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Development and testing of pineapple peeling machine suitable for cottage industries

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Abstract
Manually peeling of pineapple is a time consuming and labor intensive process. Pineapple peelers are required for removing the outer skin and inner core of pineapple quickly. Therefore, a hand operated pineapple peeling machine was designed to remove the core which works satisfactorily with easy operation. Twenty numbers of pineapple fruits can easily be peeled by worker in one hour with this designed device. Static simulation of the developed machine was carried out to check the strength of newly designed cutting blade. Peeling time and peeling weight loss of the developed machine was found to be 191 s and 35.5%, respectively.

Keywords: Pineapple peeling machine, peeling time, peeling weight loss, cutting blade

Introduction

Pineapple (*Ananas Comosus*) is a popular non-citrus tropical and subtropical fruit of the Bromeliaceae family. It is popularly known as Ananas all over the India and it has an attractive flavor as well as high nutritive value. Pineapple is a good source of vitamin A and B and fairly rich in vitamin C and minerals like calcium, magnesium, potassium and iron (Singh *et al*., 2013) [9]. With over 0.11 M-ha area, India ranks second just after Nigeria (0.18 M-ha) in terms of area under pineapple cultivation by contributing more than 10 percent of the total pineapple producing area of the world. While, in terms of production India is sixth largest producer of pineapple with a production value of 1.80 MT (Anon., 2021) [1]. Though the production of pineapple is increasing day by day in India, but still there is no such equipment or device in the market for the Indian households, small businesses which can reduce their difficulty of peeling the pineapple. Pineapple processing activities starts with the manual peeling task that is quite repetitive, time taking, laborious in nature and involves drudgery to the workers (Kumawat and Raheman 2022) [4]. In spite of the various peeling related issues, the workers adhere to these traditional peeling methods as they don't find any solution appropriate to their context of use. If the workers are provided with a comfortable and effective peeling aid with the consideration of prevailing conditions of the small processing units, the solution would not only improve occupational health and efficiency of the workers; and productivity of the units but also encourage many other small and marginalized entrepreneurs to get into this business. The purpose of this study was to design and develop a pineapple peeling device for household people of India, which can solve the ergonomics issues for pineapple peeling. The pineapple skin is thick and it is not easy to peel the skin off. Due to that, after one pineapple is peeled, a person will feel the pain around the hand and the upper body including the arms. The pain that a person experienced is called musculoskeletal disorders (MSD). Due to these reasons, the development of Portable Pineapple Peeling Machine is very much needed. The pineapple peeling machine (PPM) peels the pineapple to form a cylindrical shape pulp of pineapple. Pineapple pulp is the inner content of the pineapple between outer skin and core. The outer skin of pineapple is naturally hard and thick to cut. Pineapple core is the innermost portion or the central part of the pineapple. The core of pineapple is hard structure and tough. The PPM will peel the whole outer skin of pineapple and at the same time the core of the pineapple also will be removed. Pineapple pulp is used to produce juice, flavor, pineapple cocktail, pineapple jam and canned pineapple pulp. Raub and Breton (1989) [8] patented a pineapple peeler where it was claimed as semiautomatic pineapple peeler in which adjustable width knife blades sever the ends of the pineapple and concentric cylindrical knives core and peel it, leaving the detached core in the peeled pineapple.

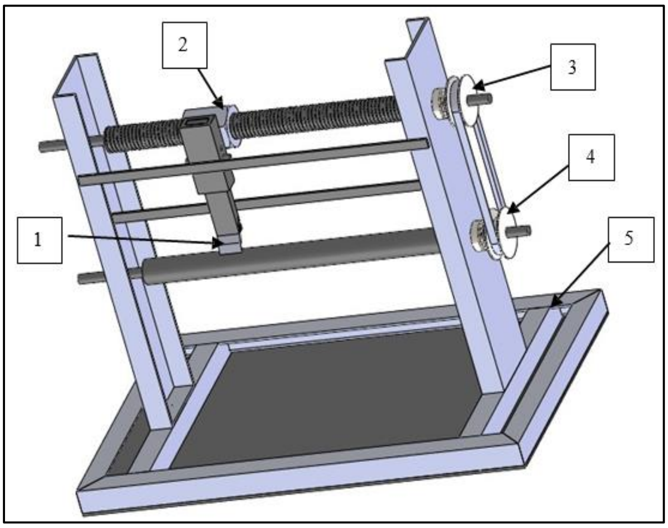
The one step process was driven by two D.C. electric linear ball screw actuators, sequenced by an integrated circuit logic board and magnetic proximity limit switch arrangement. The peel was split in half by two radially mounted fins on the top and bottom of the large cylindrical knife, allowing the waste to be collected below. Mohamad (2010) [7] designed a portable pineapple peeler using ergonomics approach in order to avoid or minimize the risk of developing Musculoskeletal Disorders (MSD) among workers in pineapple industry. Some of physical activity risk factors related to MSD were application of force, repetitive movement and awkward posture. Mazlan (2011) [6] developed automatic pineapple peeler machine using PLC. The machine was designed for use in the small and medium scale industries. It was used to control the whole operation in the Pineapple Peeler Machine and was connected with a motor to run the machine. The machine was equipped with a sensor for the safety. The PLC was programmed with Ladder Builder software to carry out the ladder diagram programming. Singh *et al*. (2013) [9] developed a pineapple peeler-cum-slicer with slicing plate of diameter 7 cm and core diameter of 2.5 cm. It removes the core and produces pineapple rings of uniform thickness & diameter in a single motion. This is a hand operated peeler cum slicer which works satisfactorily with easy operation.

Hence, a study was undertaken to design and develop a pineapple peeling machine which is suitable for cottage industries. This will help small scale cottage industries to increase the pulp recovery and to increase their profit margin. The proposed system aims at peeling at a constant depth from the surface of the fruit and should be economically affordable for rural household and small business purpose. A cutter with depth controlling system and drive system will be used for the purpose.

Material and method

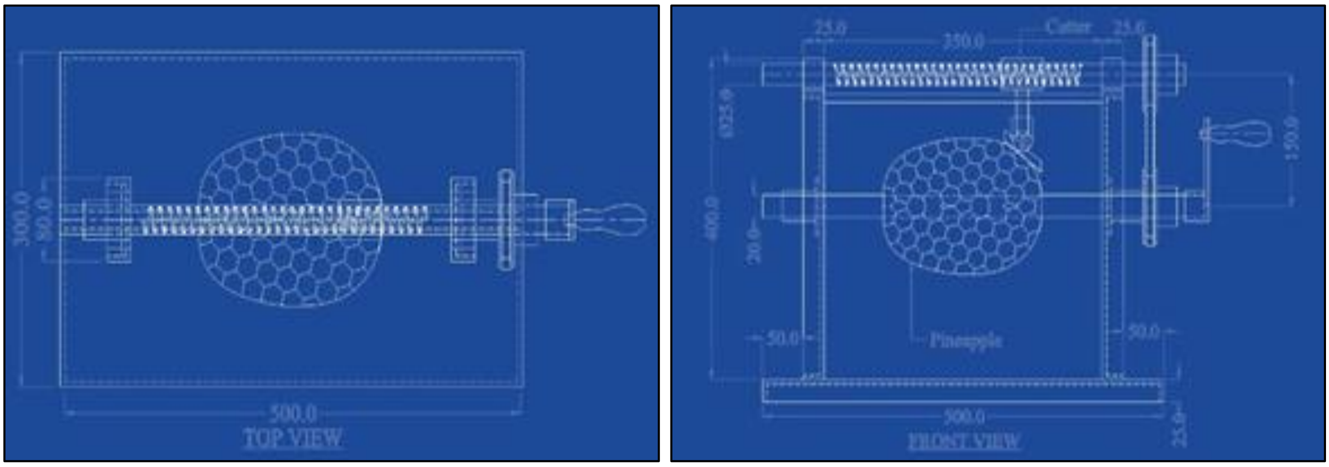
3D Model of Pineapple Peeling Machine (PPM)

A 3D-CAD view of the proposed model of the pineapple peeling machine was made using SolidWorks-2015. Isometric view of the proposed model of the PPM is shown in Fig. 1. The drawings of the CAD view of PPM is illustrated in Fig. 2 (a, and b).



1. Cutting blade; 2. Cutter moving assembly; 3. Driven pulley; 4. Driving Pulley, 5. Base

Fig 1: Isometric view of the proposed model of the pineapple peeling machine



(a) Top view (b) Front view

Fig 2: CAD Drawings of the PPM with relevant dimensions

Cutting unit

A cutting unit consisted of a cutting blade and holder. A stainless steel rectangular cutting blade with sharp cutting edge was designed to remove the skin of the pineapple. A cutting blade was inserted in the holder for proper movement of the cutter.

Cutter Moving Assembly

A spiral thread shaft having 6 threads per inch was used to move the cutting unit forward and backward to cover entire surface of the pineapple.

Power Transmission System

A belt and pulley arrangement was made to transfer power from driving pulley to the driven pulley. A driving pulley was rotated using handle by manual power. 50 mm B type pulleys were used for both driving and driven pulley.

Base Frame

A Mild steel frame was designed to hold the entire assembly of the proposed model of the PPM

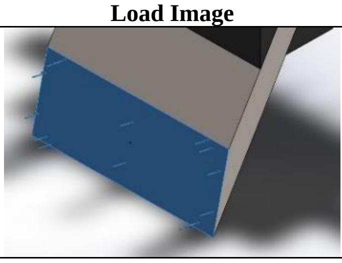
Static Simulation of PPM

Static simulation using Soild Works 2015 software was carried out to check the strength of the proposed cutter used for peeling the pineapple in terms of the stress and strain. A 50 kPa pressure was applied perpendicular to the blade surface. Assumptions, applied forces and boundary conditions taken during simulation study are given in Table 1 and Table 2.

Table1: Properties of the material used for the cutting blade

Name	Annealed Stainless Steel (SS)
Yield strength, N/m2	2.92 × 108
Tensile strength, N/m2	6.85 × 108
Elastic modulus, N/m2	2.07 × 1011
Poisson's ratio	0.27
Mass density, kg/m3	7860
Thermal expansion coefficient, /Kelvin	1.7× 10-5

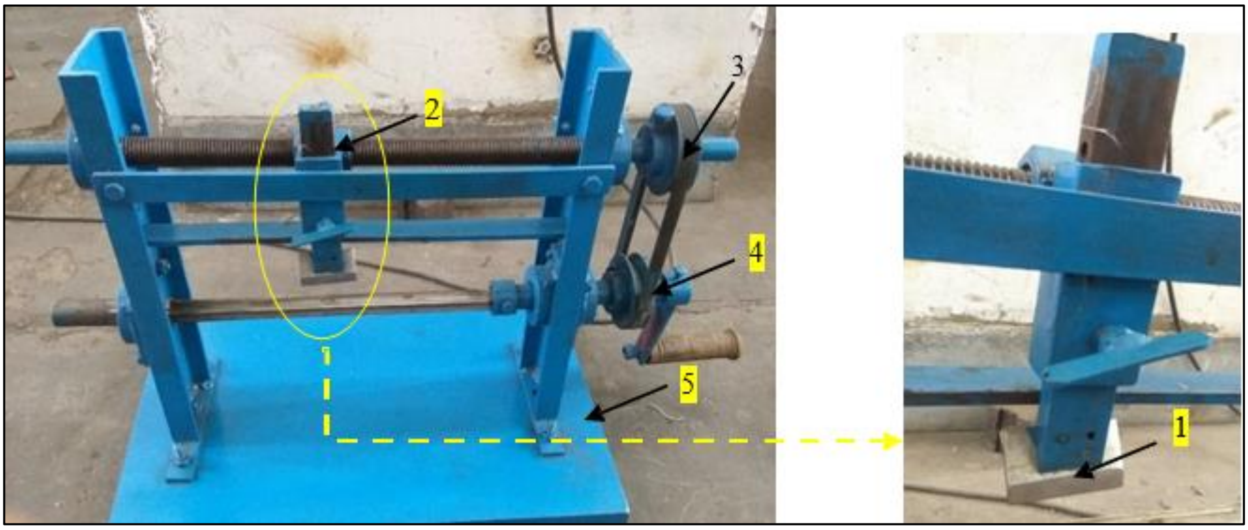
Table 2: Boundary conditions applied for the simulation study

Load name	Load Image	Load Details
Pressure-1		Entities: 1 face(s) Type: Normal to selected face Value: 50000 Units: N/m2 Phase Angle: 0 Units: degree

Results and Discussion

Development of PPM

The proposed model of the PPM was fabricated in the workshop of Agricultural and Food Engineering Department, IIT Kharagpur, India. The isometric view of the developed PPM with nomenclature is shown in Fig 3.



1. Cutting blade; 2. Cutter moving assembly; 3. Driven pulley; 4. Driving Pulley, 5. Base

Fig 3: The isometric view of the developed ppm with cutting unit

Simulation Study of the PPM

The results obtained after simulating the CAD model of the proposed model showed that maximum stress coming over the system was 3.76 Mpa and minimum stress was 156.42 Pa as shown in Fig. 4 and maximum displacement under the load was 0.013 mm as shown in Fig. 5. The Annealed Stainless Steel (SS) was chosen as material for the cutting blade. The minimum yield strength of Annealed Stainless Steel was found to be more than 292 MPa. It indicates that the model can survived that much load. A maximum strain of 2.67 × 10-5 was observed over the blade.

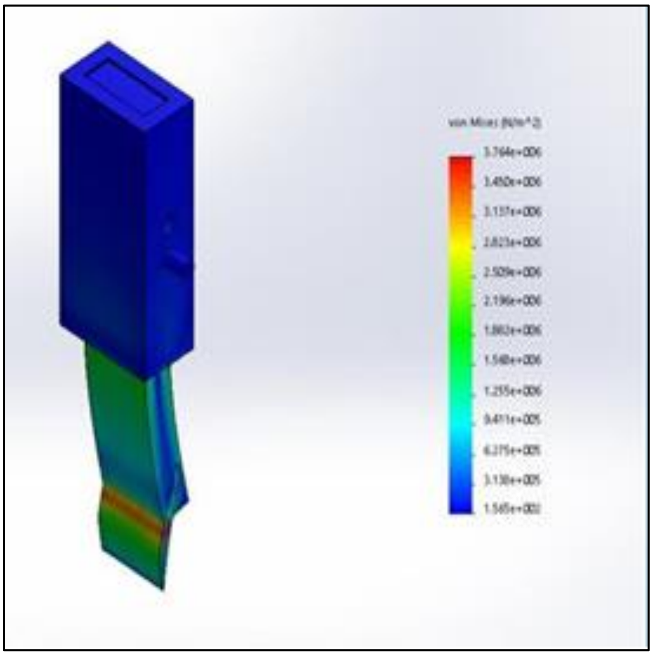


Fig 4: A plot of stress analysis

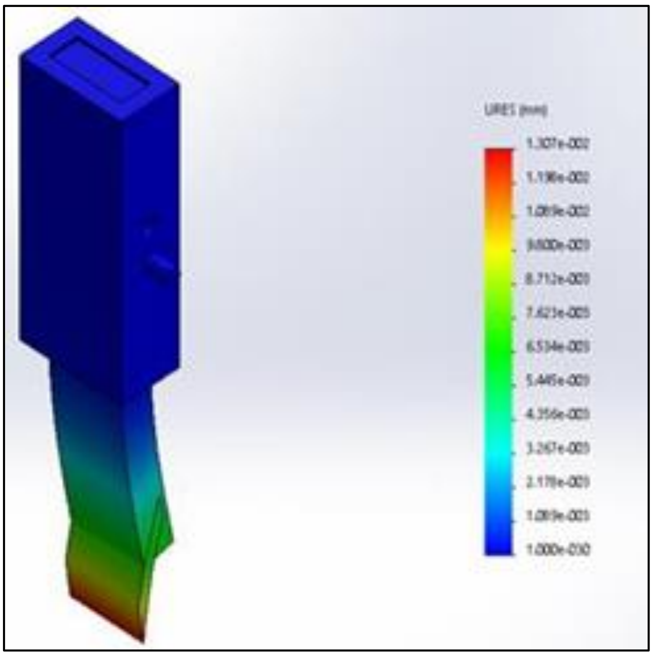


Fig 5: A plot of displacement analysis

Testing of the Developed PPM

The developed PPM was tested in the Research Farm of Agricultural and Food Engineering Department, IIT Kharagpur, India. Before testing of the PPM, pineapples were chopped off from both the ends by hand using knife. Afterwards, the core of pineapple was removed using a hollow stainless steel pipe of 10 mm diameter and later shaft was inserted across the pineapple for mounting it to the developed PPM. After fixing the pineapple in the PPM, cutting unit was set to the upper surface of the pineapple. The handle was used to turn the pineapple, and the cutting unit started to move ahead and peel the skin of pineapple at the same time. The depth of peeling was adjusted through adjustable system by which blade could be lifted or lowered according to the diameter and shape of the pineapple. At last, remaining inner core was removed using 25 mm hollow stainless steel pipe. This procedure was employed for all the pineapples. A random picture during the testing of PPM and peeled pineapple is presented in Fig. 6 and 7.

Fig 6: A view of the developed PPM during testing

Fig 7: A sample picture of the peeled pineapple

Performance Evaluation of the Developed PPM

Performance evaluation of the developed PPM was carried out in terms of percentage loss in weight of peel by machine and peeling time as compared to by hand. Ten random pineapple samples were chosen. Weight of pineapple and peel was measured using digital weighing machine whereas stopwatch used to measure peeling time. Performance parameters such as weight loss of peel and peeling time are given in Table 3 and Table 4.

Table 3: Percentage weight loss of peel by machine vs hand

Sample	By Hand			By Machine		
	Pineapple weight (kg)	Peel weight (kg)	Loss (%)	Pineapple weight (kg)	Peel weight (kg)	Loss (%)
1	1.068	0.461	43.16	1.179	0.432	36.64
2	1.357	0.612	45.10	1.493	0.537	35.96
3	1.560	0.724	46.41	1.729	0.562	32.50
4	1.754	0.803	45.78	1.814	0.605	33.35
5	1.823	0.859	47.12	1.906	0.711	37.30
		Avg.	45.51		Avg.	35.15

Table 4: Percentage loss in peeling time by machine vs hand

	By Hand		By Machine	
Sample	Pineapple weight (kg)	Peeling time (s)	Pineapple weight (kg)	Peeling time (s)
1	1.068	183	1.179	182
2	1.357	184	1.493	185
3	1.56	190	1.729	192
4	1.754	197	1.814	196
5	1.823	202	1.906	200
	Avg.	191.2	Avg.	191

From Table x it can be seen that loss in peel weight by machine and by hand was found to be 35.15% and 45.51%, respectively. Percentage loss in peel weight was observed less using machine than by hand. However, from Table y it can be observed that peeling time was found to be approximately same in both the cases.

Conclusion

A PPM was successfully developed and tested for few samples of pineapple to measure the % weight loss of peel and peeling time. It could satisfactory peel a pineapple on an average in 191s. The weight loss through peel was found to be reduced by 10.36% using the developed PPM than by manual peeling.

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