

Modification and Testing of Manually Operated Rocker Sprayer

Saptashish Deb¹, Sonu Kumar², K.R. Jolvis Pou^{3*}, Sanat Das¹ and Mrinmoy Biswas²

¹College of Agricultural Engineering and Post Harvest Technology, Central Agricultural University, Gangtok, India

²North Eastern Regional Institute of Science and Technology, Itanagar, India

³Department of Agricultural Engineering, School of Technology, Assam University, Silchar, India

*Correspondence author: jolvispou@gmail.com

Paper No. 584

Received: 19-1-2017

Accepted: 18-5-2017

Abstract

This study was done to modify the existing rocker sprayer. Manually operated lever was replaced with an electric motor and the speed of the motor was regulated by a voltage regulator. For determining the power requirement, the speed of the manually operated sprayer was regulated by subjects' analysis and was found to work with an average speed of 74 rpm of the piston movement. Modification was done to get the same boom length of the sprayer. The power requirement of the sprayer was determined as 0.016 hp, but 0.25 hp motor was used due to market's unavailability. A model of the slider crank mechanism was developed to study the effect of connecting rod length, crank angle and rpm on the piston displacement and the linear velocity for the modification of the rocker sprayer. It was found that, the piston displacement and the velocity decreases with an increase in the length of the connecting rod and vice versa. Piston linear velocity was found to be maximum at two crank angles in the range of 90-120° and 260-280°. The weight of the implement was about 4.75 kg. The sufficient pressure of 80-90 psi was obtained for the purpose of spraying, as found in the existing manually operated sprayer. The slider-crank mechanism is useful for the development of the power operated sprayer and for other agricultural machineries.

Highlights

- With the increase of the length of the connecting rod, the piston displacement and the piston linear velocity decreases and vice versa
- Piston linear velocity was found to be maximum at two crank angles in the range of 90-120° and 260-280°
- Modification of manually operated rocker sprayer

Keywords: Sprayer, piston, crank, piston displacement, piston linear velocity

India is set to be an agricultural based country. Approximately 75% of the total population of India is directly or indirectly dependent on farming. Sikkim is one of the Northeast hilly states of India. Subtropical to temperate climate of Sikkim, fertile soil and abundant rainfall gives the state an opportunity to grow variety of vegetable crops, flowers, fruits, spices, and aromatic plants^[1]. Farmers have been and still are following different methods and equipments of spraying for ages.

There is a need for the development of the effective spraying machine for the increase in productivity. Power sprayers are used for developing high pressure and high discharge for covering large area. Power sprayers are operated by electric motors. Most of these sprayers are hydraulic sprayers and consist of a power unit to drive the pump, pump unit which employs piston or plunger pump, pressure gauges, pressure regulators, air chamber, suction pipe with strainer, delivery pipes and nozzles. The



portable sprayers use electric motor so that they can be easily taken to the spraying sites. In Sikkim, power operated sprayer is suitable for spraying in orchards, horticulture crops, rubber vineyards and field crops. Tall trees up to a height of 20 feet can be sprayed with these types of sprayers^[2]. In Sikkim, agricultural workers and cultivators are around 56.36% of the total workers. Female workers are around 1.5 times of male workers^[3-4]. In ergonomics point of view, females are weaker than male^[5]. During field preparation to harvesting operations, most of the tools used are handmade and manually operated tools. These activities involve a lot of drudgery. Therefore, keeping into consideration that Sikkim is a completely electrified state^[6] the current studies focused on the development of a power operated model of the slider-crank mechanism and the effect of different connecting rod lengths on piston displacement, velocity and pressure.

MATERIALS AND METHODS

The experiment was carried out in the Farm Power Laboratory, Department of Farm Power and Machinery, College of Agricultural Engineering and Post-Harvest Technology, Central Agricultural University, Gangtok, Sikkim, which is located between 88°03'40" to 88°57'19" East longitude and 27°03'47" to 28°07'34" North latitude.

Root of the symptom of model

Sikkim is one of the Northeast hilly states of India, having favourable climate for producing horticulture fruits such as orange and guava^[1]. These fruits are cultivated for commercial purpose on hilly terrains. Organic based pesticides, insecticides etc. are usually sprayed by means of the manually operated sprayers^[7-9] and most of time it is run by the female workers.

The height of the orange trees range from 10 to 25 feet whereas the height (stature) of the female workers range from 4.86 to 5.15 feet^[10]. The use of manually operated sprayer may cause early fatigue and musculoskeletal disorder due to repetitive task^[11-12]. For solving the problem of repetitive manual pumping with the lever at the speed of 70-110 rpm, the power operated sprayer can be a better alternative for the spraying of the orchard trees or the agricultural field.

Alternative device

To overcome the difficulties of the female workers with the existing models, and to reduce the drudgery and musculoskeletal disorder problem that occurs because of the manual operation of the rocker sprayer,^[13] a modified model was developed for the effective operation by using motor with a speed controlling device. In this modified model, the hand operated handle is replaced with a motor attached with eccentric disc through which connecting rod of piston is connected to provide reciprocating motion with the speed in the range of 70-110 rpm. This device is powered by electrical energy which is available at any place of Sikkim because Sikkim claims to be a 100% electrified state^[6]. It can also be operated either by a battery or by solar panels. The specification of the existing rocker sprayer is shown in Table 1.

Table 1: Description of the existing rocker sprayer

Pump type	Piston
Pump material	Brass
Maximum working pressure	80-90 psi
Hose length	25-75 feet
Spray system	Lance with cone brass nozzle and hi-jet gun
Minimum discharge rate	1200 cc/min

Power requirement of the rocker sprayer

In order to make the crank to rotate fully, the condition $L > R+E$ must be satisfied, where, R is the crank length, L is the length of the connecting rod and E is the offset of the slider^[14-16]. A slider crank is a RRRP type of mechanism which has three revolute joints and one prismatic joint.

Table 2: Specification of the sprayer

Displacement of piston (mm)	65
Displacement of piston in one stroke (mm)	$2 \times 65 = 130$
Eccentric point from the centre of disc (mm)	$2\pi r = 130$, $r = 20.7 \approx 25$
Crank length (mm)	25
Discharge of sprayer (ml/min)	1200
Pressure (psi)	80-90
Power (watt) = discharge \times velocity	$12.40 = 0.016$ hp
Force developed by motor at 70, 90 and 110 rpm	$T_{70} = 25.45$ N-m $T_{90} = 19.79$ N-m $T_{110} = 16.19$ N-m
$T = \frac{p \times 60}{2\pi N}$ (N-m), where, $p = 186.5$ W	



Fig. 1: Measurement of the pumping speed

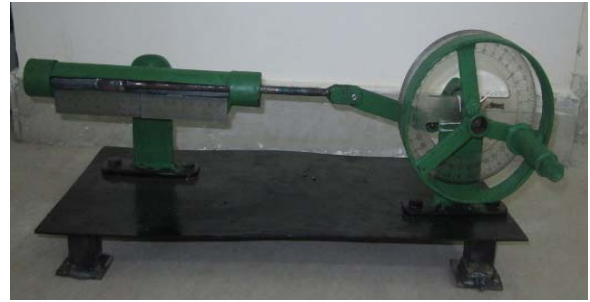


Fig. 2: Manually operated slider crank mechanism

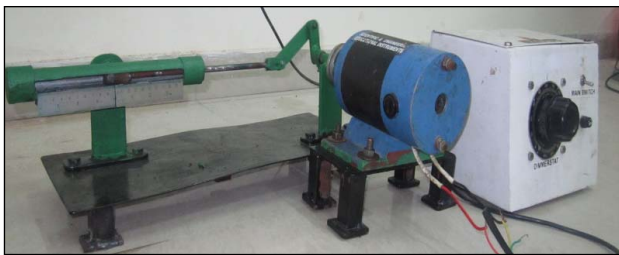


Fig. 3: Power operated slider crank mechanism

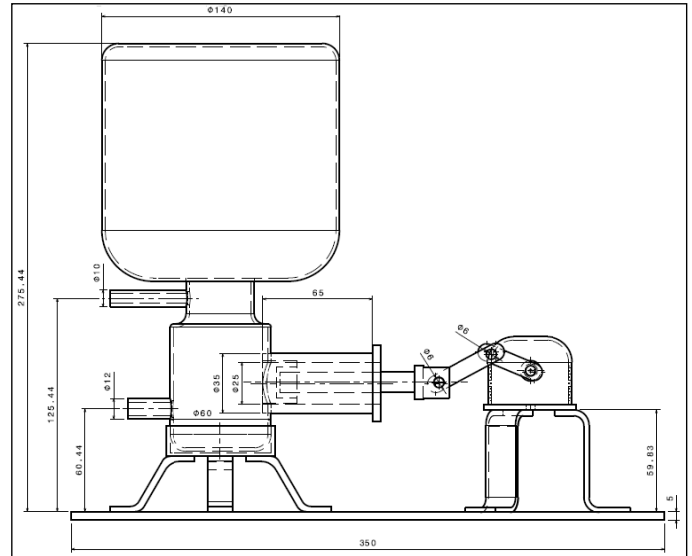


Fig. 4: 2-D view with the dimension of the spraying system

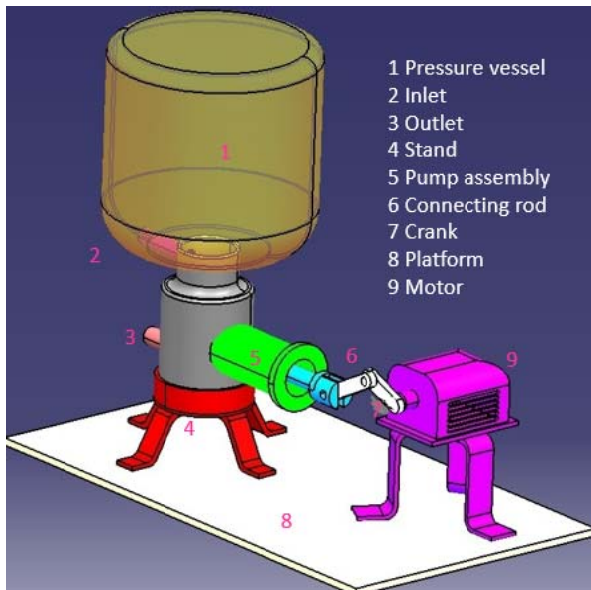


Fig. 5: 3-D view of the spraying system

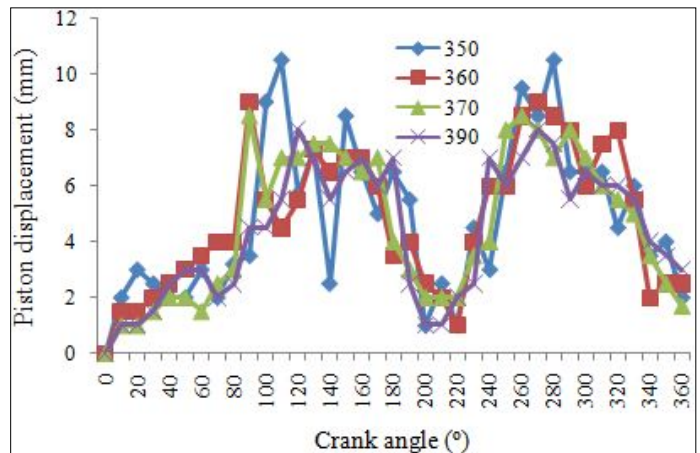


Fig. 6: Piston displacement versus crank angle, showing the comparison of plots for the connecting rod lengths of 350, 360, 370, and 390 mm

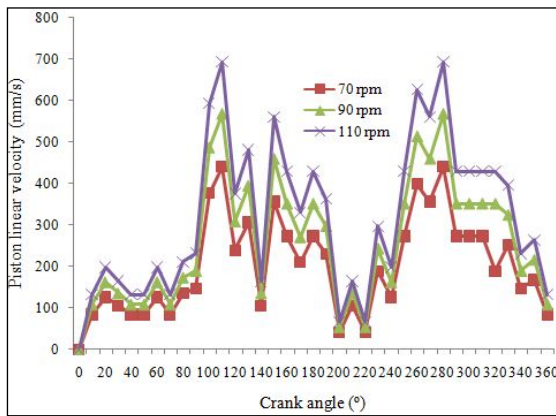


Fig. 7: Piston velocity versus crank angle, showing the comparison of plots for connecting rod length of 350 mm and angular speed of 70 rpm, 90 rpm, and 110 rpm

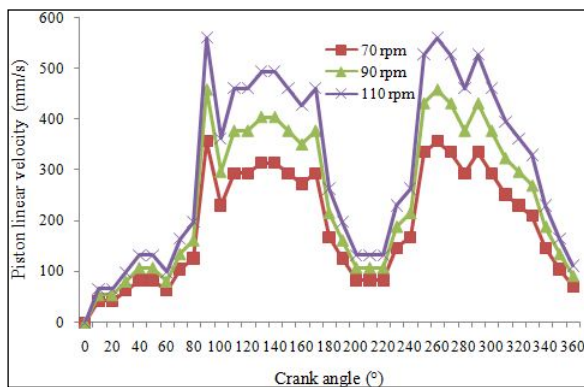


Fig. 9: Piston velocity versus crank angle, showing the comparison of plots for connecting rod length of 370 mm and angular speed of 70 rpm, 90 rpm, and 110 rpm

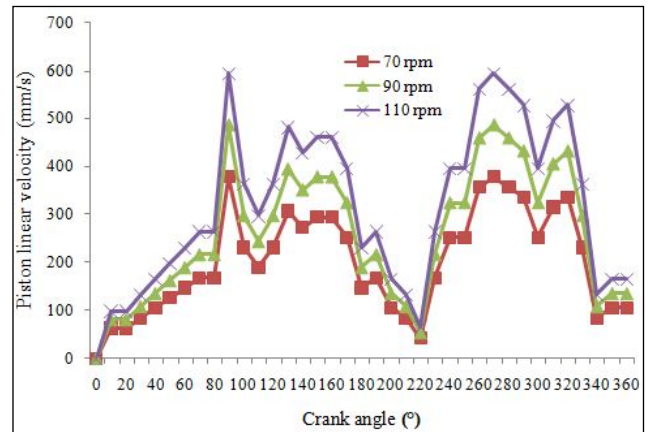


Fig. 8: Piston velocity versus crank angle, showing the comparison of plots for connecting rod length of 360 mm and angular speed of 70 rpm, 90 rpm, and 110 rpm

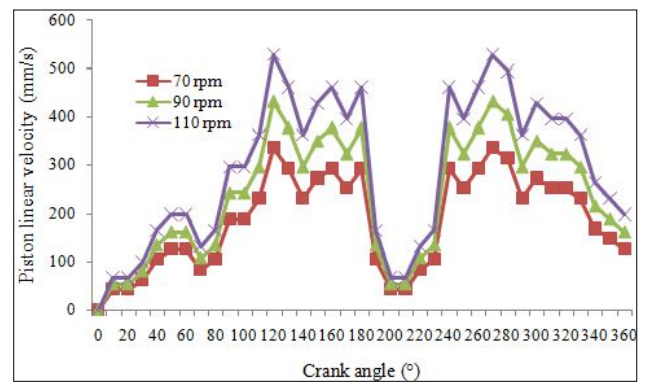


Fig. 10: Piston velocity versus Crank angle, showing the comparison of plots for connecting rod length of 390 mm and angular speed of 70 rpm, 90 rpm, and 110 rpm

For determining the power requirement, a specific speed of the sprayer was measured as shown in Fig. 1. It involved 10 subjects and speed ranges from 55-91 rpm. The average speed was calculated as 74 rpm as shown in Table 3.

Table 3: Pumping speed of sprayer

Female Subject	Speed (rpm)	Average (rpm)
1	65	74
2	55	
3	75	
4	60	
5	89	
6	73	
7	82	
8	69	
9	78	
10	91	

After calculating speed, power requirement of sprayer was calculated to select the motor power.

Description of the developed model

The model was developed at the College of Agricultural Engineering and Post-Harvest Technology, Central Agricultural University, Gangtok, Sikkim. The model consists of one mild still base plate, two supporting stands, a circular scale, a linear scale, and a wheel to give rotary motion to the crank manually as represented in Fig. 2. Rotary motion from the wheel to crank is transferred through the shaft. The crank, connecting rod and the piston are connected with nut and bolt. All the parts in the model are made up of mild steel, except the cylinder and boost which are made up of galvanized iron (GI) pipe. The weight of the model was about 4.75 kg. Four different lengths of the connecting rod (350, 360, 370 and 390 mm) were considered to study the model.

Slider displacement analysis

To find out the slider displacement against the crank angle by changing the length of the connecting rod, at first the crank angle was set at 0° with the help of a pointer and the initial position of the slider was marked. Connecting rod length of 350, 360, 370, and 390 mm were considered to determine the slider displacement for every 10° of the crank rotation.

Slider velocity analysis

A motor of 0.25 hp was used to run the developed model as shown in Fig. 3. Crank rpm of 70, 90, and 110 were considered for different lengths of connecting rod. The slider linear velocity was calculated using Eq. 1.

$$V = \frac{(2\pi N \times X)}{(T \times \theta)} \text{ mm/sec} \quad \dots(1)$$

Where,

V = Piston linear velocity (mm/sec)

N = No. of stroke

T = Time taken for N revolution (sec)

θ = Crank angle (radian)

X = Crank slider displacement for θ radian revolution (mm)

Modified sprayer

Modification of the rocker sprayer was done with the incorporation of the designed developed model of the slider crank mechanism which is power operated. The 2-dimensional (2-D) view along with the 3-dimensional (3-D) view of the modified rocker sprayer pumping system were as shown in Fig. 4 and 5, respectively.

RESULTS AND DISCUSSION

The piston displacement was observed at every 10° of crank angle for different lengths of the connecting rod (350, 360, 370, and 390 mm). The piston displacement was found to vary between 1-10.5, 1-9, 1-8.5, and 1-8 mm for 350, 360, 370, and 390 mm of the connecting rod, respectively. However, no definite trend was observed in the displacement of the piston. Theoretical analysis of the piston linear velocity for different angular velocity of crank was calculated for different lengths of the connecting rod at every 10° crank angle and compared with

the experimental results obtained. The graph plotted between piston displacement and crank angle (Fig. 6) showed that, if the length of the connecting rod was minimum then the piston displacement was found to be maximum and vice versa. For all the connecting rod lengths, the maximum piston displacement was observed at two different crank angles. As observed in Fig. 7, the maximum piston displacement of 10.5 mm was obtained at 110° and 280° of crank angle for 350 mm of connecting rod. Similarly, for 360, 370, and 390 mm of connecting rod lengths, the highest piston displacement were observed at 90° and 270°, 90° and 260°, and 120° and 270°, respectively, at which the maximum piston displacement of 9, 8.5, and 8 mm were measured, respectively.

As evident, the piston linear velocity increases with the increased of crank rpm. As shown in Fig. 7, the highest piston linear velocity of 693 mm/sec was observed at 110 rpm at 110° and 280° of crank angle for 350 mm of the connecting rod length, and 567 and 441 mm/sec were found at 90 and 70 rpm at 110° and 280° of the crank angle. For 360 mm length of the connecting rod at 90° and 270° of crank angle, the piston linear velocity were determined as 378, 486, and 594 mm/sec at 70, 90, and 110 rpm, respectively, as represented in Fig. 8. Similarly, for the connecting rod length of 370 mm at 90° and 260° angle, the linear velocity of piston were found to be as 357, 459, and 561 mm/sec, respectively, as shown in Fig. 9. In case of 390 mm of connecting rod at 120° and 270°, as observed in Fig. 10, at 70, 90, and 110 rpm, the linear velocity of piston were recorded as 336, 432, and 528 mm/sec, respectively. All the maximum piston displacements were found in between 90° to 120° and 260° to 280° of crank angle. However, no definite trend was observed in the displacement as well as the velocity of the piston. It was found that the pressure developed in the modified sprayer was in the range of 80-90 psi, which is sufficient for spraying purposes as developed in the manually operated rocker sprayer.

CONCLUSION

Manually operated sprayer was modified as power operated sprayer. Hand lever of the existing sprayer was replaced with an electric motor. Speed of the motor was regulated by a voltage regulator. Power requirement of the sprayer was determined as 0.016



hp but due to market unavailability, 0.25 hp motor was used. The speed of the manually operated sprayer was estimated by the subjects' survey and was found to work with an average speed of 74 rpm of the piston movement. It was done for getting the same boom length of the sprayer. The weight of the implement was about 4.75 kg. It was found that piston displacement and the linear velocity increases with a decrease in the length of the connecting rod and vice versa. In all the cases, piston linear velocity was found to be higher at two crank angles in the range of 90-120° and 260-280°. The sufficient pressure of 80-90 psi was obtained for the spraying purposes as found in the existing manually operated sprayer.

REFERENCES

- Afzal, A. 2004. Fatigue behaviour and life predictions of forged steel and power metal connecting rods, Thesis, Master of Science, University of Toledo.
- AICRP on ESA Progress report of Sikkim 2012. Sixth workshop, CIAE, Bhopal.
- Biswas, R.K. and Majumdar, D. 2013. Baseline data on area, production and productivity of horticulture crops in Sikkim. Agro Economic Research Centre, Visva-Bharati, Santiniketan.
- Dewangan, K.N., Owary, C. and Datta, R.K. 2009. Anthropometry of male agricultural workers of north-eastern India and its use in design of agricultural tools and equipment, *International Journal of Industrial Ergonomics* **40**: 560-573.
- Ha, J.L., Fung, R.F., Chen, K.Y. and Hsien, S.C. 2006. Dynamic modelling and identification of a slider-crank mechanism. *Journal of Sound and Vibration* **289**: 1019-1044.
- Indian standard methods of test for manually-operated sprayers.1994. Bureau of Indian Standards, New Delhi. Retrieved from <https://law.resource.org/pub/in/bis/S06/is.10134.1994.pdf>.
- Kolhe, S.L., Gajbhiye, N.B. and Deshmukh, V.B. 2014. Eco-friendly mechanically operated multipurpose spray pump. *International Journal of Research in Advent Technology* **2**: 1-5.
- Koser, K. 2004. A slider-crank mechanism based robot arm performance and dynamic analysis. *Mechanical Machine Theory* **39**: 169-182.
- Ng, Y.G., Tamrin, S.B., Yik, W.M., Yusoff, I.S. and Mori, I. 2014. The Prevalence of musculoskeletal disorder and association with productivity loss: A preliminary study among labour intensive manual harvesting activities in oil palm plantation, *Industrial Health* **52**: 78-85.
- Ranjbarbarkhan, M., Rakesh M., Hoseini, A.H., Kheiralipour, K. and Mohammad Reza Asadi, M.R. 2010. Kinematics and kinetic analysis of the slider-crank mechanism in Otto linear four cylinders Z24 engine. *Journal of Mechanical Engineering Research* **3**: 85-95.
- Rattan, S.S. 2009. Theory of Machines, Third Edition. Tata McGraw Hill Education Private Limited.
- Raut, L.P. Jaiswal, S.B. and Mohite, N.Y. 2013. Design, development and fabrication of agricultural pesticides sprayer with weeder. *International Journal of Applied Research and Studies*, **2**: 1-8.
- Salvendy, G. 1997. Handbook of Human Factors and Ergonomics, Fourth Edition. John Wiley & Sons, Inc. New York.
- Sikkim development report. 2008. Planning Commission, Government of India. Academic Foundation, New Delhi.
- Statistical profile on women labours. 2014. Labour Bureau, Ministry of Labour and Employment, Government of India. Retrieved from http://labourbureau.nic.in/Statistical_Profile_2012_13.pdf.
- Tanik, E. 2011. Transmission angle in complaint slider-crank mechanism. *Mechanism and Machine Theory* **46**: 1623-1632.