DESIGN AND FABRICATION OF

A PORTABLE MANUALLY

POWERED GARDEN ROW WEEDER

BY

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JULY 1991

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D R A W I N G S

AGRICULTURAL ENGINEERING DEPARTMENT,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

A PROJECT REPORT

ON

DESIGN AND FABRICATION OF A PORTABLE MANNUALLY POWERED GARDEN ROW WEEDER

BY

SHIRU JONATHAN JACOB

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF BACHELOR OF ENGINEERING (AGRIC.)

APPROVED

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DECLARATION

I do hereby declare that the work presented in this thesis for the award of Bachelor of Agricultural Engineering has not been presented partially or wholly for any other degree nor is it concurrently being submitted for any other degree.

_____

CO-ORDINATOR SIGN DATE

_____

SUPERVISOR SIGN DATE

D E D I C A T I O N

This project is dedicated to the following people:

1. My Lord and Saviour Jesus Christ

2. My parents Mr. & Mrs. Jacob Shiru.

ACKNOWLEDGEMENT

It's done. May God be praised and Jesus Christ be honoured for His Love and Mercy over me. I owe all my life to Him.

I am greatly indepted to my Supervisor Mr. Adisa A. F. for his devoted attention, relentless encouragement, guidance and painstaking supervision. He really gave me the motivation to think and approach the perculiar engineering problems involved in design.

I am also grateful to the acting Head of Department Mallam M.G. Yisa for his full co-operation and assistance that led to the completion of this project. My thanks goes to Dr. Oladiran and Mr. Shiawoya of the School of Agriculture and Agricultural Technology for their assistance.

My profound gratitude goes to my elder sister Mrs. V.N. Kolo with deep respect and love for making me comfortable throughout my stay, YaVicky, I am grateful. My special and unreserved appreciation goes to Miss. Dorcas Yiye Audu for her love and care, Mallam Gambo Ibrahim a good and bossom friend.

My sincere prayer is that God should really reward these and others too numerous to mention for their contribution to my life and to the project.

A B S T R A C T

Weeding can be done using Chemicals (Herbicides), mechanically (motorized or manual powered) and hand pulling of weeds. The purpose is to provide a good environment for crop performance. A mannually powered garden row weeder was designed, fabricated and tested.

The Weeding Index(e) was found to be 74.53%, efficiency of cutting blade 88.00% and field capacity was 0.0166 ha/hr.

1.1 INTRODUCTION

The rapid development of engine powered agricultural machinery with its increasing ease in use and adaptation to an ever widening range of operations most at times raise the question whether manual powered farm implements are still necessary? Despite the great progress of motorized power in Agriculture, manual workers and draught animals will continue to provide the main source of power for the farmers of many regions where the use of tractors and tractor equipment does not pay for itself. It should also be noted that the use of engine powered machinery can only be afforded where the farming system provides sufficient cash income to pay for its purchase, operation, maintenance and repairs. The advance of motorization can also be delayed when the size of the farms is small, the lay-out of fields is irregular and where there is abundance of under employed labour. Other inhibiting factors are insufficient mechanical skill accompanied by lack of training, maintenance, repair facilities and these condition favours the design of new tools.

In Nigeria 54% of the total population can be regarded to be engaged in active agricultural production (F.A.O. 1979). Man is the predominant source of power supplemented by animal power and tractors which in 1978, the density was found to be 0.3 per thousand hectares (Wagami 1983). Man provides the energy needed to operate hand tools to cultivate small land holdings. This ranges from clearing the field with an axe, planting with a hoe, weeding with a hoe, broadcasting fertilizer with his bare hands, harvesting with a harvesting hoe or cutlass and knives and also conveying his farm produce home on his head. The land cultivated is often in small fragments (average farm size of a Nigerian farmer is 1.74 hectares) and located at different places.

(Federal Office of Statistics 1976, Wagami 1983). Some of the existing hand tools in Nigerian are designed and farbricated by our local blacksmiths who acquired their skills by apprenticeship through the passages of time and practice. The tools produced have many defects and this leads to excessive drudgery and complaints by the farmer and further leads to the modifications of many of them.

All the above goes to indicate that for a good length of time manually powered tools can not be phased out, it will remain among the available equipment of Nigerian Farmers. It should be noted also that "Simple is not synonymous with PRIMITIVE". Simplicity of design and operation is often the most desirable characteristic in any equipment. The following points should be borne in mind when attempting to improve or design new tools. They should be

i. Made of easily available material in Nigeria.
ii. Of simple design, so that they can be made locally.
iii. Not be injurious to man.
iv. Light in weight for easy transportation and operation.
v. Ready for immediate use without loss of time for preparatory adjustments.
vi. Adapted to allow efficient and speedy work with the minimum of fatigue.

1.2 MAN AS A SOURCE OF POWER

Man is an essential alement in all machine system that exist in agriculture. When man is regarded as a source of power for operating implements, his strength and intellectural faculties must be considered as an indivisible whole enabling him to think and act simultaneously. Thus his capacity to perform work requiring a rapid succession of quick actions or particular skills without any great effort constitute an unequalled advantage over other souce of power.

A man normally walks at a rate of 7 to 10 kgm/s varying from 5 kg at 1.1m/s with a crankshaft to 64 kg at 0.15 m/s when treading a lader with its own weight. Working continuously he produces about 8 kg m/s or roughly 0.1 HP (Horse power) for short periods he can develop 0.4 HP. The average force a man can excet is equal to one tenth (1/10) of his own weight. If several men work together in a line, the power output per man slightly decreases as it is determined by the slowest worker in the row (Hopfen 1960).

3. ADAPTATION OF IMPLEMENTS TO MAN

Man is capable of a great variety of natural movements. The more he work with an implement follows his natural movement with regards to direction and speed the healthier and less tired he will be . Work requiring the use of only a few muscles cause fatigue sonner than work engaging various parts of the body and various muscles of the body in to each part. Therefore in designing any hand tool the following has to be put into consideration.

1. Walking motions which follows man's natural movement in direction and speed as closely as possible.
2. The use of many muscles as possible to diminish the load on each single muscle group.
3. A variety of walking motions engaging different muscles in alternating sequence.
4. A compatibility between the tool parameters and the operator biodata.

1.4 PROJECT OBJECTIVES

The objectives of this project are as follows

1. To design a portable weeder for garden
2. To produce a low cost weeder using locally available materials in Nigeria.
3. To produce a weeder which conform with the operators biodata that is eliminate health hazard (waist pain, back ache,

4. To produce a more durable and less weight weeder with high efficiency.

5. To increase garden crops production.

1.5 PROJECT JUSTIFICATION

Nowadays a lot of money and time is usually spend on weed control using the various weeding methods. Despite the money and time spent, there are lots of disadvantages associated with each method for example the use of chemical method of weed control has the disadvantage of high cost of chemicals and equipments used, effect of wind and rain, required surphisticated knowledge, environmental pollution. The use of mechanical method (motorized) is often limited due to the high cost of tractors and also the land fragmentation problem. Moreover Agricultural Machines are unique in the sense that the machines designed for American condition may not work effectively in Nigeria. Also the use of cultural method that is hoe, cutlass and hand pulling is slow and tedious and again a cross view of farmers adapted to this method reveals a higher deficiency in their body structure that is, farmers looking older than their ages or inability to stand upright.

To encourage each and individual to own a vegetable garden since weeds which are one of our great[illegible] enemy can be removed using the simple designed weeder which conform to human biodata. Also to facilitate weed control in vegetable garden leading to more vegetable production thereby bringing down the prices to the bearest minimum in the market.

To maintain the garden crops production due to their nutritional value (Appendix table 4.)

CHAPTER 2 (TWO)

REVIEW OF LITERATURES

2.1 DEFINITION OF SOME TERMS

A GARDEN: A garden is defined as a piece of land where flowers, vegetables and other plants are grown for their nutritional value.

A WEED: A weed is a plant growing where it is not desired or plant growing out of place (klingman and Ashton 1961, Ahaneku 1989).

2.2 DISADVANTAGES OF WEEDS

(i) Compete with crops for soil nutrient, water, sunshine and so no.

(ii) Habour pests and diseases

(iii) Reduce crop yield.

2.3. WEED CONTROL IN THE GARDEN

Though initial land preparation involving primary and secondary tillage, uproot, bury and destroy weeds, they are not altoughe eliminated and keep growing along with the main crop. Several control measures have been in use and include the following:

(i) Hand pulling of weeds

(ii) Weeding using mechanical and man powered weeders

(iii) Use of chemicals (herbicides).

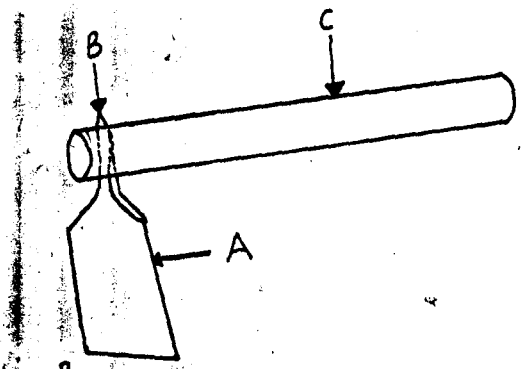
Viewing the 3 principal methods above, the only one that can stand the true test of time is the use of improved manpowered weeders.

2.4 ASSESSMENT OF EXISTING MANNUALLY POWERED WEEDERS.

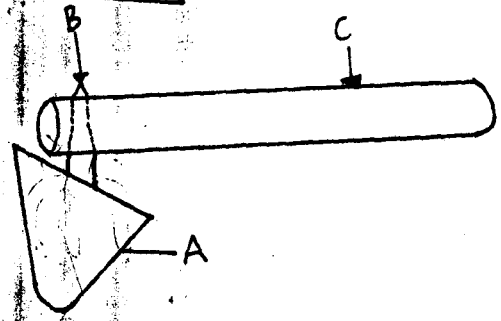
The manual powered weeders ranges from the local hoe to high range of cultavators fabricated for use to achieve the same purpose. Each of the types encountered was viewed and assessed from which a new design will have its base for coming out.

2.4.1 LOCAL HOES

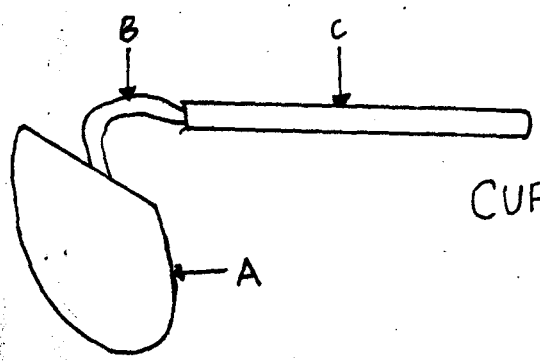
These weeders are made up of three principal part which are, the handle, the blade and the connecting device. The weeders work on impact as they are lifted up mannually and struck on the soil by impact. These tools are very effective in difficult situations.



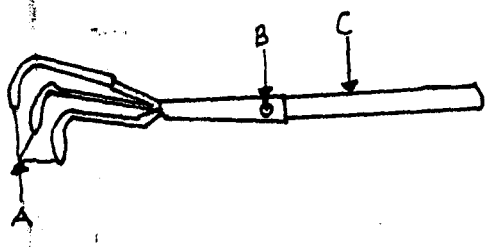
STRAIGHT BLADE HOE



VEE BLADE HOE



CURVED BLADE HOE



PRONGED BLADE HOE

KEY	
A	CUTTING BLADE
B	CONNECTING DEVICE
C	HANDLE

FIG: 2.1 LOCAL HOES

The straight blades are suitable when the weeds are to be cut at soil surface or at root zone whereas pronged blades are suitable when the weeds are to be uprooted and removed. The pronged hoes have less clogging effect and they dig deep into the soil. They also perform better in stony soil. Examples are chooping hoes, digging hoes.

These local hoes blades are inclined at an angle between 10° - 20° without much detail calculations and specification since they are designed and fabricated by our local blacksmiths who have acquired their skills through apprenticeship (with an elderly blacksmith who normally is a close relation either a father or a guardian). All of these blacksmiths are either practicing farmers or at one time in their lives have been on the farm, so they are very much familiar with the needs of the local farming systems that seems to revolve round them.

PROBLEMS - For the local hoes, there is the problem of health hazard (black ache, blisters, waist pain to mention a few) due to the short handle which does not conform to human anthropology. Also there is the problem of shaking off of the soil carried along with the weeds when uprooted.

2.4.2 NATIONAL CENTRE FOR AGRICULTURAL MECHANISATION (NCAM) IMPROVED WEEDING HOE

The NCAM improved weeding hoe consists of three principal parts, the blade, the handle and the connecting devices.

The improved weeding hoe was designed and fabricated by the Engineers at the National Centre for Agricultural Mechanisation

the human biodata which reduces health hazard (back-ache, waist pain just to mention a few) thus increasing field efficiency. When tested on maize, groundnut and Cassava plots during 1988 NCAM Field week, it was found that a person could weed from 0.02 to 0.04 ha/hour thus the labour requirements would vary between 22 and 40 man-hours per hectare depending on the Soil (NCAM welcomes you hand book)

PROBLEM: The problem associated with this improved weeding hoe is the frequent lifting up and down of the hoe thereby over engaging the muscles of the hand.

2.4.3 WHEEL WEEDER DESIGNED BY JOHN HOLT AGRICULTURAL ENGINEERS LIMITED, ZARIA

The wheel weeder designed by the John Holt Agricultural Engineers Limited Zaria is made up of a wheel, the main frame, the soil working part and the handle. This wheel weeder puts into consideration the human biodata that is, use in the normal human working position, it is a push type of weeder.

PROBLEM: The problems here are as regard to the weight of the wheel weeder and shaking off of the soil particles when the weeds are cut under the soil.

2.4.4 NCAM HAND WHEEL HOE

This hand wheel hoe is a push and pull inter row type of weeder. It consists of a ground wheel with an axle, cup and cone bearing, frame, tool bar, handle and soil working tools. It is used by pushing and pulling action. The stroke length is adjusted by the operator depending upon his arm length and ease of working The depth of penetration is adjusted by raising or lowering the wheel with the help of the holes provided on the frame.

PROBLEMS

1. The weight is much that it can not be conveniently operated for a long time therefore field efficiency is low.
2. The weed shaker is not provided so after weeding, the weeds may come up again especially if there is enough soil moisture.

2.4.5 IMPORTED MANUAL WEEDERS

There are some imported tools in Nigeria mainly from England (Chillington, forge, Edward Elwell Ltd wedmesbury and bull dog tools Manchester) Holland and Germany (Wagami 1983). These mostly are garden weeders. These tools have generally not been accepted by the farmers due to our soil conditions, i.e. sticky, stony, presence of roots and their foreign design features that did not consider the distinct farming system in Nigeria.

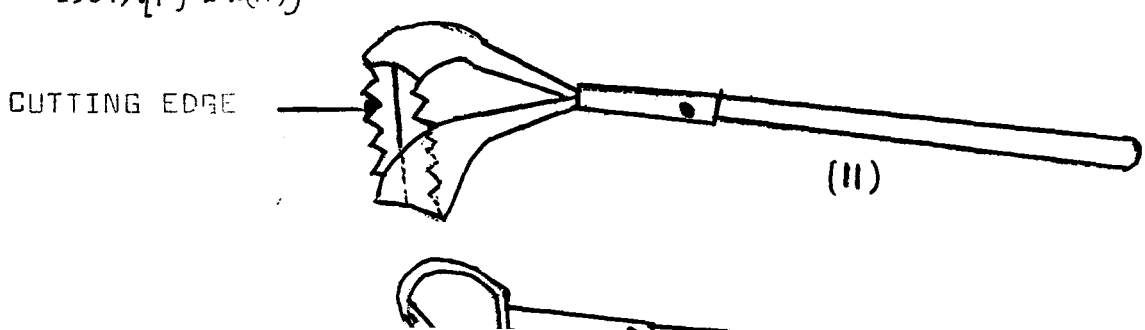
Most of the weeders can be classified into the following form:

(i) Pull type weeders

(ii) Push - Pull weeders

(i) Pull Type Weeders - These weeders work on pull action by the operator. The weeder usually have long handles so that the operator can work in standing posture and can approach longer distance. These weeders can give high output at the early stage of crop growth when weeds are small and soil is not hard. They are provided with blades of different shapes and sizes i.e. straight blades, Vee shaped blades etc. They are quite light and Vary from 1.5 - 2.5kg (H.S Biswas 1984) [fig 2.2 (i)]

(ii) Push - Pull Weeders - The Push - pull weeders are similar in construction to the pull type weeders, the only difference being the construction of the blade and mode of operation. The blade is provided with cutting edges on both front and rear sides and the weeder is operated both in forward and reverse directions. Usually the blade is of curved shape so that during operation only the cutting edges of the blade come in contact with the soil (H.S. Biswas 1984). [fig 2.2(ii)]



2.5 DEDUCTIONS - From the above assessment a good designed manual weeder must have the following charasteristics

(i) Light in weight

(ii) Operation principles must conform with the normal wotking position

(iii) The configuration must put in mind the human Anthropology/

(iv) There must be a soil (weed) cutting device inclined at a desired angle for proper operation and a shaker.

v. The implement must be operated easily and fabricated from available local materials in Nigeria.

vi. Must incoperate our soils environmental conditions into consideration. Examples sticky soils stony soils, Abbrassive soils to mention a few.

CHAPTER 3 (THREE)

DESIGN AND CONSTRUCTIONAL DEVELOPMENT OF GARDEN ROW WEEDER

3.1 ATTEMPT TO KNOW THE SIZE OF THE WEEDER

In attempt to know about the size of the weeding implement for vegetable garden, visit was paid to various vegetable garden within this area (Niger State). Four different vegetable gardens were visited at different parts of the locality, the areas include the following:

1. Vegetable garden at Okada bypass road belonging to Mallam Abubakar Bosso.
2. Vegetable garden at Bosso Lowcost belonging to Mallam Usman.
3. Vegetable garden at the new bypass road close to fertilizer company.
4. Vegetable garden at Landzu close to Bida Royal Cinema.

The discussion I hard with two of the owners of the vegetable garden was based on the following

(a) Spacing (inter-row) of their various products for example spinnach, ayoyo, pepper, okro, tomatoes.

(b) Time of weeding and height of weeds at weeding time.

3.11 S P A C I N G

The Spacing was associated with pepper, tomatoes, Okro, for the case of leaves like spinach broadcasting is their method due to space and for the fact that the leaves grow rapidly. The average spacings are as follows:

For Pepper : 25.10 cm

For Okro = 30.65 cm

For tomatoes = 36.60 cm

Literatures were also consulted and there was a little difference which may be due to variety of crop or environment (see table 5 traditional plant and row spacings for vegetables). For common vegetables within this area the spacing varies between 30 cm to 50 cm. Knotts hand

were dictated almost entirely by the space requirement of cultivating equipment. Many of the traditional row spacings can be traced back to the horse cultivator. (Appendix Traditional plant and row spacings for vegetables Table 5)

3.1.12 TIME AND HEIGHT OF WEEDS

Time of weeding was not fixed but depends on weeds appearance (between 3 - 4 weeks). The height of various weeds were taken on the plots of Okro, peper, tomatoes and their average computed.

For okro Average weed height = 7.875 cm

For tomatoes Average weed height = 9.737 cm

For pepper plots average weed height = 5.687 cm

Since weeds height will depend on the nature of soil, it follows that for different soil, weeds will grow in response to availability of nutrients. Weeds height was assumed to be 12 cm and clearance of 3 cm was given. Total weed height is [weed height (assumed value) + clearance] = 15 cm.

3.2 PARTS OF THE DESIGNED GARDEN ROW WEEDER

The vegetable garden weeder was designed to weed one row of plants during a pass. The design include the following, the wheel (land and support), the frame, the handle, the soil tearer and the spikes. The design and the materials used put the following into considerations.

i. Cost

ii Ease of Fabrication

iii Availability of the materials

iv Weight

v Human Anthropology

vi Safety of the Operator

vii Soil conditions (hard, abbrassive, Stony).

viii Weather conditions.

3.22 THE WHEEL

The land wheel is responsible for moving the weeder from one place to another. The diameter of the wheel was taken to be 30 cm based on total weed height of which was 15 cm from ground level. The support wheels are for the support of wheel weight and balancing. The wheels were fabricated from 40 x 4 mm mild steel flat bar.

3.23 THE HANDLE

The handle is responsible for transfer of power from the operator to the weeder. The height was based on the fact that for proper and effective operation the arm must be at 90^{θ} to the elbow arm. Sample measurement were taken and the average was found to be 0.925m which was approximated to be 0.930m. It was febricated from Ø 20mm hollow pipe.

3.24 THE SOIL TEARER (WEEGE)

This is responsible for cutting the weeds from their root level. It was fabricated from an used mild steel disc. Difference shapes were considered and from testing, V shape was found to be more effective.

3.25 THE SPIKES

The spikes are responsible for shaking off the soil particles from the roots of the weeds thereby expossing them to the sun. The spikes were made from Ø 4mm rod.

3.26 THE SHAFT

The purpose of the shaft is to connect the various components of the designed weeder together. Here diameter 15mm was used based on calculation and design considerations. (See plates of photographs Section 3.4)

3.30 DYNAMIC ANALYSIS

3.31 DEFORMATION OF SOIL/WEEDS WITH WEDGE ACTION - Soil/Weeds may be deformed in a variety of ways when it is worked by a simple wedge. The nature of deformation depends upon the physical and mechanical properties of the soil and angle α substended by the working face to the horizontal plane (N.I Klenin et al). Soil/weeds deformation consists of two successive alternating phases.

PHASE ONE: In the first phase the working face crushes the soil. Particles a, b ---- and so on (see figure 3a,) in contact with the surface of the wedge, slide over the working face and are forced into the adjacent surroundings. When the wedge moves to position I to position II, particles a moves to position a', b moves to position b' and son on. The shift in the intercept aa' and bb' governs the displacement of the soil. Since aa' is greater than bb', bearing stress at point a' would be greater than at point b'. The extent to which soil is crushed by the wedge depends upon its bearing resistance .

PHASE Two: Breaking of the soil/weeds begins with the appearance of fissures and fractures or the tearing of the soil layer, as a result of which prism shaped blocks are formed. The direction of the fissures relative to the row, characterized by angle θ may vary widely and depends upon the properties of the soil. Angle θ is obtained from Goryachikin formula.

$$\theta = \frac{\pi}{2} - \frac{\alpha + \phi + \phi'}{2}$$

ϕ is the angle of friction between the soil layer and the wedge.

ϕ' is the angle of internal friction.

3.32 FORCES ACTING ON A WEDGE

The resultant R of normal reaction and the friction forces N tan ϕ is inclined from the normal to the surface of the wedge at the friction angle ϕ. Resolving the resultant R into two

the ability of the wedge to penetrate further into the soil and this is balanced by the vertical component of the tractive effect and the supporting parts.

The tractive force applied to the wedge is the external force P which is necessary to balance the resultant force R acting on it due to the resistance of the soil. The force P is applied in a direction opposite to that of the resultant R. For a simple wedge based on equilibrium conditions of the forces acting on it, the horizontal component Px of the tractive force, that is the force causing displacement is obtained as

$$P_x = N\sin\alpha + N\tan\phi\cos\alpha = (N/\cos\phi)\sin(\alpha+\phi)$$

and the Vertical Component as

$$P_z = N\cos\alpha - N\tan\phi\sin\alpha = (N/\cos\phi)\cos(\alpha+\phi)$$

CHAPTER FOUR (4)

TESTING AND RESULTS ANALYSIS

4.1 TESTING OF DESIGNED WEEDER

APPARATUS:
(1) Stop Clock
(2) Measuring Tape
(3) Recording Book and Pencil
(4) Spring balance

METHODOLOGY:

Set the weeder properly fixing the Vee blave as required for both comfort and stability. Start the stop clock and weeding operation simultaneously. Weed a single row of the Okro plot and then stop the stop watch. Record the time t, the length of the row s, measure the depth of the Cut Lp and width of cut Lw. Record properly in the book. Then start the stop clock and carry out weeding for 6 - 10 rows and note the time t it takes to complete weeding the rows. Measure the length of the rows Lr and width of Wr using measuring tape. From the above calculate the following.

(i) Speed of operating (s/t)

(ii) Calculate the efficiency y of the cutting blade from the below relationship.

$$Y = \frac{\text{Effective width of cut } (Lw)}{\text{Designed width of Cut } LD} \times 100\%$$

(iii) Calculate the field capacity of the weeder as follows:

$$\frac{\text{Total area}}{\text{Time}} = \frac{Lr \times Wr}{t_t}$$

(iv) Calculate the weeding Index (e) as follows

$$e = \frac{Wi - W2}{Wi} \times 100$$

Where Wi = Number of Weeds before weeding

W2 = Number of Weeds left unweeded

Mark an area in a row say 30cm x 20cm, count the number of weeds on the area (Wi), weed the area and go back to count the number of weeds left (W2). Calculate weeding Index for the area and then extend the knowledge to that of an hectare (100m x 100m).

(v) Calculate percentages of plant deformed as follows

$$\frac{\text{Total number deformed plants} \times 100\%}{\text{Total number of plants}} \quad 1$$

(vi) Calculate the power requirement using the relationship below

$P = FV$ $\quad P$ = Power required (watts)

F = Pulling force (N)

V = Speed (m/s)

Obtain the pull by attaching the spring balance to the weeder and then pulling it. Recall that $F = Ma$, M = Mass

g = acceleration due to gravity.

4.2 RESULTS AND RESULTS ANALYSIS

TABLE 4.1

	1	2	3	4	5	6
Distance (m)	10.0	8.9	9.0	9.5	9.3	10.2
Time (Sec.)	40	5.6	53	38	38	36
Speed (m/sec.)	0.25	0.16	0.17	0.26	0.24	0.28

SAMPLE CALCULATION

For 1 Speed $= \frac{\text{Distance}}{\text{Time}} = \frac{10.0\text{m}}{40\ \text{Sec}} = 0.25\text{m/Sec}$

Average Speed $= \frac{0.25 + 0.16 + 0.17 + 0.26 + 0.24 + 0.28}{6}$

$= 0.23\text{m/Sec.}$

TABLE 4.2

	1	2	3	4	5	Average
Dept of cut Lp (cm)	2	3	2.5	2	2	2.3
Width of cut Lw(cm)	28	26	26	25	27	26.4

TABLE 4.3

	1	2	3	4
Number of weeds before weeding (Wi)	19	46	25	13
Number of Weeds left Unweeded after weeding (W2)	4	10	7	3

Average Weeding Index = $\frac{78.95 + 78.26 + 64 + 76.92}{4}$ = 74.53%

TABLE 4.4

Total Number of Plants Pi	42	34	42
Total Number of Plants deformed P2	6	8	4
Percentage deformed %	14.28	23.53	9.5

Sample Calculation = $\frac{6}{42} \times \frac{100}{1}$ = 14.28%

Average Percentage deformed = $\frac{14.26 + 23.53 + 9.52}{3}$ = 15.79%

FIELD CAPACITY

13 minutes was used to weed (9x4) m^2 = $36m^2$

In 60 minutes the area to be covered is calculated as below

Let the area to be covered in 60 minutes be Xm^2

$$Xm^2 = \frac{60}{13} \times 36m^2$$

$$= 166.15m^2$$

The above Value is further coverted to hectare per hour and gave 0.0166 hectares per hour.

i.e. 1 hectare = 100m x 100m

Field capacity in hectare per hour = $\frac{166.15}{100x100}$ = 0.0166 ha/hour

FIELD EFFICIENY OF CUTTING BLADE.

Field efficiency of implement = $\frac{\text{Effective field capacity}}{\text{Theoretic Field capacity}} \times 100$

= $\frac{26.4}{30.0} \times 100$

= 88.00%

POWER REQUIREMENT

P = FV, where P = Power in Watts

F = Force in Newton

V = Velocity in m/sec

F = Mass x acceleration due to gravity

= 9 x 10

90N

V = Velocity of operation = 0.23m/sec.

P = 90 x 0.23 20.7 watts

The least power required to operate the weeder was found to be 20.7 watts.

4.3 WEEDING USING THE MANUAL HOE

SPEED

TABLE 4.5

Distance (m)	10	9.3	9.65
Time (Sec)	106	108	107
Speed m/s	0.094	0.096	0.09

Average speed = $\frac{0.094 + 0.086 + 0.09}{3}$ = 0.09 m/s

WEEDING INDEX

TABLE 4.6

Number of Weeds before Weeding Wi	36	42	39	33
Number of Weeks left unweeded after Weeding W2	4	8	6	9
Weeding Index (%)	88.89	80.95	84.62	72.73

Average weeding Index = $\frac{88.89 + 80.95 + 84.62 + 72.73}{4}$

= 81.791%

TABLE 4.7

Total Number of Plants Pi	38	39	43
Total Number of Plants deformed P2	4	3	2
Percentage deformed %	10.56	7.69	4.65

Sample Calculation = $\frac{4}{38} \times \frac{100}{1}$ = 10.56%

Average percentage x deformed $\frac{10.56 + 7.69 + 4.65}{3}$

= 7.63%

FIELD CAPACITY

1.5m ✕ 9m = 13.5m^2 was completed in 16 minutes

In 60 minutes the area to be covered is calculated as below

$Xm^2 = \frac{60}{16} \times 13.5$

= 50.63m^2/hr.

Further coverted to hectare per hour as follows

= $\frac{50.63}{100 \times 100m}$ = 0.005 ha/hr

manual hoe used was 81.79% (Table 4.6), this was because one is facing the weeds directly, therefore one can see the weeds and use hand in pulling them and at the same time operate the manual hoe. The cutting blade efficiency of the implement was found to be 88.06%.

The fabricated weeder can weed efficiently the Interrow spacing and the weeds in the Interplant spacing can be pull out later or left as further growth of the plants will form canopy thereby suppressing the weeds. The least power required was found to be 20.7 watts which is far less than the designed horse power 75 watts this implied that the power an average man can supplied is enough to power the fabricated wedder.

Health Hazard waist pain, backache was totally eliminated and the weeder was fabricated bearing in mind the enthrometric consideration of human beings which is the source of tractive power to the weeder. The issue of cut of legs, hands in using manual hoe is eliminated as the cutting blade is not facing the operator. Blisters and swaller palms was reduced.

The percentage of crops deformed was 15.79% (Table 4.4), for the Fabricated weeder this was due to inalignment of the plants in rows and the longer time of plants weeding life before which enables the crops to grow leaves and may interfere with the implement while working. Deformation can not be totally eliminated even with manual hoe it was found to be 7.63% (Table 4.7)

4.5. RECOMMENDATIONS

1. TO FABRICATOR

1. A lighter material should be used in fabricating the chain cover, this will reduce the weight of the fabricated weeder.

2. A protective device should be put in between the spikes and the operator to prevent sand particles and weeds from coming in-contact with the operators legs.
3. A wider and thicker pipe should be used to house the spikes for strength and stability.
4. The dimmeter of the land wheel should be increased to give allowance for front sprocket from the ground level.
5. Housing should be provided for each bearing to facilitate change when damage occurs.
6. All dimensions should be followed according to design specifications.

TO THE USER:

1. Weeding should be done as earlier as possible, by this the plants leaves will not be damaged by the weeder and it also aerates the soil with increase in infiltration capacity of water.
2. The crops should be drill in straight line to facilitate easy operation of the weeder.
3. Good seed bed preparation is required i.e. properly cleared and levelled land, this will facilitate uptake of mutrient by the plant and easy use of the design and fabricated weeder.

ECONOMY

MATERIALS	QUANTITY	₦	K
20mm Hollowpipe	3.20m	70	00
40 X 4mm Flat bar	2.02m	120	00
ø 4mm rod	as required	20	00
ø 50mm pipe	0.220m	5	00
Bolts and Nuts	as required	7	00
Bearings	6	36	00
Old disc	as required	15	00
20 X 2mm flat bar		15	00
Hack Saw blade		20	00
Electrodes		15	00
Chain and sprockets		70	00
Miseellanenous Expenses		40	00
Total		433	00
Labour. 10% of Cost Price		43	30
Total Cost of Implement.	=	476	30

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SPEED CALCULATION

A. A man normally watks at a rate of 7 to 10 kgm/s varying from 5kg at 1.1 m/s with a crankshaft to 64 kg at 0.15 m/s when treading a water ladder with his own weight (Hopfen 1969)

B. From previous designed weeders we have the following.

1. Single - row lowland rotary paddy weeder Capacity = 0.028 ha/hr working width = 150mm We obtain the working speed as follows

1 hectare = 100m x 100m = 10,000 m^2

$$\frac{10,000 \times 0.028}{3,600 \times 0.150} = 0.52 \text{ m/s}$$

	NAME OF WEEDER	CAPACITY (Ha/hr)	WORKING WIDTH (M)	WORKING SPEED M/S
1.	Single row Low land rotary paddy weeder	0.028	0.150	0.52
2.	Two row Indian rotary paddy weeder	0.03	0.280	0.30
3.	Rotary Paddy Weeder	0.029	0.140	0.58
4.	NCAM hand Wheel hoe	0.05	0.30	0.46
5.	NCAM Weeding hoe	0.0286	0.150	0.53

Sources (1) NCAM's hand book

(2)

Assertion

From the above two information, a man can walk at 1.1m/s (normal watking) this implies that if he is to exert a force (push an object) the speed will be lower than 1.1m/s.

Analysing the working speed of already existing hand push weeders above, it can be seen that the speed varies from 0.30 m/s to 0.58 mls. For design purpose the speed of the weeder is assumed to be 0. 50 m/s.

Average speed of the person pushing the weeder is 0.50 m/s.

Wheel diameter choosen (from design consideration) is Ø300 mm = 00.30m. From the below relationship. $2\pi rn$ = Speed (m/min). Where n = Number of revolution per minute

$$r = \text{Radius of wheel} = \frac{0.30}{2} = 0.15m$$

$$\pi = 3.14$$

Speed = 0.5m/s = 30m/min. [0.5 x 60 = 30]

$$2\pi rn = 30$$

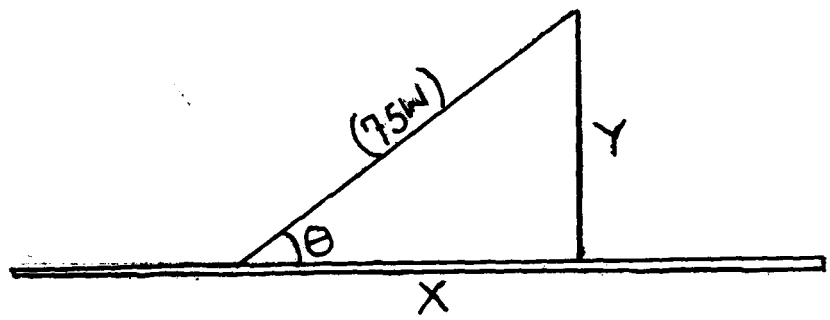
$$n = \frac{30}{2x\pi x0.15} = 31.91 \simeq 32 \text{ rev/min}$$

$$n = 32 \text{ rev/min}$$

ATTEMPT TO GET VARIOUS ANGLES OF INCLINATION

For any force that is applied at an inclined anlge θ to produce a forward motion, the horizontal component must be greater than the vertical component.

Over an 8 - hour day for a 48 - hour work, a useful norm for a 35 years old labourer for total power expending including basal metabolism energy is 0.49 hip (366w) of this expenditure, approximately 0' 1hp (75w) is available for useful work [Eugene et al]



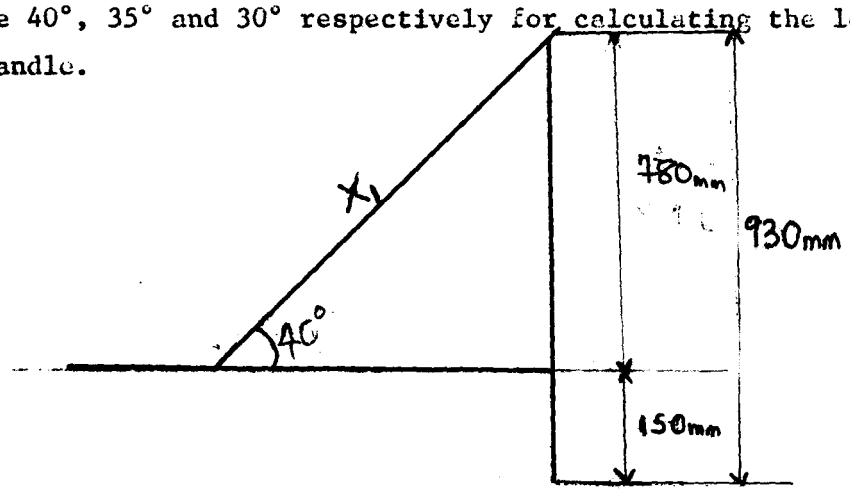
SAMPLE CALCULATION OF FORCES

Vertical Component	Horizontal Component
Assume θ = 45°	$\frac{x}{75}$ = Cos 45°
$\frac{Y}{75}$ = Sin 45°	x = 75 Cos 45°
y = 75 Sin 45°	x = 53.03w
Y = 53.03w	

OBSERVATION: The Vertical and Horizontal values are the same, this implies that there will not be displacement in any direction. For the object to have horizontal displacement θ has to be less than 45°, that the horizontal component should be greater than the Vertical force.

ANGLES OF INCLINATION θ	VERTICAL COMPONENT (W)	HORIZONTAL COMPONENT (W)
45	53.03	53.03
40	48.21	57.45
35	43.02	61.44
30	37.50	64.95

Selected angles of inclination θ for the handle to the main frame are 40°, 35° and 30° respectively for calculating the length of the handle.



Using trigonometric identities [SoH, CAH, TOA]

$\text{Sin } 40° = \frac{780}{x_1}$

$x_1 = \frac{780}{\text{Sin } 40°} \triangleq 1\,2\,1\,3.5\text{mm}$

But 1200 mm was used in the design,. Checking for the other angles the value of y.

For θ = 35°

$\text{Sin } 35° = y/x_1$

$\therefore\ y = x_1 \text{ Sin } 35° \triangleq 688.3 \text{ mm}$

For θ = 30°

$\text{Sin } 30° = y/x_1$

DETERMINATION OF SHAFT DIAMETER

To determine the shaft diameter, we have to consider both the vertical and horizontal components of the forces acting on the shaft.

a. Vertical loading on the shaft. The Vertical loads on the shaft are as follows:

(i) The Wheel

(ii) The sprocket

(iii) The bearings

(iv) The main frame

(i) Weight of Wheel = 1.5 kg from calculation and 1.485 kg from measurement which is approximately 1.5 kg.

(ii) Weight of bigger sprocket = 0.400 kg obtained from weighing using weighing balance.

(iii) Weight of bearing = 0.06 kg.

(iv) Weight of mainframe on the front shaft = 0.5 kg. obtained from calculation.

see figure Vertical loading.

Efy = 5.6 + 15.0 + 6.5 + 4.06 - Pi-P_2 = 0 - (1) Taking moment about A.

15x0.145 + 6.5x0.255 - P_2x0.255 + 4.06x0.29 = (2)

2.175 + 1.6575 + 1.1774 = 0.255 P_2

$$P_2 = \frac{5.0099}{0.255} = 19.65N$$

from equation (1)

31.16 - Pi - P_2 - 0

P_2 = 19.65

31.16 - 19.65 = Pi

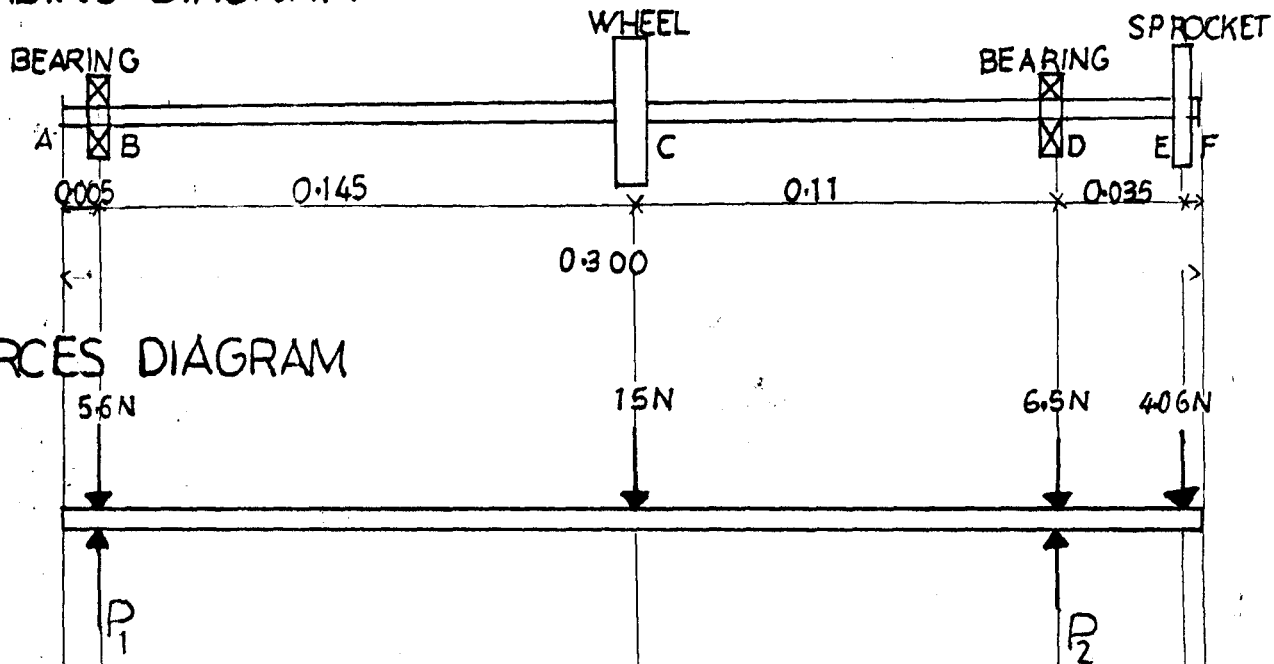
11.51N = Pi

Pi = 11.51N

Taking bending moment along the Shaft at distance x

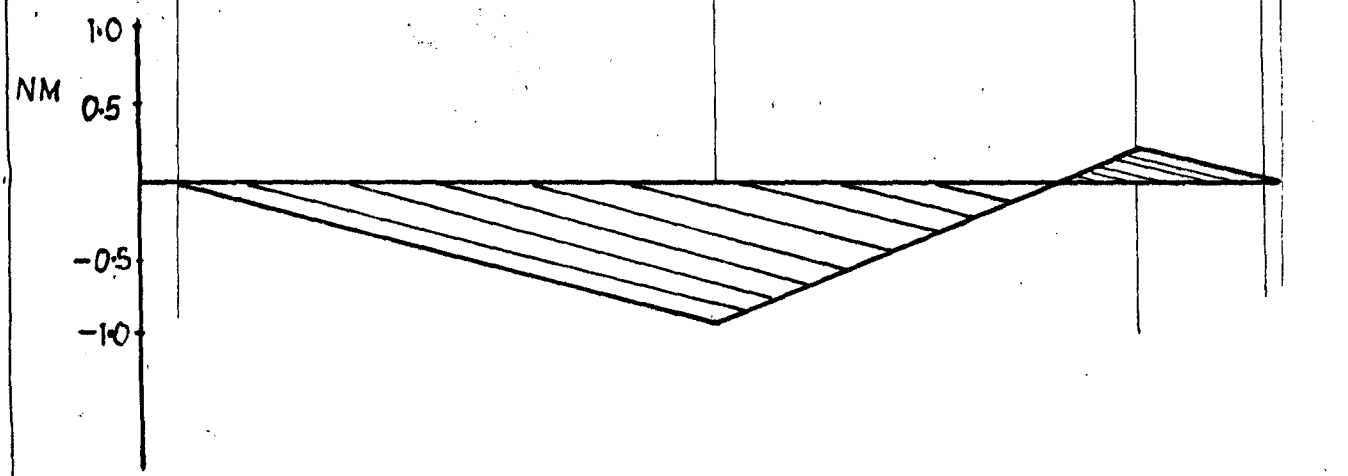
VERTICAL LOADING

LOADING DIAGRAM



FORCES DIAGRAM

BENDING MOMENT DIAGRAM



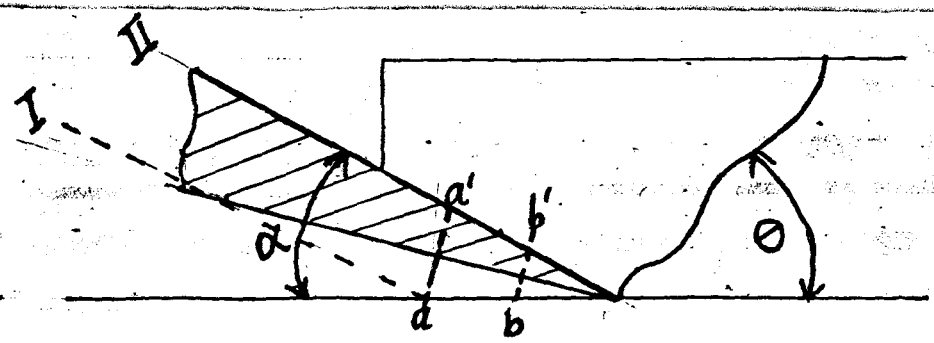


FIG 3a

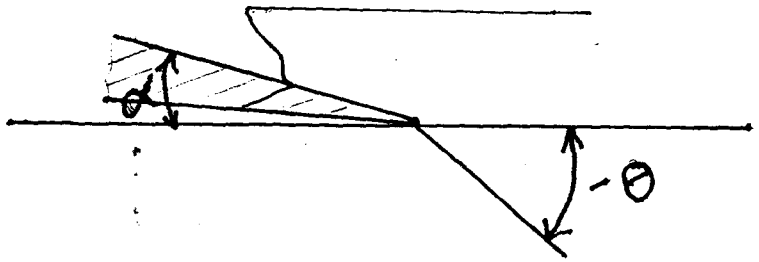
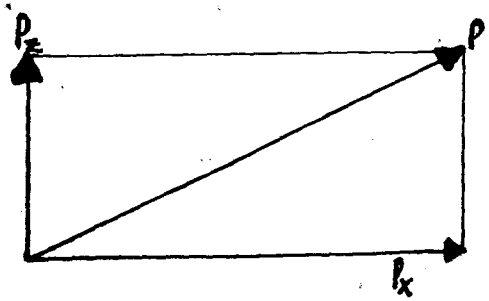


FIG 3b

DEFORMATION OF THE SOIL LAYER BY A SIMPLE WEDGE



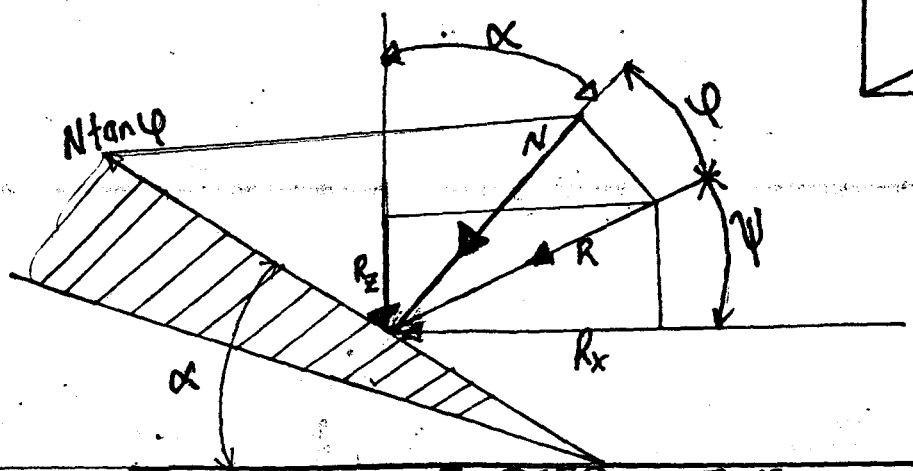
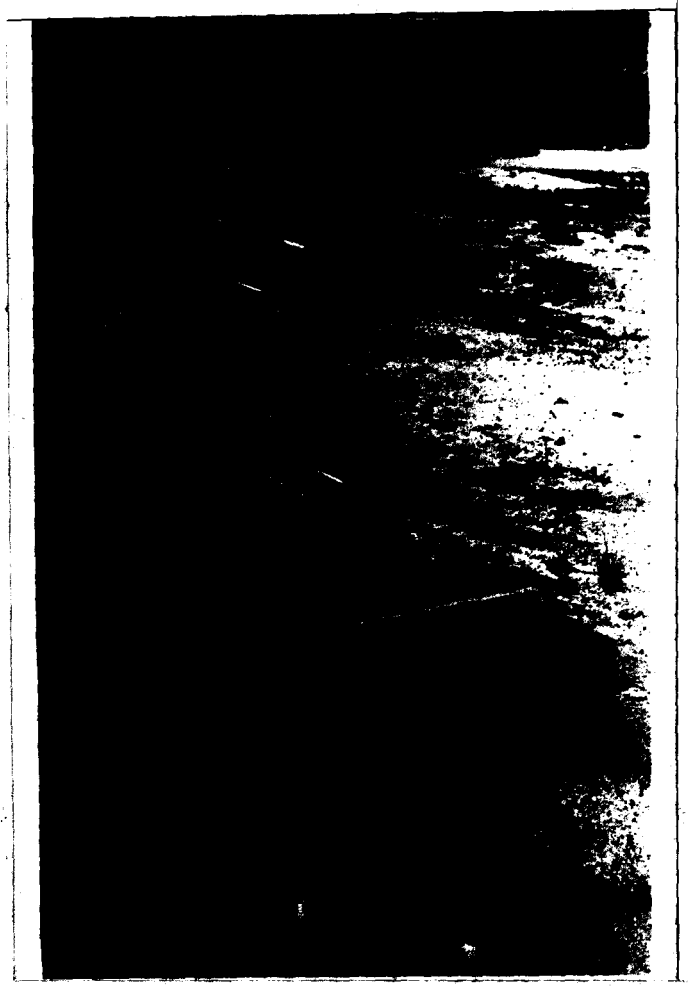


FIG 3c

FORCES ACTING ON A WEDGE

3.4 Plates of Photographs



(A) Pictorial View of the Fabricated Weeder



(B) View of the Okro Garden



for x = 0.15 m

Banding moment (Bm) 5.6 x 0.145 - 11.51 x 0.145

= 0.812 - 1.66895 = -0.85695NM.

for x = 0.26m

B.M. = 5.6 x 0.255 - 11.51 x 0.255 + 15x0.11

= 1.428 - 2.93503 + 1.65

= 0.14295 NM

for x = 0.295m

Bm = 5.6x0.29 - 11.51x0.29 + 15x0.145 + 6.5x0.035 - 19.65x0.035

= 1.624 - 3.3379 + 2.175 + 0.2275 - 0.5895

= = 4.0265 - 3.9274

= 0.0991NM

for x = 0.30m

BM = 5.6x0.295 - 11.51x0.295 + 15x0.15 + 6.5x0.40 -19.65x0.040 = 0

= 1.652 - 3.37545 + 2.25 + 0.26 - 0.784

= 4.162 - 4.162

= 0

b. Horizontal Loading on the Shaft. The horizontal loading is due to the Chain pull. Power exerted through the handle is 65w (maximum) Recall that power (P) = Mass in Kgf x Velocity in m/s

where P = Power watts (Nm/s)

M = Mass Kgf (N)

V = Velocity

P = MV - (i)

M = P/V from (1)

P = 65 obtained from earlier calculation.

V = 0.5m/s from initial assumption.

M = 65/0.5 = 130 kgf

M = 130N

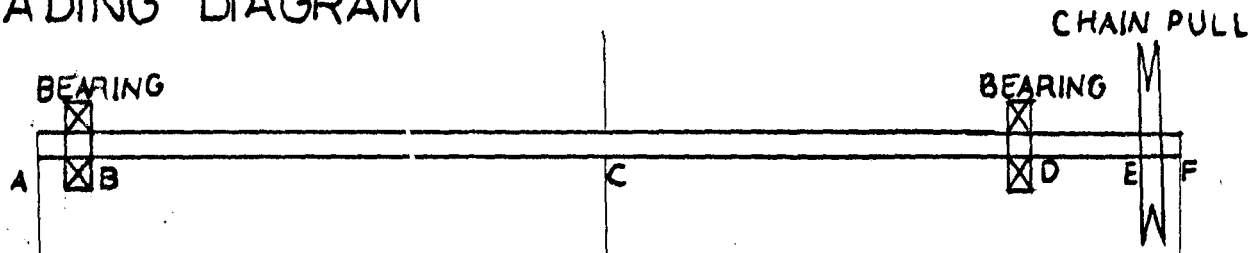
See figure Horizontal loading

Efy = 130 - Oi - Q2 = 0 - (i)

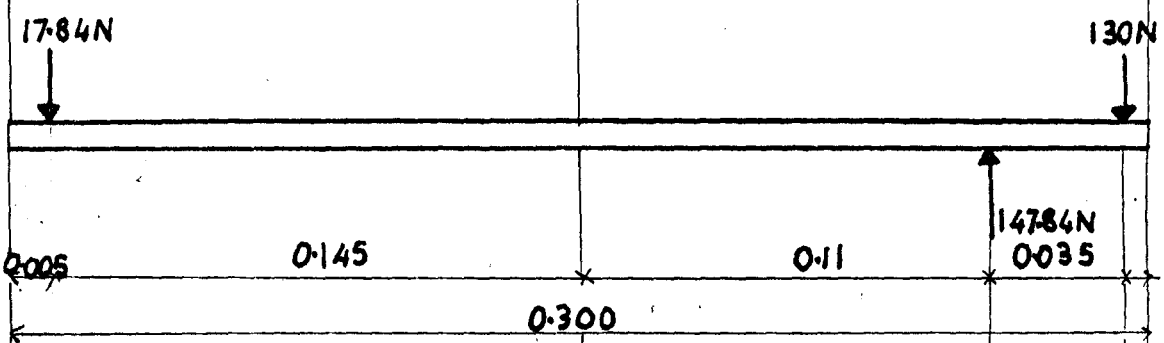
Taking bending about A

HORIZONTAL LOADING

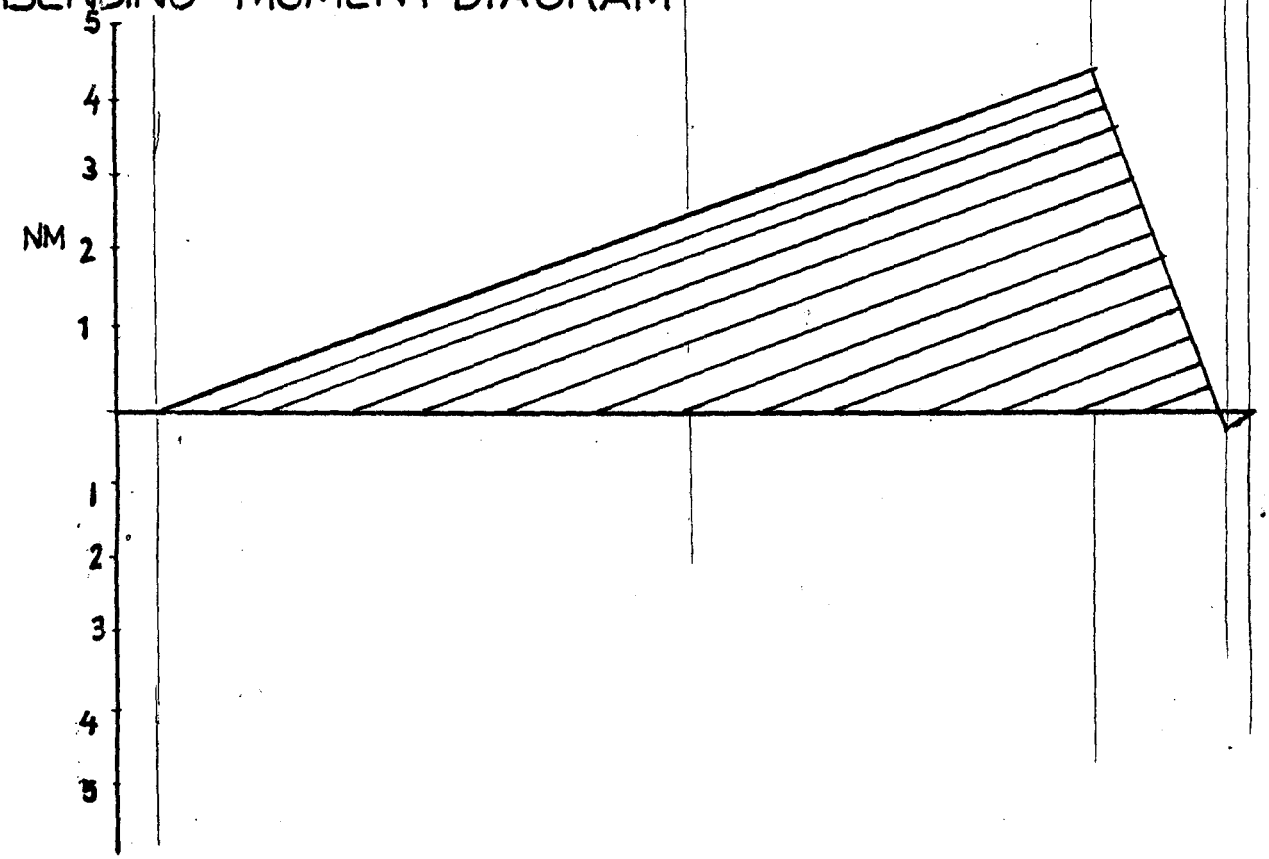
LOADING DIAGRAM



FORCES DIAGRAM



BENDING MOMENT DIAGRAM



$$Q_2 = \frac{37.7}{0.255} = 147.84N$$

Substitute the value of Qz in equation 1

$$130 - 147.84 = Q_i$$

$$- \quad 17.84 = Q_i$$

Note

The negative sign indicates that the reaction is in opposite direction of the initial direction choosen. Bending moment along with the shaft.

At x = 0.005 BM = 0

At x = 0.15

BM = 17.84x0.145 = 2.5868NM

At x = 0.26

B,M. = 17.84 x 0.255 = 4.5492 NM

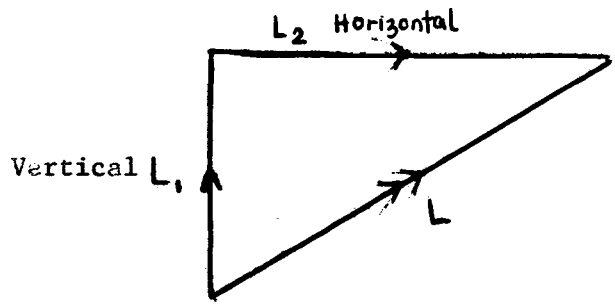
At x = 0.295

BM = 17.84x0.29 - 147.84x0.033 = -0.0008NM

At x = 0.30

BM = 17.84x0.295 - 147x0.04 + 130x0.005 = 0

For the overall bending moment, we have to get the equivalent bending moment at each point. We then use pythagoras theorem i.e. $L^2 = Li^2 + 1_2^2$ (L.H. Clarke)



At point A. L. = 0

At point B.L. = 0

At point C.L. = $\sqrt{(0.85695)^2 + (2.5868)^2}$

$= \sqrt{(0.7344 + 6.6915}$

L = 2.725 NM

At point E.L $= \sqrt{(0.0991)^2 + (0.0008)^2}$

$= \sqrt{0.0098 + 0.00000064}$

$= 0.098$NM

At point f.L = 0

Therefore maximum bending moment = 4.55 NM

TORGUE

For rotational movement

$P = \frac{E}{T} = \frac{T\theta}{t} = \frac{Tx\theta}{t} = Txw$ - (1) Silsoe College Agric Eng. Department Manual No. 639-102/2

where P = power transmitted

T = Torgue in KNm

θ = Angle of rotation

W = Angular velocity in radians/second

T = p/w from equation 1 above

P = 65w = 0.065 KW

$W = \frac{2ii \times 32}{60} = 3.35$ rad/s

$T = \frac{0.065}{3.35}$

$= 19.4$NM

From the relationship below we can calculate our shaft diameter.

$$d = \sqrt[3]{\frac{5.1}{T_{max}}\left[(C_m M)^2 + (C_T T)^2\right]^{1/2}}$$ maitra etal

Cm = Combine shock for rotating sudden shocks 2.0] Kruitz etal

Ct = fatigue shock for rotating sudden shocks 1.5] Maitra etal

M = Bending moment 4.55 NM obtained from earlier calculation.

T = Torgue = 19.4NM obtained from earlier calculation

Tmax = allowabnle shear stress for mild steel = 115x106 NM obtrained from croton et al.

substituting in the formula

$$d = \sqrt[3]{\frac{5.1}{115 \times 106}\left[(2 \times 4.55)^2 + (1.5 \times 19.4)^2\right]}$$

$$= \sqrt[3]{4.43 \times 10^{-8}\left[82.91 + 846.81\right]}$$

$$= 0.01105\text{m}$$

$$= 11.05\text{ mm}$$

Shaft diameter obtained from calculation = 11.05mm but for design and safety precaution, 15mm diameter was used.

WEIGHT ESTIMATION

1. The Wheel

Material used = 40mm x 4mm flat bar mild steel

breadth = 0.040m

Width = 0.004m

Area = Breadth x width

= 0.040x0.004 = 0.000160m^2

= $1.6x10^{-4}$ m^2

Length of the Steel (L) = Circumference of the wheel•circumsference

= πd

where π = a constant = 3.14]

d = Diameter of the wheel = 0.30m

L = 3.14x0.30 = 0.942m

Number of components = 1

Total length (LT) = length of steel x Number of component

0.942m x 1 = 0.942m

Volume = 0.942m x $1.6x10^{-4}m^2$ [Total length x Cross Sectional area].

= $1.507x10^{-4}m^3$

Mass of Steel = Total Volume x Density (P), P = 7830 kg/m^3

= $1.507x10^{-4}m^3$ x 7830 kg/m^3

= 1.179981

= 1.18 kg

2. The spokes

Material used = Ø8mm rod mild steel = 0.008m

Area = $\frac{\pi d^2}{4}$, where d = diameter of rod

π = a constant = 3.14

= $\frac{3.14x(0.008)^2}{4}$ = 5.02×10^{-5} m^2

Length of spokes = 13cm = $0.13m^2$

Number of SPOKES = 4

total length = 0.13x4 = 0.52m

Total Volume = Total length x Area

= 0.52m X $5.02x10^{-5}m^2$

= $2.61 \times 10^{-5}m^3$

= 7830kg/m^3 X 2.61 x 10-5$_{m^3}$

= 0.204 kg

Weight of wheel and spokes = 1.18 + 0.204

= 1.384 kg

Due to additional weight resulting ffom fabrication and ∅ 20mm pipe used at the Centre to connect the spokes to the wheel, the total weight of the wheel and spokes was taken as 1.5 kg

3. MAIN FRAME WEIGHT

Material used - 40mm x 4mm flat bar mild steel

Breadth - 0.040m

Width = 0.004m

Area = 0.040 x 0.004 = 1.6x10-4$_{m^2}$

Length of Steel = 590mm = 0.59m

Number of component = 1

Total length = length of steel x number of components

- 0.59 x 1

- 0.59 m

The length of soil, tearer attachment = 13cm = 0.13m

Total length of material used = 0.59 + 0.13 = 0.72m

Total volume = Total length of material used x area

= 0.72mx 1.6 x 10^{-4}m^2

= 1.152 x 10^{-4}$_{m^3}$

Mass of steel = Density (p) xtotal volume

= 7830 kg/m^3 x 1/152 x 10^{-4}$_{m^3}$

= 0.902 kg

For additional weight due to fabrication, the weight of the frame was taken to be 1.0 kg. Since the main frame is supported at two ends each end will carry 0.5 kg.

4. Weight of the shaft.

Material used = ∅ 15mm rod mild steel

Area = $\frac{\pi d^2}{}$ where d = Diameter

$= 1.766 \times 10^{-4} m^2$

Length of the shaft = 30cm = 0.30m

Number of components = 2

Total length of the shaft = 2 x 0.30 = 0.60m

Total volume = Total length x Area

$= 0.60m \times 1.766 \times 10^{-4} m^2$

$= 1.0596 \times 10^{-4} m^3$

Mass of Steel rod = Density (P) xtotal volume

$= 7830 kg/m^3 \times 1.0596 \times 10^{-4}$

$= 0.8296kg$

For Chains in agricultural machines and implements, when used must be checked for the following:

1. For breakage due to tensile force.
2. Wear of the components caused by bearing pressure.

1. TO CHECK FOR BREAKAGE DUE TO TENSILE FORCE

Power exerted = 65w

Velocity of chain = $\frac{PxNxRPM}{376}$ (Krut et al)

Where V = Average chain velocity m/sec

P = Number of teeth, on sprocket

N = Sprocket speed in revolution per minute

P Bicycle chain pitch = 15.875mm (measured) = 0.635

Recall that 1" = 25mm

X = 15.875mm

$X = \frac{1x15.875}{25}$ = 0.635"

N = 44 counted from sprocket

RPM = 32 rev/min as obtained earlier

$V = \frac{0.635 \times 44 \times 32}{376}$ = 2.38m/s

PC = Power rating of chain

$Pc = \frac{pm}{C_1 x C_3}$ - Maitra et al

Pm = Motor power in Kw = 0.065 Kw

Knowing our velocity we can choose our C_2. C_2 takes care of lubrication aspect of chain drive. C_2 from table 9.33 = 0.3 C_3 obtained after knowing Y Impact factor for chain drives. Y = 1.5 assume the value as that of milling machines from table 9.34

1 = Transmission ratio 1:2

1:2 1.05 Y = 1:0

x Y = 1:5

$x = \frac{1.5 \times 1.05}{1}$ = 1.575 = C_3

$PC = \frac{0.065}{0.3 \times 1.575} = 0.14$ kw

Knowing Pc and Number of revolutions we can use these to select our chain.

The circumferential force fu

$Fu = \frac{102\ P\ (Kw)}{V}$ P = Power in Kw Maitra et al.
V = Velocity in m/s

$= \frac{102 \times 0.065}{2.30} = 2.79N$

FC = The cantrifugal force produce

$FC = \frac{WV^2}{9.81}$ where U = Weight of chain kg f/m
V = Velocity

W fox pitch 15.875 = 0.95 from table 9.28

$FC = \frac{0.95 \times (2.38)^2}{9.81} = 0.548N$

The total tensile force on the chain is FT = Fu + FC

FT = 2.79 +0.548 = 3.338N

For Sector of safety against breakage Sst = Static factor of safety $\frac{FB}{FT} \geq 7$

Sdyn = dynamic factor of safety $\frac{Fb}{FT \times Y} \geq 5$

Where Fb = breaking load obtain from table 9.28 FB = 2,270

$Sst = \frac{2,270}{3,338} = 680 > 7$

$Sdyn = \frac{2,270}{3,338 \times 1.5} = 453 > 5$

Both the static and dynamic factor of safety are therefore sufficient.

2. TO CHECK FOR WEAR OF THE COMPONENTS CAUSED BY BEARING PRESSURE

The bearing pressure Pb on the link is given by

$Pb = \frac{FT}{A}$. Where FT = Total Tensile force N

A = Bearing Area in Cm^2

The Value of A from table 9.28 = 0.67 Cm^2

FT = 3.338 Obtained earlier

$P_b = \frac{3.338}{0.67} = 4.98 \ N/Cm^2$

The allowable bearing pressure P is given by

$P_{b_p} = P_o \ Ci \ C_2$

Po = Bearing pressure obtained from table 9.31

Ci C_2 are correction factors, C_2 = 0.3

Ci depends upon the impact Coefficient Yi transmission ratio and the Centre distance a, Ci is therefore obtained by table 9.32, Ci 0.72 knowing V = 2.38

V = 2 - 250

V = 4 - 21 11

Interpolation

250 - 211 = 39

2.1, 2.2, 2.3 ——— 3.3, 3.9 = 20

39/20 = 1.95

Each interval is 1.95, 1.95 x 4 = 7.8 = 8

.! Po = 250 - 8 = 242.

Pb_p = 242 x 0.3 x 0.72 = 52.3N/Cm^2

Pb = 4.98 N/Cm^2

The condition for checking for wear of the Components caused by bearing pressure is that

Pb must be less than Pb_p

Therefore the component is safe against failure due to wear caused by bearing pressure.

BEARING LIFE CALCULATION

For shaft of diameter 15mm, the following bearing with their numbers can serve.

(1) Bearing number 6002

(2) " " 6202

(3) " " 6302

For bearing number 6002

$$\frac{Fa}{Co}$$

Fa = actual axial bearing load, N

Fa = Sum of Vertical loading

Fa = 15.0 + 6.50 + 4.06 + 5.60

Fa = 31.16 N

Co obtained from table 9.58 = 2,500

$$\frac{Fa}{Co} = \frac{31.16}{2,500} = 0.01246$$

$$\frac{Fa}{fr}$$

Fr = as a result of Chain pull

Chain pull = $1000 \frac{P}{V}$ Krutz et al.

P = Power in Kw

V = Chain Velocity m/sec.

$$= \frac{1000 \times 0.065}{2.38}$$

$$\frac{Fa}{Fr} = \frac{31.16}{27.31} = 1.1409$$

The nearest value to 0.01246 in Table 9.59 is 0.025 and corresponding to this Value of e= 0.22. The calculated Value of Fa/Fr is 1.1409 which is greater than 0.22. Hence X = 0.56 Y = 2 From the below equation, we obtain the equivalent dynamic load P.

$$P = XFr + YFq$$

P = equivalent dynamic load N.

Fr = actual radial bearing load, N

Fa = actual axial bearing load, N

X = radial load factor

Y = axial load factor

From

$$Lh = \frac{1{,}000{,}000}{60n}\left\{\frac{C}{P}\right\}^{k}$$

where Lh = life of the bearing in operating hours

n = Speed in revolution per minute.

P = equivalent dynamic load

C = basic dynamic load rating in newtons.

K = an exponent which is 3 for ball bearing and 10/3 for roller bearings.

n = 32, C = 4300 from table 9.58 Deep groove ball bearings

P = 77.61N, K = 3

$$Lh = \frac{1{,}000{,}000}{60 \times 32}\left\{\frac{4300}{77.61}\right\}^{3}$$

$521 \times (55)^3$

86681375

8.66×10^7 hours

The Value is greater than 3,000 hours so the bearing can serve the purpose.

STEPS. CHAIN LENGTH DETERMINATION BY A C M E CHAIN CATALOG

1. Add the number of teeth in the smaller Sprocket to the number of teeth in the larger sprocket. Then divide the sum by 2.

$$44 \pm 20 = 64 = m. \frac{m}{2} = \frac{64}{2} = 32$$

44 = Number of teeth in larger sprocket

20 = Number of teeth in smaller sprocket

2. Substract the number of teeth in the smaller sprocket from the number of teeth in the larger sprocket. This provide the constant F used in selecting the constant S from the table

$$44 - 20 = 24 = F$$

3. Divide the Centre distrance in inches by the chain pitch to obtain C

$$C = \frac{\text{Centre distance}}{\text{Chain pitch}}$$

$$= \frac{520 \text{ (measured)}}{15.875 \text{ (measured)}} = 32.76$$

4. Chain length in pitches = $\frac{m}{2} + 2C + S/C$

Knowing that f = 24, we can get our S from table 4.

For F = 24 S = 14.59

Chain length in pitches = $32 + 2 \times 32.76 + \frac{14.59}{32.76}$

$$= 32 + 65.52 + 0.445$$

$$= 97.965$$

Note: Chain length in pitches must be a whole number preferably an even number. Therefore chain length in pitches = 98.

5. Multiply the number of pitches by Chain pitch to get the Chain length in inches or mm.

98 x 15.587 = 1527.53 mm = 152.753 Cm

1.52753 m.

Table 4

Nutritional Content in Vegetables per 100 g of Edible Part (from K. W. King, 1971)

Crop	Caloric value		Protein, g	Ca, mg	P, mg	Fe, mg	Vitamin content				
	Calories	Joules					A, μg	B_1, mg	PP, mg	C, mg	B_2, mg
Pumpkin	31	130	0.6	19	22	0.5	920	0.04	0.5	15	0.04
Watermelon	23	96	0.5	6	7	0.2	70	0.02	0.2	5	0.03
Melon	25	104	0.5	15	15	1.2	350	0.04	0.6	29	0.03
Chayote	31	130	0.9	12	30	0.6	5	0.01	0.4	20	0.04
Cabbage	28	117	1.7	43	36	0.7	30	0.06	0.3	43	0.04
Tomato	21	88	0.8	7	24	0.6	180	0.06	0.7	23	0.05
Brinjal	27	113	1.0	23	31	0.8	0	0.04	0.8	5	0.04
Bean	36	150	2.0	55	45	1.7	110	0.08	0.6	18	0.11
Okra (gumbo)	42	176	2.2	78	62	1.1	100	0.06	1.1	29	0.12
Shallot	72	301	2.6	37	60	1.3	0	0.06	0.2	1	0.02
Green peas	97	405	7.6	24	124	2.0	215	0.38	2.2	26	0.14
Carrot	41	171	0.8	34	26	0.9	3530	0.06	0.6	5	0.04
Beet	44	184	1.7	14	38	0.8	0	0.01	0.2	5	0.04
Cucumber	15	63	0.7	16	24	0.6	5	0.03	0.2	14	0.04
Onion	45	188	1.4	30	40	1.0	5	0.04	0.3	10	0.03
Turnip	27	113	0.8	32	26	0.4	0	0.03	0.5	28	0.03
Pepper	38	159	1.9	20	28	1.7	470	0.08	1.5	91	0.13
Swiss chard	27	113	1.6	110	29	3.6	875	0.03	0.4	34	0.09
Radish	23	96	0.9	26	30	1.2	0	0.03	0.3	28	0.03
Lettuce	13	54	1.0	16	23	0.4	0	0.05	0.3	7	0.03
Sweet potato	116	485	1.3	31	37	1.0	1815	0.11	0.8	31	0.04

TABLE 5:

TRADITIONAL PLANT AND ROW SPACINGS FOR VEGETABLES

Vegetable	Between Plants in Row (in.)	Between Rows (in.)
Artichoke	48-72	84-96
Asparagus	9-15	48-72
Bean, broad	8-10	20-48
Bean, bush	2-4	18-36
Bean, Lima, bush	3-6	18-36
Bean, Lima, pole	8-12	36-48
Bean, pole	6-9	36-48
Beet	2-4	12-30
Broccoli	12-24	18-36
Broccoli raab	3-4	24-36
Brussels sprouts	18-24	24-40
Cabbage	12-24	24-36
Cardoon	12-18	30-42
Carrot	1-3	16-30
Cauliflower	14-24	24-36
Celeriac	4-6	24-36
Celery	6-12	18-40
Chard, Swiss	12-15	24-36
Chervil	6-10	12-18
Chicory	4-10	18-24
Chinese cabbage	10-18	18-36
Chive	12-18	24-36
Collard	12-24	24-36
Corn	8-12	30-42
Cress	2-4	12-18
Cucumber	8-12	36-72
Dandelion	3-6	14-24
Dasheen (Taro)	24-30	42-48
Eggplant	18-30	24-48
Endive	8-12	18-24
Florence fennel	4-12	24-42
Garlic	1-3	12-24
Horseradish	12-18	30-36
Jerusalem artichoke	15-18	42-48
Kale	18-24	24-36
Kohlrabi	3-6	12-36
Leek	2-6	12-36
Lettuce, cos	10-14	16-24
Lettuce, head	10-15	16-24
Lettuce, leaf	8-12	12-24
Muskmelon and other melons	12	60-84
Mustard	5-10	12-36
New Zealand spinach	10-20	36-60
Okra	8-24	42-60
Onion	1-4	16-24
Parsley	4-12	12-36
Parsley, Hamburg	1-3	18-36
Parsnip	2-4	18-36
Pea	1-3	24-48
Pepper	12-24	18-36
Potato	6-12	30-42
Pumpkin	36-60	72-96
Radish	½-1	8-18
Radish, storage type	4-6	18-36
Rhubarb	24-48	36-60
Roselle	24-46	60-72
Rutabaga	5-8	18-36
Salsify	2-4	18-36
Scolymus	2-4	18-36
Scorzonera	2-4	18-36
Shallot	4-8	36-48
Sorrel	½-1	12-18
Southern pea	3-6	18-42
Spinach	2-6	12-36
Squash, bush	24-48	36-60
Squash, vining	36-96	72-96
Sweet potato	10-18	36-48
Tomato, flat	18-48	36-60
Tomato, staked	12-24	36-48
Tomato, processing	2-10	42-60
Turnip	2-6	12-36
Turnip greens	1-4	6-12
Watercress	1-3	6-12
Watermelon	24-36	72-96

Table 9.58 (*Contd.*)

Boundary dimensions			Basic load ratings dynamic, static		Limiting speeds Lubrication		Mass	Designation
d	*D*	*B*	*C*	C_o	grease	oil		
mm			N		r/min		kg	
70	110	20	29 000	24 500	6 000	7 000	0.60	6014
	125	24	47 500	37 500	5 000	6 000	1.05	6214
	150	35	80 000	63 000	4 500	5 300	2.50	6314
	180	42	110 000	104 000	3 800	4 500	4.85	6414
75	115	20	30 500	26 000	5 600	6 700	0.64	6015
	130	25	51 000	40 500	4 800	5 600	1.20	6215
	160	37	86 500	72 000	4 300	5 000	3.00	6315
	190	45	118 000	104 000	3 600	4 300	6.80	6415
80	125	22	36 500	31 500	5 300	6 300	0.85	6016
	140	26	54 000	45 000	4 500	5 300	1.40	6216
	170	39	95 000	80 000	3 800	4 500	3.60	6316
	200	48	125 000	125 000	3 400	4 000	8.00	6416
85	130	22	38 000	33 500	5 000	6 000	0.89	6017
	150	28	64 000	53 000	4 300	5 000	1.80	6217
	180	41	102 000	90 000	3 600	4 300	4.25	6317
	210	52	134 000	134 000	3 200	3 800	9.50	6417
90	140	24	45 000	39 000	4 800	5 600	1.15	6018
	160	30	73 500	62 000	3 800	4 500	2.15	6218
	190	43	110 000	98 000	3 400	4 000	4.90	6318
	225	54	140 000	146 000	3 000	3 600	11.5	6418
95	145	24	46 500	41 500	4 500	5 300	1.20	6019
	170	32	83 000	69 500	3 600	4 300	2.60	6219
	200	45	118 000	110 000	3 200	3 800	5.65	6319
100	150	24	46 500	41 500	4 300	5 000	1.25	6020
	180	34	95 000	78 000	3 400	4 000	3.15	6220
	215	47	134 000	132 000	3 000	3 600	7.00	6320
105	160	26	56 000	51 000	4 000	4 800	1.60	6021
	190	36	102 000	90 000	3 200	3 800	3.70	6221
	225	49	140 000	143 000	2 800	3 400	8.25	6321
110	170	28	63 000	57 000	3 800	4 500	1.95	6022
	200	38	112 000	100 000	3 000	3 600	4.35	6222
	240	50	156 000	166 000	2 600	3 200	9.55	6322
120	180	28	65 500	61 000	3 400	4 000	2.05	6024
	215	40	112 000	100 000	2 800	3 400	5.15	6224
	260	55	160 000	166 000	2 400	3 000	14.5	6324
130	230	40	120 000	112 000	2 600	3 200	5.80	6226
	280	58	176 000	193 000	2 200	2 800	18.0	6326
140	250	42	127 000	122 000	2 400	3 000	7.45	6228
	300	62	196 000	224 000	2 000	2 600	22.0	6328
150	270	45	134 000	137 000	2 000	2 600	9.40	6230
	320	65	212 000	250 000	1 900	2 400	26.0	6330
160	290	48	143 000	146 000	1 900	2 400	45	6232

Table 9.59

Calculation factors dynamic					
F_a/C_o	e	$F_a/F_r \leq e$		$F_a/F_r > e$	
		X	Y	X	Y
0.025	0,22	1	0	0,56	2
0.04	0,24	1	0	0,56	1.8
0.07	0,27	1	0	0,56	1,6
0,13	0,31	1	0	0,56	1,4
0,25	0,37	1	0	0,56	1,2
0,5	0,44	1	0	0,56	1

Table 9.28 Data for Transmission Chains (See Fig. 9.7)

Chains dimensions, measuring loads and breaking loads of base chains
(All dimensions in mm)

ISO Chain Number	Pitch p	Roller Diameter d_1 Max.	Width Between Inner Plates b_1 Min.	Bearing Pin Body Diameter d_2 Max.	Chain Path Depth h_1 Min.	Inner Plate Depth h_2 Max.	Outer Intermediate Plate Depth h_3 Max.	Transverse Pitch p_t	Width Over Inner Link b_2 Max.	Width Between Outer Plates b_3 Min.	Width Over Bearing Pins: Simple b_4 Max.	Duplex b_5 Max.	Triplex b_6 Max.	Measuring Load, kgf: Simple	Duplex	Triplex	Breaking Load, kgf: Simple Min.	Duplex Min.	Triplex Min.
05B	8.00	5.00	3.00	2.31	7.37	7.11	7.11	5.64	4.77	4.90	8.6	14.3	19.9	5	10	15	460	800	1 140
06B	9.525	6.35	5.72	3.28	8.52	8.26	8.26	10.24	8.53	8.66	13.5	23.8	34.0	8	15	22	910	1 730	2 540
08B	12.70	8.51	7.75	4.45	12.07	11.81	10.92	13.92	11.30	11.43	17.0	31.0	44.9	13	26	39	1 820	3 180	4 540
10B	15.875	10.16	9.65	5.08	14.99	15.73	13.72	15.90	13.24	13.41	19.6	36.2	52.8	20	40	60	2 270	4 540	6 810
12B	19.05	12.07	11.63	5.72	16.39	16.13	16.13	19.46	15.62	15.75	22.7	42.2	61.7	29	57	86	2 950	5 000	8 850
16B	25.40	15.88	17.02	8.28	21.34	21.08	21.08	31.88	25.45	25.58	36.1	68.0	99.9	51	102	152	4 310	8 620	12 930
20B	31.75	19.05	19.56	10.19	26.68	26.42	26.42	36.45	29.01	29.14	43.2	79.7	116.1	79	159	238	6 580	13 160	19 740
24B	38.10	25.40	25.40	14.63	33.73	33.40	33.40	48.36	37.92	38.05	53.4	101.8	150.2	113	227	340	9 980	19 960	29 940
28B	44.45	27.94	30.99	15.90	37.46	37.08	37.08	59.56	46.58	46.71	65.1	124.7	184.3	154	308	463	13 160	26 320	39 480
32B	50.80	29.21	30.99	17.81	42.72	42.29	42.29	58.55	45.57	45.70	67.4	126.0	184.5	204	408	612	17 240	34 480	51 720
40B	63.50	39.37	38.10	22.89	53.49	52.96	52.96	72.29	55.75	55.88	82.6	154.9	227.2	318	635	953	26 770	53 540	80 310
48B	76.20	48.26	45.72	29.24	64.52	63.88	63.88	91.21	70.56	70.69	99.1	190.4	281.6	454	907	1 361	40 830	81 650	122 470
56B	88.90	53.98	53.34	34.32	78.64	77.85	77.85	106.60	81.33	81.46	114.6	221.2	–	621	1 243	–	55 340	110 680	–
64B	101.60	63.50	60.96	39.40	91.08	90.17	90.17	119.89	92.02	92.15	130.9	250.8	–	812	1 624	–	72 580	145 150	–
72B	114.30	72.39	68.58	44.48	104.67	103.63	103.63	136.27	103.81	103.94	147.4	283.7	–	1 030	2 059	–	91 630	183 260	–

Approximate weight and bearing area in case of simple chain

Pitch = mm	8	9.525	12.7	15.875	19.05	25.4	31.75	38.10	44.45	50.80	63.50	76.20
Weight = (kgf/m)	0.18	0.14	0.70	0.95	1.25	2.70	3.60	6.70	8.30	10.50	16.0	25.0
Bearing area = (cm^2)	0.11	0.28	0.50	0.67	0.89	2.11	2.96	5.55	7.41	8.47	12.76	20.63

(To find the weight and bearing area for multi-strand chain, multiply the above values by the relevant number of strands)

Table 9.30 Impact Factor for Chain Drives

Driven machine → Y =	Lathe, drilling m/c	Milling m/c	Slotting m/c	Drawing m/c	Press	Reciprn. Compr.	Centrifugal Compressor
	1.4	1.5	2.3	1.8	2.5	2.5	1.6
	Blower	Ventilator	Reciprn. Pump	Centrif. Pump	Rolling Mill	Ball Mill	Hammer Mill
	1.5	2.5	2	1.5	2.5	1.8	2.5
	Vibrating Screen	Elevator	Mixing Drum	Excavator	Agitator	Hoists	Stacker
	2	2	1.7	3	1.6	2.5	3

Table 9.31 Bearing Pressure for Chain Links

v (m/sec)	No. of teeth of small sprocket z_1							
	11	13	15	17	19	21	23	≥ 25
	Bearing pressure p_o (kgf/cm²)							
0.1	319	319	320	324	326	331	331	335
0.4	284	281	290	295	299	302	305	311
0.8	229	250	262	271	276	281	285	291
1	217	238	252	261	269	273	280	285
2	170	197	215	226	237	244	250	256
4	116	147	170	185	195	204	211	218
7		98	126	146	159	168	176	184
12			77	101	120	131	140	147
18				64	83	97	109	118
24					51	68	82	93

Table 9.32 Correction factor C_1 for Chain Links*

Impact coefficient Y	$a = 20\,p$			$a = 40\,p$			$a = 80\,p$			$a = 160\,p$		
	i			i			i			i		
	1 : 1	3 : 1	7 : 1	1 : 1	3 : 1	7 : 1	1 : 1	3 : 1	7 : 1	1 : 1	3 : 1	7 : 1
	C_1											
1	0.69	0.87	1.04	0.83	1.00	1.15	1.00	1.19	1.32	1.24	1.45	1.54
2	0.50	0.64	0.76	0.60	0.73	0.84	0.73	0.87	0.97	0.91	1.06	1.15
3	0.44	0.55	0.66	0.52	0.63	0.73	0.63	0.75	0.83	0.78	0.92	0.99
4	0.40	0.51	0.61	0.48	0.56	0.67	0.58	0.69	0.77	0.72	0.84	0.91

Table 9.33 Correction Factor C_2 for Chain Links*

v (m/sec)	Recommended type of lubrication		Condition of lubrication			
			perfect	Insufficient clean	dirty	dry
	Favourable	Permissible	C_2			
up to 4	Light, drip lubrication	Grease lubrication	1	0.6	0.3	0.15
4 to 7	Splash lubrication	Drip lubrication		0.3	0.15	Not permissible
7 to 12	Pressurized circulatory lubrication	Oil bath lubrication				
> 12	Spray lubrication	Pressurized circulatory lubrication		Not permissible		