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Design and Development of a Potato Seed Cutter Machine

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Abstract— **Potato growers in Pakistan obtain disease free seed from Holland, plant it as spring crop, cutting tubers into few pieces for seed multiplication using manual labor. Keeping in view of extensive labor involved in cutting of potato seeds manually for planting, a simple, efficient and easy to operate mechanical cutter machine powered by 1/2 hp electric motor using eight cam driven reciprocating cutting plungers was designed, fabricated and tested for quantitative as well as qualitative performance. Foreign makes of the seed cutters costs are too high to be purchased. The working capacity of locally made developed fixed cam machine varies between 410-490 kg/hr. For smooth operation, speed reduction of motor from 1450 to 406 rev/min was further reduced to 9.0 rev/min using worm and worm gear assembly. A novel idea to use a fixed cylindrical mild steel cam enhanced the cut pieces tuber seeds production. Machine cutting and manual cutting of potato tubers resulted in 5.0 % and 2.5 % seed damages respectively. A cost comparison of machine cutting versus manual cutting indicated that manual labor for cutting potato tubers is 6.0 times costlier than the mechanical cutter.**

Index Terms— Cylindrical Cam; Potato Seed cutter; Seed damage; Worm and worm gear assembly.

I. INTRODUCTION

Potato by virtue of its inherent potential for tonnage production, remunerative income and food values, has been highly esteemed as a food as well as cash crop. Potato has been an important food crop for growers and consumers not only in Pakistan but all over the globe. It is a crop that can generate high production and more income with more nourishing value. It attained its high rank among the most important crops due to its high volume of production and benefits. Its high returns attract the farmer to cultivate more and more. Globally it is playing a key role in food security and rising as a big source against hunger. It is assuming that one day it will be a leading crop and the hunger from the earth will be eaten by it [1].

Last decade has a two fold increase in area under potato cultivation in Pakistan. Total area for spring, autumn and spring crops amount to 179.30 thousand hectares with a total production of 3,849.5 thousand tons in Pakistan [2]. Potato has played a significant role in human diet as supplement to Wheat and Rice and it has found to produce more food per unit area than the cereals [3]. Being a short duration and high yielding crop, potato can feed more people per unit area and significantly help improving the food situation in Pakistan. The present per hectare yield of 10.50 tons is considerably low against 25-40 tons obtained in the main potato growing countries [4]. A low production per unit area in Pakistan can be attributed to the non-availability of disease free and certified seed of high yielding potato varieties and poor agronomic practices.

Buchele's second law of machine [5] stated that mechanization of any process of production results in surplus. Thus, if more production of any item is desired, the process of its production should me mechanized.

Presently, farmers in Pakistan are growing three crops, namely spring and autumn crop in plains and a summer crop in hilly areas. Growers obtain diseases free seed from Holland, plant it as spring crop, cutting tubers into few pieces manually for seed multiplication. Seed rate of potato planting ranges from 2.0 tons/hectare to 3.5 ton/hectare. For spring crop 60-80 gram potato is cut into two pieces, 80-100 grams is cut into three pieces and 100 grams and above is cut into four pieces. Small size is planted without cutting. It should be noted carefully, that each cut Generally 25-30 potato crates, 50 kg each are required for planting a hectare [4], (see figure 1). Each crate takes 1-2 man hours to be cut into desirable pieces. Thus seed for a hectare requires up to 60 man hours for cutting it. Labor problem aggravates further and assumes alarming dimensions as the area to be planted per day increases. In view of extensive manual labor involved in cutting of potato seed, there was a dire need to design and develop a machine that could

efficiently cut potato seed and reduce the manual labor involved in potato planting [6].

Figure 1 Potato crates of imported hybrid seed

The present study was planned to design and develop a machine (see figure 2) using local materials and workmanship for mechanical cutting of potato tubers into desirable pieces and to test the machine for its performance.

Figure 2 Potato seed cutter machine

II. Design and Development of Machine Cutter

In the light of literature reviewed, the seed cutter machine was conceived. This machine was powered through a small electric motor of 1450 rev/min. For reducing speed of motor (M) to about 9.0 rev/min at the shaft S, a two-step reduction was planned viz; using pulleys (P1), (P2) and worm and worm gear mechanism W&W (see figure 3).

The shaft passes through plates D, J, L and cam C. The plate D would hold pockets to accommodate potatoes to be cut. The plates J & L would hold plungers restricting their movement in the horizontal plane. The cylindrical cam C is stationary, whereas plates J, L and D would rotate with the shaft at approximately 9.0 rev/min. The plungers would move up and down cutting potatoes at the bottom dead center position of the stroke (see figure 3).

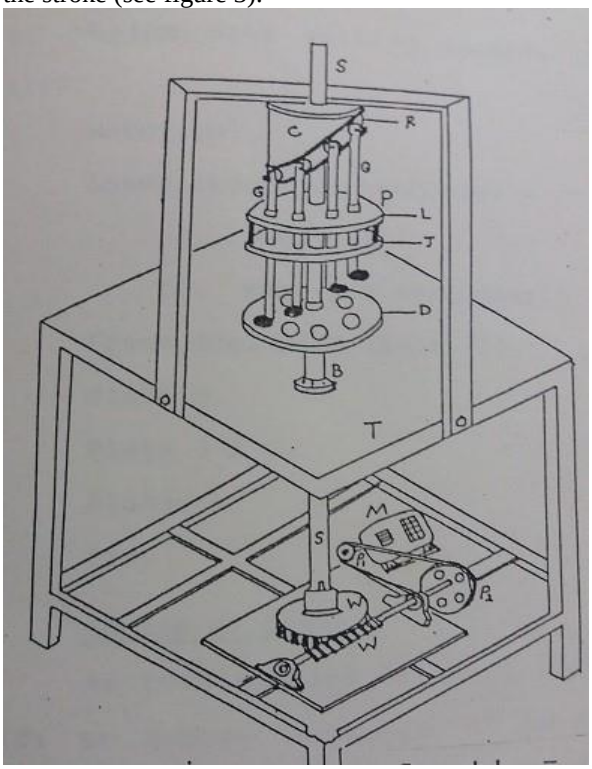

Figure 3 Isometric view of Potato seed cutter

Where P = Plungers, C= Cylindrical Cam, M = Motor P1 & P2 = Motor and Worm pullies, W&W = Worm and worm gear, T = Feeding/ Discharge table,
D = Pocket plate, S = shaft, J & L= Plungers holding plates.

III. Development of Different Parts of Potato Seed Cutting Machine

A. Source of Power

As this machine is to be operated in agricultural field at remote locations of farms, tractor would be an appropriate source of power for the machine. However, for villages where electricity is available a laboratory model, a single phase 1450 rev/min, ½ hp AC motor was considered appropriate.

B. Pulleys and V-belt selection for seed cutter

A single, heavy duty A-size, V-belt for minimum small sheave motor pulley dia. of 2.75 inch was appropriate. A 10.0 inches large sheave pulley was selected to transmit motor power to run worm shaft of 1.50 inch. The length measured of outer periphery of belt was 53.0 inches. Specifications of pulleys and belt are shown in figure 4.

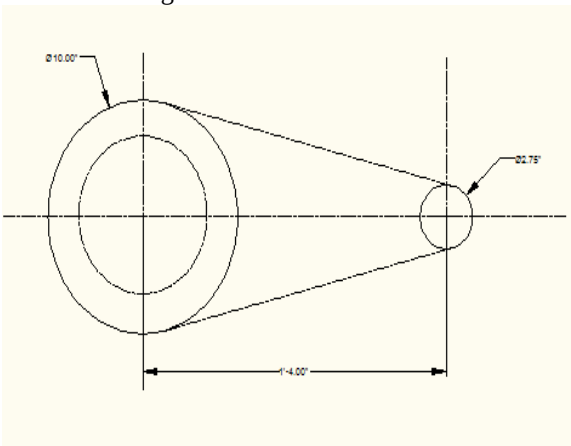

Figure 4 Specifications of machine small and large sheave pulleys.

C. Design of speed reduction mechanism

The speed of 1450 rev/min motor powering the unit was reduced in two steps. Firstly the ratio of the diameters of pulleys were so selected to cut down the speed to 406 rev/min.

$N_m D_m = N_w D_w$ [7]

Where:

N_m = Motor speed, (1450 rev/min)

D_m = Dia. of motor pulley (2.75 in)

N_w = Speed of worm, rev/min

D_w = Dia. of worm pulley (10 in)

$$N_w = \frac{1450 \times 2.75}{10.0} = 406 \text{ rev/min}$$

This speed of 406 rev/min was further reduced by selection of worm and worm gear assembly. If speed reduction is 48:1, then it was found that output speed of worm gear was about 9.0 rev/min. Single threaded worm with 50 worm gear teeth was developed for better performance giving speed of worm shaft equal to 8.45 rev/min as shown in figure 5.

D. Fabrication of Main Frame

Development of the Main frame consisted of the reduction mechanism at lower end and feeding, cutting and discharging mechanism at the top, is a table of (30 in x 36 in x 32 in) made of hollow rectangular square section pipes of (1 in x1.82 in) dimensions. This table has sufficient stiffness to carry machine load and rotating parts. A rectangular steel plate of thickness 1/16 in is screwed at the top of the table for feeding and discharging access.

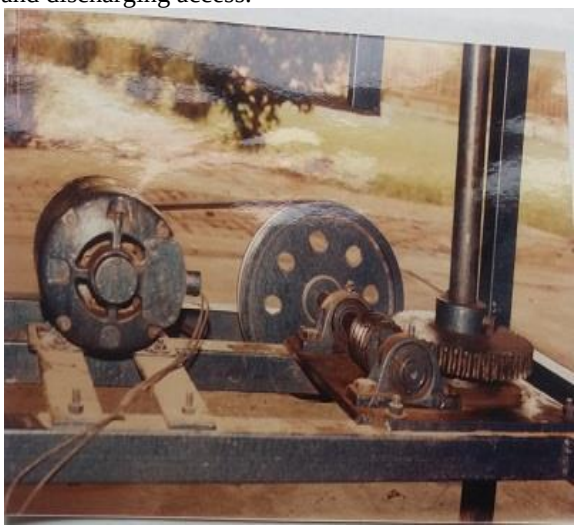

Figure 5 Worm and worm gear assembly

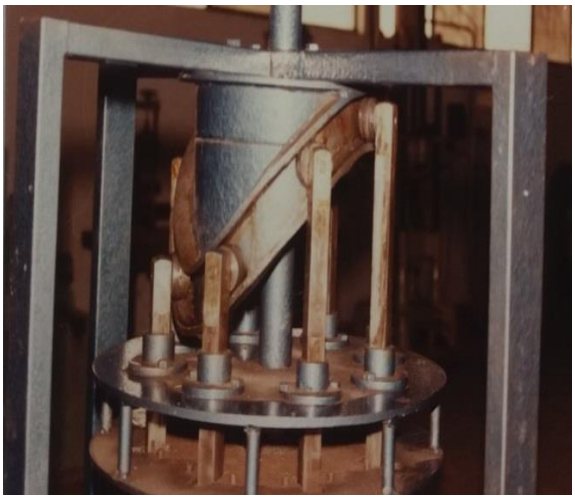

Figure 6 Cylindrical cam holding cutting plungers in vertical plane

E. Design of Cylindrical Cam

The most challenging feature of the machine was the design and fabrication of a cam required to bring about reciprocating motion of cutting plungers in the vertical plane (see figure 6). Several cam motions were studied. In any mechanism, usually a cam is a part which rotates and follower (plunger) is a part which reciprocates doing useful work. However, the nature of the work here was, cutting and discharging of cut seeds should be done at the same time. In this machine the cam is fixed but plungers move up and down 6.0 inches and rotate simultaneously. This problem was solved with the selection of cylindrical cam having groove in the outer periphery of the cam. Another

problem while designing cam was solved by careful consideration, it was decided that for some portion of the cam there should be no up and down motion of the plungers i.e. dwell. This dwell time of rotation was safely used as hand feeding time, at the point when fall of plungers is completed smoothly after the seeds has been cut. The groove shown in the unwrapped cylinder will give the roller follower the proper rise of 6 inches when cut into the actual cylinder.

Plungers are to be moved upward 6 inches up to 90 degrees, dwell for 180 degrees and then falls 6 inches with Simple harmonic motion (S.H.M). Front view of developed cam and plungers is shown in figure 7.

Initially mild steel cutting blades were used. Cutting action was not fine rather crushing due to larger thickness of the blades. Surface pitting and rusting of mild steel blades was observed. Therefore mild steel blades were replaced with 1/32 inch thick stainless steel blades. Due to smaller thickness and desirable materials, cutting of seeds was accomplished without visible sign of crushing. Similarly pitting and rusting of blades became obsolete. In order to overcome crushing of the cut pieces, rubber disks each ¼ inch thick were glued to the lower ends of ½ inch disks. Grooves were also arranged in the rubber disks. The grooves of both the steel and rubber disks were aligned properly.

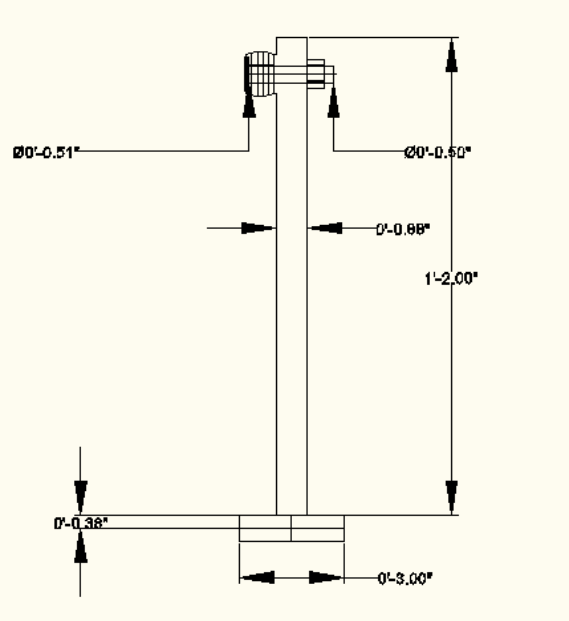

Figure 7 Cam and plunger assembly cutting blades

F. Feeding System of potatoes tubers

In the model conceived the potatoes are manually fed into pockets at a point where plunger is at the top dead center position. As the 1.5 inch round center shaft moves at 9.0 rev/min with 8.0 plungers moving up and down and rotating simultaneously in the cam groove, the number of potatoes to be fed manually stand 72.0 per minute. The top of the table is used as feeding platform. The height of the table is so selected that it is comfortable for standing person. Potatoes cut into pieces during operation are delivered under the bottom dead center position of plungers on the table.

G. Materials used for fabrication of different parts of machine

Following materials and working summary for fabrication of potato seed cutter were used for different parts (see table 1). After the development and fabrication of the machine, it was decided to undertake testing for quantitative as well as qualitative performance of the machine as whole and /or its parts individually.

Table 1 Summary of potato seed cutter Materials specifications and working details

No.	Parts	Materials	Working details
1	Pulleys	Cast Iron	Driven by A-size V-belt
2	Center shaft	1.50 inch Mild steel	clockwise Rotation
3	Worm and worm wheel	Carbon steel	Speed reduction ratio of Worm and worm gear, 48:1
4	Plunger Rods	Mild steel ¾ inch square bars	Eight cam driven cutting plungers with rotary and reciprocating operation
6	Main Frame	Pressed steel rectangular hollow X-section	Welded and screwed
7	Cylindrical Cam	Mild steel	plate of 1/8 inch thickness configured to the cylindrical shape for 6 in. rise and fall
8	Roller and thrust Bearings	High carbon steel	Universal type to withstand radial as well as axial thrust
9	Capacity		0.5 tons cut seeds/hr.
10	Motor	NEEMA standard	Single phase, 50 cycles, 0.5 hp,

			1425 rev/min, 220-240 V and 2.7 amp.
11	Cutting		Continuous
12	Feeding, Discharge		Manual semi-automatic

H. Testing and Working capacity of the machine

An important feature of the machine is its output capacity that was the weight of the cut pieces discharged per unit time. In order to determine output capacity of machine, it was operated for three complete revolutions by feeding potato tubers in each cup and the output of cut pieces at the discharge end was weighed. This was repeated 10.0 times. As the machine was moving at a speed of 8.75 rev/min totaling into 525 rev/hr., thus the discharge (kilograms of cut pieces) at the end of each 3 revolutions was multiplied with 175 to provide machine's output in kg/hr as given in figure 8.

The mean capacity of machine approximated 450kg/h with a standard deviation (STDEV) of 12.38. This suggests that the machine capacity would be 438-462, 425-475 and 413-487 kg/h for 66 %, 95% and 99 % of the times, respectively. It can be generalized that the capacity varied 410-490 kg/h approximately. A larger variation in the capacity resulted from variation in the sizes of the tubers.

In order to properly conceive the variations in machine's capacity potato size distribution was also studied. Potatoes were randomly picked from the lot, weighed and their volumes determined in a graduated cylinder having water. The data are given (figure. 9).

It is obvious from the mean/volume and their standard deviation (STDEV) that the variation in size of tubers is considerable. A wide variation in size of potatoes explains the variation in machine capacity. This variation also suggests that single size pockets may not be desirable to accommodate all sizes of potatoes.

Thirty pieces of cut pieces were randomly picked from each of the lots cut by machine and manual labor. All the pieces were weighed individually. Unpaired T-test was employed to test significant differences in the two means. The results revealed that the difference between the means was insignificant cleared suggested that the machine and manual cutting operations were similar as regards the uniformity of cut pieces. This reflects well on the precision of machine operation, that is, the distribution of sizes of cut pieces is same both in machine and manual cutting being viable. These losses are chances occurrences which can be seen even in the manual cut lot where the damage was up to 2.5 %.

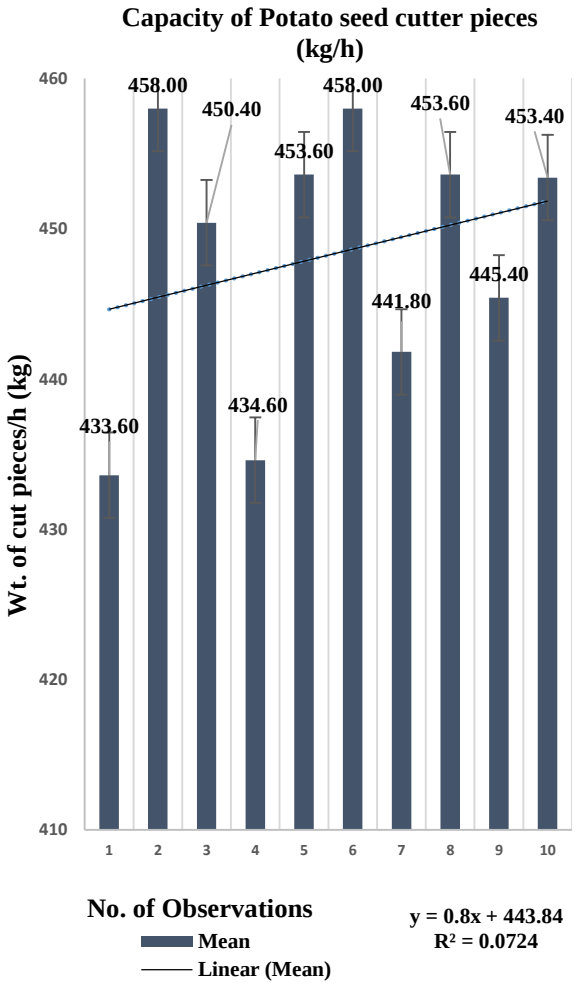

Figure 8 Working Capacity of Machine

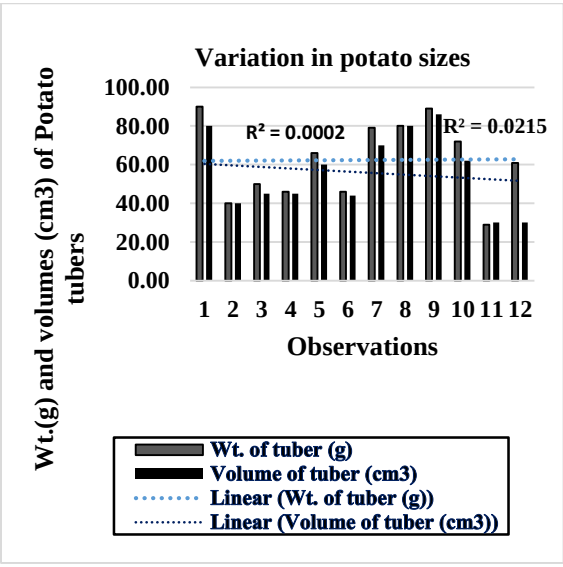

Figure 9 Variation in potatoes sizes

IV. RESULTS AND DISCUSSION

Cost of manual cutting, 450 kg potatoes = Rs. 680/hr.

Cost ratio = $\frac{\text{Cost of manual cutting}}{\text{Cost of machine cutting}} = \frac{818.00}{131.79}$

= 6.206

It is clear from the cost of operation/h calculations that the manual cutting is approximately 6.0 times costlier compared with machine cutting of potato seeds. Naturally the initial investment of Rs. 1, 00,000 on the machine is a discouraging factor for the farmer. However, it may be remembered he will be saving about Rs.3650/acre if he will be using the machine. The farmer may recover the cost of machine after planting 60.0 acres. In addition to the considerable cost savings, the farmer using the machine may avoid the management and supervision of labor. Above all he can avoid delayed planting which generally results in poor yield. Thus the machine/mechanical cutting of potato seeds brings with it fringe benefits.

Table 2 Cost analysis of machine

Cost Analysis of Machine			
Sr. No.	First Cost of Machine	Rs. 1,000,00	Cost (Rs.)/h
1.	Salvage value (10% of first cost for most of agricultural machines [8] [9] [10]	Rs. 10,000	
2.	Life in years	10 Years	
3.	Expected hours of operation/year	500 hrs.	
4.	Total life of machine	5000 hrs.	
5.	Working capacity of machine	450kg/hr.	
6.	Lubricants/year	7.0 L	2.0
7.	Taxes, insurance and shelter expenses	Negligible for the seed cutter	Nil
8.	Depreciation	= $\frac{\text{First cost-salvage}}{\text{Life in hrs.}}$ $\frac{1,000,00-10000}{500}$	180.0
9.	Repair and maintenance cost	10 % of first cost = $\frac{10,00,00 \times 10}{5000 \times 100}$	2.0
10.	Interest rate	(14% of first cost/year) $\frac{1,000,00 \times 14}{500 \times 100}$	28.0
11	Labor cost	Rs. 500/labor / day =$\frac{500}{8}$	62.50
12.	Energy cost 1/2 hp motor	= (0.373 kW x 1.0 hr.) 0.373 kWh x 16	5.968
13	Overhead cost	(50% of labor) = 62.50/2	31.25
14.	Total cost of operation per hour for cutting 450 kg potato seed	= Sum of serial Nos.(6+9+10+11+12+13)	131.718

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