Modelling and Analysis of Design and Performance Indices of Apple Harvesting Machine using SOLIDWORKS

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***Abstract*—Apple harvesting is one of the most popular fruit growing activities pertaining to the people of Jammu and Kashmir. It has become the predominant source of income and employment due to restrained resource endowments in other sectors. The workers in plucking are facing several health issues especially muscoskeletal issues due to the present system of plucking. The paper provide remedy to burning issues which the workers are facing during practice of harvesting in a cost-effective way. Apple plucking system will be designed in accordance with the principle of ergonomics. It will make plucking process optimized in terms of labour, cost and above all, in terms of safety concerns.**

Data pertaining to research was collected through survey at different sites of the Kashmir region and data so obtained formed the basis of the design of machine parts for the proposed harvesting system. The sketches were modelled using SOLIDWORKS. Individual modelled part intended to be used in proposed apple harvesting system were investigated for stress, deflection. The result validates the safe design of system so designed and permits its fabrication into working model.

Index Terms: **Apple harvesting system, analysis, deflection, load, modelling, SOLIDWORKS.**

1.INTRODUCTION

Horticulture is the most essential enterprise of the people of Jammu and Kashmir Union territory of India and would. It constitutes a vital area of the state's economy, contributing about Rs 4000 million of the state's domestic products. The annual fruit manufacturing in the country is well worth Rs 2000 million inclusive of export of walnut really worth Rs 300 million (Dixit and Ali 2017) Apple, pear, walnut and almond are the principal fruit vegetation grown in the region. Harvesting of fruits is a vital operation in horticultural practice. Economics as associated to timeliness, opposition for labour and right market expenditures have pushed for mechanization of nearly all agricultural operations. Mechanization of small farms is uneconomical as per Indian situation. In the Kashmir region, due to the unavailability of efficient tooling and machinery, people have devised and tailored distinctive approaches to harvest their fruits consisting of handpicking, the usage of a ladder, using a pole to hit the fruits, or the use of a barrel in an attempt to attain high treetop fruits. Most of the fruits are harvested when they are ripe for on-the-spot marketing. The harvesting of clean fruits like apple, pears, cherry, peach, plum, apricot, etc. is finished manually by the usage of a common orchard ladder as shown above in Fig.1.

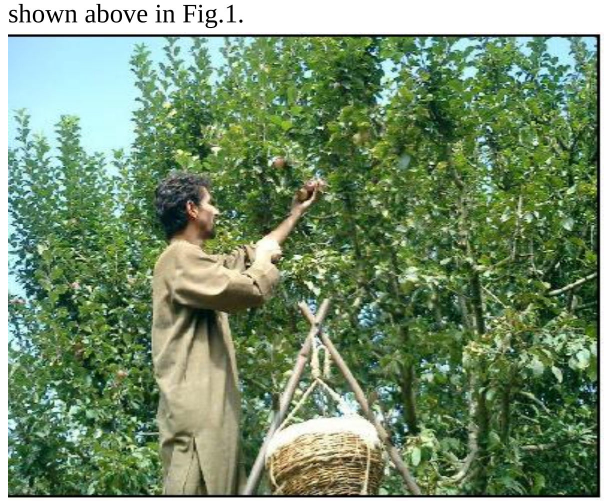
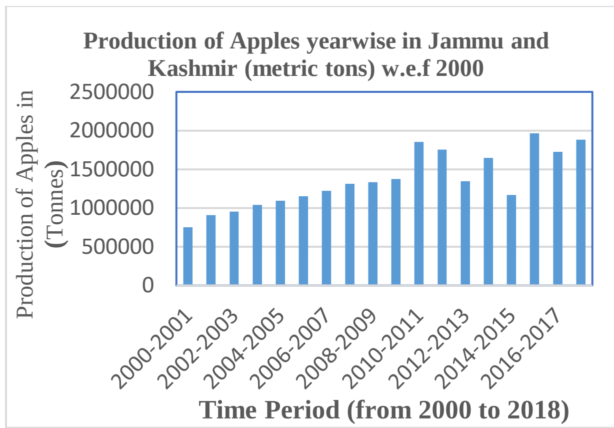


Fig.1. Harvesting of apple by the conventional method

These primitive techniques are inefficient and inflict huge loss on the fruit quality due to inevitable injuries caused to the fruit during plucking. Moreover, the agencies have filed severe incidents of accidents to human beings e.g., falling from trees with younger adolescents and old people being the most vulnerable. In many cases, the most common choice is to leave the unreachable fruit which is counted as a loss to the farm or garden resulting in a major loss to a family's income. Harvesting has been a great challenge since ancient times, and every civilization has tried to improve upon harvesting systems. The right time and proper method of harvesting are very essential as it influences productivity. The harvested item, may it be any crop, vegetable or fruit does not remain for long. This leads to decreased productivities if timely harvesting is not done. Moreover, if a poor harvesting device is being used, it may additionally harm fruit or might also cause some injury to the worker. This also will result in reduced productivities. The harvesting additionally relies upon the type of crop i.e., whether or not products are to be picked up in masses or individually. Workers or laborers carrying out harvesting have been following traditional strategies that are still being used in many parts of the world. The conventional hand-harvesting approach has made growers stop or minimize their production as labor costs amount to three fourth of their total expenditure This traditional method involves a lot of workers and time. Therefore, it has become a necessity to optimize these variables such as the method of harvesting, concerned labors, and timing for harvesting.

Picking of fresh fruits is a difficult job as they are more prone to injury e.g., apples, mangoes, peaches, etc. Such fruits are picked up manually in most of the countries, and the picking charges holds an outstanding share of the production cost. In the recent past, some fruit picking systems have been designed, however they resulted in excessive fruit injury and health problems amongst the employees. The previous studies have also stressed upon the decrease in labor productivity due to musculoskeletal problems faced by the workers. The use of ladders and bucket during fruit picking has resulted in odd postures which are ergonomically not safe, therefore making labors susceptible to health issues. Absenteeism is one major factor leading to reduced labor productivity due to health problems. Thus, there has always been an emergent need for reviewing the previously developed harvesting systems and discover their shortcomings. These shortcomings will help in developing a new harvesting machine which will increase productivity.

Productivity describes various measures of the efficiency of production. Often, a productivity measure is expressed as the ratio of aggregate output to a single input or an aggregate input used in a production process, i.e., output per unit of input, typically over a specific period. A most common example is the (aggregate) labour productivity measure, e.g., such as GDP per worker. Productivity is a crucial factor in the production performance of firms and nations. Increasing national productivity can raise living standards because more income improves people's ability to purchase goods and services, enjoy leisure, improve housing and education, and contribute to social and environmental programs. The state has the largest doable for the manufacturing of exceptional temperate horticulture crops. It has created niche production of apple, pear, cherry, and dry fruits. Among temperature fruits, apple ranks first for mass production and productivity. The annual manufacturing of apple in the state is about 9.09 lack tones at an average yield 0f 10.09 tons per hectare. However, the manufacturing and productivity of apple crops have been fluctuating during the last two decades which is due to drought or some other climatic conditions.



Graph 1: Production of apples in Jammu and Kashmir from the year 2000 to 2018.

There are conventional apple harvesting systems that are being used for apple picking. Fig.2 shows the traditional technique used to pluck apples. It can be seen from the figure that people involved in apple plucking are subjected to musculoskeletal disorders due to risky postures. As prescribed via Experts, the following anthropometric measurements ought to be taken care of while performing any lifting. These measurements are:

- The distance of fingers from midpoints between ankles.
- The height of palms to attain an object.
- Frequency of picking.
- The trunk rotation.
- Load to be lifted.
- The kind of grasp.

All the above-mentioned measurements if exceeding the secure limit will result in musculoskeletal problems amongst laborers. With the existing system, there is a decrease in productivity due to fruit damage and labor absenteeism. It can be seen in Fig.2 that the posture of men and women for reaching apple is hazardous and will result in arm and wrist fatigue. Moreover, standing posture with the ladder is also not safe. In such postures, labor cannot focus on the job as he has to keep balance and simultaneously pluck the apple.This additionally causes harm to apple due to slip from the hands. These conventional systems have been explored by researchers and more recent systems have been proposed which were designed taking into account technological know-how and safety.

Fig. 2: Traditional method of Apple picking/plucking

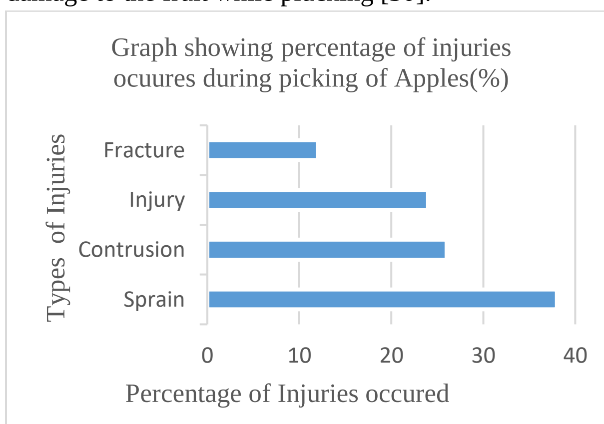
2. LITERATURE REVIEW

Various researches have been related to the evolution of apple plucking mechanisms. A lot of work has been carried out in a similar kind of system. The fresh fruit market has grown over the past decades and has taken the shape of a big Industry. Fruits such as apples, peaches, cherry, pear, and so on are grown in Kashmir valley. On the other hand, Apple is the fundamental fruit of Kashmir which is widely circulated in India and abroad. The picking/plucking of apples has been carried out traditionally i.e., manually apples are picked from the trees. With the growth of the apple orchards, plucking is being carried out through hired laborers nowadays which additionally adds to the expenditure. A lot of deliberations and innovations have been tried on apple picking in several countries, however, none of the innovation has been standardized. In present times, the majority of the countries still observe manual plucking, and throughout manual picking, the fatigue happening in employees is of main concern for the experts. In Kashmir, 55% of the total area is being used for apple cultivation which is roughly 150,000 hectares of land. For this reason, it is the largest contributor to the J & K GDP. The apple cultivation in India is mostly in the mountainous areas of Jammu and Kashmir, Himachal Pradesh and Uttaranchal. This fruit is grown at high altitudes of 4000 to 11000 feet. Amongst the apple developing states, Kashmir holds 67 percent of the total production of apples, 50% of which is exported to the different components of the country and overseas (Malik, 2013; Malik, 2014). The height of the apple tree is in the range of 3 to 12 meters and is full of dense twigs. The dimension of the apple is generally 5 to 9 cm in diameter and is enriched with nutrients (Mittal, 2007). The involvement of labour and mechanization in apple harvesting has always been a great challenge for the researchers as it directly impacts productivity. Researchers have reported the problem in the plucking of apples from the trees. The authors also stressed the fact that there is no such machine that can be considered as a healthy alternative for the manual method of plucking. The possibility to pick out the ripe fruit is more in the manual system than any other system (Sanders, 2005). The apple picking in most of the places has been carried out manually, and there has been an intensive requirement of labour hours i.e., up to 215 hours per hectare. This time spent in harvesting amounts to 70% of the whole time involved in apple harvesting such as grading and transportation (Sichert, 2006). The demerits of poor mechanization in apple harvesting have also been deliberated upon by scientists. They have stressed on the emergent need for mechanization to increase the productivity in the apple harvesting (Dixit et al., 2014). The bruising of apples during plucking was studied by Fu et al., (2016). Three affected zones of apples were located i.e., center to bottom, middle to the top, and middle to center. The study revealed that there was no bruising if the impact pressure on the apple was less than

16N. As per the investigation, up to 28N and 53N impact force, 98% and 94% quality apples can be obtained. The existing design of the buckets used for apple plucking was studied and then modified. The objective was to offer comfort to the apple pickers whilst carrying out their work. A hip belt with the bucket was supplied to the workers. The findings of the investigation published that 78.6% of the employees appreciated the modified bag, 71.4% noticed a difference in neck/ shoulder postures, whereas 64.3% denied constant use of modified bag as it would gradually affect their back (Richardson et al., 2005). Freivald et al., (2006) developed a belt/bucket system for apple harvesting and had tested the system on workers. The effects have shown less pain in the shoulder due to the transfer of load to the hip by using the belt. Zhou et al., (2014) in their work investigated the impact of the excitation position on the effectiveness of fruit plucking and also on the fruit injury using a handheld limb shaker for harvesting sweet cherry. From the results, it was concluded that fruit plucking efficiency may amplify to 97 percent with fewer fruit injuries as compared to the existing plucking methodologies. A high-quality small scale working mechanism to pick peach fruit was developed by researchers. The mechanism was designed considering the minimum possible injury to the fruit during plucking. The authors additionally investigated the effect of the gadget on the productivity of pickers, and the devised systems have shown excellent performance (Caplan et al., 2014). A fruit picking device was developed and fruit harvesting was carried out with the developed system. The investigation was carried out on 210 fruits and it was found that except for 9%, the rest of the fruits were picked by the system. The developed machine has proven its effectiveness and also verified the opportunity of using robots in the harvesting of fruits (Bakhtiari and Hematian, 2013). The authors have fabricated and examined three sorts of catching systems, i.e., a pair of canvases, a catching trailer, and a pair of canvases with direct discharge to boxes. The investigation revealed that 90% (average) of the fruits fell from the trees with hand-held shakers and less than 2.4% of the fruits were severely damaged. The study revealed that harvesting charges per worker to increase with the first two systems followed by the third system (Torregosa et al., 2008) Basic mechanical harvesting systems such as limb shakers, air blast, cover shaker, trunk shakers, etc. were studied by Li et al., (2011). They have elaborated on the functioning of these structures alongside the fruit removal efficiency and fruit injury. Thamsuwan and Johnson, (2015) investigated the ergonomic hazard factors between the traditional technique of apple plucking and a novel apple picking technique with cellular platforms. The essential objective was to deal with the threat related to the top arm postures and the lower back during the picking process. The outcome revealed that the people adopting the novel method with the cellular platform were less exposed to postural problems as compared to the traditional method. Gilad, (1995) studied the impact of repetitive motions on the health of the people involved in apple harvesting. These motions were carried out by the muscle of the hands, arms, and shoulders. Further, the extreme function of eyes and neck during plucking also results in fatigue. The authors concluded that the common repetitive motions will consume low energy, however, if the period of the job is short and cyclic, the worker will be subjected to musculoskeletal disorders. Picking of clean fruits is a difficult job as they are more susceptible to injury e.g., apples, mangoes, peaches, etc. Such fruits are picked up manually in most of the countries, and the selecting value holds a great percentage of the production cost. In the recent past, certain selecting systems have been designed but have resulted in moderate fruit harm and health issues amongst the workers (Sarig, 1993). The fruit removal efficiency was connected to the extent of shaking amplitude at a positive range for such apple trees. A fruit plucking efficiency of 94% was achieved with a shaking amplitude of 30 mm. To obtain a higher proportion of extra fancy grade fruit, taking of close pictures of the fruit was endorsed for the localized shake-and- capture harvesting system. (Han Fu et al., 2019). The author describes the development and performance of an Autonomous Fruit Picking Machine (AFPM) for robotic apple harvesting. The key factor for the success of the AFPM is the integrated method which combines many industrial factors with the newly designed flexible gripper. The gripper consists of a silicone funnel with a digital camera installed inside. The purpose is to reduce the choosing cycle duration from an average of 9 to about 5 seconds (or less). In that case, the productivity of the AFPM will be close to the workload of about 6 workers, which makes the machine economically viable. Special attention will be towards the improvement of the true apple detach movement with the aid of taking into account the relative pose of the apple with respect to the branch. This should lower the stem pull percentage (Baeten et al., 2007). This paper details the complex biological and economic relationships existing in an apple orchard system and describes a dynamic simulation model primarily based on these interactions. The model is bio economic in nature and may be used to check out a variety of issues of relevance to the business apple orchardist. These problems consist of perception of how organic elements have an effect on apple-tree productivity, and how to pick out among numerous vary of apple orchard systems. The bioeconomic model is used to maximize the net present price of one orchard system via choosing the most beneficial thinning techniques over 15 years (Hester & Cacho, 2003). The author introduced the design of an end effector for the selection of apple in 9 degrees of freedom adopting the direct-current (DC) motor without delay pushed joints. The machine can produce a hold comparable to the human hand-picking system using particular control of the joint motor, radically enhancing the exceptional and effectivity of the picking. The test suggests that the designed effector can efficiently hold an apple with a mass between 0.18 kg and 0.25 kg and the force of the selecting manipulator meet the requirement (Shi et al., 2018,). The author discussed that the hand-picking of apples poses a challenge to the quality of harvested fruits and problems of the musculoskeletal system of people during the harvesting. The performed checks helped to decide the impact of repeated muscle contractions, which generated forces at the fingertips to the extent of not inflicting injury to the fruit tissue. The maximal allowable frequency of clamping fingers on picked apples has been used to decide specific methods of apple gripping, exceptional values of the pressure exerted on apples and the range of frequencies and intervals of the work (Mlotek et al., 2015). The author presented bruise injury as the most quintessential barrier for the utility of mechanical harvesting structures for sparkling market apples. One of the fundamental causes of bruising is the fruit-to-catching floor and fruit-to-fruit contact when the fruit has been detached through harvester. In this work, a fruit catching mechanism was once designed and fabricated using air suspension as a cushion to minimize fruit bruising all through mechanical harvesting (Ma, 2016). The author discussed the growing value and reduction in the availability of skilled orchard labour to be the greatest worries for orchardists, and have led to the developments of possible mechanical options for pruning and harvesting. A first step in creating mechanical options is the institution of precision of orchard structures primarily based on precise pruning rules. In this study, the authors have evaluated pruning severity levels (PSL) on apple fruit removal efficiency (FRE) and harvested fruit high-quality using a shake-and-catch vibratory harvesting system (Zhang et al., 2018). The author presented this simulation as the groundwork for future simulations and to pick out the most efficient robotic configuration to fit the workspace to the fruit-space whilst minimizing the whole wide variety of joints and algorithm design (Wang et al.,2018). Two structures have been developed to robotically harvest quality apples. The shake-catch harvester has been established for harvesting apples, grading a common 87% extra fancy from a tree. The second system makes use of a rod-press harvester designed to get rid of fruit from narrow trellis supported canopies. This harvester was able to harvest each “Delicious” and “Golden Delicious” apples grading with almost 90% extra fancy grade (Peterson, 1989). The authors have presented the paper about the entire improvement of a fruit harvesting device primarily based on the use of a stereovision system connected into the gripper device of the robotic arm. The gripper device has been designed to facilitate fruit preservation and manipulation whereas the stereovision machine presents fruit size and positioning facts relative to the gripper tool (Davinia et al.,2014). Setiawan et al., (2004) introduced special gripper specifically designed to choose apples from trees. It is a low-price gripper with quite a functionality to pick out an apple preventing the scratching of apple skin. The gripper has been designed in accordance with the apple orchard surroundings and robotic specification. The researchers have introduced a framework for motion and hierarchical task planning, which allows the manipulator to pick out apples in the orchard. The hierarchical venture planning assures that the manipulator performs the harvesting with higher control by using other components such as sensors system, mobile platform, etc. The motion planning gives the skills to the manipulator to keep away from the obstacles, to attain the targets, and to perform the detaching motion (Nguyen et al., 2013). Machine vision devices have been used to estimate the size of apples. An over-the-row the platform with a tunnel shape was used for imaging under managed lightning stipulations in order to enhance apple segmentation accuracy. In such systems, colour cameras, and 3D PMD camera were used to obtain 3D region data for apples (Gongal et al., 2018). Zhang et al., (2016) observed in their work that harvesting apples used to be and still it is a very difficult task. The mechanization in this sector is taking location at a very gradual pace. The labours have been taking care of apple harvesting, and value of labour is also increasing day by day. This has given an impetus to researchers to focus extra on cost high-quality apple harvesting mechanisms. The studies carried out on computerized harvesting mechanisms, robots, etc. have revealed that there are positive drawbacks associated with these mechanisms, e.g., bruising of apples with computerized or semi-automatic mechanisms, high value related with robots. The article revealed the possibilities of developing price satisfaction and efficient apple harvesting mechanisms.

Poor styles of picking, old standard methods etc. have resulted in increased, labour cost, accidents, etc. Many researchers have worked upon the awkward postures in manual activities, and as a result have advised a number of suggestions (Ng et al., 2013). Roger et al., 2016 investigated three types of mango pickers namely, the pull type, trigger type and modified trigger type outfitted with a scissor blade equipped by means of metal wire to reduce the stems. The findings have proven that in opposition to the selecting capacity of 22 fruit/min with the conventional choosing system, the pull and trigger type mechanisms have proven the choosing capacity of 21 fruit/min and 12 fruit/min respectively. Negligible injury to the mangoes during plucking was also found with the help of these mango pickers. El –Iraqi et al., 2010 have developed a fruit picking mechanism the place in telescopic pipe, fruit collection pipe and cutting mechanism have been incorporated. The authors have used disc cutters related using fuel engine and electrical motor. Electrical scissors along with cutting part hook were also used in this study. The effects have revealed lowest accidents to the fruit during choosing manner.

The ergonomic risks associated with human skeleton while carrying out apple plucking have been studied (Fulmer et al., 2002). Human beings feel safe and comfortable by applying Ergonomics, a science which deals with the design and arrangement of machines. If the working surroundings is designed in a way, keeping in view the Ergonomics it will always enhance productivities and in today's world, Ergonomics play an important role in every Industry for designing various systems. With ergonomics, quite a few health problems to which a worker is subjected can be resolved. Health problems amongst the workers associated with apple picking has also been of great concern (Dul et al., 1996, Grandjean & Hünting, 1997). Many authors have studied the impact of repetitive activities on the employees worried in apple harvesting. These activities are carried out through the muscular tissues of the hands, arms, and shoulders (Muggleton et al., 1999.Prussia 1985) Den-An et al.,2011 studied about a robotic machine consisting of a manipulator, end-effector and image-based vision servocontrol device used to be developed for harvesting apple. The harvesting robotic autonomously carried out its harvesting assignment the use of a vision-based module. By the usage of a support vector computer with radial basis function, the fruit awareness algorithm used to be developed to observe and locate the apple in the bushes automatically. The manipulate system, consisting of industrial computer and AC servo driver, carried out the manipulator and the end-effector as it approached and picked the apples. The effectiveness of the prototype robotic machine used to be verified by way of laboratory checks and field experiments in an open field. The success rate of apple harvesting used to be 77%, and the common harvesting time was once about 15 s per apple. The authors have elaborated automatic fruit harvesting systems such as various sensor-based mechanisms, robots etc. A cost-effective small scale working mechanism to pick peach fruit was developed. The mechanism was designed considering minimum possible damage to the fruit while plucking [30].



Graph 2 : Graph showing different type of health hazards(Injuries) occurred during picking of Apples

After going through the literature, an emergent need for an efficient and cost-effective apple harvesting system has been discovered. Although there is no standard system developed for apple harvesting, growers in developing nations still prefer the conventional system of apple plucking. However, certain drawbacks in conventional systems have been found and are discussed below:

- The risk associated with the balance of stairs. At times, stairs are adjusted again and again which results in wastage of effort and time.
- Fatigue encountered in the persons involved in the process. Also, the risk of falling from the stairs due to imbalance.
- A huge risk encountered when the man has to use both hands for plucking.
- This process is time-consuming.
- No Ergonomic principle applied during plucking.
- Wrong-way of plucking.
- The person has also to hold a bucket or some container for gathering apples.
- Ladder fall during picking of apples.
- Bruising of apples when they fall from trees during picking operation.

The proposed apple plucking system will be dealing with these issues in a cost-effective way. Ergonomics will be induced in the design of the apple plucking system so that the worker is safe and also motivated. This invention will also reduce the number of workers involved in apple plucking. Along with this, with the proposed invention, male as well as females, both can carry out plucking with ease. Based on the literature and brainstorming, the following objectives have been framed:

- To prepare a data collection sheet for the conduct of a survey of the existing apple trees and apple plucking system.
- To record and analyze the data gathered through the survey.
- To sketch raw drawings of the apple harvesting system.
- To design and analyze a CAD Model for the proposed system
- To fabricate and test the apple plucking system

3. METHODOLOGY

The methodology devised for the present research study comprises the following steps:

- Preparation of the Questionnaire:
- Collection and analysis of the data
- Sketching raw drawings of the apple harvesting system:
- Design and analysis of CAD model:
- Fabrication of the apple plucking system:

Table 1: List of material required:

S. No	Parts to be Designed	Material proposed
1	Main Pipe	Aluminium Alloy
2	Cutter	Mild Steel
3	Ball and Socket joint	Mild Steel
4	Bracket/Hinged joint	Aluminium Alloy
5	Operating handle	Mild Steel

Table 2: Data (average) collected from various sites

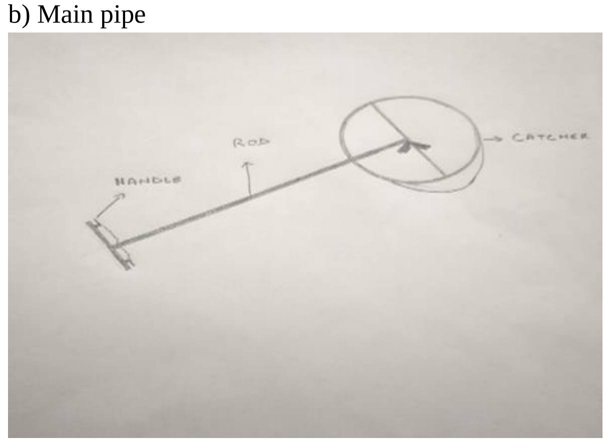
DESCRIPTION	DATA
Height of the tree:	12-14ft
Diameter of the stem	10-12inches
Periphery of the tree	8-10ft
Labour involved for plucking per tree	3-4
Quantity of apples plucked per tree	1800-2000Kg
Damage to fruits per day	80-100Kg
Time spent in plucking per season	One month
Pain reported by workers	60-70%

4. RAW SKETCHES OF THE PROPOSED SYSTEM

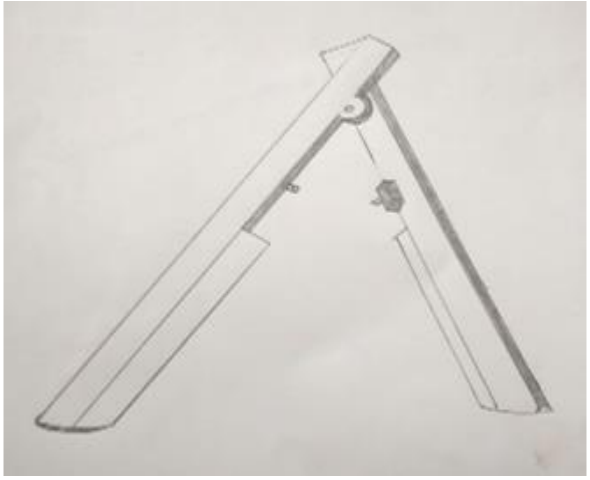
After brainstorming sessions, the following drawings were finalized for the proposed system.

a) Tripod stand

b) Main pipe



c) Cutter



d) Ball & socket joint

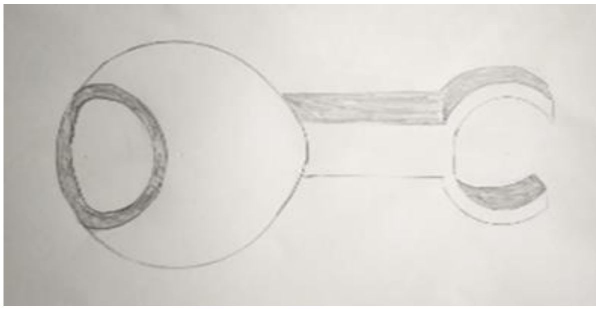


Figure 3: Raw Sketches of the proposed system

5. MODELLING OF THE PROPOSED SYSTEM:

The sketches were then given final shape by creating CAD models of them. 2D and 3D modelling were carried out using SOLID WORKS.

5.1 Assembly/ working principle of the proposed system:

The complete assembly of the proposed apple plucking system has been shown in Fig.4. The assembly comprises a cutter, main pipe, ball, and socket joint, handle with levers, and a basket. This machine can be operated by a single operator. The operator has to hold the handle and operate through levers. On pressing one lever, the cutter will function and the second lever is used to adjust the length of the main pipe. The ball and socket joint has been provided to make the main pipe move in the horizontal planes. The motion of the main pipe in the vertical plane is attained by providing a hinged joint between the main pipe and ball and socket joint. The complete setup is mounted on the tripod stand as shown in the figure. Therefore, the operator has to fix the targeted apple, hold the apple twig within the cutter blades, pressing the cutter and thus relieving the apple of the tree.

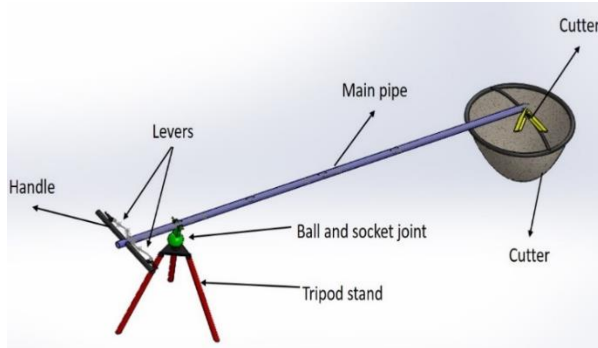


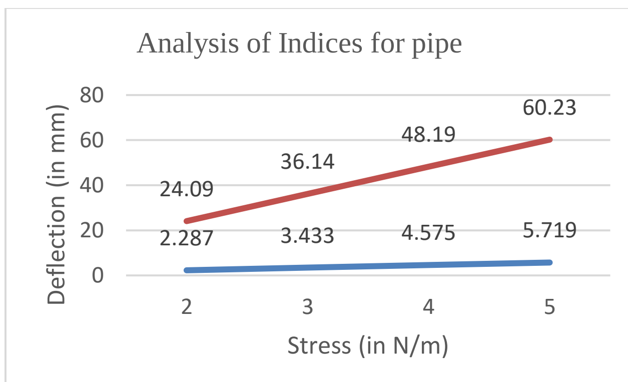
Figure 4: Assembly of the apple harvesting system using SOLID WORKS

5.2 ANALYSIS OF VITAL PERFORMANCE INDICES OF MODELLED COMPONENTS:

The following section gives the detailed analysis of the stress, deformation/deflection, of different components of the proposed apple plucking machine.

Table 3: Analysis of Stress and deflection of pipe with loading

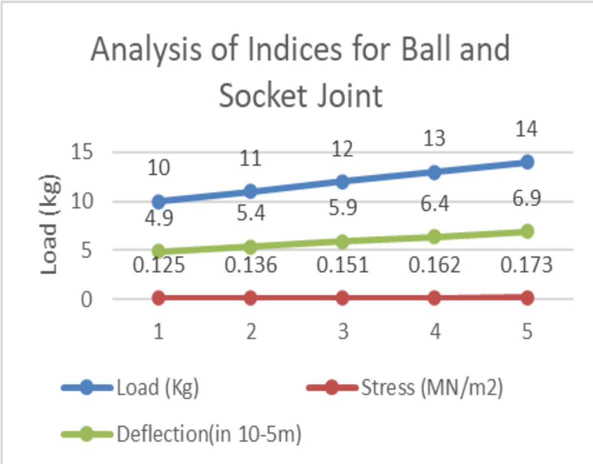
Load (kg)	Stress (in 10^7 n/m^2)	Deflection(mm)
2	2.287	24.09
3	3.433	36.14
4	4.575	48.19
5	5.719	60.23



Graph 3: Graph showing analysis of Stress and deflection of pipe with loading

Table.4 :Analysis of Ball & Socket joint

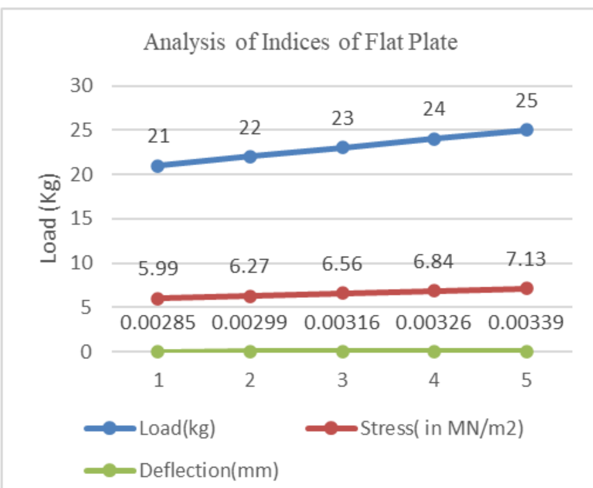
Load (Kg)	Stress (N/m^2)	Deflection(in 10^{-5}m)
10	124299	4.904
11	136729	5.394
12	149159	5.884
13	161589	6.375
14	174019	6.851



Graph 4: Graph showing analysis of Ball & Socket joint

Table 5:Analysis of the flat plate

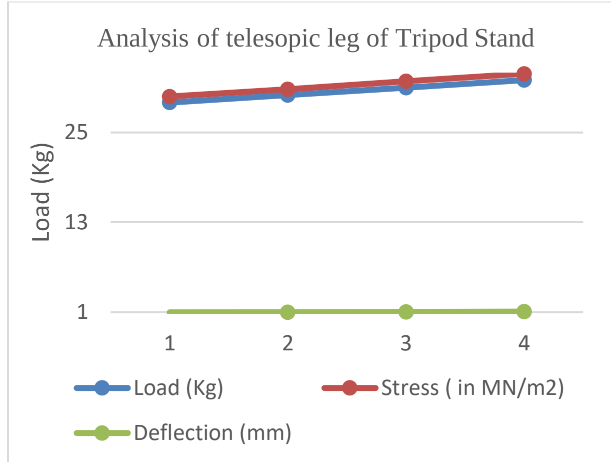
Load(kg)	Stress(in MN/m^2)	Deflection(mm)
21	5.98641	0.00285561
22	6.27135	0.00299159
23	6.55655	0.00312757
24	6.84162	0.00326355
25	7.12668	0.00339953



Graph 5: Graph showing analysis of the flat plate

Table.6 : Analysis of Stress, deflection of telescopic leg of tripod stand

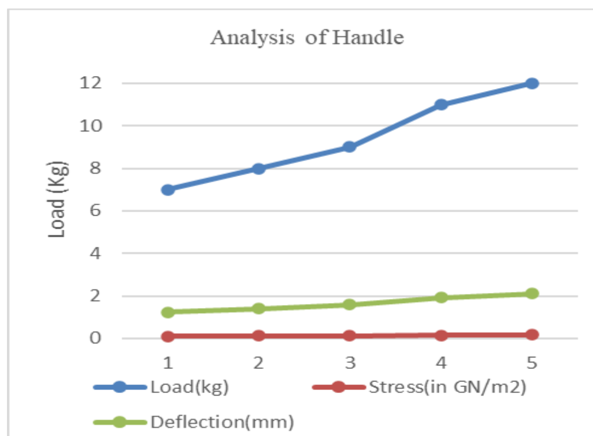
Load (Kg)	Stress(in10MN/m^2)	Deflection (mm)
29	2.9808	0.97052
30	3.0787	1.00399
31	3.1863	1.03746
32	3.2851	1.07091



Graph 7: Graph showing analysis of Stress, deflection of telescopic leg of tripod stand

Table.7: Analysis of Stress, deflection of the Handle

Load(kg)	Stress(in GN/m^2)	Deflection(mm)
7	0.099151	1.23081
8	0.113895	1.40272
9	0.128073	1.57802
11	0.156533	1.92871
12	0.170764	2.10403



Graph 8:Analysis of Stress, deflection of the Handle

From the above tables, it is found that the stress,deflection of the every component so modelled is safe.Thus, the modelled system is suitable for the performing task of apple harvesting .

CONCLUSION

An apple harvesting system has been conceptualised and then framed into a virtual system with CAD software. Following conclusions have been drawn from this study:

- The proposed apple harvesting system is the simplest and the best system as it is cost effective and involves great safety for the workers.
- One individual can operate the plucking, may it be a male or female. The person has to simply operate the device.
- There is no requirement of stairs at all with the proposed mechanism.
- A lot of time and effort is saved as one man will do the plucking while sitting or standing on the ground.
- Right and safe way of plucking is maintained.
- Ergonomic concepts will be maintained so that there is no fatigue to the person.
- No bucket or container is to be carried while plucking.
- The proposed mechanism can be used on any kind of ground, mat it be horizontal or inclined.

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