# DEVELOPMENT OF ECCENTRIC DRIVEN TRANSMISSION SYSTEM FOR GARDEN TRACTOR

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## PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

## Bachelor of Technology in Agricultural Engineering

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KERALA

1998

# DECLARATION

We hereby declare that this project report entitled "**Development of Eccentric Driven Transmission System for Garden Tractor** " is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place : Tavanur

Date : 04-5-98

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# CERTIFICATE

Certified that this project report, entitled, **"Development of Eccentric Driven Transmission System for Garden Tractor"** is a record of project work done jointly by Anvur V.A., Jayapradeep S. and Satheesan M.M. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

05/5/98

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# SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| Agrl. | - | Agricultural |
| ASAE | - | American Society of Agricultural Engineers |
| ASME | - | American Society of Mechanical Engineers |
| cc | - | cubic centimetre (s) |
| c/c | - | centre to centre |
| CIAE | - | Central Institute of Agricultral Engineering |
| cm | - | centimetre (s) |
| Co. | - | Company |
| Coeff. | - | Coefficient |
| Contd. | - | Continued |
| db | - | drawbar |
| Dept. | - | Department |
| dia. | - | diameter |
| edn. | - | edition |
| Engg. | - | Engineering |
| et.al | - | and other people |
| etc. | - | etcetra |
| Fig. | - | Figure |
| FPME | - | Farm Power Machinery and Energy |
| fs | - | Shear strength |
| fy | - | Yield strength |
| gm | - | gram (s) |
| ha | - | hectare (s) |
| hp | - | horse power |
| hr | - | hour (s) |
| ICAR | - | Indian Council of Agricultural Research |
| I.D | - | Inner diameter |
| IRRI | - | International Rice Research Institute |
| ISAE | - | Indian Society of Agricultural Engineers |
| J. | - | Journal |

| | | |
|---|---|---|
| KAU | - | Kerala Agricultural University |
| KCAET | - | Kelappaji College of Agricultural Engineering and Technology |
| kg | - | kilogram (s) |
| kgf | - | kiglogram force |
| kmph | - | kilometers per hour |
| kw | - | kilowatt (s) |
| lit. | - | litre (s) |
| Ltd. | - | Limited |
| m | - | meter (s) |
| m/s | - | meter/second |
| max | - | maximum |
| min | - | minimum |
| mm | - | millimeter (s) |
| MS | - | Mild Steel |
| No. | - | Number |
| OD | - | Outer diameter |
| pp | - | Pages |
| Proc. | - | Proceedings |
| PTO | - | Power Take Off |
| Pvt. | - | Private |
| Res. | - | Research |
| rpm | - | Revolutions per minute |
| s | - | second (s) |
| Tech | - | Technology |
| TNAU | - | Tamil Nadu Agricultural University |
| Trans | - | Transactions |
| USA | - | United States of America |
| Yrs | - | Years |
| % | - | per cent |
| $\pi$ | - | Pi (22/7) |
| $\therefore$ | - | therefore |

# INTRODUCTION

Agriculture is the backbone of Indian economy. Agriculture still forms one of the most important pillars on which the economy of developing nations rest. The arable lands, however are at a premium and individual holdings are relatively small. An increase in food production is achieved by the combined effect of increased power input., improved seeds and modified production technology in agriculture. The entire farm operations can be completed efficiently and in time only if sufficient power is available in the farms. The only way is to improve on yield per unit area by intensive agriculture through better management.

Man by himself can produce a little only but with the help of machinery he can, easily produce more and get relieved of the tiring field work.

Farm economy can be accelerated by adoption of farm mechanization. Mechanization in agriculture is a must not only for higher productivity but also for reducing the cost of production. The use of selected machinery results in 7.5 - 40 percent increase in agricultural productivity. Timeliness of operation with available farm power can enhance the agricultural production several folds. The man power utilization can be enhanced through effective farm mechanization.

Continuance of the use of less efficient indigenous implements by Indian farmers can be considered as an important reason for low productivity.

Mechanization of Indian agriculture is in its primary stage. Human power predominates even through it can be substituted by other available sources of power. The availability of adequate power for agicultural operations is now recognised as an important factor to achieve higher production per unit area. The current power availability is shown in Table 1.

**Table 1. Farm power available for Indian Agriculture through various sources.**

| Sources of power | Number Million | Power (Million kw) | Percentage |
|---|---|---|---|
| Draft animal | 80 | 31.50 | 25.70 |
| Human power | 200 | 11.94 | 9.40 |
| Diesel engines | 4.6 | 17.16 | 14.04 |
| Electric motors | 8.3 | 30.96 | 25.32 |
| Tractor | 1.3 | 30.96 | 25.32 |
| Power tiller | 0.09 | 0.54 | 0.44 |

Source : Singh,G (1992)

## 1.1. Animal Power

Animal power is the most important source of power on the farm in India. It is estimated that nearly 70 percent of the total draft power used in agriculture is still provided by animals. The average force that a bullock can exert is estimated to be $^1/_{10}$ $^{th}$ of its body weight. But for a short period it can exert many more times the average force. Generally a medium size bullock can develop between 0.5-0.75 hp. The utilization of animal power depends on various factors. Owing to high maintenance cost animal power is becoming uneconomical to the farmers.

## 1.2. Tractor

In Agriculture, the importance of tractor lies mainly in the improvement of soil condition and transportation. Tractor owners earn four to five times more than the bullock owners and get 20% higher yield. Majority of the Indian farmers cannot afford to purchase tractors due to the high capital investment. Also their land holdings are small or scattered, so they prefer to hire a tractor. The availability of tractors in peak season is considerably low.

Tractors can cover a larger area within a short time and can perform various operations like harvesting, threshing and so on.

## 1.3. Power tiller

The power tiller costs less than a tractor and can serve for multifarious jobs comprising tilling, ploughing, inter cultivation and haulage.

The cost of transmission system of conventional tiller comes between 30-40 % of the total cost. Moreover they are designed and developed abroad to meet specific requirements there. Power tillers are not gaining popularity in India because their construction is complex, implement is heavier, cost is comparatively high, local repair is difficult and are mass produced in factories. Hence the Government of India is encouraging the manufacture of two wheeled tractors at reduced price for the benefit of the small farmers of the country. The small power operated and low cost agricultural machines are found to be most suitable. They would have maximum annual use as well. Unlike a large tractor, these machines would replace animals but not people and would help materialise the objectives of the country namely to promote economic development, better income distribution and employment.

It was felt that intermediate technology for a light weight low cost garden tractor if designed and developed could serve as a link between animal power and factory made power tiller or tractor. With this background several attempts were made by various institutions and technocrats.

In the department of agricultural engineering in K A U, M. Sivaswami studied a low cost garden tractor. Its power transmission consisted of sprockets, chains and belt drive. C.P. Mohammed had brought out a unique infinitely variable torque convertor design based on the principle of varying crank radius. The convertor mountable directly on engine shaft does away with all conventional components like clutches, gears, sprocket, chain pulley and belt. Yet it allows change of torque easily from zero to maximum and back to zero. This mechanism was simple and therefore the cost would be substantially low. In the present study an attempt is being made to incorporate this principle for transmitting the power.

The main objectives of this study include the following :

1. To design an eccentric driven power transmission system suitable for K A U Garden Tractor.
2. To fabricate this power transmission and fix it to the K A U Garden Tractor.
3. To evaluate the field performance of the prototype developed.

# REVIEW OF LITERATURE

## 2.1. History and Classification of Garden Tractors

Two wheel tractors are generally called walking tractors, garden tractors or power tillers. Generally the output power of the garden tractor ranges from 3-19 hp.

A garden tractor may be defined as a self propelled, wheeled vehicle designed for general purpose, lawn and garden work and is controlled by an operator on foot.

Policarpio (1973) classified garden tractors according to power output and type of general construction as

1) Light duty single axle 4-6 hp garden tractor.
2) Medium duty single axle garden tractor upto 8 hp
3) Heavy duty double axle 8-14 hp garden tractor

## 2.2. Power tillers in Indian Agriculture

Indian Agricultural Research Institute, New Delhi introduced Japanese power tiller or garden tractors in India to test their feasibility in Indian condition (ISAE 1975)

In India there are six firms producing garden tractors of power ranging from 5-12 hp, designed to meet specific requirements (Table No.2). Garden tractors are not gaining popularity in India because of the higher cost, complex construction and non availability of local repair and maintenance. This indicates the necessity to develop a simple and low cost garden tractor for the benefit of small and marginal farmers.

**Table 2. Details on the garden tractors produced in India**

| Sl No | Name of the firm | Make | hp |
|---|---|---|---|
| 1 | M/s Indequip Engg. Ltd., Baroda, Ahmedabad | ISEKI | 5-7 |
| 2 | M/s J.K. satoh Agrl. Machines Ltd., Kanpur | SATOH | 5-7 |
| 3 | M/s Kerala Agro Machinery Corporation Ltd., Athani, Alwaye | KUBOTA | 9-12 |
| 4 | M/s Krishi Engines Ltd., Hyderabad. | KRISHI | 5-7 |
| 5 | M/s Maharashtra co-op Engg Society Ltd., Kolhapur | YANMAR | 8-12 |
| 6 | M/s VST Tillers Tractors Ltd., Bangalore | MITSUBISHI SHAKTI JANATA | 8-10 |

## 2.3. Low Cost Garden Tractor

### 2.3.1. Work Done Abroad

The International Rice Research Institute, Phillippines developed a low cost 5 -7 hp garden tractor and conducted a series of tests to determine the performance and feasibility for small farms of the developing countries . In IRRI garden tractor ( Fig .1), first step speed reduction and clutch have been combined by using a V-belt drive with an idler and it has a three step speed reduction with standard chain and sprocket transmission. It has been found that this type of transmission system reduced the cost of production, repair and total weight of the unit (Policarpio, 1973). IRRI (1979) reported that as an improvement, the idler pulley type clutch was eliminated by mounting a pivoted counter shaft where the clutching is effected by swinging the countershaft with the clutch lever which changes the centre distance between engine shaft and the countershaft. This could serve as a safety device against overload and sudden shock other than the mere transmission of power.

IRRI first developed an externally mounted steering clutch and noticed improper functioning due to mud clogging . Hence a pair of totally enclosed jaw clutch sliding on the hexagonal axle was tried and it was found that disengaging was difficult under full load condition. For avoiding that, a more compact steering clutch was designed and fabricated . Here the drive engaging sleeve slides on the ball bearings during engagement and disengagement. Under normal straight travel, spring pressure holds the clutch in the engaged position. However these type of clutches are not functioning satisfactorily under field conditions and the garden tractors with this arrangement are not popular in developing countries ( Khan *et al*, 1975) .

Wijewardena (1976) reported a 5-7 hp hand tractor called 'Land Master' for upland and low land farming . It had very simple means for turning the tractor at headlands.

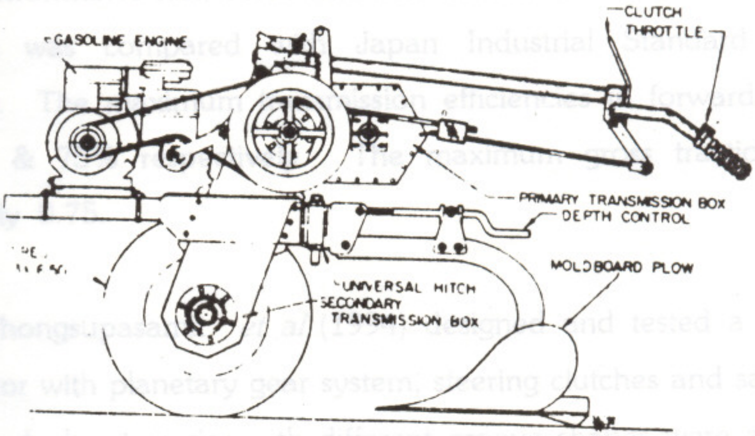



Fig. 1 IRRI 5-7 hp Garden Tractor

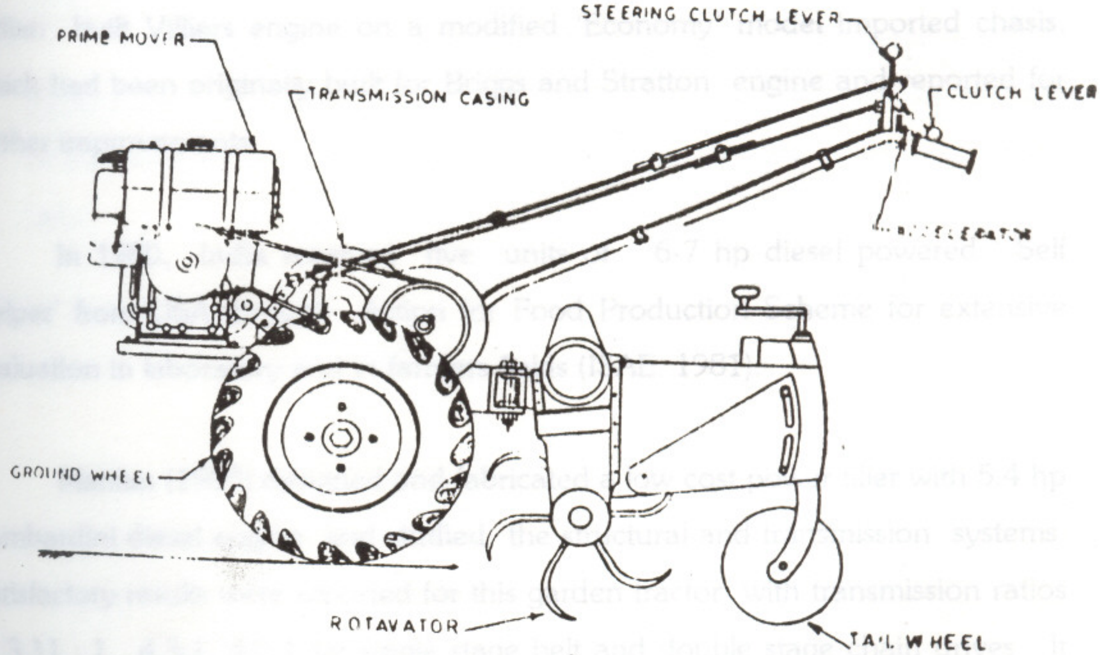



Fig. 2 5.4 hp Powertiller developed at TNAU (1980)

Phongsupasamit .S (1992) conducted studies on power transmission system of Thai walking tractors. The walking tractor was assessed by means of an engine performance test, bench test and traction test. The measured engine performance was compared with Japan Industrial Standard for engine performance. The maximum transmission efficiencies in forward gears 1& 2 where 81% & 75% respectively. The maximum gross traction ratio was approximately 0.75.

S. Phongsupasamit *et al* (1994) designed and tested a new type of walking tractor with planetary gear system, steering clutches and safety designs. Three types of planet carrier with different groove shapes were also designed and tested. The slot shape of planet carrier was found to provide the best function of the stearing clutch. The overall mechanical efficiency was also improved in the new design.

### 2.3.2. Work Done in India

Samuel (1970) fabricated a light weight garden tractor with a 3.5 hp Indian built Villiers engine on a modified 'Economy' model imported chasis, which had been originally built for Briggs and Stratton engine and reported for further improvements.

In 1980, India received five units of 6-7 hp diesel powered ' Self Helper' from USA through Action for Food Production Scheme for extensive evaluation in laboratory and in farmers fields (ISAE, 1981).

Manian (1980) designed and fabricated a low cost power tiller with 5.4 hp Lombardini diesel engine and studied the structural and transmission systems. Satisfactory results were reported for this garden tractor with transmission ratios of 3.11 : 1, 4.5:1, 4.0:1 for single stage belt and double stage chain drives. It had separate steering clutches and the total weight was 178 kg. He found that 5.4 hp garden tractor had the break even point of 500 hours as against 800 to 1130 hours for other available garden tractors and hence the ownership of this type of garden tractors would be profitable even to the small farmers.

Yadav *et al* (1980) reported that a prototype 8-10 hp garden tractor had been designed and developed to serve as ideal source of power for small and medium sized Indian farms in comparison with the existing power tillers.

M/S National Engineering Co. Pvt. Ltd. , Chennai started manufacturing the IRRI type 5.4 hp power tillers but it has not gained much popularity in Indian agriculture.

Sivaswami. M (1982) developed a low cost KAU garden tractor with 5.4 hp Lombardini engine running at 1800 rpm and a simple three step speed reduction system having a single stage V-belt drive and double stage chain drives with a pivoted counter shaft clutch. A pair of simple overrunning clutches for differential action had been used. The unit was found to work efficiently in the pull range of 50 - 60 kgf (Fig. 3)

Jose .C.M (1990) developed and tested a rotary tiller attachment to KAU garden tractor to make it a versatile farm power unit. The actual field capacity of the machine was 0.054 ha/hr and fuel requirement of the machine is 0.86

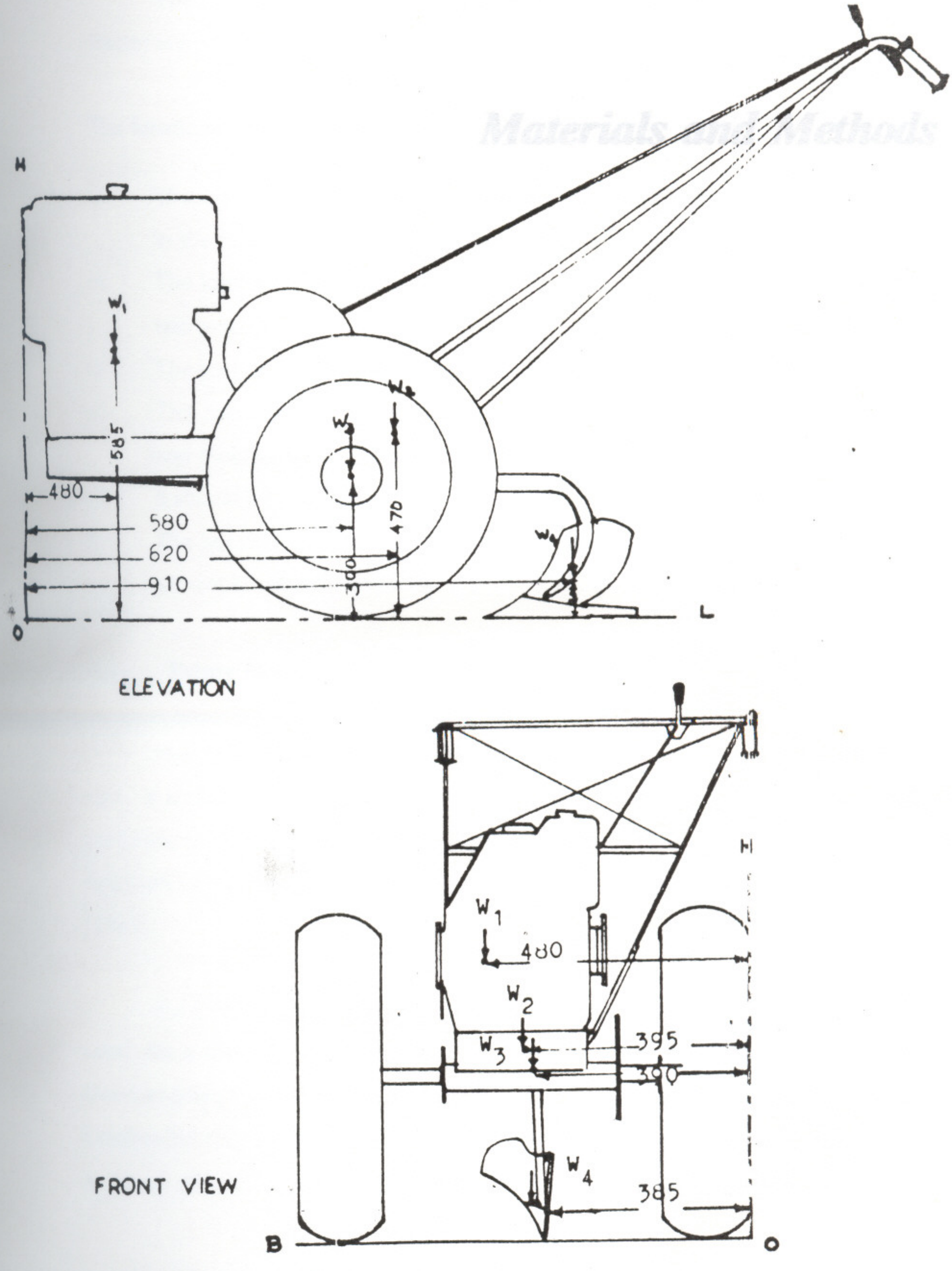



Fig. 3 Low Cost KAU Garden Tractor (M . Sivaswami 1982)

# MATERIALS AND METHODS

The design details and selection of individual components of the garden tractor are presented in this chapter.

The functional requirements of a low cost garden tractor is enlisted as follows;

a) The garden tractor along with the implements should be able to operate in the field at the walking speed of a man.

b) The total weight of the unit should be in such a way that it can be lifted by two persons.

c) The cost should be within the reach of an average Indian farmer.

d) The number of components should be least for easy manoeuvrability and maintenance by the farmer.

e) It should be repairable by local mechanics

f) The position of controls, handle and vibration level should be within the allowable ergonomic levels.

## 3.1 Prime Mover

The horsepower of the prime mover should be of the most economical size. It should be of low weight, easily available, compact, efficient and the performance should match with the field requirements. M. Sivaswami suggested optimum hp for KAU garden tractor as 3.98 by a method derived by Chancellor (1967).

A critical review also indicated that an engine in the range of 5 - 6 hp is ideal for a low cost garden tractor. A light weight ideal 38 kg (dry weight) diesel engine producing a maximum 5.4 hp at a1800 rpm ( Type 523, Greaves Lombardini engine) is selected. It has the maximum torque of 2960 kgmm at a speed of 1200 rpm. The specific fuel consumption corresponding to

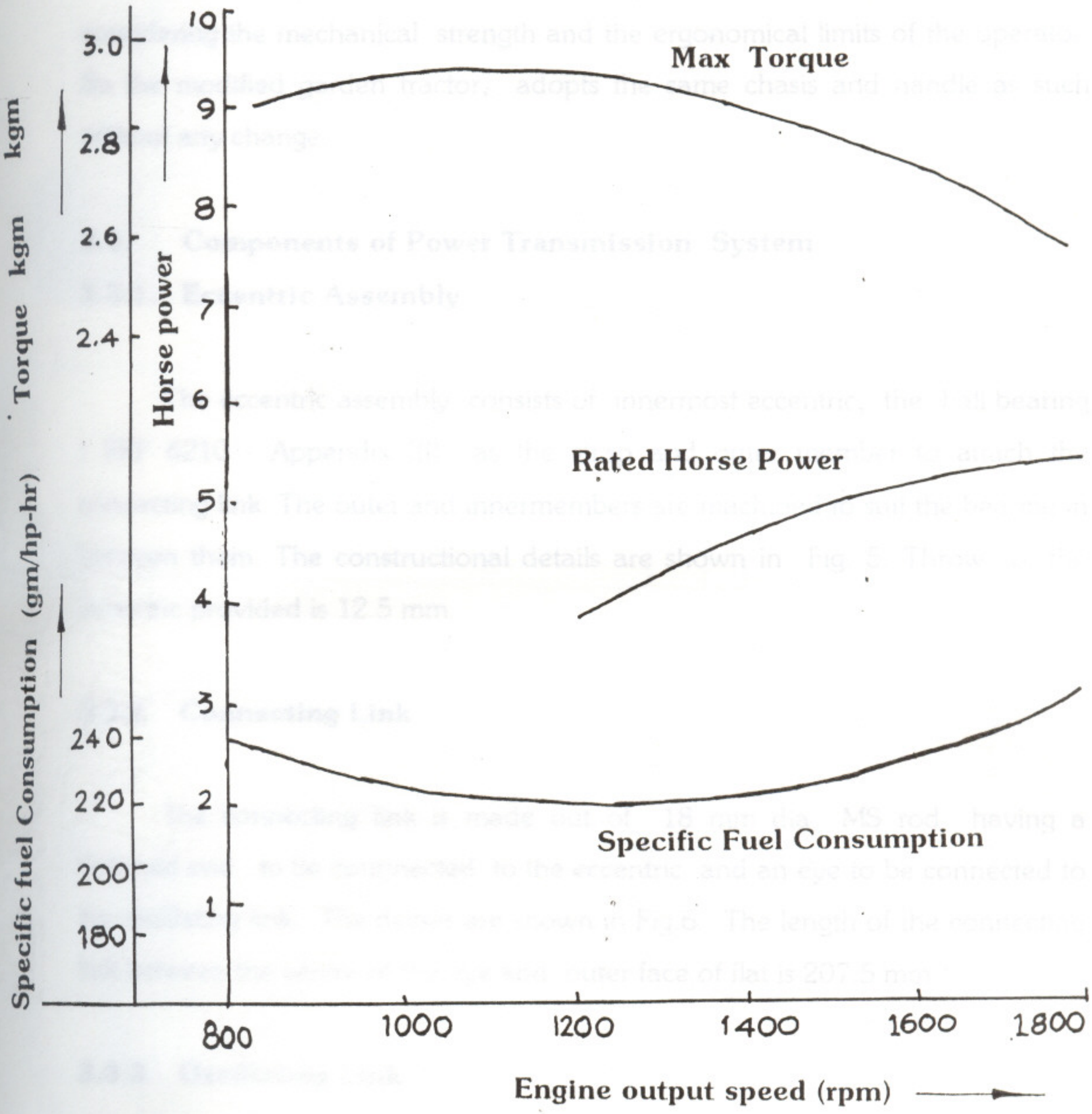



Fig. 4 Characteristics of type 523 Lombardini diesel engine

this is 0.20 kg /hp -hr (Fig. 4). The specifications of the engine is given in Appendix I.

## 3.2 Chasis and Handle

The design of chasis and handle of KAU garden tractor was done by considering the mechanical strength and the ergonomical limits of the operator. So the modified garden tractor, adopts the same chasis and handle as such without any change.

## 3.3. Components of Power Transmission System

### 3.3.1. Eccentric Assembly

The eccentric assembly consists of innermost eccentric, the ball bearing ( SKF 6210 - Appendix III) as the strap and outer member to attach the connecting link. The outer and innermembers are machined to suit the bearing in between them. The constructional details are shown in Fig. 5. Throw of the eccentric provided is 12.5 mm.

### 3.3.2. Connecting Link

The connecting link is made out of 18 mm dia MS rod having a flattened end to be connnected to the eccentric and an eye to be connected to the oscillating link. The details are shown in Fig.6. The length of the connecting link between the centre of the eye and outer face of flat is 207.5 mm.

### 3.3.3. Oscillating Link

The oscillating link as shown in figure 7 consists of an arm and a clevis pin. Big end of the arm is keyed to the final drive axle, and the other end is pivoted to the connecting link by a clevis pin.

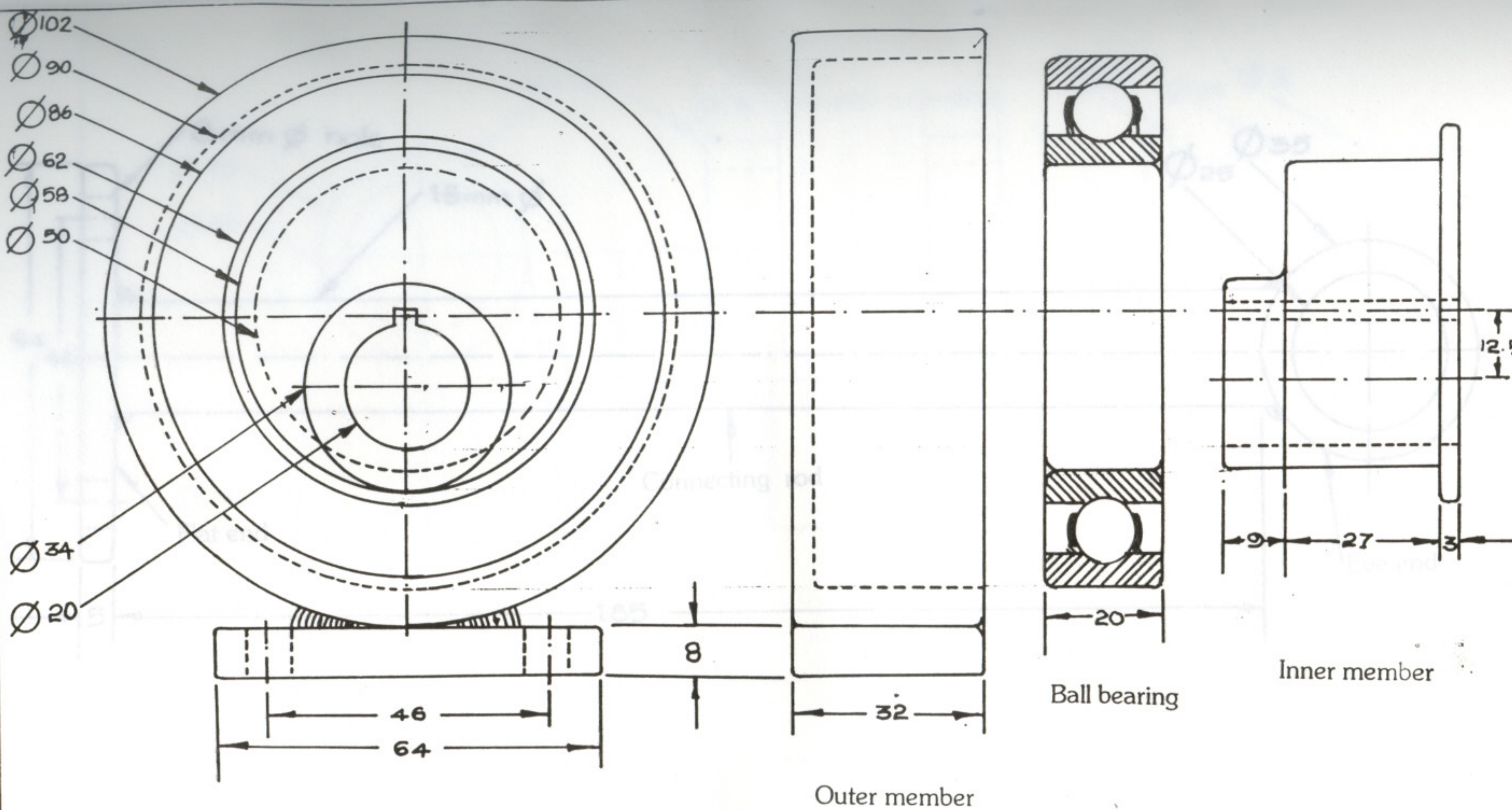



Fig. 5 Constructional details of eccentric

All dimensions in mm

Scale 1:1

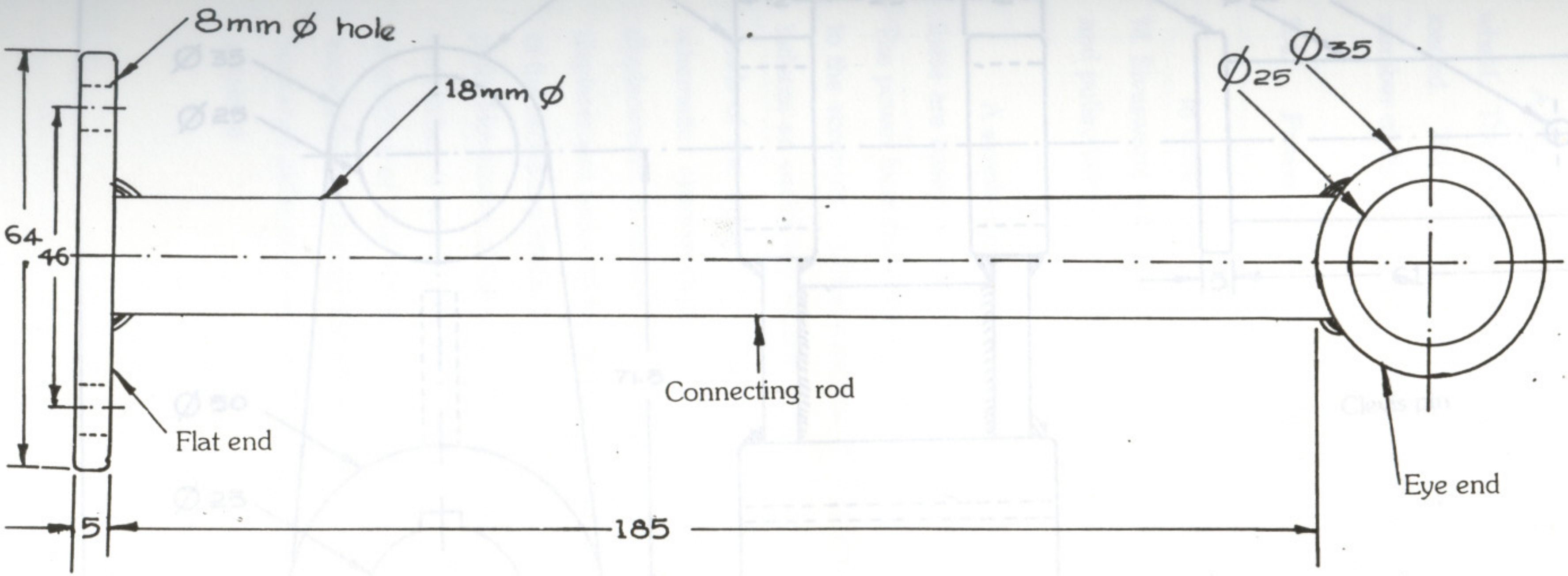
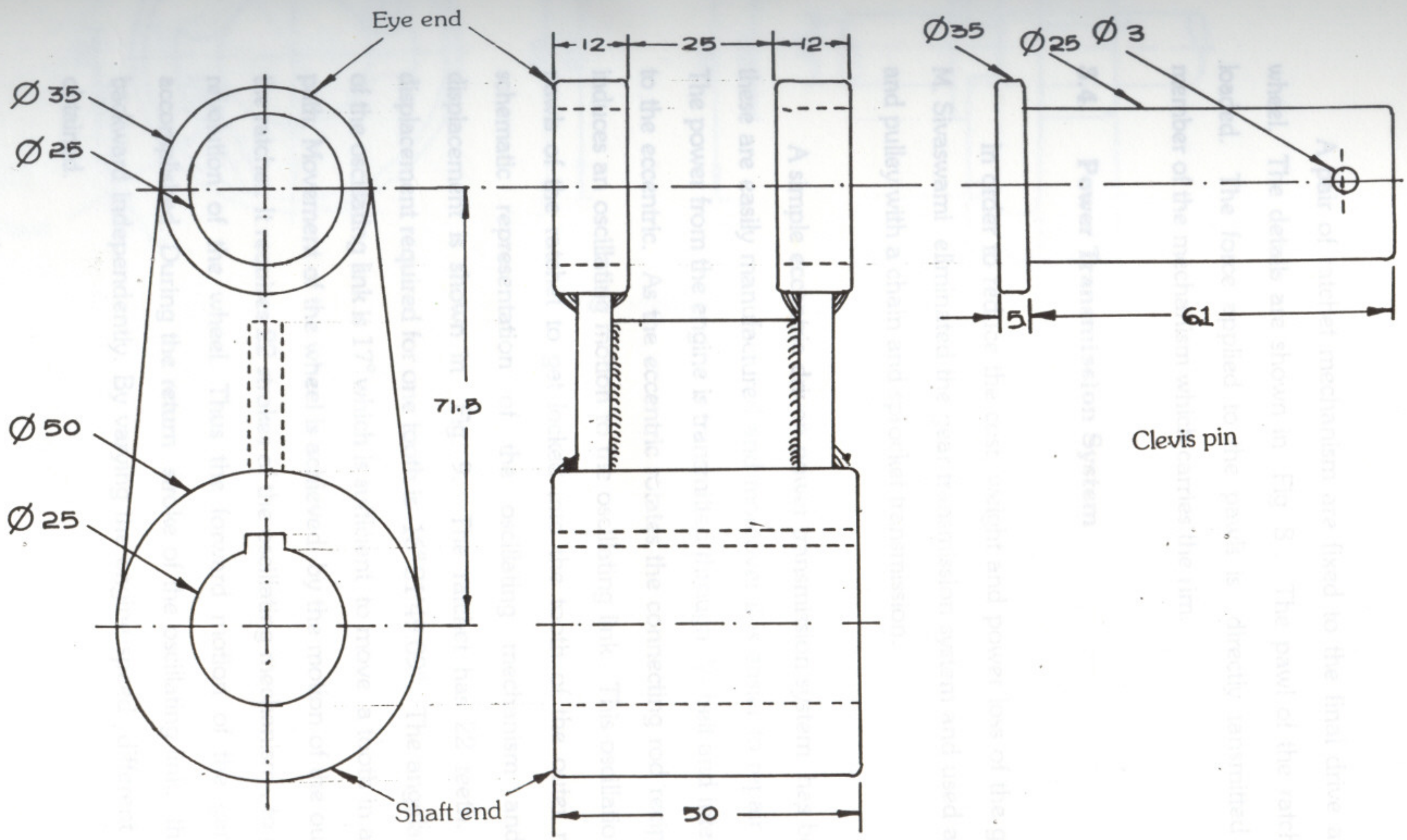



Fig. 6 Details of connecting link

All dimensions in mm

Scale 1:1




All dimensions in mm

Fig. 7 Details of Oscillating Mechanism

Scale 1:1

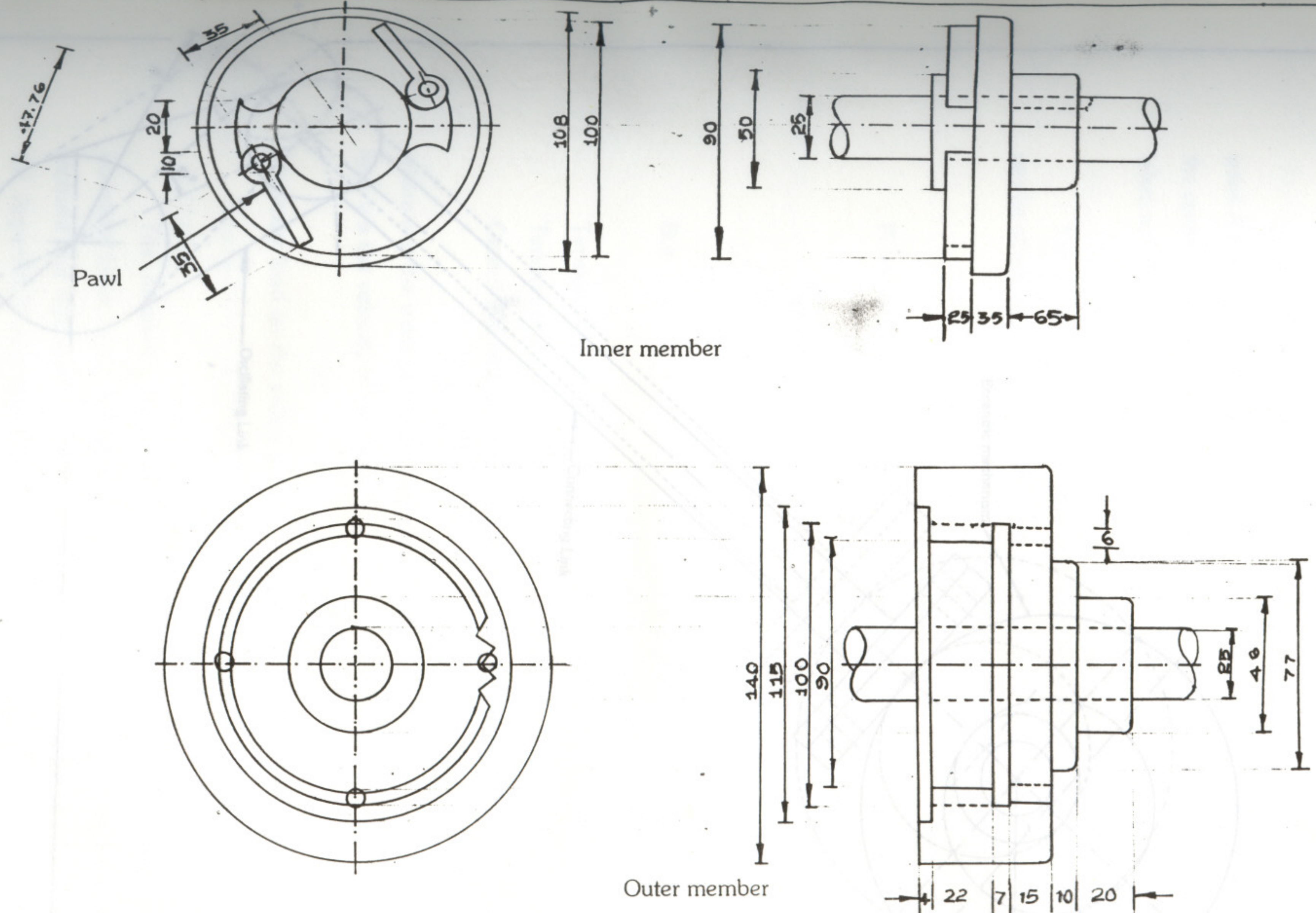
### 3.3.4. Ratchet Mechanism

A pair of ratchet mechanism are fixed to the final drive axle, and the wheel. The details are shown in Fig. 8 . The pawl of the ratchet are spring loaded. The force applied to the pawls is directly tansmitted to the outer member of the mechanism which carries the rim.

## 3.4. Power Transmission System

In order to reduce the cost, weight and power loss of the garden tractor, M. Sivaswami eliminated the gear transmission system and used a simple V-belt and pulley with a chain and sprocket transmission.

A simple eccentric driven power transmission system has been chosen as these are easily manufactured and moreover it is easier to repair and maintain. The power from the engine is transmitted through V- belt and intermediate shaft to the eccentric. As the eccentric rotates the connecting rod reciprocates which induces an oscillating motion to the oscillating link. This oscillation causes the pawls of the ratchet to get locked into the tooth of the outer member. The schematic representation of the oscillating mechanism and its angular displacement is shown in Fig. 9. The ratchet has 22 teeth. The angular displacement required for one tooth is $16° 21' 49.09''$. The angular displacement of the oscillating link is $17°$ which is sufficient to move a tooth in a unidirectional path. Movement of the wheel is achieved by the motion of the outer member of the ratchet. It requires 22 strokes of the oscillating mechanism , to get a complete revolution of the wheel. Thus the forward motion of the garden tractor is accomplished. During the return stroke of the oscillating link, the pawl pushes backward independently. By varying the engine speed different speeds can be obtained.




All dimensions in mm

Scale 1:2

Fig. 8 Details of Ratchet Mechanism

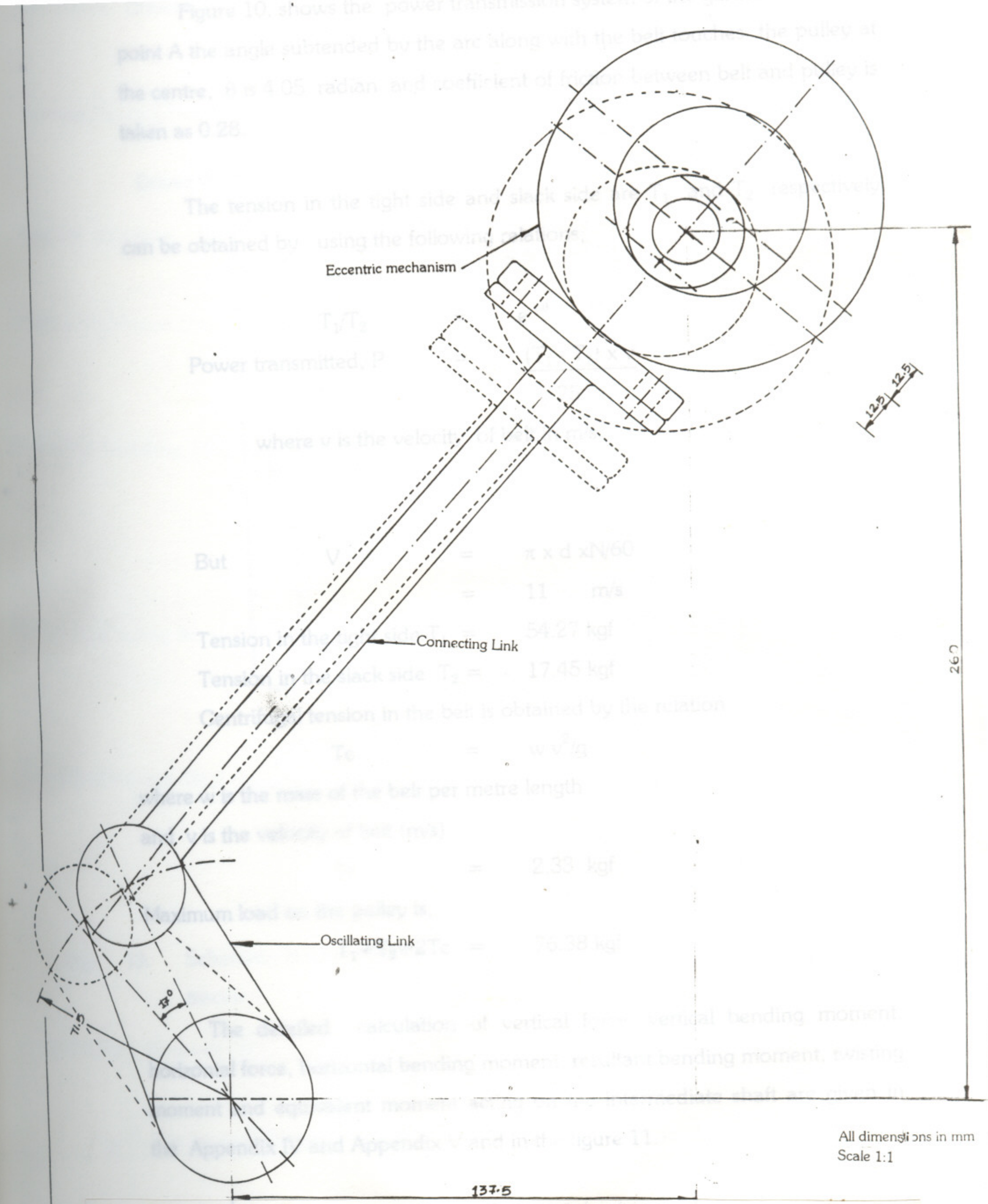



**Fig.9 Schematic representations of eccentric driven power transmission system. All dimensions in mm**

### 3.4.1. Design of Intermediate Shaft

Figure 10. shows the power transmission system of the garden tractor. At point A the angle subtended by the arc along with the belt touches the pulley at the centre, $\theta$ is 4.05 radian and coefficient of friction between belt and pulley is taken as 0.28.

The tension in the tight side and slack side are $T_1$ and $T_2$ respectively can be obtained by using the following relations;

$$T_1/T_2 = e^{\mu\theta}$$

$$\text{Power transmitted, } P = \frac{(T_1 - T_2) \times v}{75}$$

where v is the velocity of belt in m/s.

But $V = \pi \times d \times N/60$

$= 11$ m/s

Tension in the tight side $T_1$ = 54.27 kgf

Tension in the slack side $T_2$ = 17.45 kgf

Centrifugal tension in the belt is obtained by the relation

$$Tc = w v^2/g$$

where w is the mass of the belt per metre length

and v is the velocity of belt (m/s)

$$Tc = 2.33 \text{ kgf}$$

Maximum load on the pulley is,

$$T_1 + T_2 + 2Tc = 76.38 \text{ kgf.}$$

The detailed calculation of vertical force, vertical bending moment, horizontal force, horizontal bending moment, resultant bending moment, twisting moment and equivalent moment acting on the intermediate shaft are given in the Appendix IV and Appendix V and in the figure 11.

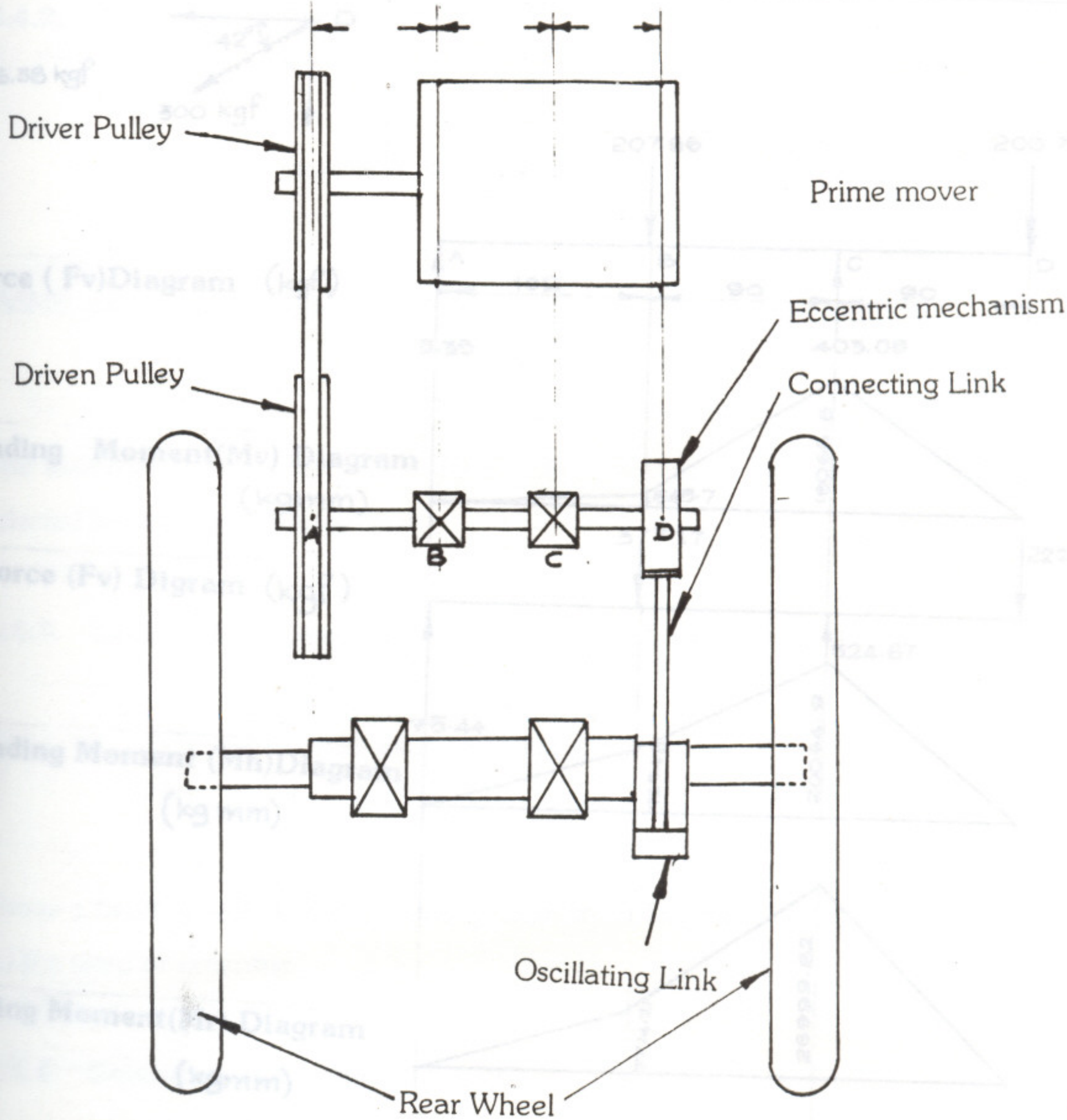



Fig. 10. Schematic Representation of Power Transmission of modified Garden tractor

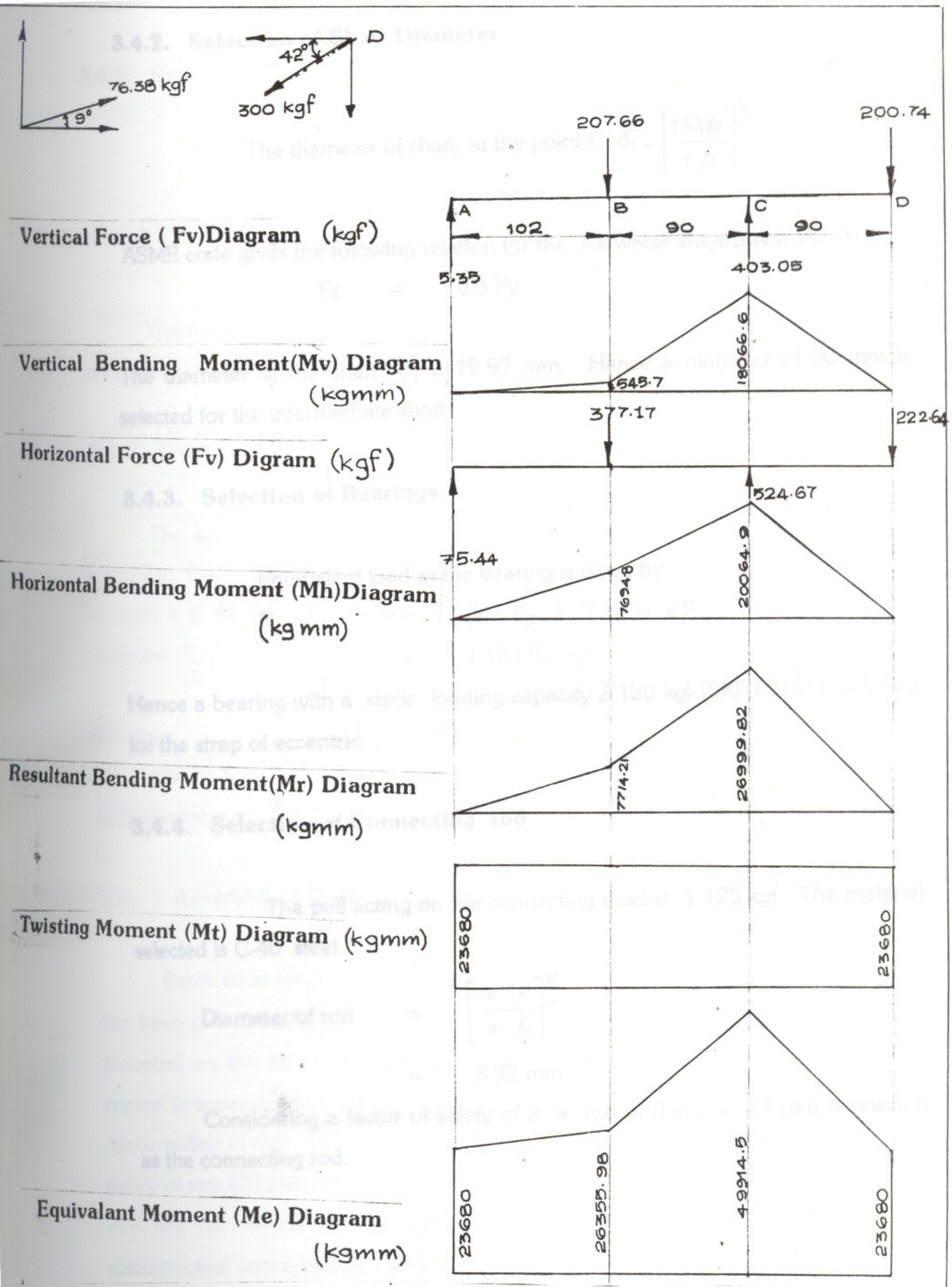



Fig-11 Force and Moment Distribution on Intermediate Shaft

### 3.4.2. Selection of Shaft Diameter

The diameter of shaft, at the point C, $d_1 = \left[\frac{16Me}{\pi\ fs}\right]^{1/3}$

ASME code gives the folowing relation for the allowable shear stress Fs,

$$Fs = 0.3\ Fy$$

The diameter of the shaft $d_1$ is 19.97 mm. Hence a diameter of 20 mm is selected for the intermediate shaft.

### 3.4.3. Selection of Bearings

Equivalent load at the bearing is given by

$$P = (X \times F_D + Y \times F_A) \times S.$$

$$= 1\ 124.91 \text{ kgf}$$

Hence a bearing with a static loading capacity 2 120 kgf (SKF 6210) is selected for the strap of eccentric.

### 3.4.4. Selection of Connecting rod

The pull acting on the connecting road is 1 125 kgf. The material selected is C-40 steel.

$$\text{Diameter of rod} = \left[\frac{4}{\pi}\ \frac{P}{fs}\right]^{1/2}$$

$$= 8.92 \text{ mm}$$

Considering a factor of safety of 2 a rod of diameter 18 mm is selected as the connecting rod.

### 3.4.5. Selection of Clevis Pin

The pin is subjected to double shear, hence

$$\text{diameter} = \left[\frac{4\,P}{\pi\, fs\, 2}\right]^{1/2}$$

$$= 6.31 \text{ mm}$$

The material selected is C-40 steel. Considering a factor of safety of 4, a pin having a diameter of 25 mm is selected as clevis pin.

### 3.4.6. Design of Oscillating Link

The load of 1125 kgf is being equally transmitted through two legs of oscillating link. Therefore the load on each leg is 562.5 kgf. The material selected is C 40 steel. The width (b) required for the C 40 steel flat of 5 mm thickness (t),

$$b \times t \times fs = P$$

therefore $b = 6.25$ mm.

Hence two C 40 steel flats of size 35 mm x 5 mm are selected for the legs of oscilllating arm.

## 3.5. Assembling Details

Fabrication work of the power transmission system of the garden tractor has been completed at the workshop of K C A E T, Tavanur. The engine is mounted on the frame by fastening foundation bolts . The power from the engine is transmitted to the intermediate shaft through V-belt and pulley. The driver pulley of size 175 mm dia is fixed on the engine shaft and the driven pulley of size 231 mm dia is mounted on the same side on the intermediate shaft. A V- belt (B - 47 ) is used to transmit the power. The power from the engine is disconnected/ connected by using an idler pulley which can be operated with a lever and handle. The speed reduction ratio achieved is 1.32. The intermediate shaft is housed on two bush bearings. On the intermediate shaft the eccentric assembly is keyed at the other side of the driven pulley. The details are shown in Fig. 12 and Fig. 13.

The final drive axle (Fig. 14) is passed through the housing in the base of chasis bearing. The oscillating link is fixed on the same side of the eccentric assembly with a key. The eye end of the connecting link is pivoted by a clevis pin on the oscillating link. The other end of the connecting link is bolted to the strap of eccentric.

Outer and inner members of the ratchet are assembled by pressing the pawls of the inner members. The correctness o the assembling is checked by uniform sound, when it overturns. The inner members of the ratchet are keyed to the final drive axle on both ends and locked with grub screws. The wheel rim is bolted to the outer member of the ratchet. The pneumatic wheels are assembled by wheel bolts to the outer member and locked by set collars and grub screws.

The idler pulley is fixed on a bell crank le ver which is linked to the clutch handle.

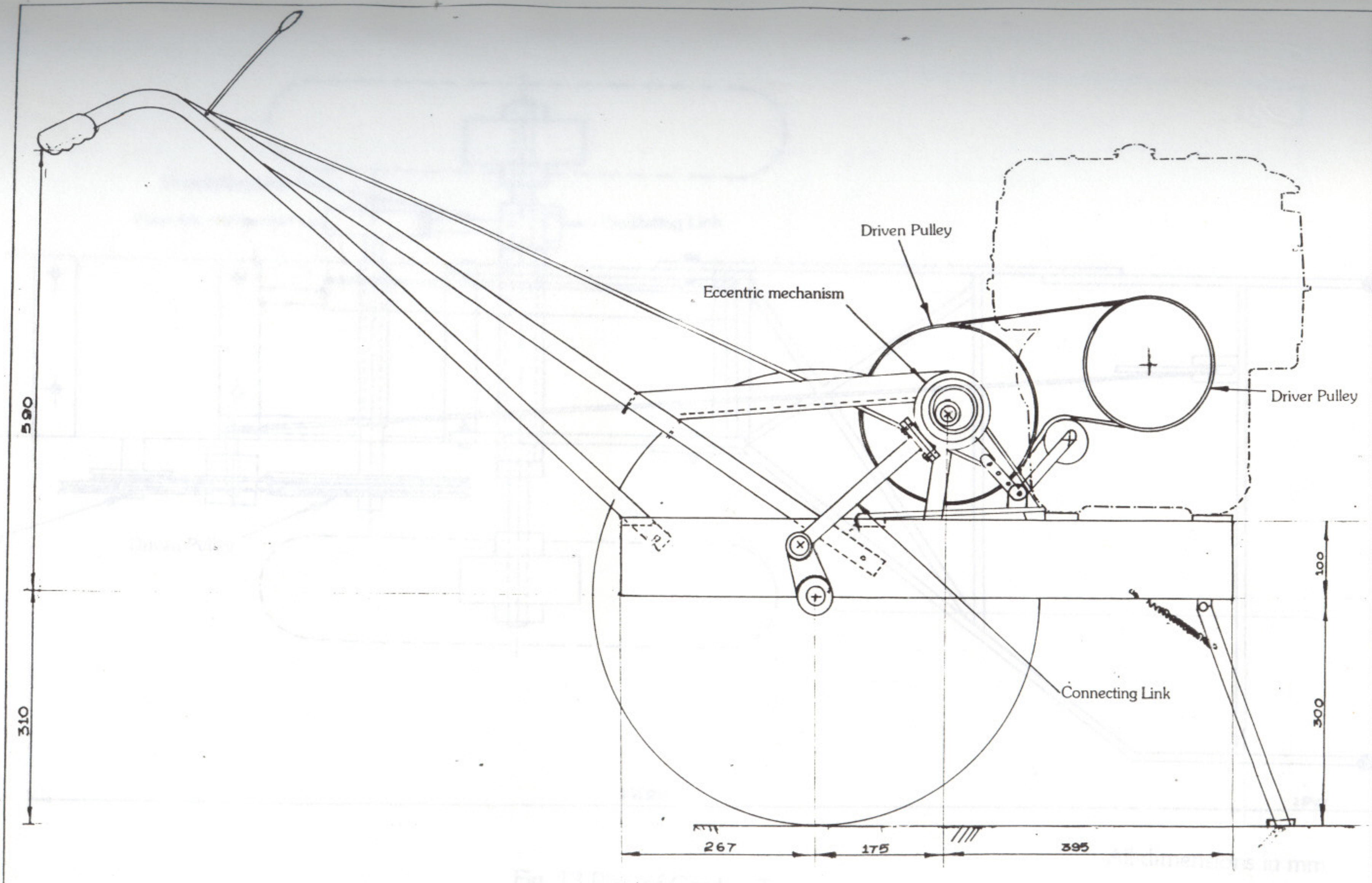



Fig. 12 Elevation of Garden Tractor

All dimensions in mm

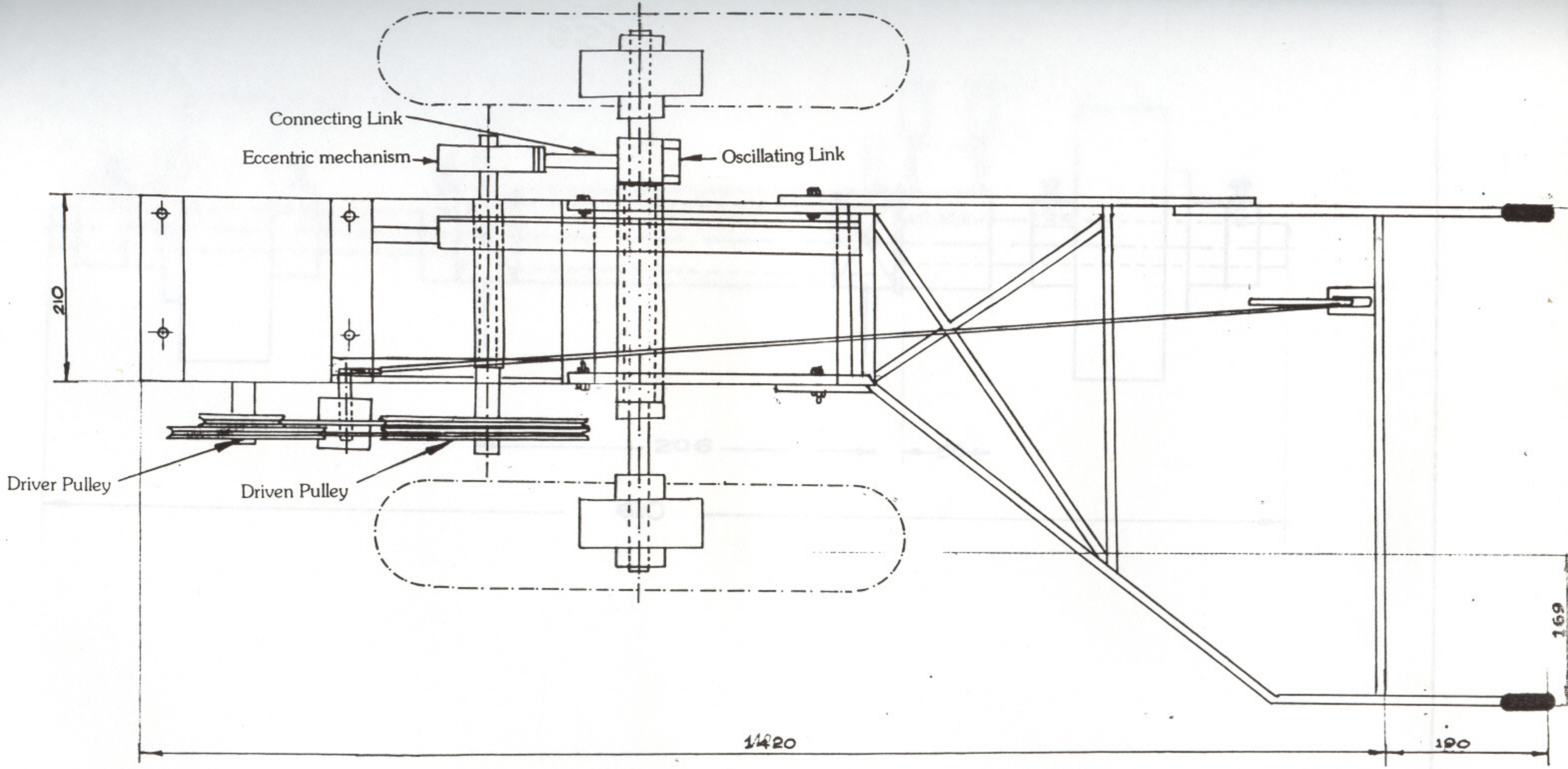



Fig. 13 Plan of Garden Tractor

All dimensions in mm

Scale 1:5

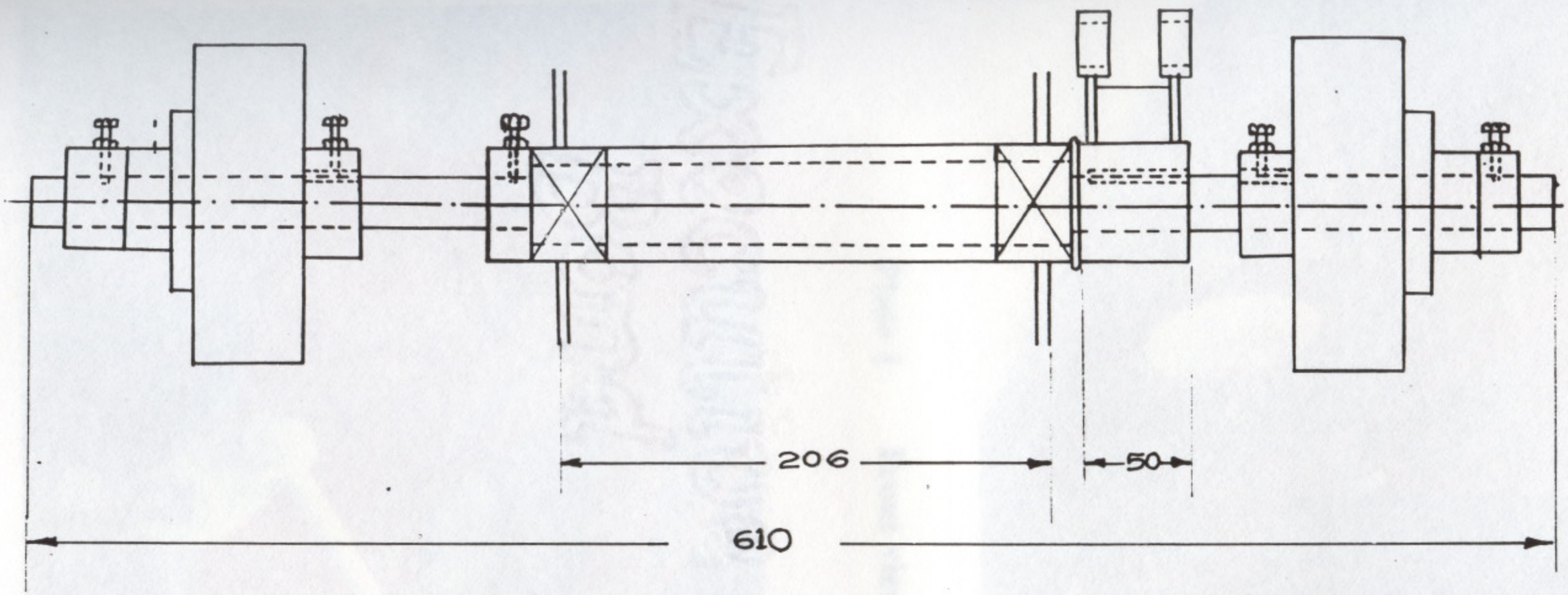



Fig. 14 Details of Final drive axle

All dimensions in mm

Scale 1: 3

Plate I Front view of Garden Tractor

Plate II Eccentric power transmission system (Right wheel removed)

# RESULTS AND DISCUSSION

The performance parameters of the low cost garden tractor were analysed and results of the analysis and the economic feasibility of the unit is presented in this chapter.

## 4.1. Field Tests

Field tests on the garden tractor has been done at K C A E T Tavanur for evaluating the following performance parameters:

| | | | |
|---|---|---|---|
| (a) | Drawbar pull | (b) | Draw bar power |
| (c) | Slip | (d) | Coefficient of rolling resistance |
| (e) | Rolling resistance | (f) | Soil thrust |
| (g) | Tractive efficiency | | |

These tests were conducted for pneumatic tyre 6.00 x 12 size in the sandy loam soil with static weight of tractor (W) 120 kg. The weight of the garden tractor was found out by direct weighing.

The weight of the modified K A U garden tractor is less than that of previous garden tractor which weighs 140 kg.

Drawbar power is the potential of the vehicle to pull the load which is given by the product of vehicle velocity and drawbar pull (P). Wheel slip has been found out from the velocities at no load (Vo) and with load (V).

$$\text{Wheel slip, } S = \frac{(Vo - V)}{Vo}$$

The coefficient of rolling resistance (Cr) and the soil thrust (F) are calculated from the following equation by substituting the value of slip (S) and static weight of garden tractor (Manian, 1980).

$$S = 2 + 220\ Cr^2$$

$$F = P + W\ Cr$$

The tractive eficiency is the ratio of drawbar horse power to the power input to the tractive member or final drive axle.

$$\text{Tractive efficiency} = \frac{\text{drawbar power}}{\text{power from prime mover}}$$

Coefficient of traction is the ratio of drawbar pull to dynamic load on wheels of the garden tractor (Wong, 1978). The Table 3 shows the traction characteristics of garden tractor.

Figure 15. shows the influence of pull on slip. It is seen that the rate of increase of slip with respect to pull upto 70 kgf is constant and beyond that it deviated from a linear relation. It is also noticed that with increase in pull, the forward speed is reduced.

Figure 16.shows the relationship between the coefficient of traction and coefficient of rolling ressistance with respect to forward speed. From this figure it is clear that the increase in the speed reduces both coefficient of traction and the coefficient of rolling resistance.

The change of tractive efficiency (TE) with respect to pull of the garden tractor is illustrated in Fig.17. Tractive efficiency indicates an increasing trend with increase of pull.

**Table 3 Traction characteristics of garden tractor for pneumatic wheel**

| Sl. No. | Drawbar pull (P) kgf | Draft (D) kgf | Vehicle speed (v) kmph | Slip (S) % | Coeff. of traction | Coeff. of Rolling resistance Cr | Rolling resistance (W.Cr) | drawbar power (hp) | Soil thrust (F) | Tractive efficiency (TE) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 9.78 | 3.654 | 5.16 | 0.083 | 0.1198 | 14.38 | 0.1353 | 24.38 | 2 51 |
| 2 | 25 | 24.45 | 3.495 | 9.29 | 0.2.83 | 0.1820 | 21.84 | 0.3383 | 46.84 | 6.26 |
| 3 | 40 | 39.12 | 3.279 | 14.89 | 0.3333 | 0.2420 | 29.04 | 0.4858 | 69.04 | 9.00 |
| 4 | 55 | 53.79 | 3.147 | 18.32 | 0.4583 | 0.2723 | 32.67 | 0.6411 | 87.67 | 11.87 |
| 5 | 70 | 68.46 | 2.986 | 22.50 | 0.5833 | 0.3.52 | 36.62 | 0.7741 | 106.62 | 14.34 |
| 6 | 85 | 83.13 | 2.793 | 27.51 | 0.7083 | 0.3458 | 41.49 | 0.8793 | 126.49 | 16.34 |
| 7 | 100 | 97.13 | 2.438 | 36.72 | 0.8333 | 0.3972 | 47.66 | 0.9030 | 147.66 | 16.72 |
| 8 | 115 | 112.47 | 2.212 | 42.56 | 0.9583 | 0.4294 | 51.53 | 0.9421 | 166.53 | 17.45 |

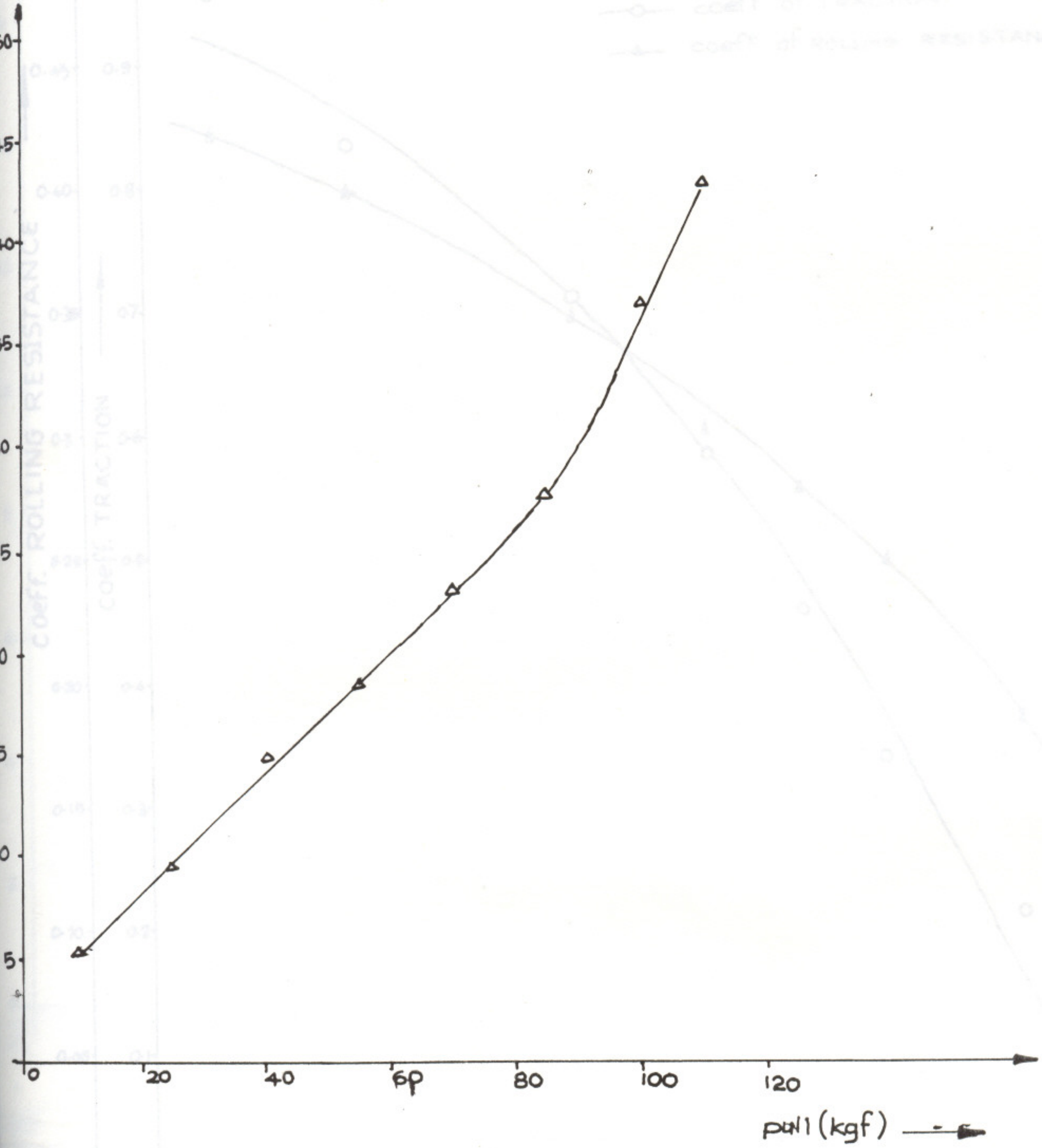



FIG. 15 INFLUENCE OF PULL ON SLIP

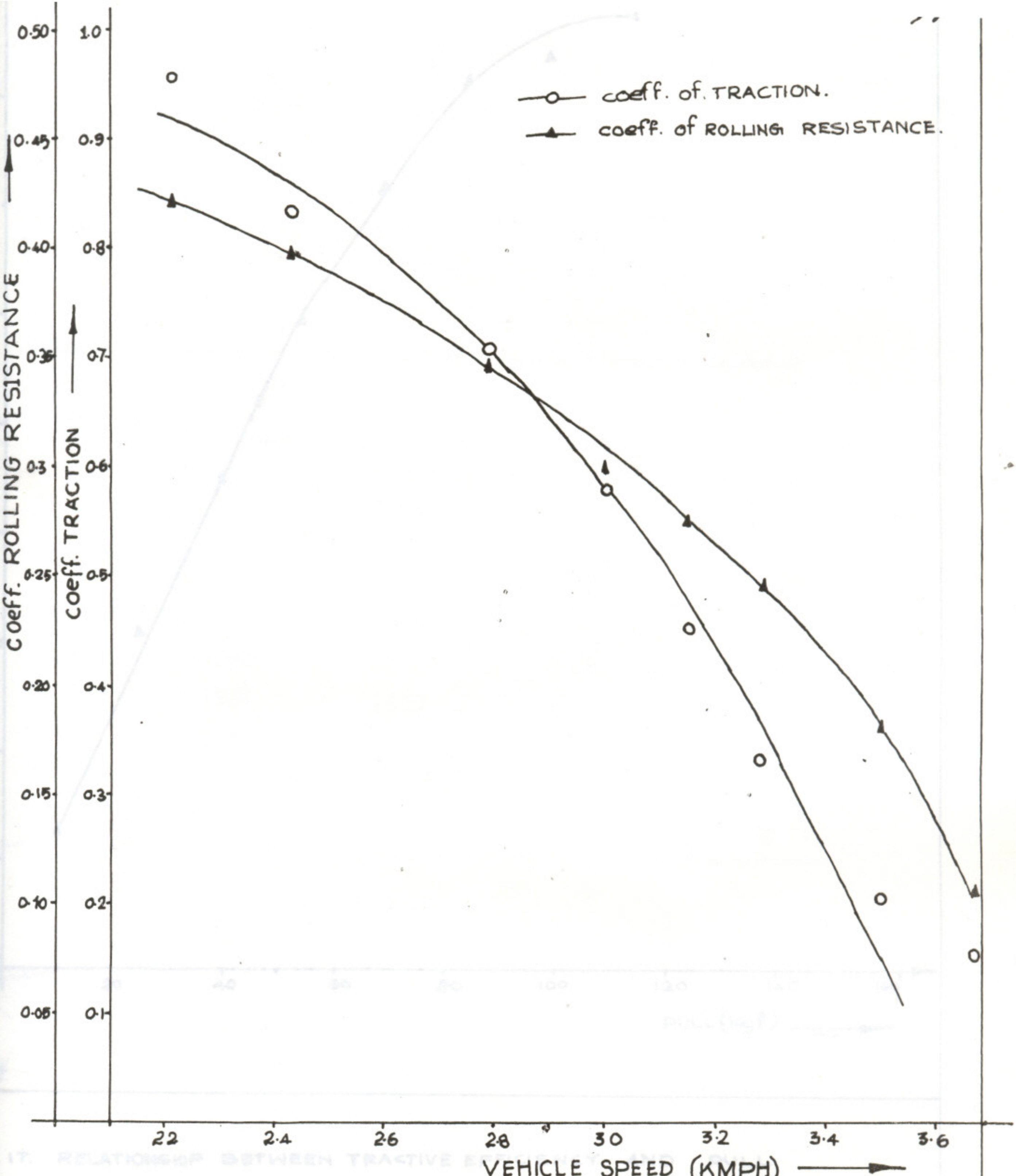



FIG. 16. RELATIONSHIP BETWEEN COEFF. OF TRACTION AND COEFF. OF ROLLING RESISTANCE WITH SPEED.

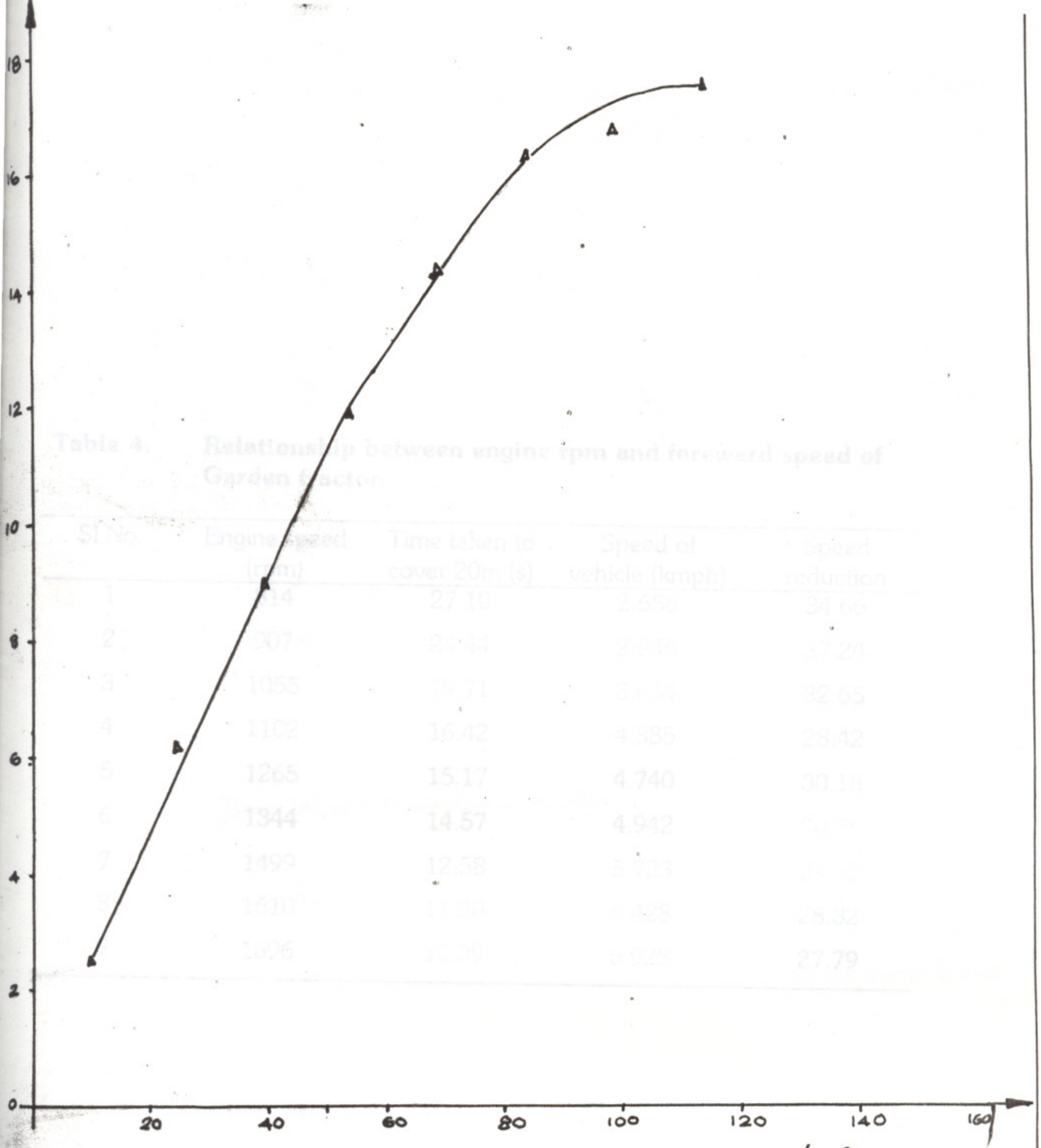



FIG. 17. RELATIONSHIP BETWEEN TRACTIVE EFFICIENCY AND PULL

**Table 4. Relationship between engine rpm and foreward speed of Garden tractor.**

| Sl No. | Engine speed (rpm) | Time taken to cover 20m (s) | Speed of vehicle (kmph) | Speed reduction |
|---|---|---|---|---|
| 1 | 814 | 27.10 | 2.656 | 34.66 |
| 2 | 907 | 24.44 | 2.946 | 37.24 |
| 3 | 1055 | 19.71 | 3.654 | 32.65 |
| 4 | 1102 | 16.42 | 4.385 | 28.42 |
| 5 | 1265 | 15.17 | 4.740 | 30.18 |
| 6 | 1344 | 14.57 | 4.942 | 30.76 |
| 7 | 1499 | 12.58 | 5.723 | 29.62 |
| 8 | 1610 | 11.20 | 6.428 | 28.32 |
| 9 | 1696 | 10.39 | 6.928 | 27.79 |

The forward speed of the modified K A U garden tractor were tested at different engine revolutions ranging from 800 to 1600 rpm, with no load and wth loaded condition. The relationship between the engine revolution and forward speed and the speed reduction are tabulated in Table 4.

It is seen that the ratio of speed reduction ( i.e., engine rpm to forward speed of vehicle) is not constant, but it reduces with increase in engine speed. This may be due to the fact that both the wheels act as flywheel and outer member of ratchet gets a unidirectional motion which increases the forward speed of the garden tractor.

The one and only disadvantage of the modified garden tractor is that, it has no reverse movement. The reason is that , the final drive axle is constrained to oscillate with an angular displacement of 17° . But this disadvantage can be neglected because the turning radius of garden tractor is very less. The turning radius is less, due to the differential action given by the ratchet mechanism.

## 4.2. Material and Economical Analysis

The materials required for fabrication of the garden tractor is grouped into 'fabricated components' and 'purchased components'. A detailed material list with specification, cost and quantity is prepared and given in the Table 5 and Table 6.

| | | |
|---|---|---|
| Cost of fabricated components | = | Rs. 25473.50 |
| Cost of purchased components | = | Rs. 5034.50 |
| **The total cost of the unit** | **=** | **Rs. 30508.00** |

**Table 5 Details of Fabricated Components and their cost**

| Sl No. | Part | Specifications | Weight (kg) | Quantity (No.) | Cost (Rs.) |
|---|---|---|---|---|---|
| 1. | Driver pulley | B-section V-pulley | 3.8 | 1 | 250.00 |
| 2. | Driven pulley | B-section V-pulley | 6.6 | 1 | 300.00 |
| 3. | Intermediate shaft | Stepped 22.5 mm , 20 mm | 1.1 | 1 | 200.00 |
| 4. | Intermediate casing | 20 mm ID,32 mm OD | 0.9 | 1 | 100.00 |
| 5. | Eccentric strap | | 0.4 | 1 | 200.00 |
| 6. | Eccentric sheave | | 0.6 | 1 | 250.00 |
| 7. | Connecting link | | 0.5 | 1 | 80.00 |
| 8. | Oscillating link | | 1.1 | 1 | 290.00 |
| 9. | Final drive axle | Stepped 35 mm,25mm | 1.5 | 1 | 250.00 |
| 10. | Ratchet Mechanism | | 5.2 | 2 set | 1140.00 |
| 11. | Chasis | 10 mm x 5mm | 121.1 | 1 | 1960.00 |
| 12. | Stand | GI pipe 26 mm dia | 0.6 | 1 | 22.00 |
| 13. | Drawbar pin | 16 mm dia | 0.7 | 1 | 80.00 |
| 14. | Idler clutch | | 1.1 | 1 | 40.00 |
| 15. | Bell crank lever | | 0.4 | 1 | 20.00 |
| 16. | Clutch lever | 10 mm dia | 0.4 | 1 | 17.00 |
| | | **Total Cost of Components** | | | **5199.00** |

**Table 6 Details of Purchased Components and their cost**

| Sl No. | Parts | Specification | Quantity (No.) | Cost (Rs.) |
|---|---|---|---|---|
| 1. | Diesel engine | Greaves Lombardini, 5.4 hp Type 523, 1800 rpm | 1 | 20274.50 |
| 2. | V- Belt | B-45 | 1 | 153.00 |
| 3. | Bush | Gunmetal liner, 42mm OD, 30 mm ID, 20 mm length | 2 | 140.00 |
| 4. | Ball bearings | SKF 6210 | 1 | 260.00 |
| | | SKF 6203 | 1 | 120.00 |
| 5. | Circlips | light B-47, IS : 3075-1965 | 5 | 17.50 |
| 6. | Keys | | 6 | 60.00 |
| 7. | Set collars with grub screws | Type A 25 mm dia. | 3 | 35.00 |
| 8. | Spring | | 1 | 10.00 |
| 9. | Accelerator cables | Kubota spare parts | 2 | 44.00 |
| 10. | Cable release clamp | Kubota spare parts | 2 | 30.00 |
| 11. | Pneumatic tyre wheel (tyre, tube and rim) | 6.00 x 12 size | 2 each | 4000.00 |
| 12. | Primer and paint | | 600 ml | 108.00 |
| 13. | Hexogonal bolts, nuts and washers | | 40 No. | 57 |
| | | **Total cost of purchased components** | | **25473.5** |

## 4.3. Cost of Operation.

Cost of operation in Rs/year is expressed by,

$$Co = [C_f + R]/100 \times P/h + (L + F + O)$$

where

Co = cost of operation per hour, Rs.

$C_f$ = fixed cost in percentage of capital cost.

P = capital cost,Rs

h = hours of operation per year

R = repair and maintenace per year in percantage of capital cost

L = cost of labour, Rs/hr.

F = cost of fuel, Rs/hr.

O = cost of oil & lubrication, Rs/hr.

The fixed cost includes the folloing components

a. Depreciation, 10 percent of P

b. Interest, 14 percent of P

c. Tax, 1.25 percent of P

d. Insurance, 0.25 percent of P and

e. Housing , 1 percent of P

Hence fixed cost is 26.5 percent of P .Repair and maintenace cost is taken as 6 percenrt of P and the life period of the modified garden tractor is assumed as 10 years.

| | | |
|---|---|---|
| Cost of fuel | = | Rs. 12.00 / lit. |
| Cost of oil and lubricant | = | 1/3rd of the cost of fuel |
| Cost of labour | = | Rs. 15.63/Hr. |

Let the fuel consumption be x lit/hr. Then the cost of operation per hour,

$$Co = 0.325\ P/h + 15.63\ b + 16\ x$$

Hence the cost of operation per hr for the modified garden tractor, when

$$P = 30508 \text{ and } x = 1.4 \text{ lit/hr}$$

$$Co = 9915.1/h + 38.03$$

and the rate of decrease of cost of operation,

$$dCo / dh = -9915.1/h^2$$

The cost of operation per hour for the Kubota Power Tiller , when P = 84000 and x = 2.7 lit/hr

$$Co = 27300/h + 58.83$$

and the rate of decrease of cost of operation,

$$dCo / dh = -27300/h^2$$

The cost of operation and the rate of decarease of cost of operation for different hours of yearly use are given in the Table7. It justifies the advantage in socio-economic aspects for having an own unit of low cost garden tractor than the factory made power tillers by the average Indian farmers.

It is observed that an increase in yearly use for both the units will reduce the cost of operation per hour. But the cost of operation per hour is changing, less gradually from 800 hours/ year for newly developed garden tractor, where as the cost of operation for the factory made power tiller changes gradually from 1200 hours/year.

**Table 7. Cost of Operation and Rate of Decrease of Cost of Operation in Relation of the Yearly Use.**

| Sl No. | Hours of Operation | P = 30508.00 & x=1.4 l/hr | | P=84000 & x=2.7 l/hr | |
|---|---|---|---|---|---|
| | | Cost of Operation (Rs) | Rateof Decrease of Cost of Operation | Cost of Operation (Rs) | Rate of Decrease of Cost of Operation |
| 1. | 200 | 87.61 | 247.88 | 195.33 | 682.50 |
| 2. | 400 | 62.82 | 61.97 | 127.08 | 170.63 |
| 3. | 600 | 54.56 | 27.54 | 104.33 | 75.93 |
| 4. | 800 | 50.42 | 15.49 | 92.96 | 42.66 |
| 5. | 1000 | 47.95 | 9.92 | 86.13 | 27.30 |
| 6. | 1200 | 46.29 | 6.89 | 81.58 | 18.96 |
| 7. | 1400 | 45.11 | 5.06 | 78.33 | 13.93 |
| 8. | 1600 | 44.23 | 3.87 | 75.89 | 10.66 |

## SUMMARY

The small power operated and low cost garden tractors are found to be most suitable for country like India. The two wheel garden tractor stands between animal and four wheel tractor. These machines would replace animals but not people and would help materialize the objectives of the country namely to promote economic development, better income distribution and employment.

In order to simplify the power transmission system and to reduce the cost and weight of garden tractor, development of a new eccentric driven power transmission system was taken up for the study. This power transmission system was fixed to K A U garden tractor and its field performance was evaluated.

The prime mover of 5.4 hp (Greaves Lombardini type 523) diesel engine with 1 800 rpm is selected. This engine weighs only 38 kg. The modified garden tractor has a new power transmission system which uses the eccentric drive. The driving eccentric fixed on intermediate shaft is designed by considering adequate factor of safety. The throw of eccentric provided is 12.5 mm.

The driving eccentric and oscillating link is connected by connecting link of dia. 18 mm. The oscillating link swings about the axis of final drive axle with an angular displacement of 17°. The oscillating link is to impart an oscillating motion to the final drive axle. The final drive axle transmits the swinging motion to the inner members of the ratchet. The pawl of the ratchet converts swinging motion into rotary motion by turning the outer member of the ratchet in a unidirectional pattern.

From the dynamics and kinematics of the garden tractor the following aspects are studied.

In the field test by changing the pull which was measured by a hydraulic dynamometer the characteristics of slip, coefficient of traction, coefficient of rolling resistance, drawbar power and tractive efficiency are found out for the 6.00 x 12 size pneumatic tyre. The rate of increase of slip with respect to pull upto 70 kgf is constant, and beyond that it deviates from a linear relation. The forward speed of the garden tractor varies according to the engine speed.

The cost of the modified garden tractor estimated as Rs. 30 508/-. The cost of operation of the garden tractor was also estimated . It clearly indicates the adaptability of low cost garden tractor.

Further improvements on the modified low cost garden tractor may be attempted as follows :

(a) The idler clutch can be replaced by a multiple plate clutch and fix it on the intermediate shaft for easier engaging / disengaging of the power transmission system and to eliminate the power loss due to slippage over the idler.

(b) By developing a mechanism to vary the effective length of the oscillating mechanism which results in variation of torque transmitted.

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* Orginal not seen.

# APPENDIX I

## Specifications of the prime mover

| | | | |
|---|---|---|---|
| 1. | Make | : | Greaves Lombardini |
| 2. | Model | : | Type 523<br>[Four stroke, aircooled, direct injection on piston, gear pump lubrication, automatic governor, rope crank starting) |
| 3 | No. of cylinders | : | 1 |
| 4 | Bore | : | 78 mm |
| 5 | Stroke | : | 68 mm |
| 6 | Displacement | : | 325 cc |
| 7 | Compression ratio | : | 18:1 |
| 8 | Rated speed | : | 1800 rpm |
| 9 | Power | : | 5.4 hp |
| 10 | Maximum torque | : | 2960 kgmm |
| 11 | Specific fuel consumption | : | 220 gm/hp-hr |
| 12 | Fuel tank capacity | : | 4.5 lit |
| 13 | Oil consumption | : | 0.013 kg/hr |
| 14 | Oil sump capacity | : | 1 lit |
| 15 | Air cleaner oil bowl capacity | : | 0.15 lit |
| 16 | Maximum angularity | : | 35 degree |
| 17 | Dimension mm | : | 427 x 352.5 x 476 |
| 18 | Dry weight | : | 38 kg |

## APPENDIX II

### Design of V-belt

Pitch circle dia of driver pulley (d) = 15.95 cm

Pitch circle dia of driven pulley (D) = 21.5 cm

The two pulleys are placed at a distance of 28 cm c/c

The length of belt is given by the equation,

$$L = 2C+(d+D)\pi/2 + (D-d)^2 /4C \quad \text{.................................(1)}$$

where, C is the c/c distance between pulley

Using equation (1)

$$L = 2 \times 28 + (21.5+15.95)\ \pi/2 + (21.5-15.95)^2 /4 \times 28$$

$$= 115.1 \text{ cm} \ (45.32 \text{ inches})$$

Provide an allowance of 2 inches for proper functioning idler clutch, select a belt of length 47 inches. Hence belt selected is B-47.

# APPENDIX III

Specification of ball baring used in the eccentric (SKF 6210)

| Sl No. | Details | |
|---|---|---|
| 1. | Series | 62 |
| 2 | Inner dia., mm | 50 |
| 3 | Outer dia., mm | 90 |
| 4 | Width, mm | 20 |
| 5 | Corner radii on shaft and Housing,mm | 2 |
| 6 | Basic static capacity, kgf | 2120 |
| 7 | Basic dynamic capacity, kgf | 2750 |
| 8 | Permissibile speed, max. rpms | 8000 |

# APPENDIX IV

# FORCES ACTING ON THE ECCENTRIC

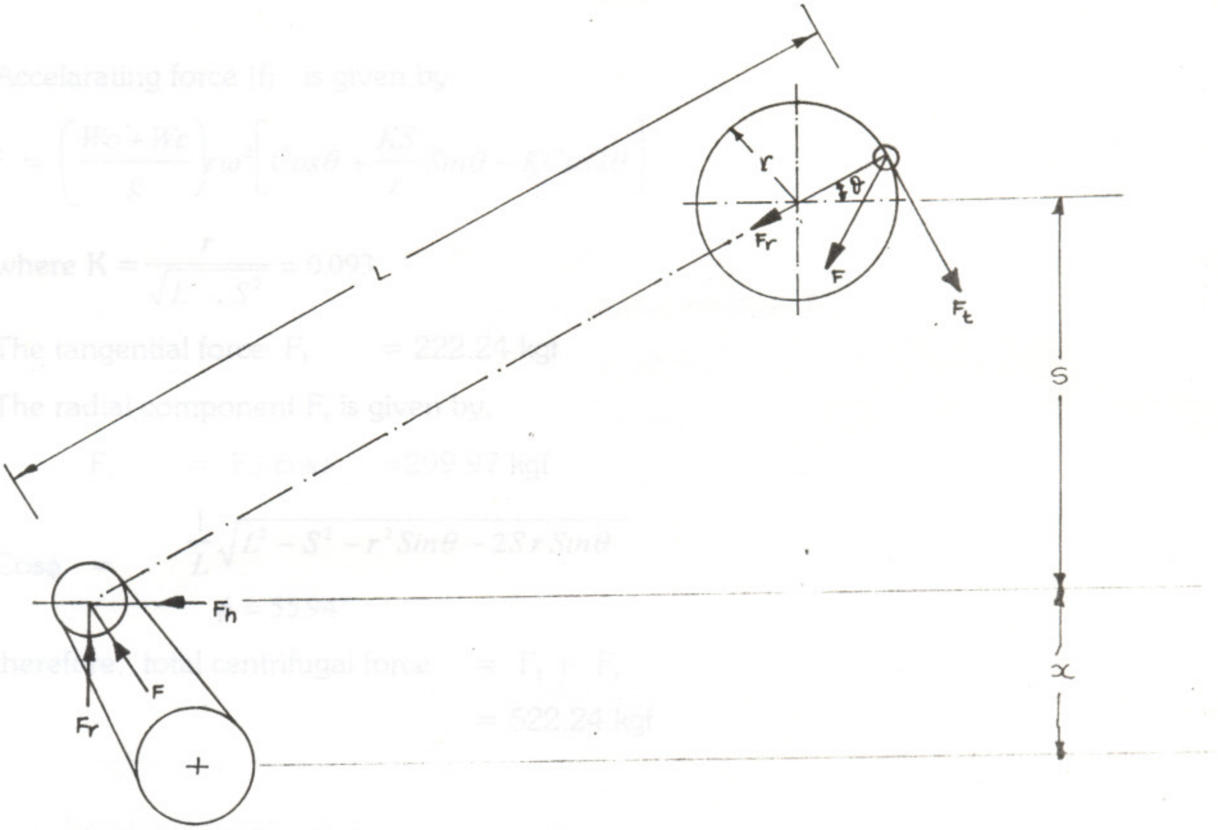


**Fig schematic representation of eccentric**

If r = throw of the eccentric

= 12.5 mm

L = length of the connecting link between the centres of oscillating link and eccentric

= 237.5 mm

S = height of the intermediate shaft centre from the centre of the clevis pin

= 196 mm

θ = angular rotation of the eccentric

ϕ = angular rotation of the oscillating link

weight of the oscillating arm, Wo = 1.1 kg

weight of the eccentric, We = 1.4 kg

weight of the connecting link with pin, Wc = 0.5 kg

therefore, total weight W = 3.0 kg

Accelarating force (f) is given by,

$$f = \left(\frac{Wo + Wc}{g}\right) r\omega^2 \left[ Cos\theta + \frac{KS}{r} Sin\theta - KCos2\theta \right]$$

where $K = \frac{r}{\sqrt{L^2 - S^2}} = 0.093$

The tangential force $F_t$ = 222.24 kgf

The radial component $F_r$ is given by,

$F_r$ = F / cosϕ =299.97 kgf

$$Cos\phi = \frac{1}{L}\sqrt{L^2 - S^2 - r^2 Sin\theta - 2S\,r\,Sin\theta}$$

$$\phi = 55.94^o$$

therefore, total centrifugal force = $F_t$ + $F_r$

= 522.24 kgf

# APPENDIX V

## FORCE AND MOMENT DISTRIBUTION ON INTERMEDIATE SHAFT

a) Vertical force ($F_v$) diagram

The Vertical force at A due to belt tension

$F_{va}$ = 76.38 x sin 9° - 6.6

= 5.35 kgf

The vertical downward force due to eccentric drive at D

$F_{vd}$ = 300 x Sin 42 °

= 200.74 kgf

Taking moment about to get the vertical force acting at B and C.

5.35 x 102 - $F_c$ x92 + 200.74 x 182 = 0

therefore $F_c$ = 403.05 kgf

$F_b$ = 207.66 kgf

b) Vertical bending moment ($M_v$) diagram

Bending moment at B, $M_{vb}$ = 5.35 x102 =545.7 kgmm

Bending moment at C. $M_{vc}$ = 200.74 x 90 =18066.6 kgmm

c) Horizontal force ($F_h$) diagram

The horizontal force on the pulley at point A,

$F_{ha}$ = 76.38 x Cos 9 °

= 75.44 kgf

The horizontal force due to eccentric drive

$F_{hd}$ = 300 x Cos 42 °

= 222.94 kgf

Taking moment about point B,

75.44 x 102 - $F_{hc}$ x 92 + 222.94 x 182 = 0

$F_{hc}$ = 524.67 kgf

$F_{hb}$ = 377.17 kgf

d) Horizontal bending moment ($M_h$) diagram

Bending moment at B, $M_{hb}$ = 75.44 x 102

= 7694.88 kgmm

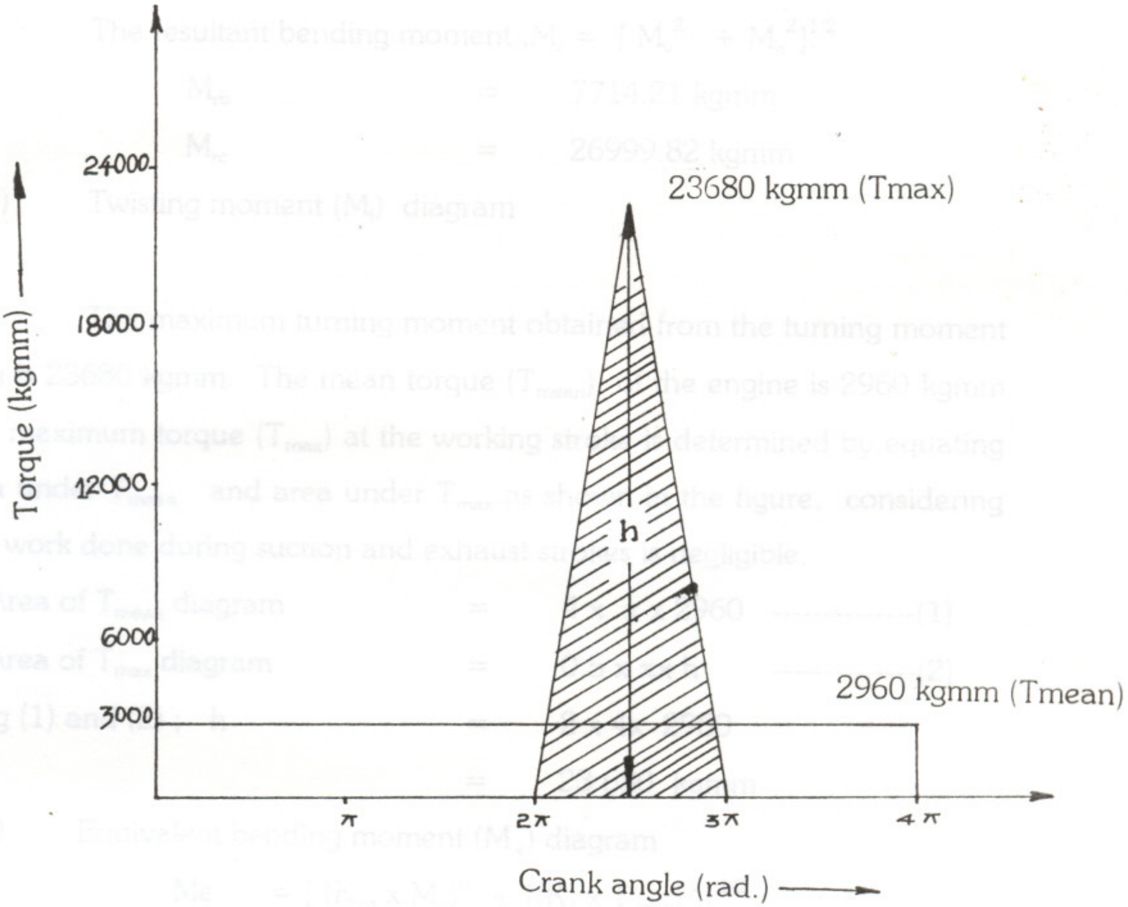


Fig (ii) Turning Moment Diagram of diesel engine

$M_{hc}$ = 222.94 x90

= 20064.6 kgmm

e) Resultant bending moment ($M_r$) diagram

The resultant bending moment , $M_r = [\ M_v^2 + M_h^2]^{1/2}$

$M_{rb}$ = 7714.21 kgmm

$M_{rc}$ = 26999.82 kgmm

f) Twisting moment ($M_t$) diagram

The maximum turning moment obtained from the turning moment diagram is 23680 kgmm. The mean torque ($T_{mean}$) of the engine is 2960 kgmm and the maximum torque ($T_{max}$) at the working stroke is determined by equating the area under $T_{mean}$ and area under $T_{max}$ as shown in the figure, considering that the work done during suction and exhaust strokes is negligible.

Area of $T_{mean}$ diagram = $4 \times \pi \times 2960$ --------------(1)

Area of $T_{max}$ diagram = $0.5 \times \pi x\ h$ --------------(2)

Equating (1) and (2) ; h = $2 \times 4x\ 2960$

= 23 680 kgmm

g) Equivalent bending moment ($M_e$) diagram

$Me = [\ (K_m \times M_r)^2 + [(K_t \times T_{max})^2]^{1/2}$

where $K_m = 1.5$ and $K_t = 1$

$M_{ea}$ = 23680 .00kgmm

$M_{eb}$ = 26355.98 kgmm

$M_{ec}$ = 46914.50 kgmm

$M_{ed}$ = 23680.00 kgmm

# DEVELOPMENT OF ECCENTRIC DRIVEN TRANSMISSION SYSTEM FOR GARDEN TRACTOR

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## ABSTRACT OF THE PROJECT REPORT

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# ABSTRACT

The study was conducted with the objective of design and fabrication of eccentric driven power transmission system for K.A.U low cost garden tractor and to evaluate the field perfomance of the prototype developed . Eccentric driven power transmission consisted of a single stage V- belt drive , an eccentric assembly , a connecting link , an oscillating link and an intermediate shaft . It was fixed to K.A.U. garden tractor , which was powered by a Greaves Lombardini 5.4 hp diesel engine of 1800 rpm as prime mover. An idler clutch was fabricated to engage / disengage the power transmission system with the engine. When the intermediate shaft rotates, the oscillating link swings about the final drive axle. The swinging motion of the final drive axle is transmitted to the wheel through a pair of ratchet mechanisms at either end which converts swinging motion into unidirectional rotary motion. A road speed of 6.8 Kmph was achieved by using the eccentric driven power transmission system with 6.00 x 12 size pneumatic wheel. Total weight of the garden tractor is 120 kg, with the new transmission system; thus the weight of garden tractor is reduced considerably . The cost of garden tractor was worked out to be around Rs 30,500 . The rate is low when comparred to the cost of operation of the other factory made garden tractors . Entire machine elements had been mechanically designed and garden tractor was field tested for its functional requirements. Garden tractor has a disadvantage that its backward motion is constrained. But the turning radius is very low. The unit can be fabricated by local workshops from readily available standard components and can successfully be maintained by small farmers.