P A R T - V

CHAPTER-1

PADDY CULTIVATION

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1. ERGONOMIC EVALUATION OF 'DESI' PLOUGH.

Ergonomic Evaluation of 'Desi' Plough

1. Introduction

Plough is being used as a tillage implement mostly used in Eastern India, Fig.44,45. Several improved plough models were made by the department of agriculture, West Bengal, but the use of them were not observed working in the fields of coastal zone.

In 1946, Government of India passed a resolution to make standardization of the farm implements used in India (325). Introduction of a wing containing mould board plough suitable to draw by bullocks was made by Bandopadhya (280). National Institute of occupational health is now also working on this line, problem associated with occupational hazards.

Ploughing implements are mainly observed in this study with a view point to betterment through ergonomics. Equipment design with proper application of human factors principles can result in increased efficiency and productivity, decreased operators effort, increased reliability, improved safety, improved flexibility, increased comfort and consumer acceptance. The product safety is closely related to man-machine relation system andto man's physical and physiological limitations. The more efficient and trouble free a machine can be made the safer it will be (282).

2. Aims and Objectives:

This is to justify the usefulness of existing implements in present situation and if possible to modify them for betterment, is the aim of this study rather than to sweep out the existing by completely newer one.

3. Methods and Materials :

The present investigation was conducted at village Egra, Midnapur district of West Bengal, on 15 highly experienced agricultural workers. It deals with surveying the existing design of indigenously prepared primitive type of 'Desi' (local) plough, locally available. Considering the troubles found in the design and operative aspect, modifications on existing plough designs were made. Suggestions were made with trials on them and results obtained from experiments and from workers' opinion, on plough, based on ergonomic principles.

3.1 New device supporting experiment :

To assess some anthropometric measurements and suitable dimensions of plough for use by the Indians, one new wooden device was made, Fig.55. It was a solid wooden block (15 cm broad, 30 cm long and 6 cm high) approximately similar to the base of the existing plough. It has a wooden goniometer of 12 cm diameter and marked beam of 100 cm, was adjusted at the centre of the goniometer which can be move to any angle between 0° to 90° in respect of the surface of the block. The beam has an adjustable (marked in cm) handle of 30 cm long. Trials were made on 15 male agricultural workers with the device and measurements were also made on them against an anthropometric board and a goniometer. Subjects were asked to push the device held by the handle after adjusting all the angles and heights so that it was suitable for use on different soil surface.

From the above study, it came to know that working elbow angle should be parallel to hand-body angle and other dimensions are more or less similar to the existing design of 'desi' plough.

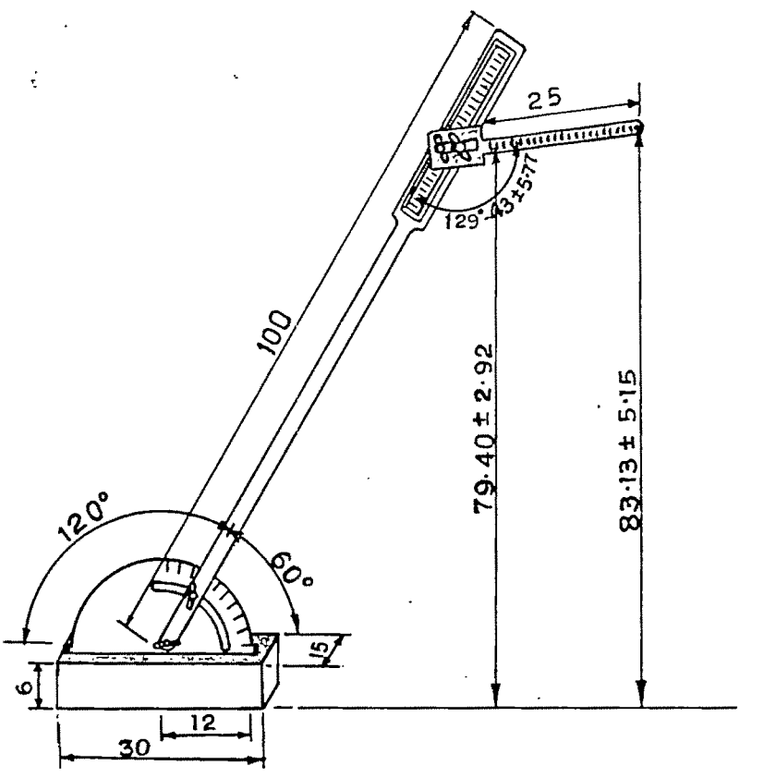


Fig. 55 NEW DEVICE USED FOR DYNAMIC ANTHROPOMETRY IN PLOUGH DESIGN AND DESIGN DIMENSIONS. VALUES (in cm) ARE MEAN ± S.D. OF 15 SUBJECTS.

Experimental Prototype:

3.2. Considering the merits and demerits of the existing designs of the plough, ~~with an identical structure of existing one~~, with the results of questionnaire survey and workers' opinion, and the experiments of the above said device a modified prototype design of plough was made, and presented in Fig.56.

During questionnaire study and direct observation of ploughing operation with existing plough, it was observed that subjects were hanging their hands while it was not in use, ~~But~~ a rar handle hold produces fatigue in the hand muscles due to continuous holding in a same manner. So it has three ergonomic handles. Fig.57 This model contains another two handles at the top with 90° angle side by the existing a rar handle. The handles were groved, so that rubber sheet or cloth may be wrapped on it to ~~make~~ soften the handle surface. At the three handle junction, the tip was made round headed according to palmer medial depression, because while operation man sometimes uses it to press or to rest palm.

Work study, during ploughing operation and trials on prototype, were taken, as well as physiological responses e.g., 1. heart rate-resting, working and recovery values determined by the radial or carotid pulse suitable to measure and 2. oral temperature keeping clinical thermometer under the tongue for at least 5 minutes, as resting and working values, were observed.

4. Results and Discussions:

4.1 Design Considerations: Existing and modified:

According to the above study and based on questionnaire survey and worker's opinion, the following modifications were established on existing plough. The village

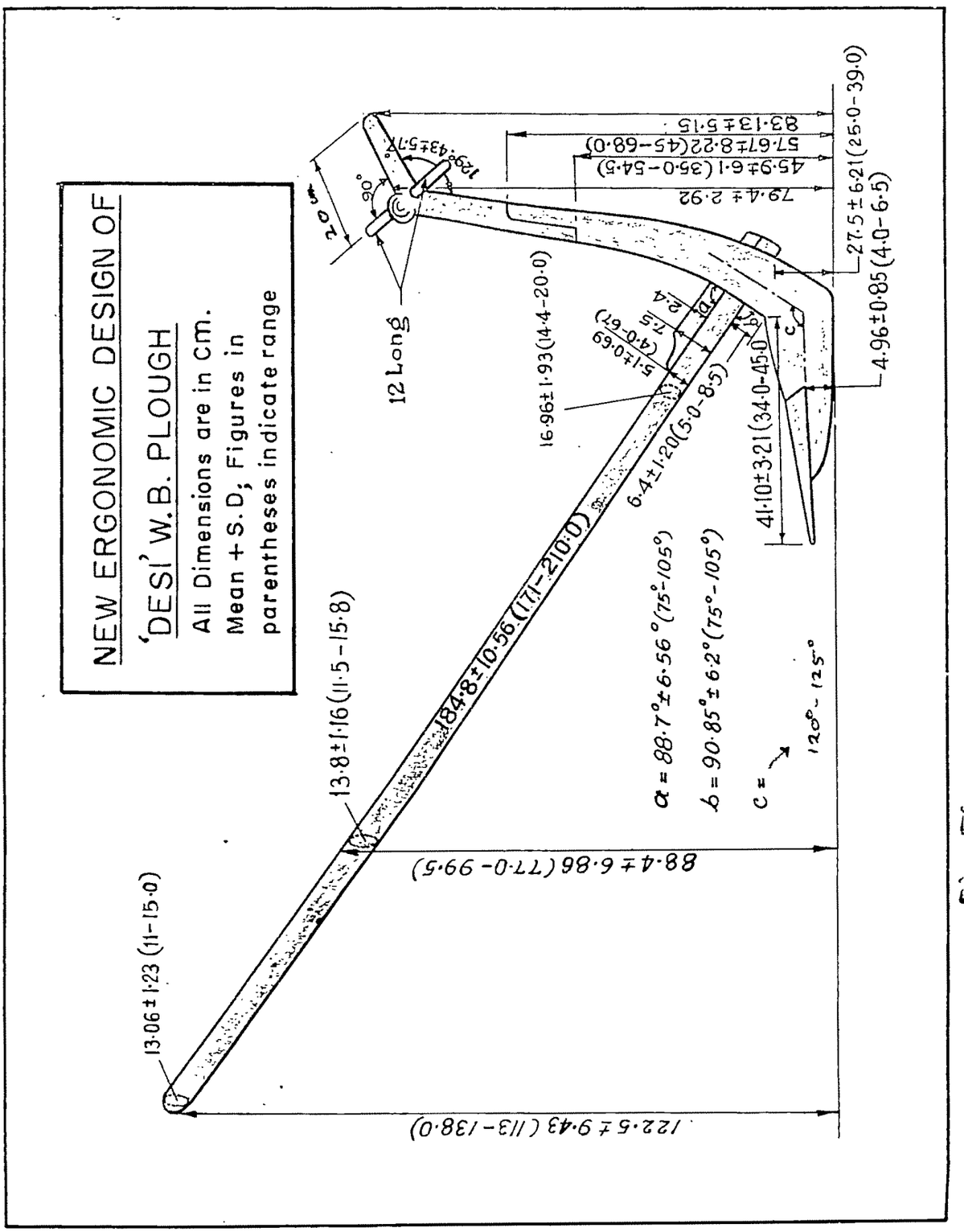

NEW ERGONOMIC DESIGN OF
'DESI' W.B. PLOUGH
All Dimensions are in cm.
Mean + S.D; Figures in
parentheses indicate range
13·06 ± 1·23 (11–15·0)
122·5 ± 9·43 (113–138·0)
184·8 ± 10·56 (171–210·0)
88·4 ± 6·86 (77·0–99·5)
13·8 ± 1·16 (11·5–15·8)
α = 88·7° ± 6·56° (75°–105°)
β = 90·85° ± 6·2° (75°–105°)
c = 120°–125°
12 Long
16·96 ± 1·93 (14·4–20·0)
6·4 ± 1·20 (5·0–8·5)
41·10 ± 3·21 (34·0–45·0)
5·1 ± 0·69 (4·0–6·1)
2·4
7·5
4·96 ± 0·85 (4·0–6·5)
27·5 ± 6·21 (25·0–39·0)
79·4 ± 2·92
45·9 ± 6·1 (35·0–54·5)
57·67 ± 8·22 (45–68·0)
83·13 ± 5·15
90°
20 cm
135° 43' ± 5·7'

Fig. 56.

artisans are accustomed to manufacture this existing type as well as the workers to work on it. If the radically changes be done to learn the new technology time and energy may spent, considering cost may not be accepted by the poor agriculturists. Modifications on this existing model may serve well and be well accepted by them. So, the considerations done here, on the modifications were based on the existing model.

The existing design of 'desi' plough, Fig.44,45, has no facility to change the positions of hands on handle which is being held by the fingers converging in flexing in a position of only ventral side facing upward. So the use of three ergonomic handles in modified prototype, Fig.57, were at a height of 80 cm, one rear central handle of 20.0 cm, with provision to hold by both palms at an angle of 129.4° ± 5.77, Table-29, and two wooden side handles of 12 cm at 90° to rear handle at handle body junction. At the top of handle base a ball like structure was made. Handles were wrapped by cloth pieces and/or rubber guard at the time of trials, in improved model, help to reduce fatigue in hand muscles used to keep the hands in a static position, as some time workers hold base area while ploughing to press or rest the palm. Corn marks were noticed on palmer inner-side. So, the soft rubber or cloth pieces wrapped on the handles may serve better against these hazards. This modification helps to improve the ploughing posture also.

The sequence of hands used on three handles, Fig.57 and time taken for each position against that of existing handle were observed and presented in Fig.58, showing operational improvement. At the time of single handle holding, the other hand is used to insist the bullocks run or hangs sidewise idle. Grip diameter of 7.5 cm found in this investigation (right hand 7.5 ± 0.47 cm and

TABLE - 29

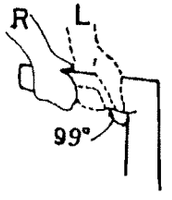
Some Working Dimensions on New Device to Justify Plough Dimensions (*Fig. 55 below)

	Age yr	Height cm.	Acromian ht. cm.		Elbow ht. cm.		Knuckle ht. cm.		Elbow angle cm.		Front foot to vertical trochanteric length cm. (plough lever & front foot dist.)		Grip length cm		Handle body angle of the model 0°	Handle ht.	
			Right	Left	Right	Left	Right	Left	Right	Left	$\overline{YZ}$	$\overline{XY}$	Right	Left		Base	Free end
Mean	37.6	161.2	132.4	133.9	101.7	89.8	69.4	71.3	127.3	126.6	35.4	36.6	7.5	7.5	129.4	79.4	83.1
± SD	11.91	5.74	4.45	3.88	4.61	5.27	3.42	4.08	5.91	10.39	2.70	6.25	0.47	0.58	5.77	2.92	5.15
Range		150.5 -170.2	126.1 -139.7	127.5 -139.2	95.8 -105.8	98.5 -107.5	64.3 -72.7	66.1 -78.0	120.0 -134.0	115- 145	31- 40	25- 43	6.8- 8.3	6.7- 8.6	119- 136	73.2 -83.5	74.0 -88.8

Fig. 57

Use of three handles in new design of plough.

EXISTING PLOUGH



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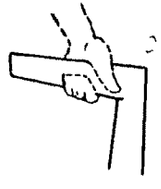
26·66%



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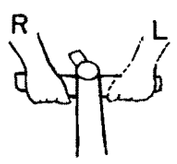
IMPROVED PLOUGH DESIGN



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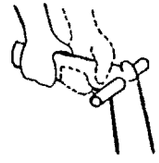

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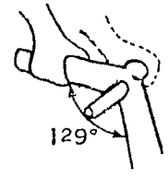

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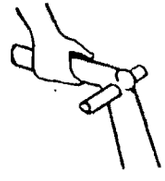

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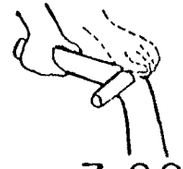

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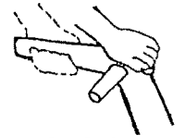

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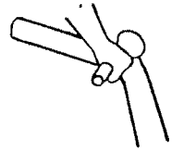

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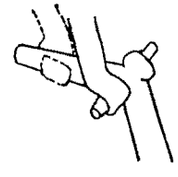

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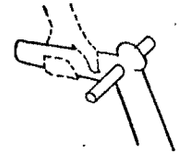

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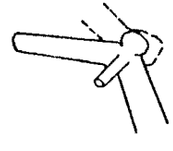

0·74%

Fig. 58.

DIFFERENT POSITIONS OF HANDS ON HANDLES OF EXISTING AND MODIFIED DESIGNS OF DESI PLOUGH AND % OF TOTAL PLOUGHING TIME TAKEN IN EACH POSITION.

left hand of 7.5 ± 0.58 cm) Table-29. So the side handles of 12 cm for single and double palm grip and rear handle of 20 cm with provision to hold by single palm, including clearance allowance, were used in modified design.

Handle angle be preferable to equal to working elbow angle. Handle angle found 129.4° ± 5.77 which is near about the working elbow angle (right) on plough handle of 127.3° ± 5.91, Table-29., where as in the existing plough design the handle angle was found 99.6° ± 5.86.

The curvature of the plough body, which is an artistic view may be replaced by straight one, but the existing whole structure acts as liver pivoting on heel of the plough. Handle from vertical heel distance gives safe walk during operation. As rear heel angle found 55° -60° by the new device trials, suitable to push so it can be said the front angle of existing plough 125° is acceptable. Workers' step length during ploughing operation was found to be 47 cm with side deviation of 23 cm from the furrow line, where the normal step length at walking observed 56 (± 0.07) cm (26( ).

Result of the experiment on the experimental device (device showing the trial results are presented in Fig.55) made for dynamic anthropometry show equal to existing one in blade body angle of around 120° to 125° for all type of soil surface was suitable to just start the movement and to keep a safe distance, observed around 37 cm from plough base to front foot. The main force applied on plough as pulling force through beam. The pulling point far from plough-beam joint and lesser angle 'C' may not serve well as, while pulling from far, the given force is more effective forward where the friction is lesser amount.

As the higher neck height the larger the bullocks required, yoke adjustment takes place and can easily

drive bullocks mainly controlled by the bullock's neck. The bullocks neck point around 30 cm on yoke from middle, yoke-beam tieing point, Fig.45, is well accepted and it also gives a safe distance from bullocks legs to blade. The more distance the more safety but difficult to control by man manually. Sometimes it has been seen that yokes are quadrangular shaped attached to bullocks neck causes neck corn mark than round shaped yoke. To reduce pain, yoke at the shoulder touching side be curved surface same as shoulder curvature of bullock serve well. Some where thick round bamboo piece are used as yoke also. Yoke at the shoulder tying side may be attached with rubber pad or cloth piece to soften the hard woody surface.

As the clods diameter is around 8 to 10 cm and as blade turns over the soil by the sides of furrow, the resistance comes from clods is not so important here, but to give a clearance the existing gap at shoe to beam-body junction, of 6.4 $\pm$ 1.2 cm is more or less well. Too much increase, will do increase the pulling force on blade and also handle control will have to increase. The cross section will better if the shape be double conical-convex ' ○ ', to increase clearance capacity and also will decrease the resistance from clods.

The toe serves well as existing one, flattened bottom and gradually conical at the tip. This toe part holds iron blade. Flat blade used in 'desi' ploughs cuts soil into furrows in 'V' shape. Cultivated soil turn towards the side of the furrows, and between two furrows land are kept unploughed. So to cultivate the whole land by 'desi' plough, 3 to 4 even 5 to 6 times ploughing requires crosswise and lengthwise. By the use of blades of wider and mould board type having wing to upturn the soil downward no land kept uncultivated, but requires more druft than flat-conical shaped blades.

Soil of upper surface including weeds turn downward, and requires less ploughing than previous one, and after ~~putrid~~ rotting it serves as organic manure.

First time ploughing is suitable to use the conical narrow flat pointed tip blade to cultivate hard dry soil, and the next by mould-board blade. So, there should be provision to change the blades in the same plough.

To control or exert the force on ploughing task at different angle through different body posture, the operator sometimes proceeds by keeping legs wider by steps one forward and backward to shift the center of gravity of body forward. All the movements depend on a combination of three types of leverage system. The whole body is a combination of leverage system. To keep head in a particular position to see forward horizontal line by the neck muscles in different body position, neck muscles pain is observed due to continuous first class leverage activity and backpain due to uneven pressure at inter vertebral disco. All the leverage system favours speed and range of motion of extrimities and distal ends, as well as whole body. In ploughing operation say in all work, though a single body part involves to exert a force all the body muscles more or less support the work.

4.2 Physiological responses:

The physiological responses observed during ploughing operation are presented in Table-30, shows that it is ~~under~~ a heavy category job (241), whether it may be use of existing or new design. The 'Δ' (delta) heart rate per minute was reduced by the use of new model to 44.2 where as it was 59.6 min^{-1} in the case of existing model. The delta values of oral temperature, in the case of improved model trial also decreased by the use of new model (Table-30).

TABLE - 30

Physiological Responses of the Workers During Ploughing Operation Using Existing Design & Modified Prototype.

	Deferences of physiological responses from resting to working values.		
	Pulse beats min^{-1}	Oral Temperature °F	(Recovery Pulse sum min^{-1} and resting Pulse beat min^{-1}
Operation, using existing plough.	59.6 ± 6.03 (52 - 64)	1.28 ± 0.58 (0.8 - 2.0)	45.8 ± 3.35 (41 - 49)
Operation, using modified prototype.	44.2 ± 8.14 (37 - 58)	1.20 ± 0.52 (0.7 - 1.8)	27.2 ± 12.46 (15 - 46)
't' Test values between existing design and modified prototype plough operation.	t = 3.61 df = 8 $0.01 > p > 0.001$	t = 0.23 df = 8 $0.9 > p > 0.8$	t = 3.23 df = 8 $0.02 > p > 0.01$

Values: mean ± SD and (Ranges)

Above said alterations in the existing plough design, used in modified prototype, show no significant change in physiological responses, i.e., heart rates and oral temperature, providing that these will not increase the ploughing work stress on workers.

The following benefits were noted when the workers used the modified design, and also presented in Table-31.

1. Improvement of ploughing posture.
2. Facilities to change the hand positions on the handle and thereby-
3. Reducing fatigue in the hand muscles.
4. Facilities to rest the hands on the handle,
5. Reduces the monotony of handle holding,
6. Same manufacturing cost as existing one,
7. Softness by the use of soft pads increase comfort and reduces the chances for growing of corn on palm, which is generally observed on ploughman's palm,
8. Safe feet position from the plough base while ploughing.

4.3 Suggestions for further improvement:

1. The new handle may be made up of hollow iron and entered on the plough.
2. Latest bullock drawn iron body mould board plough, developed by Bandopadhyaya (280) suitable for primary tillage operation effects complete inversion of soil for quick decomposition of weeds, furrow prominent and no furrow gaps (saving of ploughing time) observed after ploughing. The use of modified handle in this will serve well.

3. The use of mould board plough is found limited as small sized bullocks fail to drive it though it was claimed suitable for them.

Existing type of long flat conical shaped blade is suitable to plough the hard soil. The mould board type (280) requires more draft. So this type of blade can be used after 1st time ploughing by existing blade or in soft soil.

So the new design suggested that, with the provision to change the blades on the same wooden plough and use of new type handle would fulfil the overall demands on ploughing operation for increasing the productivity, efficiency, safety and comfort for man at agricultural work.

5. Conclusions:

The existing design of 'desi' plough, with three ergonomic handles and above said modifications on the whole will be well adopted to local condition, made up of locally available wood by village artisans, with manufacturing cost of Rs. 100 (about 7.7 $).

6. Summary:

After a survey of the existing designs of the 'Desi' (indigenous) plough and critical examination of its operation attempts were made for betterment of the existing design. A new device to note proper anthropometric dimensions of ploughing operation was made. A new prototype on the basis of the merits and demerits of the existing designs of the plough and also on the result of a questionnaire survey and worker's opinion, and the experiments with experimental device was made. It has three ergonomic handles - two additional handles by the sides at 90° and with one central handle at an angle about 129 °. The handles were at a height of 80 cm. The indigenous plough,

on the whole is well adopted to local condition, and with the above alterations and with some provision to change flat conical and one wing containing (mould board type) blades in a same plough shoe, would fulfil the overall demands on ploughing operation for increasing the efficiency of man at agricultural work.

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