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Research Paper :

Design and development of tractor mounted hydraulic lifter for harvesting spraying and pruning of horticultural fruit trees

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ABSTRACT

The harvesting, pruning and spraying are still a manual task and need to be mechanized. The study of various control systems such as pneumatic, hydraulic, hydro-pneumatic and electrical control reveals that the use of hydraulic control system will be more beneficial and reliable for the current development. The tractor mounted hydraulic lifter for fruit harvesting, pruning and spraying was developed by integration of Agricultural and Mechanical Engineering concepts, manufacturing processes, material properties and tree characteristics. The principles of hydraulics circuit were used and accordingly turn table, harvesting arm, harvesting bucket and tractor mounting assembly was designed and developed. The cost of tractor mounted hydraulic lifter is Rs.1, 30,000/- (US $ 3250). Research is underway to develop hydraulic man-positioner, which would be easier for harvest, pruning tree and spraying by hand or machine.

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The cultivation of fruit crops like mango, cashew, coconut and arecanut etc. is on large area in India. Harvesting, pruning and spraying of horticultural fruit trees are difficult due to height of trees and non availability of machines. It requires fairly large numbers of seasonal labour. Tree taller than six meter are hard to pick and usually cost more for harvesting, pruning and spraying operations. The number of labourer required dependes upon size of tree, its characteristics and time available within season. Mango (Mangifera indica), the "King of Fruits", has prime importance among the commercial fruits grown in India, the largest producer and exporter of mango in the world. In Gujarat state of India, about 382 thousand tones of mango are produced annually over an area of 57 thousand hectare (Gupta *et al*., 2004, Anon. 2000). India produces export quality of mango mainly the Alphonso and Kesar varieties. The quality of the fruits mainly depends on their maturity stages, harvest and post-harvest techniques adopted by the mango growers. Manually operated low capacity gadgets and tree-shaking methods prevail, which are time consuming, drudgereous, damage fruits, damage tree branches. The damage and bruising are very serious problem. The fruits should not be allowed to fall on the ground as the injured fruits cause spoilage to other healthy fruits during packaging and storage. Fruits harvested with 8-10 mm long stalks appear better on ripening as undesired spots on the skin caused by sap burn are prevented. Such fruits are less prone to stem-end and other storage diseases (Sapovadia *et al*., 2001). Harvesting of fruits in India is mostly done manually by means of curved knife, pair of scissors or blades attached to a hanging basket to the distal end of bamboo sticks (Devnani, 1980). According to economic studies, harvesting labor represents over 40% of citrus production cost and will need to be cut by 50% in order to maintain global competitiveness (Brown, 2002). In Srilanka, harvesting of coconut is done from the ground with the help of a knife attached to a long bamboo pole. In countries where there is shortage of skilled labour the nuts are not harvested and allowed to fall of their own accord and the fallen nuts are collected from the ground at intervals (Thampan, 1983). RTTC, worked on fruit harvesting devices, manually operated unit worked on the principle of individual fruit cutting by sickle/ blade and collecting the fruit in a bag. The unit was found suitable for average size and big fruits, which would be damaged if allowed to fall freely on the ground. The other unit worked on the principle on mechanical shaking of tree. This unit was suitable for hard fruits. It has been reported that fruits harvested by mechanical shaking have more injuries in the form of splits, internal and external bruising and superficial peel sears than manually-harvested fruits. In cooperation with the Washington Tree Fruit Research Commission an experimental mechanical harvester was developed, tested, and yielded fruit quality comparable to that obtained by commercial hand harvesting as shown in Fig. 1 (a). The experimental harvester also significantly improved harvest labor productivity. Presently, the biggest obstacle to commercialization of this harvesting technique is the fact that tree-training systems in commercial

Fig. 1: Method of harvesting and pruning of fruit trees

orchards are not compatible with this experimental technology. The experimental harvester demonstrated potential for harvesting fruits with not more than 4 per cent more damage than commercial hand harvesting. The improved methods of pruning of tree branches observed in literature are shown in Fig. 1(b). In literature it is reported that the catching/collecting system was effective with low damage inflicted to the cherries. Harvesting rate down the row ranged from 85 to 158 trees/hr with harvester capacity up to 1590 kg/hr. This harvester allows user to reach approximately 4.3 m (this includes the 1.8 m. reach of the user, plus the 2.4 m. pole). To reduce the harvesting time and fruit damage, it is essential to develop a tractor-operated hydraulic lifter. Viable solutions will require engineers and horticultural scientists who understand crop specific biological system and production practices, as well as the machinery, robotic and control issues associated with the automated production systems. This paper presents an overview of development of tractor mounted hydraulic lifter for fruit harvesting, pruning and spraying considering the biological systems, manufacturing practices and engineering aspects of design.

Material studied:

The mechanical design of a tractor mounted hydraulic lifter is an iterative process involving evaluation and choice among a science, engineering and technical considerations. A purely static, rigid body approach to design is not sufficient and factors like mechanical system, stiffness, natural frequency, control system, compatibility need to be considered. A tractor mounted hydraulic lifter for harvesting; pruning and spraying should be designed flexibly to perform the range of tasks. The various design considerations are

System specification: It includes possible work range, maximum height, work envelope, load capacity.

System configuration: It includes the joint configuration, degree of freedom, joint travel range and drive configuration.

System Performance: It includes system velocity and acceleration, repeatability, resolution, accuracy, component life and duty cycle.

Anthropometrical dimensions of the operator

Tree characteristics.

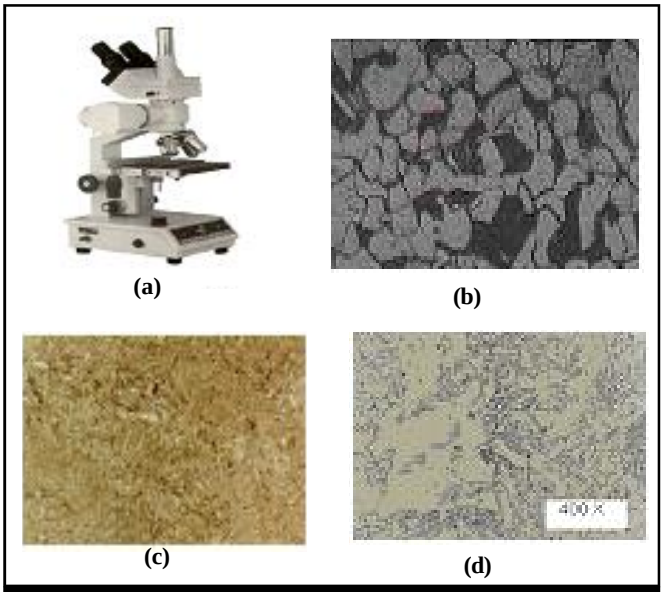
The major components are arm joints, transmissions, oil flowing pipes, hose pipe peripheral units integrated into system unit. The arm joint has relative motion among them. One joint has one degree of freedom. The joints can be classified as L joint, O joint, T Joint, C joint etc.

METHODOLOGY

The materials used for fabrication of different components were selected by considering chemical compositions, mechanical properties, weldability, wear resistivity of the material (Kolhe and Datta, 2007). The chemical compositions and the mechanical properties of material used are given in Table 1 and the micrographs of selected material are shown in Fig. 2. The electric arc welding using 3.2 mm and 4.00 mm coated electrode was used for welding. According to the size of electrode; the initial welding parameters were adjusted (Kolhe *et al.*, 2004). The composition of electrode was same as that of base material, to do the robust weld joint properties. The hydraulic cylinder is made up of chromium vanadium steel to protect it from wear and other atmospheric conditions (Kolhe and Datta, 2004) .The hydraulic pump of pressure range 150-200 kg/cm^2 and 15 liter per minute discharge was selected. The hydraulic motor having torque of 7 Nm for turn table operation is used. The fabrication was carried out as per ASTM standard. The metallurgical investigation was done by metallurgical microscope,

Table 1 : Chemical Composition and mechanical properties of material used for the development

Spec No	Chemical composition % max					Mechanical properties		
IS: 226/75	C	S	P	Si	Cu	Tensile strength N/mm^2 Kg/mm^2	Yield N/mm^2(kgf/mm^2)	Stress elongation (%)
	0.25	0.055	0.055	-	0.20-0.35			
Nominal plate thickness from 6-20mm						410-530(42-54)	240(24)	23
Nominal plate thickness from 20-40mm						410-530(42-54)	230(23)	23
Nominal Bar (round/ square) thickness from 20-40mm						410-530(42-54)	340 (24)	23



(a) (b) (c) (d)

Fig. 2: (a) Metallurgical microscope, used for the metalburgical analysis
(b) Microstructure of mild steel mateial used for showing white portion as ferrite and dark portions as pearlite observed under metalbirgicla microscope at 400X for getting improved mechanical properties and weldabity
(c) Shows the same sample of used material after heat treatment for improved mechanical properties
(d) Microstructure of tractor mounted hydraulic lifter for fruit harvesting welded specimen

Model RMM- 1 with non-erect image Binocular head having high magnifications 800 X, objectives of Bright field / dark field Photo micrographic system, image recording equipment attached with digital camera. The metallurgical investigation was essential for the safety and avoiding any type of failure during operation.

The Anthropometrical dimensions of the operator of age group 20-50 years are presented in Table 2 . The height to weight ratio was considered for development of harvesting bucket. The height to weight ratio 1:3.06 was considered for design. The characteristics of mango, cashew, coconut trees are presented in Table 3, 4, 5 and 6. Two major obstacles impede efficient mechanized harvesting: (1) Locating fruit occluded by the tree height, leaf canopy, distance between two trees etc. and (2) Harvesting fruit located in the plant interior. In both cases, a plant system that presented the majority of fruits at the canopy surface would improve the harvestibility. The two strategies seem to be in conflict under normal tree behavior. Sparsely leafed trees tend to have more interior fruit accessibility, while densely leafed trees will make it more difficult to sense the interior fruits. A tree which is naturally fruited at the limb extremities with minimal interior fruit might resolve this problem.

Basic components of tractor mounted hydraulic lifter

Table 2 : Anthropometrical observations of the operator

Age, (Year)	Sex	Height / Weigh ratio	Palm size, cm	
			Length	Width
21	M	1:2.8	21.00	9.00
25	M	1:3.06	20.50	8.00
35	M	1:2.84	19.00	7.50
23	M	1:2.56	20.00	8.00
21	M	1:2.68	20.00	7.00
50	M	1:2.69	21.00	8.00
26	M	1:2.74	19.50	8.00
28	M	1:2.78	21.00	9.50
24	M	1:3.71	18.00	8.50
46	M	1:2.57	21.50	9.00
Average		1:2.70	20.20	8.30

Table 3 : Characteristics of mango and fruits distributions within the tree (variety Kesar)

Sr. No.	Height (m)	Canopy, radius (m)	Distance between the trees (m)	Outside %	Inside %	Top %
1.	7.0	7.0	11.00	50	20	30
2.	6.0	10.0	10.00	57	20	23
3	8.0	8.0	11.00	50	18	23
4.	10.0	12.0	11.00	70	12	17
5.	7.0	7.0	11.00	58	17	25
6.	8.5	8.5	12.00	58	20	22
7.	6.5	10.0	12.00	62	18	20
8.	9.0	7.5	10.00	60	15	25
9.	11.0	7.0	12.00	71	12	17
10.	7.5	10.0	11.00	64	16	20
Average	8.5	8.0	11.1	60.5	16	22

Table 4 : Characteristics of mango tree (Alphanso variety)

Sr. No.	Height (m)	Canopy, radius (m)	Distance between the trees (m)	Age (year)
1.	6.66	7.00	10.02	25 year
2.	5.33	6.00	10.46	25year
3.	7.00	8.00	9.16	25 year
4.	6.33	5.00	9.00	25 year
5.	6.00	7.00	10.00	25 year
6.	7.00	9.00	10.00	25 year
7.	6.33	5.00	9.00	25 year
8.	6.66	6.00	10.33	25 year
9.	7.00	8.00	10.00	25 year
10.	3.00	2.00	10.00	25 year

Table 5 : Characteristics of cashew tree (variety Vengurla-4)

Sr. No.	Height (m)	Canopy, radius (m)	Distance between the trees (m)	Age
1.	3.0	4.0	07 to 10	10 year
2.	5.0	5.0	07 to 10	10 year
3.	5.0	5.0	07 to 10	10 year
4.	4.0	5.0	07 to 10	10 year
5.	4.0	8.0	07 to 10	10 year
6.	4.0	6.0	07 to 10	10 year

Table 6 : Characteristics of coconut tree (Variety T\D)

Sr. No.	Height (m)	Canopy, radius (m)	Distance between the trees (m)	Age (Year)
1.	9.00	--	8.33	10 year
2.	10.00	--	8.33	10 year
3.	10.67	--	9.00	10 year
4.	9.66	--	9.00	10 year
5.	8.66	--	8.33	10 year
6.	10.00	--	9.00	10 year
7.	7.00	--	9.00	10 year

are shown in Fig. 3. The control of the harvester is working on the principle of hydraulic system. The power required for hydraulic pump operation is taken from tractor PTO shaft. The hydraulic oil flows from the hydraulic tank to hydraulic pump and from pump to the multi position multiway direction control valve. The direction control valve with control lever is attached at the harvesting bucket. The operator controls movement of fruit harvester. The operator can move towards the tree and the fruit on the tree can be harvested. The fruit harvester consists of following major parts : Turntable, Hydraulic tank, Hydraulic pump, Hydraulic motor, Upper and lower operating arms, Hydraulic cylinders, Directional control valve, Hydraulic oil flow pipeline, Harvesting bucket.

(a) Hydraulic pump valve (b) Hydraulic motor (c)Hydraulic multiposition multiway direction control

Fig. 3 (a, b, c) : Special purpose hydraulic devices used

Hydraulic system:

The tractor mounted hydraulic lifter for fruit harvesting, pruning and spraying is shown in Fig. 4. The 270^0 rotating turntable with hydraulic motor forms the foundation of the fruit harvester assembly. The total vertical reach of this harvester is 9.1 m. (upper arm of 4.6 m. and lower arm of 3.7 m. length) when assembly is at 1 m height from ground level. The power to operate hydraulic lifer is taken from tractor PTO. The hydraulic pump is operated by PTO through belt pulley. The hydraulic pump has two ports - inlet port connected to hydraulic tank and outlet port connected to the hydraulic multi position multi way hydraulic direction control valves. The hydraulic direction control valve has 8 inlets and 8 outlets connected to the cylinder 1, cylinder 2, hydraulic motor, harvesting bucket, hydraulic valve and the hydraulic tank. Single operator can control the motion of the cylinders, hydraulic motor, and harvesting bucket through control panel. In forward stroke, the oil flow from the tank to hydraulic pump and pump to cylinders. While in reverse stroke, the hydraulic oil returns to the hydraulic tank and arms moves downward. The hydraulic motor rotation can be controlled clockwise or anticlockwise to control the movement of turn table.

Following steps were followed in the development of the unit:

– Design of tractor mounting bracket for the fruit harvester mounting on tractor,
– Design of hydraulic circuit ,
– Design of power transmission,
– Design of turntable,
– Selection of hydraulic pump,
– Design of hydraulic tank ,
– Selection of multi position multi-way hydraulic

flow control valve,

– Design of upper and lower arm ,
– Design of harvesting bucket.

The above mentioned parts and accessories were designed and developed at College of Agril. Engineering and Technology, Dapoli (India).

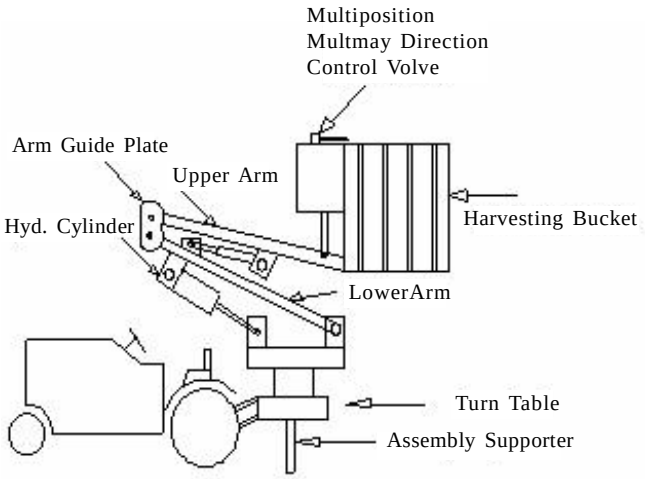


Fig. 4: Design of tractor mounted hydraulic lifter

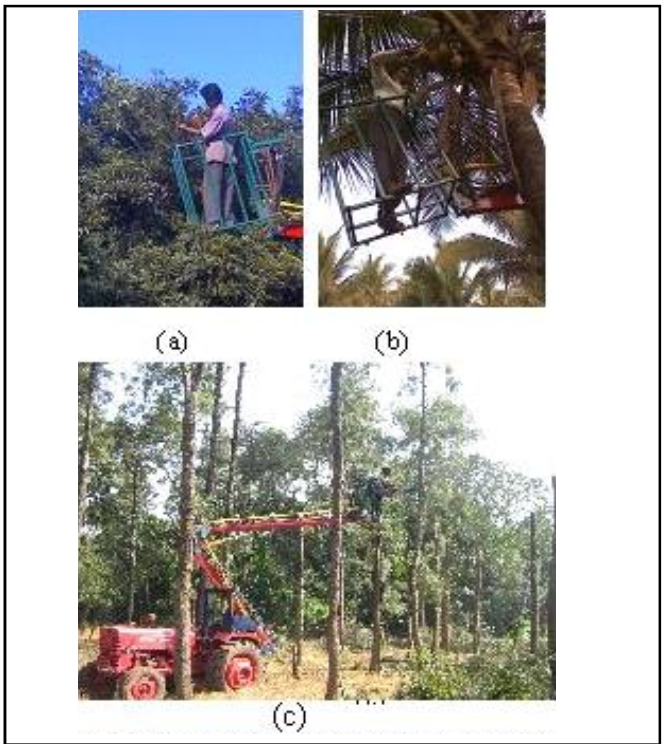


Fig. 6 : Application of developed hydraulic lifter for harvesting and pruning

RESULTS AND DISCUSSION

The various steps of development of the tractor mounted hydraulic lifter are shown in Fig. 5 (a-d). The feasibility trial of developed tractor mounted hydraulic lifter for fruit harvesting, pruning and spraying was carried out at University farm (Fig. 6). The load carrying capacity of bucket is 1000 kg. The lifter works satisfactory for harvesting fruits from tree up to 9.1 m height and also for spraying and pruning operation. The demonstration of this tractor-operated lifter was carried out directly on the farmers farms. As many as 500 farmers operated this lifter themselves and agreed for this development and very useful feedback were received from the farmers. From the farmers feedback the new tractor mounted lifter is being modified. This is a new design, which is very useful to the farmers to improve the overall productivity of agricultural produce productivity and farmers economy. The cost economics of this developed unit is in progress.

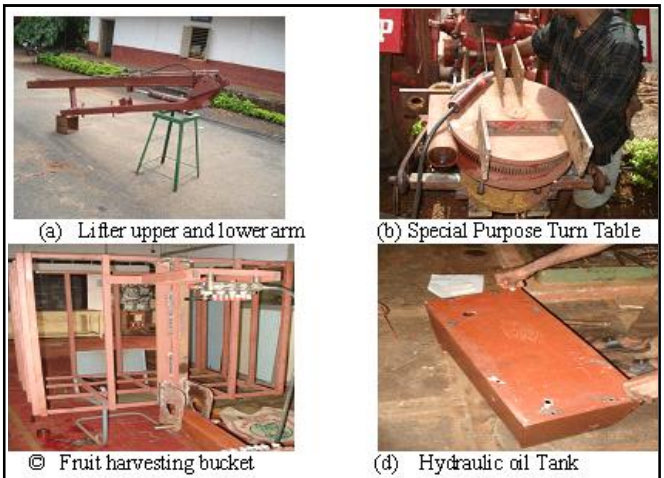


Fig. 5: Steps while development of hydraulic lifter

Conclusion:

The developed tractor mounted hydraulic lifter is useful for fruit harvesting without any mechanical injury, spraying and pruning by man or machine. All fruits were harvested with stems, no sap burns were found on harvested fruits. Hydraulic arm can be rotated by 270^0 and can lift 1000 kg load up to 9.1 m height.

The tractor-mounted lifter is used to prune tall trees with less fatigue and with minimum time and less labour.

The tall trees get sprayed from very close distance to assume to removal of dust particles from the trees.

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