants at the farm. As a result of different programs implemented by the Government of India over the years, the total farm power availability is estimated to have been increased from 0.47 kW/ha in 1981-82 to 1.5 kW/ha in 2005-06 having a 46.75% contribution of tractor power [5]. Autonomous agricultural robots have also been deployed in many countries for seeding and plantation works [6]. Hence is more important to research work on the fuel and its weigh is very important.

The purpose of tractor is to convert fuel power into useful power at drawbar or hitch point with producing sufficient traction. The hitch itself is defined as a single articulated point or combinations of articulated points and links through which tractor delivers tractive effort in the form of pull or push to counteract a draft force of an implement or draft producing body. Hitch point may be in rear, front or side of a tractor [7]. Rear three-point linkages now became a necessary component of tractor. Earlier only single point hitch was available in the rear of the tractor. In late 1930, Ferguson developed a system named as Ferguson system having two lower links and an adjustable length top link which makes a triangular hitch point [8]. The system was comprising hydraulic lift system to lift and drop the implement. Ferguson system enables the use of weight transfer from a mounted implement in producing light weight tractor [9].
In search of higher productivity, farmers are taking two-three crops in a year. In this farming pattern they don’t have much time for field preparation due to which rear mounted plough have become longer and heavier, necessitating the use of additional front-end weights and assister rams on the hydraulic lift [10]. As plough length increases, so the evenness of working depth over the full length of the implement deteriorates. Front linkages make possible the use shorter ploughs for the same number of furrows as well as removing the need for front end ballast [11]. Front linkages considerably increase the versatility of an agricultural tractor, enabling equipment to be mounted in a position where it can be seen more easily by the driver [12-14].

When front linkage is used in a combination with rear linkages, multiple operations in a single pass can be achieved and better use can be made of the potential of four-wheel drive. The earliest front linkages for tractors were of lightweight design for use typically with haymaking and forage equipment. Later in 1970s in France heavier front linkages were introduced which were capable of handling ploughs and other tillage tools [15-17]. Front linkages also follow the traditional Ferguson design of two lower links with hydraulic lift and a manually adjustable top link. Stability of the tractor with front linkages is of great concern in its design. When a ground engaging implement is mounted on front linkages, stable behavior is found to be more difficult to achieve [18]. In case of front linkages front converging linkages are found to be more stable than rear converging. Front linkages are readily available in other countries but in India this is not in use. Front mounted reaper is tried but it didn’t popularize. Rear mounted offset implements are available which shows the necessity of front linkages [19].

2. Materials and Methods

This chapter deals with the dimensions of links, link points, cylinders and other designed brackets, specification of tractor, FEM analysis of designed brackets, theoretical Prediction of fuel and time saving, lifting and lowering speed calculation of front linkage, research plan for laboratory and field test. A detailed description on these aspects has been presented under the following major headings:

a. Selection of tractor and implements
b. Design of linkages, cylinder and other parts
c. FEM analysis of designed brackets
d. Prototype fabrication of the parts
e. Theoretical prediction of time and fuel saving
f. Lifting and lowering speed of front linkage
g. Research plan for laboratory and for field test

2.1 Selection of tractor and implements

The tractor selected for the research must be able to generate sufficient power as well as traction to produce the draft required for two implements. Table 1 states some good combination of front and rear implements which are used readily.

| Front                              | Rear                             |
|------------------------------------|----------------------------------|
| Forage Chopper                     | Trailer                          |
| Mower                              | Baler                            |
| MB Plough                          | MB Plough / Cultivator           |
| Off-Set Cultivator                 | MB Plough                        |
| Cultivator                         | Harrow                           |
| Tiller packer / Clod breaker /     | Planter / Seed drill             |
| Cultivator                         |                                  |

Table 1. Combination of front and rear mounted implement
The maximum power requiring combination which is also suitable for Indian condition is the combination of MB Plough and Cultivator. Draft and power requirement of MB plough and cultivator is shown in table 2.

**Table 2. Draft and power requirements for MB plough and cultivator**

| Parameter                | MB Plough (Bottom) | Cultivator (9 Tine) |
|--------------------------|--------------------|---------------------|
| Width of operation ( m ) | 0.9                | 2.02                |
| Depth of operation ( cm ) | 25                 | 15                  |
| Speed of operation ( km/h ) | 5                | 5                   |
| Draft ( kN )             | 17.54              | 5.6                 |
| PTO Power required* ( kW) | 33.8              | 10.8                |

* The power mentioned is the power required by the implement not the availability of the tractor.

Total PTO power required to produce the draft required for the above combination of implements is 44.6 kW. Keeping a reserve power of 10 % power required is 49.56 kW. As front mounted implement increases load on front axle, traction decreases while using a rear wheel driven tractor. So, front wheel driven tractor is required. Also, precaution must be taken that the front axle load must not increase than carrying capacity of front axle and tyres. The tractor selected for the research purpose was MF 2640. A Brief specification of tractor is given in table 3.

**Table 3. Specification of the selected tractor**

| Make                | Massey ferguson |
|---------------------|-----------------|
| **Engine**          | Simpson         |
| Maximum gross engine power | 59.7 kW @ 2200 Erpm |
| Maximum gross engine torque | 289.5 N-m @1000 Erpm |
| SFC @ maximum power | 194.6 g/hp-h  |
| PTO power           | 48.4 – 49.8 kW |
| Steering            | Hydrostatic     |
| Brake               | Oil immersed brake |

**Dimensions**

| Front track | 1502 mm |
| Rear track  | 1626 mm |
| Wheel base  | 2230 mm |
| Front tyre  | 12.4 X 24 |
| Rear tyre   | 18.4 X 30 |

**Tractor weight**

| Complete tractor    | 3410 kg |
| Front axle          | 1450 kg |
| Rear axle           | 1960 kg |

**Hydraulic**

| Pump capacity (basic) | 18 lpm @ 2200 rpm |
| Relief valve setting  | 204 – 239 kgf / cm² |
| Pump capacity Auxiliary pump-I | 40.5 lpm @ 665 PTO speed |
Lower link was designed for the maximum force conditions i.e. lift capacity condition. Material selected for lower link was SAE 4140, having yield strength of 417.1 MPa. Top link was designed for the maximum force condition i.e. MB plough condition. The material for the top link adjusting tube was according to standard ASTM A106/B and eye bolt assembly EN 8/8D. Cylinder was design for lift capacity condition to lift a load of 4082 kg.

Lifting and lowering speed is very important parameter of a three-point linkage. Higher lifting and lowering speed may lead to damage of implement while slow lifting and lowering speed reduces the sensitivity of the hydraulic system. For the front three-point linkage hydraulic oil was taken from rear spool valve of the tractor having a flow rate of 40 lpm at rated speed. The two cylinders were connected in parallel connection to maintain the same lifting and lowering speed of both lower links.

![Figure 1. Rear spool valve of tractor](image1)

2.2 FEM analysis of designed bracket

Designed parts were simulated in ANSYS to check the stress and feasibility of the part in loading condition.

![Figure 2. Equivalent stress in FES bracket](image2)
Figure 3. Total deformation in FES bracket

Figure 4. Forces in Main bracket assembly
2.3 Prototype fabrication of the parts

Prototype of the parts was fabricated except the lower link and top link. Lower link and top link were selected from similar available links. Before that the 3D models were converted in 2D drawings with standard specifications and notations. Finally, the whole assembly was mounted on FES and battery tray of the tractor using seven bolts in each side. Bolts were selected according to internal thread size and depth of the thread in FES.
3. Results and Discussions

This work deals with the results of the study after laboratory and field tests. Simulation result of FEM analysis, dimensions of front three-point linkage and implement, its performance in laboratory as well as in field test are disused. Designed parts were simulated in ANSYS software to validate the design. Maximum equivalent stress and deformation is presented in the table below. Equivalent stress is found less than the yield strength and Maximum deformation found under acceptable limit.
After assembling all the parts in front of the tractor, dimensions of the three-point linkage geometry and tractor hitch point were taken. The tractor hitch points were designed to meet the requirement of Category-II hitch point. Link points and the other dimensions were found to satisfy the requirement of Category-II hitch point. Dimensions of the linkage geometry are stated in Table 5.2 while dimensions of tractor three-point hitch are discussed in Table 5.3. Lift and movement range are discussed in Table 5.4.

### Table 4. Equivalent stress and deformation in different parts

| Particular          | Maximum equivalent stress | Yield strength | Maximum deformation |
|---------------------|---------------------------|----------------|---------------------|
| FES Bracket         | 73.8 MPa                  | 240 MPa        | 0.2 mm              |
| Main bracket assembly | 185.7 MPa                | 240 MPa        | 1.2 mm              |
| FES                 | 160 MPa                   | 320 MPa        | 0.65 mm             |

### Table 5. Dimensions of front three-point linkage geometry

| Particulars          | Dimensions                                                                 |
|----------------------|-----------------------------------------------------------------------------|
| Lower link point     | 590 mm ahead and 123 mm below front axle centre line                          |
| Top link point       | 768 mm ahead and 400 mm above front axle centre line                          |
| Length of lower link | 760 mm                                                                      |
| Length of top link   | 540 – 660 mm                                                                |
| Cylinder mounting points |                                                                 |
| Bore end             | 629 mm ahead and 412.5 mm above front axle centre line                        |
| Rod end              | 225 mm away from lowerlink point on lower link.                               |

Time required in lifting and lowering of front lower link was measured and compared with the calculated value as well as with the rear lower link also. Table 5.5 describes the time required in different condition. The theoretically calculated time in lifting and lowering was 2.0 and 2.6 sec at 2000 engine rpm while the measured values were 2.1 and 2.5 sec.

### Table 6. Time required in lifting and lowering of rear and front lower link

| Engine rpm | Front | Rear |
|------------|-------|------|
|            | Lifting | Lower ring | Response | Lifting | Lowering |
| 1500       | 2.5 sec | 3.0 sec | Slow     | 2.9 sec | 10.6 sec |
| 2000       | 2.1 sec | 2.5 sec | Fast     | 2.7 sec | 4.6 sec  |

Lifting performance of the front three-point linkage was measured at hitch point and at standard frame. Lift capacity was measured at 90% of the relief valve setting. The table below shows the results of lift capacity performance.
Table 7. Lift capacity performance of front three-point linkage

| Characteristics        | At standard frame       | At lower hitch point                  |
|------------------------|-------------------------|--------------------------------------|
|                        | At horizontal           | 21.6 kN 2204.1 kg                   | 26.1 kN 2663.3 kg |
|                        | Throughout range        | 16.5 kN 1683.7 kg                   | 25.2 kN 2571.4 kg |

Table 8. Field performances with front and rear mounted implement

| Performances                  | Rear mounted | Front and rear mounted |
|-------------------------------|--------------|------------------------|
|                               | Cultivator   | Harrow            | Front cultivator/Rear-Harrow |
| Av. Speed (km/h)              | 5.6          | 6.24               | 4.58                         |
| Wheel slip (%)                | 21.95        | 20.24              | 18.46                        |
| Field coverage (ha/h)         | 0.88         | 0.92               | 0.58                         |
| Total time required (min)     | 50           | 47.8               | 76.4                         |
| Fuel consumption (l)          | 6.55         | 5.78               | 10.2                         |
| Total fuel consumption        | 12.33        |                      | 10.2                         |

4. Conclusion

Based on the results, the use of implements with front three-point linkages increases load on front axle which leads to decrease in traction. So, a four-wheel drive or mechanically front wheel driven tractor must be used while using front linkages. Designed front three-point linkage and the modified implement were found to satisfy the requirements of category-II hitch point. The lift capacity of front three-point linkage at standard frame was 2204.1 kg at horizontal position and 1683.7 kg throughout range. While lift capacity at hitch point was 2663.3 kg at horizontal position and 2571.4 kg throughout range. Use of cultivator in front and harrow in rear could save 21.9 % of time and 18.9 % of fuel.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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