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Design, Simulation and Analysis of Dual Nozzle, Leg Operated Pesticide Sprayer

Upendra Dani
B-Tech. Mechanical Engineering
Vishwakarma Institute of Technology Pune, India

Vishwajeet Desai
B-Tech. Mechanical Engineering
Vishwakarma Institute of Technology Pune, India

Ashish Mali
B-Tech. Mechanical Engineering
Vishwakarma Institute of Technology Pune, India

Anshul Dahiwalkar
B-Tech. Mechanical Engineering
Vishwakarma Institute of Technology Pune, India

Milind Rane
Professor,
Vishwakarma Institute of Technology Pune, India

Abstract— **Agriculture is the livelihood of 58 percent of India's population. A pesticide pump is a mechanical tool which is used by farmers to spray insecticides, pesticides, weedicides, and other liquid chemicals. Hand operated pesticide pumps consists of a handle and a spraying nozzle. It is a cheaper option than that of its electrical and combustion engine powered counterparts. But its operating efficiency is lesser than the others. The main benefit of the proposed design is that it will be a balance of both cost and efficiency by using twin piston pump arrangement. The additional design goals were to achieve better ergonomics and dual nozzle while spraying. To assess the pressure and performance ANSYS-FLUENT and for simulation solid works and Linkage have been used**.

Keywords— Agriculture, Bell crank, ergonomics, leg operated, pesticides , pump, pistons ,weeder pump.

I. INTRODUCTION

As India is said to be an agriculture-based country, we can observe that the farmers are using conventional equipment which have little to no development in past few years [1]. One of such equipment is Pesticide sprayer.
Due to increase in labor cost and decrease in labor availability there is a need to increase efficiency and decrease in time consumption for such equipment. So, to minimize human effort by maximizing working efficiency of conventional pesticide pump by altering pumping actuation mechanism is our goal.
The pumping function is done by two individual piston pumps which are operated by a self-design bell crank-based actuation mechanism connected to individual legs/thigh.
This can spray twice as much as fluid as of a conventional single piston hand operated pump. This will help saving time and human efforts.
To investigate the flow, pressure, and structural durability we used ANSYS Fluent and ANSYS static structural model. (For such we used no slip streamline model for CFD).

II. LITERATURE REVIEW

Started studying with the working mechanism of conventional hand operated pesticide pump. The design of it was also observed thoroughly.
The alternative pumping was also studied which made our concepts regarding pesticide pump clear**.**[1]

<u>1)Pre-requisites & calculations</u>
<u>Measurement of pumps per minute.</u>

- Reading taken by physical testing of conventional pesticide pump for 3 different people.
- This data is used for calculation of bore and stroke of our pump.

Reading no.	Readings (ppm)	Time (s)
1	26	60
2	24	60
3	25	60
Average=	25 ppm	60 sec

Table 1-Observations 1

<u>Measurement of leg movement frequency</u>

- This test has been done on 3 different people for minimizing error and broader reading range.
- The value has been divided by 2 because individual leg will have its separate pump and mechanism.

Reading No.	Value	Value/2	Time (s)
1	66	33	60
2	58	29	60
3	52	26	60
Average=	58.66	29.33	60

Table 2 Observations 2

III. DESIGN OF PISTON PUMP

For designing piston, the values for conventional (OEM) pesticide pump were considered-

- OEM pump-

1)Bore =55mm
2)stroke=55 mm
3)Total volume displaced in 1 cycle=

v=pi*[(bore/2) ^2] *stroke mm^3
=130670.6194 mm^3

Hence, v=130.6 cc
Therefore, volume displaced in 1 minute by hand pump = 3250 cc = 3.25 litre.

- For keeping constant flowrate of 3.25 litre per minute the new cylinder displacement per minute should be the same.
- From the testing readings 29.33 oscillations per minute are done.
- NEW pump-

let new cylinder displacement = x
x*29.33=3250
Therefore x=110.8080 cc = new cylinder displacement-[2]

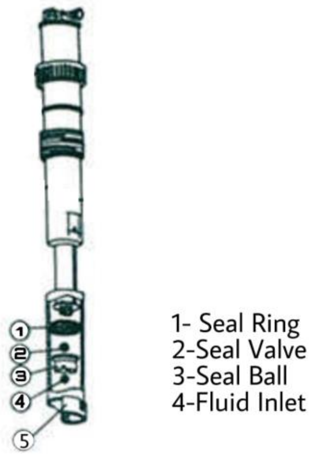

Figure 1-Piston Internals

Figure 2-Piston pump CAD

From the bore diameter and the required mass flow rate of the pump we simulated a pressure and flow simulation Analysis.

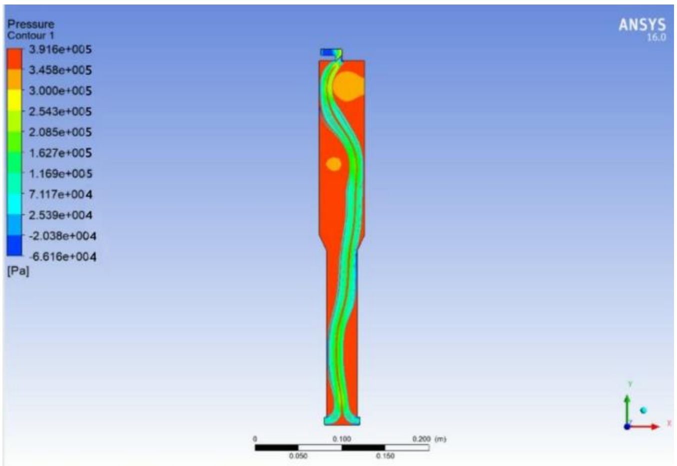

Figure 3-Pressure Inside Pump analysis

The results were verified form an OEM pump spec sheet.

Model	GF-16S-17Z	GF-20S-17Z
Capacity	16L	20L
Color	Customized	Customized
Gross weight	3.2kgs	3.55kgs
Normal pressure	0.2-0.4Mpa	0.2-0.4Mpa

Figure 4- OEM spec sheet

Therefore, the force applied on the piston will be =849.4N
Structural Analysis of Pump – [3]
Due to changes dimensions and specifications, we carried out structural analysis and found that there was not much of deformation(0.5mm) and a bearable stress was being exerted
On the plastic piston.

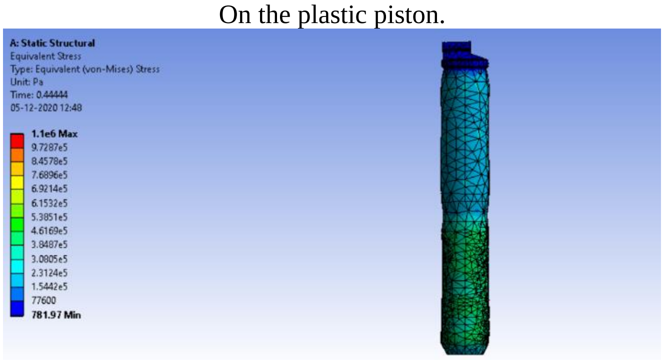

Figure 5-Structural Analysis of pump.

IV. ACTUATION MECHANISM

By using mechanism simulation software linkage, we iterated our first actuation mechanism. Considering the lengths to be ideal and a simple mechanism simulation was done.
Image-2 linkage simulation of actuation mechanism using bell crank.
-
We designed the mechanism inspired from “slider crank” Mechanism.
-From figure 1 I is the stationary/fixed point while J will be the moving end connected to the thigh and point B will be moving joint. While E is the piston head and N be TDC and M be BDC of the piston mechanism.

We had to make the piston travel from TDC to BDC within 40deg of rotation of the crank, so at the crank we designed a bell crank, and we optimized the lengths of the links (BI, EB) so that we achieved the crank rotation to be 40deg.

Then from that we got the stroke to be 100mm, then from [1] calculations of displacement the bore was calculated i.e., =37.4mm.

-New Bore=37.4mm
New Stroke=100mm

<u>Calculation of forces applied on the bell crank at the extreme conditions during its operation-</u>
Pressure "P" =0.4N/mm^2
Area (of piston) "A" =2123mm^2
Force applied on the piston head "Fp" = 849.4N
Angular velocity "ω" =0.1745 rad/s
Length of bell crank arm R=200mm
From the above data –
Velocity of piston "Vp" = ω*R (SinΘ + (Sin2Θ /n)) [3]

Vp=0.1745*200(1+0)
<u>Vp=34.9mm/s----------(Piston Velocity)</u>

<u>Force applied on the Bell crank Arm (Ft)</u>=

Fp*Vp=Ft*Vt [3]

849.48*34.9=Ft*43.625
<u>Ft=679.584N-----------(Force applied by end user)</u>
From the above forces we did structural analysis.

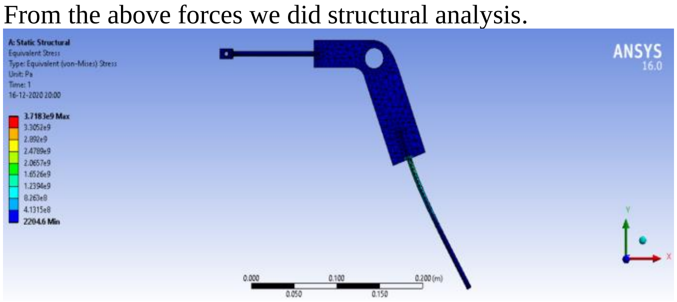

Figure 6-Structural Analysis of Bell crank.

Then we found out that there was room for optimization and weight reduction which will reduce material cost as well.

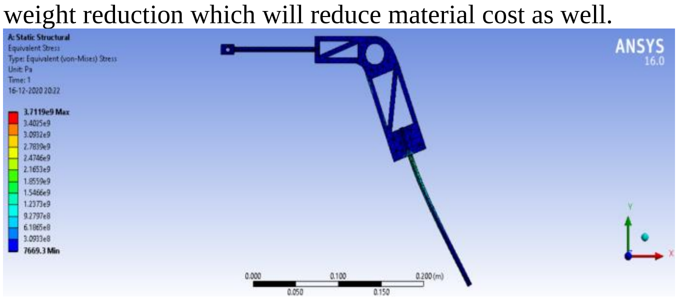

Figure 7- Structural Analysis of Optimized Part.

V. PUMP CONTAINER DESIGN

Fluid inside the container should last for a time even though the rate of flow has been doubled so we increased the dimensions of the container to hold more fluid than earlier. We tried to keep design of container simple and inspired by conventional pump so it will be easier for manufacturers to adapt.[1]

VI. ERGONOMICS

To be useful for all body types and height we worked on what could be the possible solutions with keeping the cost low to make its fitting around the waist and thigh adjustable, in the end we concluded using metal and Velcro straps, out of which metal will provide rigidity to the links when in working condition and Velcro will provide adjustability to the user.

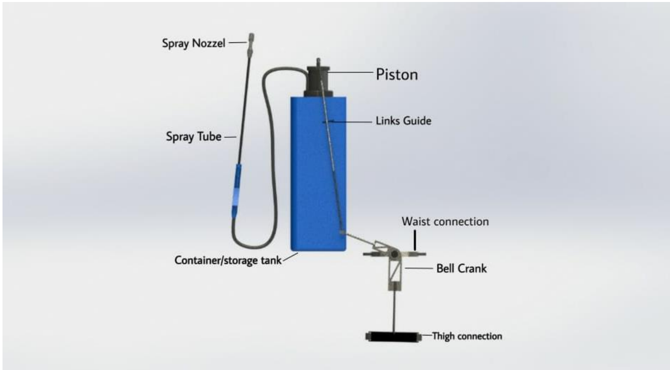

Figure 8-Side View of Mechanism On pump.

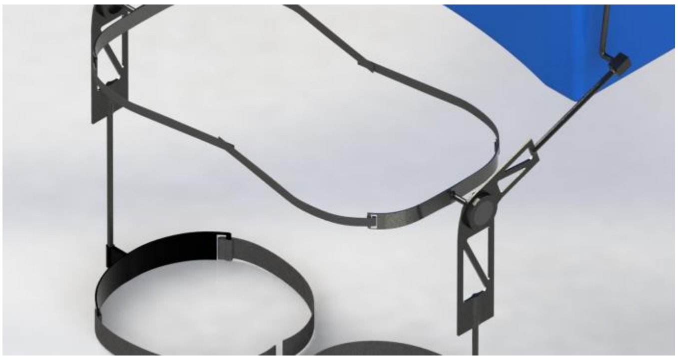

Figure 9-Waist Belts for wearing.

Figure 10- Thigh Belt for Wearing and Support.

VII. MATERIALS

<u>Materials/Components</u>

- Container, piston-plastic(polypropylene)
  Tensile strength-3200-5000psi
  Density-0.91-0.94g/cm^3
- Rods- mild steel painted hollow rods
- Bell-crank-laser cut mild steel
- Velcro

VIII. RESULTS AND DISCUSSION

A completely new type of actuation of sprayer is designed which has capability of doing twice the amount of work at the same time by a single user at cheaper cost than of its electronic and engine counterparts.
It is reliable and just as effective in spraying as conventional sprayers.
It also has ergonomic adjustable belts to suit all body types.
It is cheaper and easy to maintain and easy for farmers to repair themselves if something goes wrong.

- Bore Diameter-37.4mm
- Stroke Length-100mm
- Maximum pressure inside Piston – around 4 bars.
- Force required at piston head=849.4N
- Force to be applied by thigh=679.584N

Flow simulation results from ANSYS-FLUENT model.

Figure 11-Complete Product Assembly.

IX. CONCLUSION

Increased mass-flow rate, easy operation and almost twice the operating efficiency is achieved.
The output of the pumping rate might change with the atmospheric conditions such as temperature, density of air and liquid being sprayed.
Further we can optimize the sprayer efficiency with mass flow optimization and better piston configuration form user feedback.

Figure 12- Demonstration.

X. ACKNOWLEDGMENT

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XI.REFERENCES

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