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Ergonomic Evaluation of Spading Machine for Tillage Operation Chandrashekar and Bini Sam

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***Abstract*:** Spading is an important field operation, and a spading machine has been developed based on the principle of a four-bar mechanism. The ergonomic evaluation of the spading machine was conducted using physiological measurement techniques to assess the heart rate, oxygen consumption, and energy expenditure of the subjects. The average heart rate of the subjects during spading operation was 127 beats per minute. The estimated oxygen consumption rate was 0.798 litters per minute, which is 38% of the subject's aerobic capacity (VO_2 max). This value above the acceptable limit of 35% of VO_2 max, indicating that the subjects are working at a high level of exertion. The spading machine has field capacity of 0.096 hectares per hour and a field efficiency of 80% at a forward speed of 2 km/h.

***Keywords*:** Heart rate, Oxygen consumption, Field capacity, Work load, Discomfort

The exterior triangle of efficiency, comfort, and health is commonly referred to as ergonomics. Ergonomic research encompasses all areas of anthropometry, workload assessment, working environment, safety features, and methods for optimizing the human-machine environment system. By adapting to the skills and limitations of human operators, this helps to increase working productivity while reducing drudgery. Ergonomics research improves worker efficiency, productivity, and safety while also reducing tiredness. Any machine's performance, particularly those are controlled by manually can be significantly enhanced if ergonomic considerations are considered. The evaluation of the energy consumption of the power tiller powered spading machine is vital from a safety standpoint because when a person's physical capacity is surpassed, it is sure to create significant weariness and a significant drop in attentiveness, making the operation dangerous. As a result, research into the ergonomics of a power tiller-operated spading machine can give a reasonable basis for technique recommendations and improvements in equipment design for increased production and safety (Sam 2014).

MATERIAL AND METHODS

Selection of subjects: In order to perform ergonomic research, it is critical to choose the right subjects. To engage in the studies, the subject must be medically fit. They should also be a true representation of the user community using the chosen implementations. The subjects must not be pregnant, breastfeeding, or disabled. Subjects were chosen based on the age, anthropometric data and medical fitness. Three males between the ages of 25 and 35 will be selected for the study, with anthropometric measurements that meet statistical standards. In the lab, all the subjects were calibrated to determine the link between heart rate and oxygen uptake. During the experiment, the subject's heart rates was monitored using a polar heart rate monitor. A 10-point psychophysical rating scale (0-no pain, 10-extreme discomfort) will be utilized to measure the overall discomfort rating (ODR), and a body map approach will be used to examine the body component discomfort score (BPDS).

Heart rate: Polar pacer heart rate monitor was used to assess the heart rate (Fig. 1). It is a small, portable device that keeps track of your heart rate. This may be utilized in the field without the need for a telemetry system. The three essential components are chest belt transmitter, elastic strap and receiver. Three males between the ages of 25 and 35 will be selected for the study, with anthropometric measurements that meet statistical standards. In the lab, all the subjects were calibrated to determine the link between heart rate and oxygen uptake. During the experiment, the subject's heart rates was monitored using a polar heart rate monitor. A 10-point psychophysical rating scale (0-no pain, 10-extreme discomfort) will be utilized to measure the overall discomfort rating (ODR), and a body map approach will be used to examine the body component discomfort score (BPDS).

The mean oxygen consumption was above the acceptable limit of 35% VO_2 max indicating that the spading

machine could not be operated continuously for 8 hours without rest.

Oxygen consumption: The oxygen intake of the individual subjects were assessed using the Bendict-roth equipment for the determination of basal metabolic rate and while cycling on a bicycle ergometer (Fig. 2). A 6-litre spirometer with a speed strip chart recorder makes up the device. A chain suspends the spirometer bell, which is counter-weighted over a pulley. The light perspex ink writing pen is carried by the counter weight. With levelling screws, the primary base is constructed of aluminium casting. It contains the kymograph gear box, as well as three stop cocks, one for water and the other two for oxygen. The stopcock is connected to the two outlets on the left side of the base. One of the outlets has a rubber exit valve, while the other has a thermometer slot. Through corrugated rubber tubing, a two-way stopcock (breathing valve) is carried by an adjustable arm and equipped with a rubber mouthpiece. The inner diameter of all air hoses is 25 mm. The spirometer's speed is set to 20 minutes per revolution using the speed selector.

Energy cost operation: The physiological responses of the individual subject's were calculated using the resting heart rate and the 6^{th} to 15^{th} minute of operation (Tiwari and Gite 1998). The heart rate rises quickly at the start of a workout and then gradually decreases until it reaches a stable level by the sixth minute (Davis et al 1964). The mean value for the selected implement was calculated using the stabilized average heart rate measurement for each subject from the 6^{th} to 15^{th} minute of operation. The corresponding values of oxygen consumption rate (VO_2) of the subject's for all the selected subjects were estimated from the calibration chart of the subject's based on the values of heart rate (HR) recorded during the trials. For all of the subjects, the energy cost of operation of the selected spading machine was calculated by multiplying the oxygen utilized by the subject throughout the trial time by the calorific value of oxygen, which was 20.88 kJ lit^{-1} (Nag and Dutt 1980).

Overall discomfort rating (ODR): The subjects were anchored to a 10-point overall discomfort rating (ODR) scale prior to undertaking the trials with all of the specified devices (Borg scale). The trials for determining the level of pain for spading operations were conducted. A 10-point psychophysical rating scale (Fig. 3) (0-no discomfort, 10-intense discomfort) was employed to quantify overall discomfort. A scale of 70 cm in length was made with 0 to 10

Maximum heart rate ($beatsmin^{-1}$) = 200 - 0.65 x Age in years

Fig. 1. Polar pacer heart rate monitor

Fig. 2. Bendict-Roth apparatus

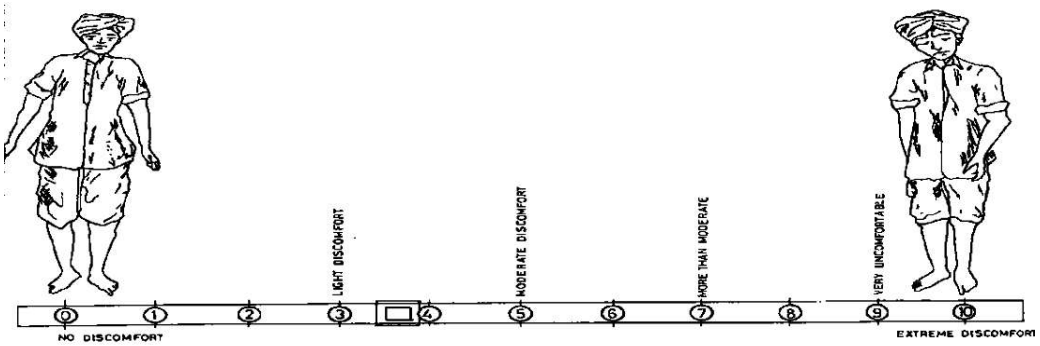
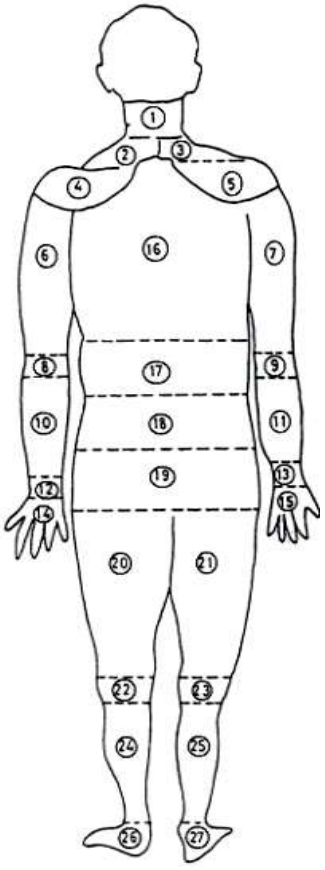


Fig. 3. Visual analogue discomfort scale for assessment of overall body discomfort

digits evenly spaced on it. The rating was indicated by a movable pointer. Subjects were asked to rate their overall pain on a scale at the end of each experiment. The mean rating was calculated by adding and averaging the overall discomfort ratings given by each of the 3 subjects. The results were tallied. All of the tests followed the same technique.

Body part discomfort score: The Corlett and Bishop (1976) approach were used to assess localized pain. The body of the subject was separated into 27 areas using this procedure (Fig. 4). To avoid a subject marking on only one body region, each body region was given a distinct number. The individual was asked to list all body parts that were bothering them, starting with the most painful and progressing down the list until no more locations were mentioned. The number of various groupings of body areas that were recognized, ranging from great suffering to no discomfort, indicated the operator's pain intensity levels. It is necessary to categorize the maximum number of pain severity levels encountered during the trial. As detailed below, the ratings were given to these categories in mathematical order.

Field layout experiments: The experimental method for evaluating machine performance as a function of soil, machine, and operational characteristics is given. The machine was developed using Pro-e software and empirical design. The development work was completed at the Department of FMPE's research workshop in KCAET, Tavanur, and the field trials were done in KCAET, Tavanur.



Body part regions
1. Neck
2. Clavicle Left
3. Clavicle Right
4. Left Shoulder
5. Right Shoulder
6. Left Arm
7. Right Arm
8. Left Elbow
9. Right Elbow
10. Left Forearm
11. Right Forearm
12. Left Wrist
13. Right Wrist
14. Left Palm
15. Right Palm
16. Upper Back
17. Mid Back
18. Lower Back
19. Buttocks
20. Left Thigh
21. Right Thigh
22. Left Knee
23. Right Knee
24. Left Leg
25. Right Leg
26. Left Foot
27. Right Foot

Fig. 4. Regions for evaluating body part discomfort score

RESULTS AND DISCUSSION

There was linear relation in heart rate and oxygen consumption rate for all selected subjects. The average working heart rate, oxygen consumption and energy expenditure of the spading machine operator were 127 beats min^{-1}, 1.20 l min^{-1} and 25.05 kJ min^{-1}, respectively. According to energy expenditure of the operator, the operation was graded as “heavy”. In spading operation, the operator was continuously walking behind the machine. More pain occurs at both arms of the operator while operating the machine. It may be suggest that, there is need to attach the seat for operator in order reduce the strain. The field capacity and field efficiency of spading machine were 0.096 ha h^{-1} and 80% respectively with forward speed 2 km h^{-1}. The maximum oxygen consumption is the subject's maximal oxygen consumption at which an increase in effort does not result in an increase in oxygen intake.

Table 1. Physiological characteristics of subjects

Variables	Subjects		
	1	2	3
Age (years)	25	25	26
Body weight (kg)	58	57	63
Height (m)	1.6	1.7	1.7
Resting heart rate (Beats min^{-1})	60	60	60
ECG	Normal	Normal	Normal
Blood pressure, mm of Hg	120/80	120/80	120/80
Body mass index (kg m^{-2})	21.05	19.5	21.5

Table 2. Classification of strains (ICMR) in different types of jobs

Grading	Physiological response		
	Heart rate (beats min^{-1})	Oxygen uptake (lit min^{-1})	Energy expenditure (kcal min^{-1})
Very light	< 75	<0.35	<1.75
Light	75-100	0.35-0.70	1.75-3.5
Moderately heavy	100-125	0.70-1.05	3.5-5.25
Heavy	125-150	1.05-1.40	5.25-7.00
Very heavy	150-175	1.40-1.75	7.00-8.75
Extremely heavy	>175	>1.75	>8.75

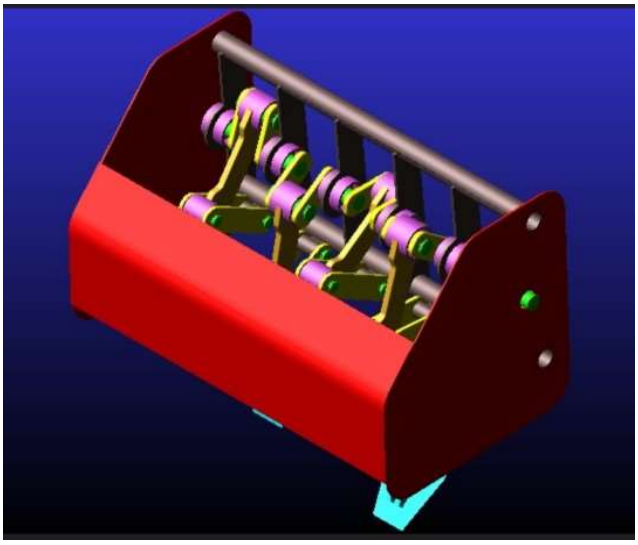


Fig. 5. Spading machine

Overall Discomfort Rating (ODR): The average overall discomfort rating was 7.0 and it scaled as "more than moderate discomfort" during spading operation.

Body part discomfort score (BPDS): The majority of discomfort was experienced in the right hand, left hand, right shoulder, left shoulder, right palm, left palm, right knee, left knee, right wrist, left wrist and mid back region of the all the selected subjects during spading operation. The average overall body part discomfort score of subjects while operating spading machine was 38.

CONCLUSIONS

An ergonomic evaluation of spading machine is carried out at research farm KCAET, Tavanur. The average working heart of operator was 127 beats min^{-1}. The operation work was grade as "heavy" the heart of the operator in spading operation is more than the limit. The mean oxygen consumption in terms of maximum aerobic capacity was calculated and it was above the acceptable limit of 35% VO_2 max indicating that the spading machine could not be operated continuously for 8 hours without rest. There is need to more than two operators for spading operation in shift for a day long work. The field capacity and field efficiency of spading machine were 0.096 ha h^{-1} and 80% respectively with forward speed 2 km h^{-1}. The average overall discomfort rating was 7.0 and it scaled as "more than moderate discomfort" during spading operation. The majority of discomfort was experienced in the right hand, left hand, right shoulder, left shoulder, right palm, left palm, right knee, left knee, right wrist, left wrist and mid back region of the all the selected subjects during spading operation.

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