Computer Aided Design of Tractor operated Pea Pod Picker

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Abstract. India isn’t just the biggest consumer of green peas, yet in addition it takes second place in worldwide green pea cultivation, following China. The area under peas in India was 540.5 thousand hectares in 2017-18. Presently, green pea crop is cultivated on approximate thirty-five thousand hectares in Punjab. Out of this 90% area is cultivated under early maturing variety of green pea. Picking of green pea is labor intensive. Therefore, to lower the involvement of manual labor, mechanized picking of pod is required. A conceptual design of tractor operated pea pod picker was done by keeping in view the harvesting of AP-3 pea variety and agronomic practices. Based upon review, important operational and design parameters were selected for the study. A computer aided design of pea pod picker was done. All the sub-assemblies like crop guide, picking drum, belt conveyor and aspirator were created using Creo 3.0 software (Make: PTC Creo) at PAU, Ludhiana. Based upon 2D drawings, a tractor operated pea pod picker was developed and fabricated.

Keywords: Pea pod picker, drum rpm, picking efficiency, damaged pods, fuel consumption.

1. Introduction

The pea is most consistently the little spherical seed and belongs to family Fabaceae [8]. Pea also holds a prominent place among vegetables due to its high nutritive value, particularly proteins [11]. Major source of protein for large population of India come from vegetables. This makes green peas, alongside different vegetables, a vital nourishment asset in the nation. The popular varieties in Punjab and India are Ap-3, Matar Ageta-6, Arkel, Punjab 89 and Mithi Phali [1]. Developed seed is very nutritive for being a rich source of edible protein, starches, minerals and vitamins. Green peas are available from September onwards till February. The northern and central parts of India are the main territories for green pea production [17]. India is not just the biggest consumer of green peas, yet in addition it takes second place in worldwide green pea cultivation, following China. The major green pea producing countries are China, India, United States, France and Egypt [16]. Also, India is the world’s largest green pea exporter. In the year 2017-18 India exported 410.11 MT of green peas to its destination countries, at a foreign exchange earnings of about Rs. 17.94 million [2]. The area under peas in India was 540.5 thousand hectares in 2017-18. The production and productivity of green peas was 5422.1 thousand MT and 10 MT/ha, respectively in 2017-18 [2]. The area under green peas in Punjab was 37.62 thousand hectares in 2017-18. The production and productivity of green peas was 394.00 thousand MT and 10.47 MT/ha, respectively in 2017-18 [2]. In Punjab state, Amritsar and Hoshiarpur districts are major producer and cultivators of green pea.

Green peas develop best in damp and cool weather. It is a cool-season crop grown in numerous parts of the world [18]. Planting can be done from winter to late-spring season depending upon the place. Perfect temperature for green pea production is between 10°C to 30°C [9]. Green pea develops best in well-drained soils with pH of 6.0-7.5 [4]. Generally, the green pea is cultivated on ridges. The ridge to ridge spacing is kept about 67.5 cm and two rows of peas are sown on either side of ridge at a spacing of 25.4 cm.
Pea cultivation is popular among farmers due to short duration and it fits well in crop rotations of rice/maize-wheat, rice/maize-spring maize, rice/maize-summer moong, rice/maize-sunflower, rice/maize-cucurbits and rice/maize-onion. Its cultivation improves soil health by fixing atmospheric nitrogen and requires less water also. Generally early maturing variety of paddy is cultivated between the month of June to September and late sown variety of wheat is cultivated from December onwards by pea growers. The available time between mid-September to mid-December, in paddy/wheat system the early maturing variety of green pea are grown, which fetches high price because during this time supply of pea is less and demand is more.

Picking of green pea is labor intensive [14]. A volume of labor is required for multiple picking and it costs Rs 3-4/kg for harvesting pods [3]. Therefore, to lower the involvement of manual labor, mechanized picking of pod is required. Agricultural mechanization helps in increasing production and overall profit to the farmers [12]. In Punjab, the state government has imported a pea harvester-cum-depodder from Holland for Rs. 3.50 crore, to increase the area under cultivation of green peas. This machine harvest and de-pods the green pea and transports the pea grains to its hopper. The initial capital cost of this machine is very high and the size of this machine is also very large which makes it uneconomical for Punjab farmers. This machine can’t be operated on pea crop sown on ridges, but the farmers of the Punjab state prefer to sow their crop on the ridges. Also keeping in view, the farm size of Punjab state, small size tractor operated pea pod harvester is required.

The idea of development of pea pod picking mechanism was derived from the study conducted by Maffei [13]. He has developed a bean pod picking equipment, which moves along a row of bean plants. It was having a plant receiving zone, a picking mechanism and a conveyor. Many similar attempts were made in development of pea harvesting machine. Coons [6] invented pea harvesting and threshing machine for shelling green peas, beans or other legumes. Ritter et al [15] invented automatic bean and pea harvester for collecting the vines and separating the peas and beans or similar pod crops. Carruthers [5] developed a machine for separating and harvesting pod type crops. The principle of this machine was to cut and separate the pods from the vines and leaves. Goodad [10] developed a pea harvester. Csimma [7] developed a vine crop harvesting machinery. Towson et al [19] developed a pod combine which consists of a harvester and a thresher mounted on a self-propelled mobile structure. So, keeping in view the above facts, the present study was focused on development of tractor operated pea pod picker with the help of CAD tool Creo 3.0 for AP-3 variety grown in Punjab region.

2. Material and Method
2.1. Conceptual design of tractor operated pea pod picker
Designed and developed picker should be simple, having less initial cost, lower repair and upkeep cost, lesser moving parts and simple to mount behind a tractor. A conceptual design of tractor operated pea pod picker was done by keeping in view the harvesting of local green pea varieties and the agronomic practices. Crop characteristic is the important factor for conceptual design of the pea pod picker.

The designed pea pod picker works on the principle that when the picker will move in the pea field, force of impact of rotating drum will strip the pea pods from the plants and rest of the plant will remain in its position in the ground. The pea pods will be detached from the plants with the help of spring tines having narrow gap among them. The stripped material consisting of clean, bruised and damaged pea pods along with leaves and other trash will be conveyed to the aspirator assembly with the help of a belt conveyor. The aspirator unit will separate the trash from the pea pods. The trash will be discharged from the aspirator outlet and the detached pea pods will be discharged from the separate outlet located at the rear side of the pea pod picker. Figure 1 shows the conceptual design of pea pod picker and flow of material during operation.

2.2. Design parameters
i. Diameter of picking drum: In Punjab state, pea cultivation is carried out on the ridges. Two rows of the pea crop are sown on the same ridge at 25 cm apart. The ridge to ridge spacing is about 60 cm. The pea vines are lying on the ground in between the ridges. The diameter of picking drum was selected 75 cm on the basis of width of the ridge.
ii. Length of the picking drum: The picking drum should get enough time to stripe out pea pods from the pea vines during the forward travel. Keeping in view the time requirement for the stripping of the pods the length of picking drum was selected to be 1.80 m.

iii. Slope of the picking drum: To avoid clogging of the picking drum with the plant material the slope of 0.03 is provided to the picking drum so that it should stripe the plant in stages.

2.3. Development of the tractor operated pea pod picker

The functional requirements of the pea pod picker for single row picking drum assembly were identified and kept in mind during its development. Three important design parameters i.e. picking drum rpm, forward speed and type of tine were selected to evaluate the performance of picker mechanism in the field. Hence, different functional requirements of the first prototype were considered as follows:

- The machine should be tractor drawn and operated by tractor PTO
- The machine should be able to move through ridges
- It should be able to detach the pea pods from pea vines
- There should be guide mechanism to convey the crop to the stripping mechanism
- Detached pea pods should be conveyed to hopper after separation from the pea vines
- Simplicity in fabrication and ease of use

2.4. Computer-aided 3D design of the pea pod picker

The CAD software was used for the study. It provides tools for design, simulation and manufacturing with high-definition 3D environments, to enable rich visual interaction and information delivery for validation, product templates and other applications reporting and analytics tools. There are four major components of pea picker mechanism. Different components of picker are as mentioned below;

i. Crop guide sub-assembly
ii. Picking drum sub-assembly
iii. Continuous belt conveyor sub-assembly
iv. Aspirator sub-assembly

2.4.1. Picking drum sub-assembly

All the elements like tines, pipes, central shaft, two end plates, center plate with PVC bushes and power transmission were mounted in this assembly. The picking drum is one of the most important part of the picking mechanism, which is solely responsible for stripping of green pea pods from the pea vines. The 4 mm high precision spring steel tines were used for stripping of pea pods from the vines. The overall length of the tine is 20 cm and having 7 cm space between its two fingers. Initially
spring-loaded tine was created in CAD software. Nut (M12×1.75×10) and bolts (M12×1.75×35.03) were created, for mounting the tines on the hollow pipe. Mild steel material was selected for the nut and bolts. These 12 tines were attached on one hollow pipe with the help of nut, bolt and washers. The total length of the pipe mounted with 12 tines was 1.7 m. The spacing between two consecutive tines was kept 70 mm. CAD views of spring steel tine and pipe mounted with tines are shown in Figure 2.

The two end plates were created to hold set of hollow pipes mounted with spring tines. MS sheet of 4 mm thickness and 350 mm was selected for generating the plate. The revolve command was used to generate 12 holes of 25.4 mm along the circumference of the plate. These circumferential holes were used to fix 12 set of pipes along with the tines. The hole of 76.2 mm was created at the center of the plate, to fix main shaft for the power transmission. CAD view of drum end plate is shown in Figure 3.

Figure 2. CAD view of spring steel tine and hollow pipe mounted with tines.

Figure 3. CAD view of picking drum end plate.

The center plate supports the picking drum assembly. MS sheet of 5 mm thickness and 250 mm was selected for generating the plate. Twelve semicircular grooves of 50 mm was created along with the circumference of the plate, to fix PVC bushes. A hole of 76.2 mm was created at the center of the plate, to fix the main shaft for the power transmission. The PVC bush was created. The outer diameter and the inner diameter of bush were 50 mm and 26 mm, respectively. The center plate mounted with the PVC bushes provides a central and rigid support to 12 set of hollow pipes fitted with spring tines. CAD view of center plate is shown in Figure 4.
The picking drum is consisting of two end plates, a center plate mounted with PVC bushes and twelve hollow pipes running through end plates and a center plate, which are fitted with spring tines. There are twelve spring loaded tines mounted on each pipe. The spacing between two consecutive tines is 70 mm. There are 144 equally spaced, steel spring tines fitted in the picking drum assembly. The picking drum is provided with center shaft for power transmission. The anti-clock rotational movement of the picking drum causes the stripping of the pea pods from the vines as tractor moves forward. CAD view of picking drum is presented in Figure 5.

2.4.2. Continuous belt conveyor sub-assembly

The anti-clock wise rotating spring tines moves through the pea vines, as the machine moves forward with tractor along the ridge. The combing action of rotational spring tines causes stripping of pea pods from pea vines along with other trash like pea leaves, small twigs, shattered pods and some other foreign material. All this mixture containing detached pods is then transferred on a continuous moving belt conveyor. The belt conveyor is made up of a rubber composite material. The rubber composite material was used for belt conveyor because it is seamless, smooth, resistant, and flexible. The belt conveyor runs around two rollers of Ø120 mm, one is driven roller and the other one is driver roller. The belt of 4 mm thickness and 400 mm width was selected. The total length of the continuous belt conveyor is 8.4 m. The belt is fitted with L-shaped angle stripes, to avoid rolling back of the pea pods under the operating condition of the machine. The overall dimensions of L-shaped angle stripe are 38×3.5×3.5 cm. These angle stripes were fastened to the belt conveyor with the help of nut and bolts.
The inclination is provided after 2 m of the horizontal belt length. CAD view of continuous conveyor belt is shown in Figure 6.

Figure 6. CAD view of continuous conveyor belt.

A retainer unit is generated, to avoid pea pods to be thrown back on the ground by the centrifugal force of the rotating tines. The retainer is consisting of 24 curved metallic strips, mounted with rubber pads. The rubber pads were used to cover metallic strips to avoid breakage of the pods. These curved stripes are running beneath half of the circumference of the rotating drum. The MS steel sheet of 4 mm thickness and 50 mm width was selected to generate retainer unit. CAD view of retainer unit is shown in Figure 7.

Figure 7. CAD view of retainer.

2.4.3. Aspirator sub-assembly
The continuous belt conveyor brings the mixture of detached pea pods and the trash to the inlet of the aspirator. The aspirator is fitted with horizontal rotating blades, which produces vacuum at the inlet of the aspirator. The vacuum created at the inlet, sucks the light weighted material such as leaves, small twigs etc. The sucked trash gets blown out of the aspiration unit through the outlet. The pea pods being heavier than the leaves remain on the belt and gets discharged through a separate outlet. This outlet is located at the rear end of the machine. The inlet of the aspirator is rectangular in shape having dimensions of 38×25 cm. The total height of the aspiration unit is about 1.45 m. CAD view of aspirator assembly is shown in Figure 8.
2.4.4. Crop guide sub-assembly
The green pea is a vine crop. The crop biomass is lying on the ground. A tapered crop guiding mechanism was created, to bring the crop near to the picking zone. A mild steel sheet of 4 mm thickness was selected for generating crop-guiding unit. The pea crop lying on the ridges starts to slide along the surface of the tapered guide, as machine moves forward. The tapered shape of the guide causes uplifting of the pea vines, and brings it nearer to the picking zone of the machine. The anticlockwise rotating drum mounted with tines causes the stripping of pea pods. CAD view of crop guiding unit is shown in Figure 9.

2.5. Power transmission (Drive line)
The power transmission is very important part of tractor operated pea pod picker. The tractor PTO was utilized to drive the various sub-assemblies of the pea pod picker. The tractor selected for experimentation was having PTO power of 35 hp with 540 rpm PTO output. The PTO power was transmitted to the gearbox (G1) with a gear ratio of 1:1, through the main drive shaft.

The power to the picking drum unit from the main drive shaft is transmitted from main drive shaft pulley (P0) to the picking drum pulley (P1). The picking drum shaft pulley (P1) delivers the power to the rotating drum, which is solely responsible for stripping of the pea pods from the pea vines. The field experimentation involved the testing of the picker mechanism for its efficiency at 3 level of the drum peripheral velocity. The pea pod picker was tested for the three different diameters of the pulley (P1). The intermediate shaft emerging out from gear box (G1) mounted with pulley (P2) rotates at the
same rpm as that of PTO. The on-board aspirator unit and continuous belt conveyor units are driven by the intermediate shaft. The power is transmitted from the double belt pulley (P2) to pulley (P3) on the input shaft of the gear box (G2) having gear ratio of 1:1.50. The gear box is mounted with a pulley (P6) which delivers power to the pulley (P7). The pulley (P7) is mounted on the aspirator shaft which delivers power to the vanes of the aspirator. The higher rpm of the pulley (P7) is needed for the separation of the trash content from the stripped pea pods. The drive line of tractor operated pea pod picker is shown in Figure 10.

![Figure 10. View of drive line of tractor operated pea pod picker.](image)

The intermediate shaft is also fitted with pulley (P4). The power to the continuous belt conveyor is transmitted from the intermediate shaft pulley (P4). The intermediated shaft pulley (P4) delivers power to the drive shaft of the continuous belt conveyor unit mounted with pulley (P5). The drive shaft pulley (P5) of the continuous belt conveyor is larger in diameter than the intermediate shaft pulley (P4). Different types of pulleys used in the drive line are shown in the Table 1.

| Name          | Mounted                  | rpm | Diameter (mm) | Face Width (mm) | Type |
|---------------|--------------------------|-----|---------------|-----------------|------|
| P0            | Main drive shaft         | 293 | 101           | 59              | 2C   |
| P1            | Picking drum shaft       | 125 | 178           | 34              | C    |
| P2            | Intermediate shaft       | 95  | 229           | 34              | C    |
| P3            | Gear box (G2) input shaft| 110 | 203           | 34              | C    |
| P4            | Intermediate shaft       | 293 | 127           | 59              | 2C   |
| P5            | Drive shaft of conveyor  | 117 | 254           | 34              | C    |
| P6            | Gear box (G2) output shaft| 337 | 203           | 34              | C    |
| P7            | Aspirator shaft          | 540 | 127           | 34              | C    |

All the sub-assemblies like power transmission, picking drum, continuous conveyor belt and aspirator unit were assembled using assembly domain of CAD software. The isometric and side-rear views generated by CAD software of pea pod picker are shown in Figure 11 (a), (b) respectively.
Figure 11. (a) Isometric view of pea pod picker.

Figure 11. (b) Side-rear view of pea pod picker.

Figure 12. Stationary view of tractor operated pea pod harvester.
The main specifications of tractor operated pea pod picker are given in Table 2.

| Sr. No. | Description               | Specification |
|---------|---------------------------|---------------|
| 1.      | Tractor power, hp         | 35            |
| 2.      | No of rows                | 1             |
| 3.      | Crop guide                |               |
|         | Length, mm                | 580           |
| 4.      | Power transmission        | V-Belts       |
| 5.      | Picking mechanism         |               |
|         | Type                      | Tine type stripper drum |
|         | Length of drum, m         | 1.80          |
|         | Diameter of drum, m       | 0.75          |
|         | No of pipes in drum       | 12            |
|         | No of tines on one pipe   | 12            |
|         | Total no of tines         | 144           |
|         | Angle of tine             | 158°          |
|         | Length of tine, mm        | 200           |
|         | Spacing between tines, mm | 70            |
|         | Harvesting width, mm      | 600           |
| 6.      | Conveying mechanism       |               |
|         | Type                      | Belt conveyor |
|         | Material                  | Composite rubber |
|         | Dimensions, mm            | 8400x400x4    |
|         | L-shaped angle strip, mm   | 380x35x35     |
| 7.      | Aspirator Unit            |               |
|         | Type                      | Radial blades and cylindrical type |
|         | Height, m                 | 1.45          |
|         | Inlet shape               | Rectangular   |
|         | Inlet dimensions, mm      | 380x250       |
| 8.      | Overall dimensions, mm    | 4230 x 1380x 2150 |

3. Conclusions
CAD tool Creo 3.0 used for designing tractor operated pea pod picker which gave superior visual effect to access the improvement. Developed pea pod picker was fabricated based on the 2D drawings and BOM. The machine was evaluated in terms of picking efficiency, percentage of damaged pods, trash content in detached pods, fuel consumption and field capacity at different independent parameters viz. different forward speed 1.5 km/h (F1), 2.0 km/h (F2) and 2.4 km/h (F3); drum peripheral speed 95 rpm (D1), 110 rpm (D2) and 125 rpm (D3) and tine type i.e. curved (T1) and straight (T2) tines. Forward speed showed significant effect on picking efficiency and field capacity. The best combination of independent parameters for the pea pod picker based on maximum picking efficiency, minimum damaged pod, trash content in detached pods and fuel consumption was found with 95 drum rpm (D1), 1.5 km/h forward speed (F1), straight tine (T2). Based on field evaluation data of tractor operated pea pod picker, feeding mechanism of the machine needed to be modified.
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