A NEW PROTOTYPE OF A PINEAPPLE PEELING MACHINE

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ABSTRACT

Processing of pineapples in third word countries is either done manually or by using mechanized systems. In both cases, the volumetric efficiency has been low due to the relatively high level of wasted flesh. In an attempt to improve the volumetric efficiency, a new prototype of pineapple peeling machine has been developed. The paper presents the design concepts of the machine and the subsequent test results of the prototype. The novel approach in the peeling process employs two toothed cutters fixed perpendicular to each other, with the chip in form of a continuous ribbon. The forces applied on the pineapple by the machine are therefore mininum, hence the deformation. The shape of the chip together with the small forces imparted on to the fruit by the machine lead to an improved volumetric efficiency.

INTRODUCTION

It is well known that third world countries produce a variety of seasonal fruits [1]. In most cases, the fruits are sold in the local market while in some countries they (fresh fruits) are processed and exported. Fruit processing and storage is therefore not very common, as is the case in developed countries. The main problem has been the technology employed, particularly when the volumetric output is considered. Furthermore, the different types of fruits may require different processing machines [2].

The discussion in this paper dwells on the peeling of a pineapple; a fruit mainly found in tropical areas. While there are a number of pineapple processing plants in developing countries, the yield of processed products has been low. The latter has been caused by the general inefficiency in the processing which has, in most places, been done manually. Where mechanized systems have been used, the volumetric efficiency has been low because much of the flesh is wasted. Pineapples have been processed and stored, either in form of juice or in slices. Like other foodstuffs, pineapple products are normally canned and stored.

An analysis of the pineapple processing has shown that a major contributing factor to the volumetric efficiency has been the peeling process. With manual peeling, the time spent is very high while the level of quality control is low, thus raising the opportunity costs. With some of the mechanized systems, the volumetric efficiency has been very low, hence affecting the input-output relationship.

In an attempt to improve the volumetric efficiency, a peeling machine has been developed with the following operations [2]

i) cut both ends to remove the stalk and the flower

ii) remove the central core

iii) subject the pineapple to an axial movement against a rotating cylindrical cutter, with an output product of a shell.

In terms of output per unit time, the machine has a fairly good performance. However, the system has low volumetric efficiency due to the relatively high level of wasted flesh. The latter has been caused by the inability of the system to peel in conformity with the geometrical profile (or structure) of the fruit. Furthermore, the design of the machine is such that the fruit is subjected to high compressive forces (stresses) which squeezes the (non recoverable) juice out of the flesh.

In the following, a novel approach in the development of a pineapple peeling machine is presented. The objective is to develop a machine which has a fast peeling process, with minimal volumetric losses of the flesh and less contamination.

STUDY OF THE PINEAPPLE AND DESIGN PARAMETERS

Physical and Geometrical Properties of Pineapples

A statistical study of pineapples grown in Tanzania was carried out. The objective of the study was to establish the physical and geometrical properties of pineapples. The results of the analysis are necessary for the establishment of design parameters. In the statistical study, a random sample of 33 pineapples was used. The geometrical parameters analyzed include the height (or length) L, the with W, the core, etc. A sketch of the pineapple and the results of the statistical analysis is shown in the appendix. Further to the analysis, the following observations can be made [3].

i) Inevitably the size varies in terms of length and diameter. Pineapples were observed to have an elliptical shape and the diametral dimension varied in function of the length, with the central axis as a frame of reference.

ii) Pineapple eyes (see appendix) were observed to follow helical patterns with separating ridges of about 20 to 30 mm.

iii) The depth of the eyes was about one third of the radius measured from the central axis.

iv) The core of the pineapple which is along the central axis has a diameter of between 20 to 30 mm.

v) The level of maturity was observed to vary with species.

vi) The surface layer (or skin) was observed to be relatively harder than the flesh.

Design, Manufacture and Testing

The main objective of designing a peeling machine was to minimize losses in the flesh. From the physical and geometrical characteristics, it appears that the eyes, together with the surface layer may be removed without much effect on the flesh. The major design concepts of the machine will therefore aim at synchronizing the helical pattern of the eyes, the hardness characteristics of the core and that of the surface layer.

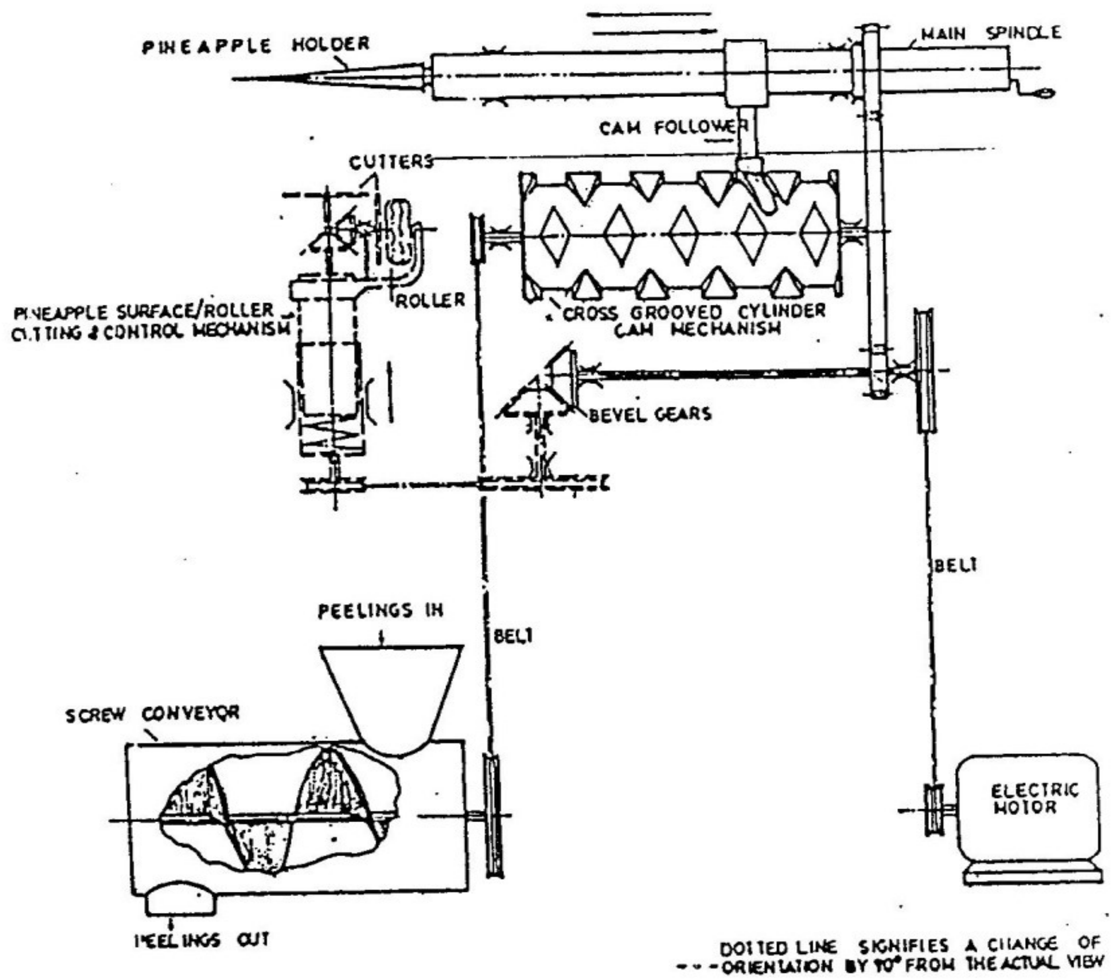

Fig. 1 A schematic diagram of the pineapple peeling machine

After analyzing a number of possible mechanisms for pineapple peeling, it was proposed to subject the pineapple to rotational motion concurrently with the feed motion against the cutter. While rotating, the pineapple is held through the core; hence rotating about an axis through the core. In order to ensure a uniform depth of cut, and in conformity with the structure of the pineapple, the surface of the pineapple was conceptualized to have similar functions as those of a cam; hence provide built-in control mechanism as shown in Figures 1 and 2. Further, toothed disc cutters are subjected to rotational motion with a sensing unit built-in to retract the cutter at a desired depth of cut. At the same time, when the product requirements include removal of the eyes during the early stages of pealing, the helical pattern characteristics may be exploited. The control unit may be designed such that deeper cuts are taken on eye regions.

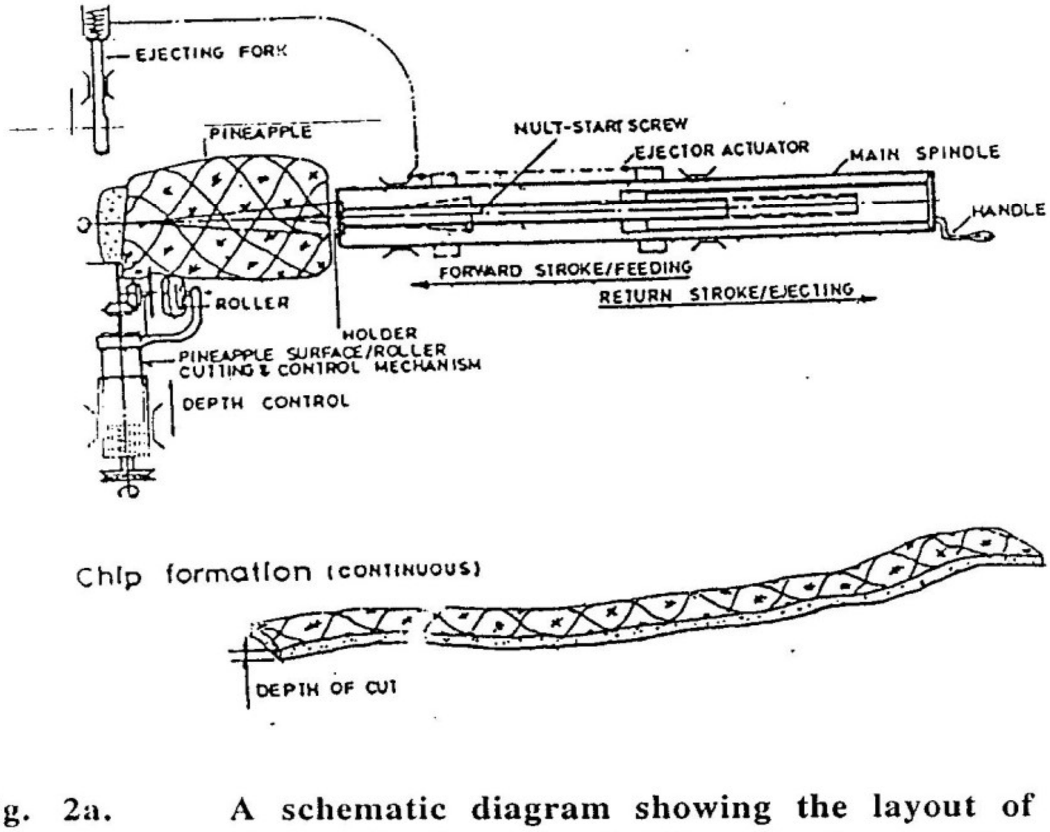

Fig. 2a. A schematic diagram showing the layout of the mechanisms for holding, feeding, cutting and ejection.

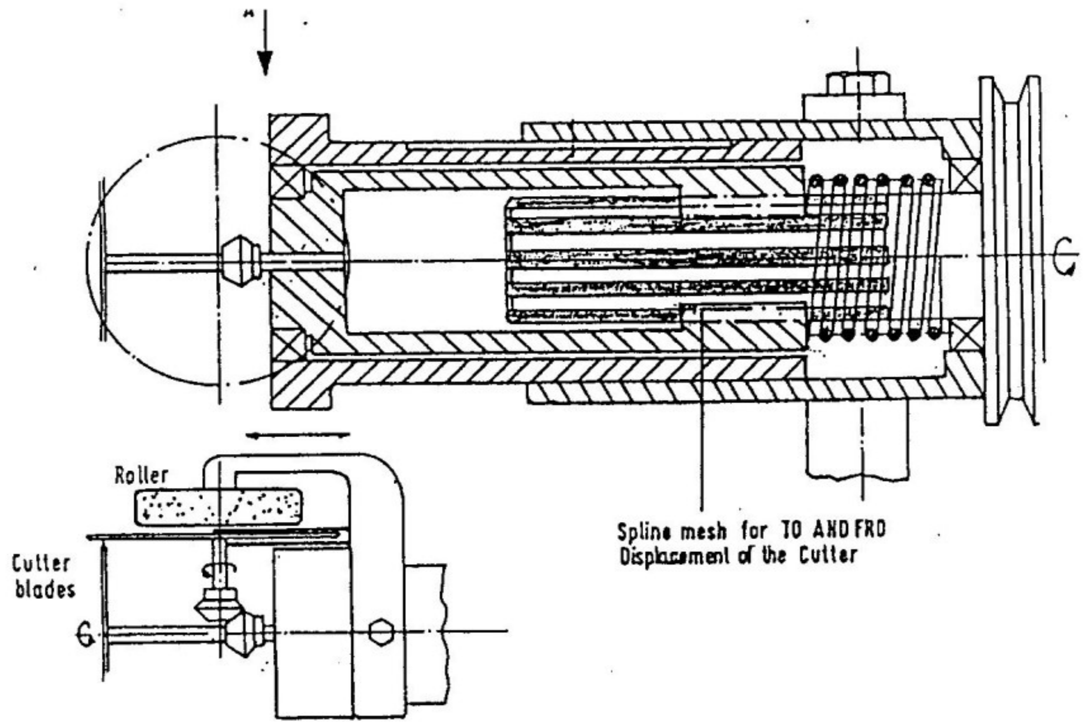

Fig. 2b. An assembly drawing for the cutter unit, showing the spline mesh for to and fro displacement of the cutter.

During the design process of the machine, emphasis was given to strength calculations of the members under dynamic loading. Detailed standard calculations can be found elsewhere[3]. The required cutting forces were found to be small (about 10N). Hence stability criterion analysis was used to determine the overall sizing of the system [4,5].

Figure 1 shows a schematic diagram of the pineapple peeling machine. The concepts of holding the pineapple during peeling, feeding, cutting and ejection are illustrated in Figures 2a and 2b. Figures 3 and 4 show the front and side views respectively of the pineapple peeling machine. The isometric view of the machine is shown in Figure 5.

Table 1 shows the main components of the machine. Detailed engineering drawings for the components are presented elsewhere [3].

A prototype of the machine was subsequently manufactured and tested. Based on calculated power requirements [3], a variable speed motor (up to 2000 rpm) of 2kW was used. An experiment to determine the speed-time response of the peeling mechanism was carried out. The time for feed and return motion was about 12 seconds at 329 RPM. Hence the peeling process for an average pineapple took about six seconds. Since the design is based on the concept of high cutting speed at low torque, the time lapse during shearing (peeling) using toothed cutters is therefore very low. The peeling speed was considered to be relatively fast compared to the respective time taken by available machines. The vibrations of the machine during the peeling process were observed to be minimal.

Table 1: Main components and size of the pineapple peeling machine

No.	NAME OF COMPONENT	WEIGHT(KG)	MATERIAL	DIMENSION(mm)
1	Frame	35	Mild steel	Height 850 Width 430 Length 1000
2	Main spindle	5	Mild steel	60mm dia x 620
3	Drum cam	20	Mild steel	120mm dia x 210
4	Cutter unit (assembly)		Mild steel & stainless steel	Overall; Height 180 Width 180 Length 200
5	Cutter blade	0.03	Stainless steel	40mm dia 3mm thick
6	Centering unit		Mild steel	Height 390 Width 150 Length 100
7	Piercing tool		Stainless steel	30 x 30 x 150
8	Peeler collector	4	Stainless steel	40 x 540 x 720
9	Screw conveyor	15	Galvanized steel	Duct size; 180mm dia x 430 Height 280 Width 180 Length 430
10	Motor			2 Kw
11	WHOLE MACHINE	126 kg		HEIGHT 1260 WIDTH 600 LENGTH 1200

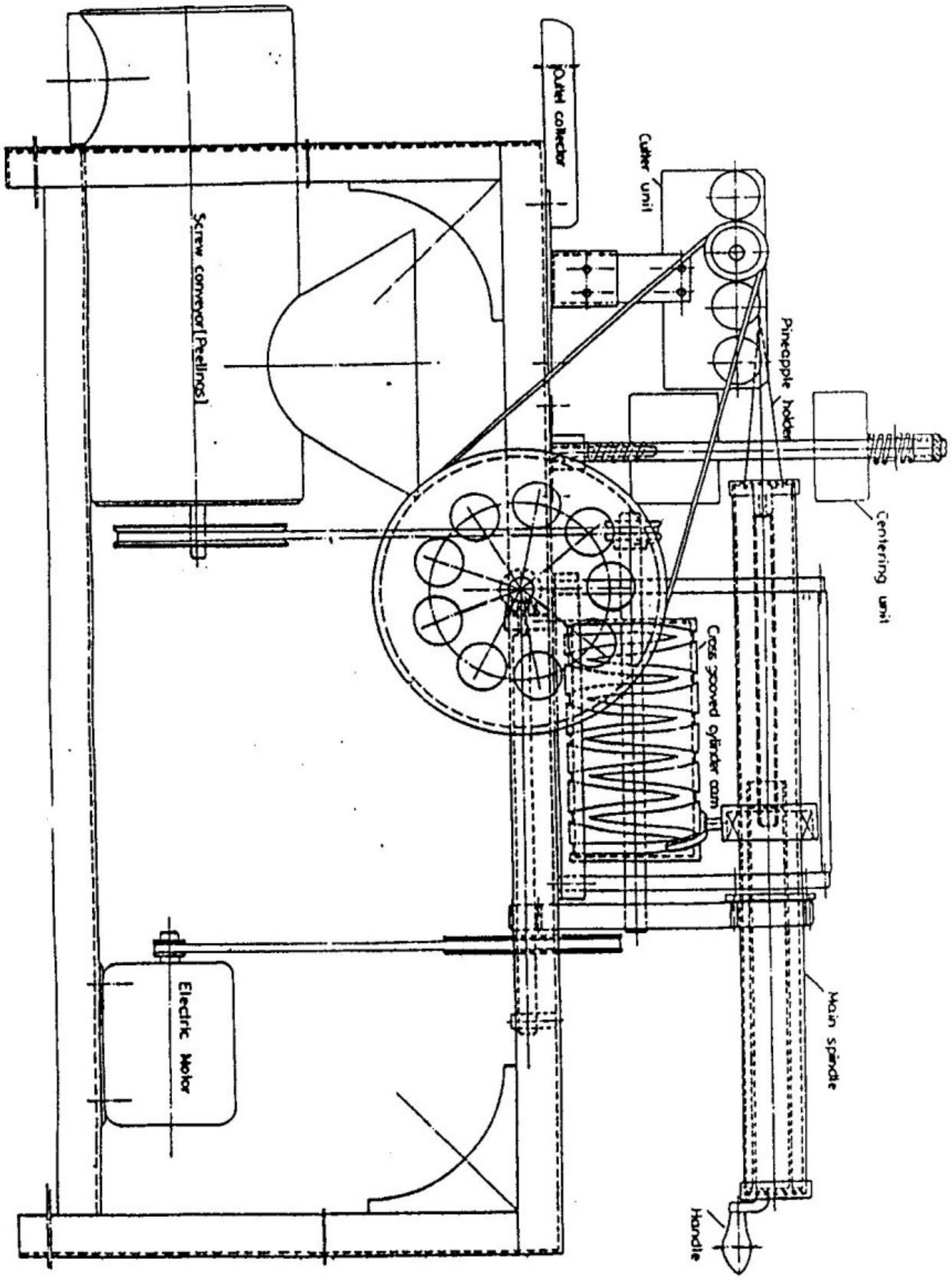

Figure 3 Front view of the assembled pineapple peeling machine.

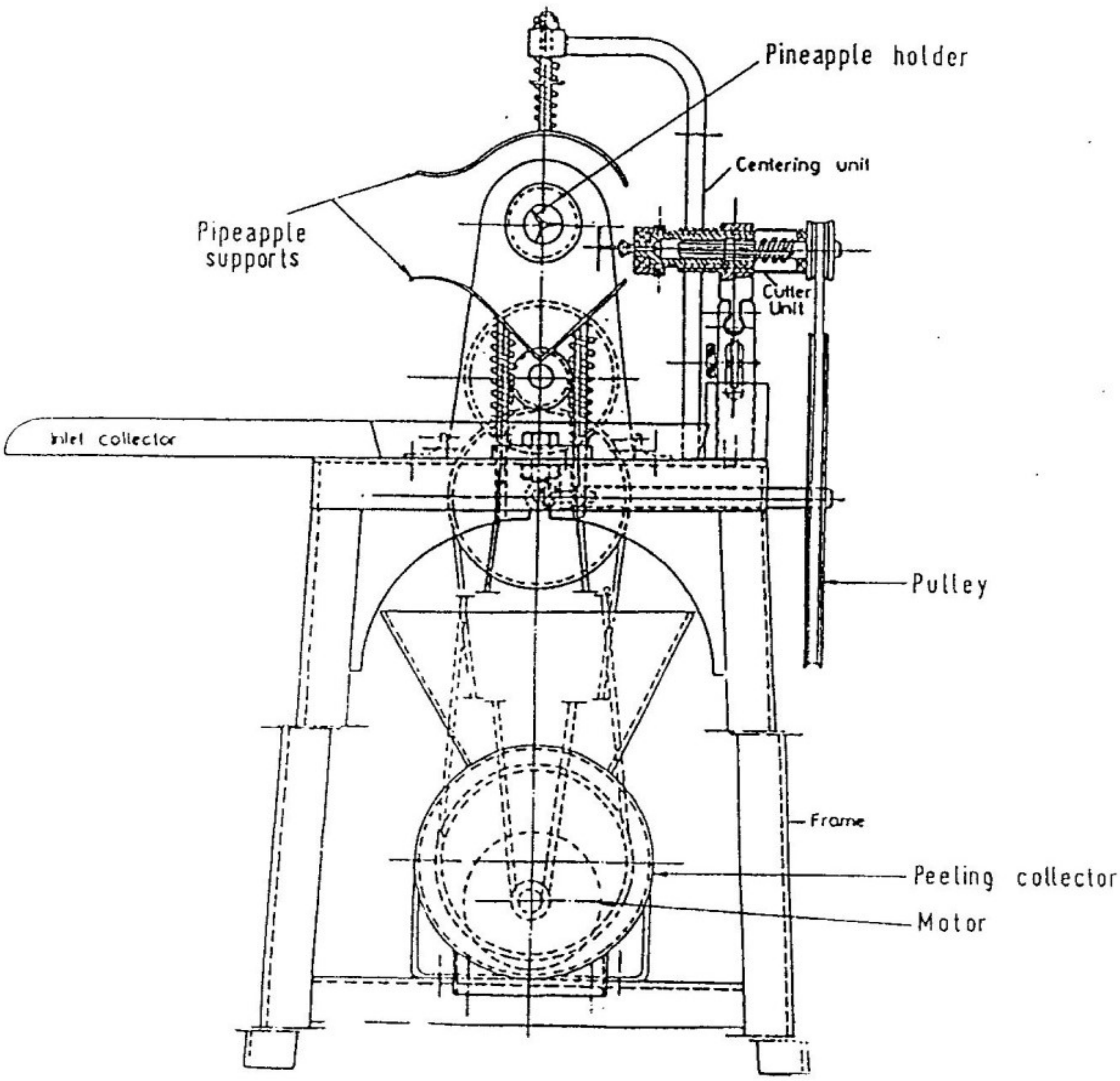

Figure 4 Side view of the assembled pineapple peeling machine, showing major components of the machine.

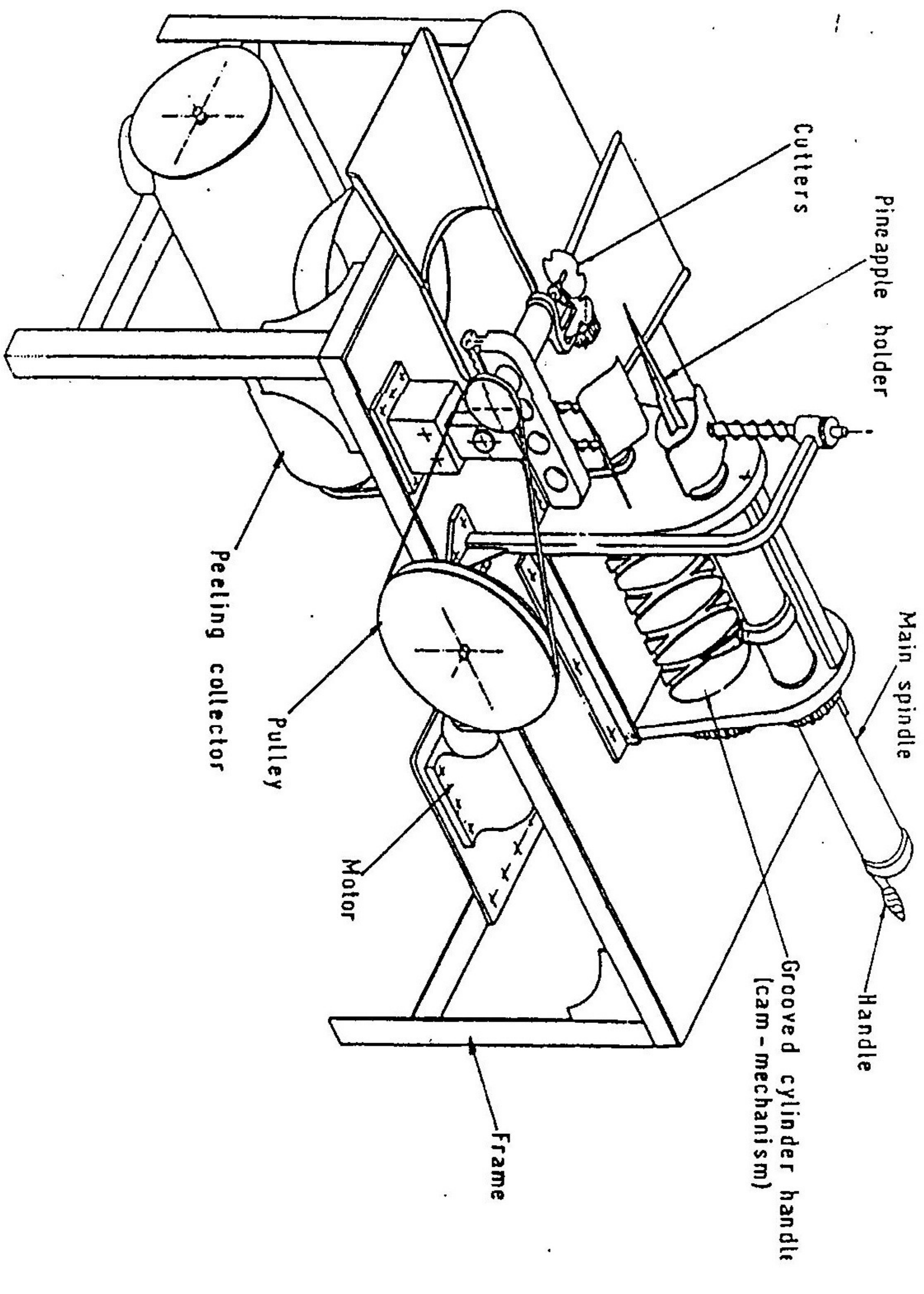

Figure 5 **An isometric view of the pineapple peeling machine, showing major components of the machine.**

Experiments were also carried out to determine the performance of the machine at various speeds and the optimal combination of cutters. Testing was done such that speeds were varied from low to high, while the cutters were changed from round shaped ones to toothed ones, both with different sizes. The optimal combination was established. With rotational speed above 400 rpm, and in the application of multiple cutters, the process proved to be ideal.

RESULTS AND DISCUSSION

After going through with manufacturing of most useful components, the machine was taken for experimental tests. The sole objective being to measure the level of effectiveness of the machine and the extent of closeness with what has been aimed before. Following are the results of the experiments.

i) When tested under no load condition; the control unit mechanism responded precisely. The cycle time was measured as 12 seconds.

ii) For a particular arrangement of cutters, it was observed that if two cutters are fixed perpendicular to each other, the chip came out in a form of a continuous ribbon. As from this result, unwanted forces from the machine which would have in a way deformed the pineapple have been minimized.

iii) The continuity of the chip and the application of multiple cutters has also made the increase of peeling speed possible.

iv) The product was peeled in accordance to the profile of the fruit and thus making a sound volumetric efficiency.

v) Owing to the small forces imparted into the fruit, fluid oozing out from the flesh has been minimal, again a positive effect toward volumetric efficiency.

vi) The machine has the capacity of peeling 40 to 60 pineapples per hour.

FLOW PROCESS

Figure 6 shows a flow chart of the peeling process. In the following, a brief description of each process is presented.

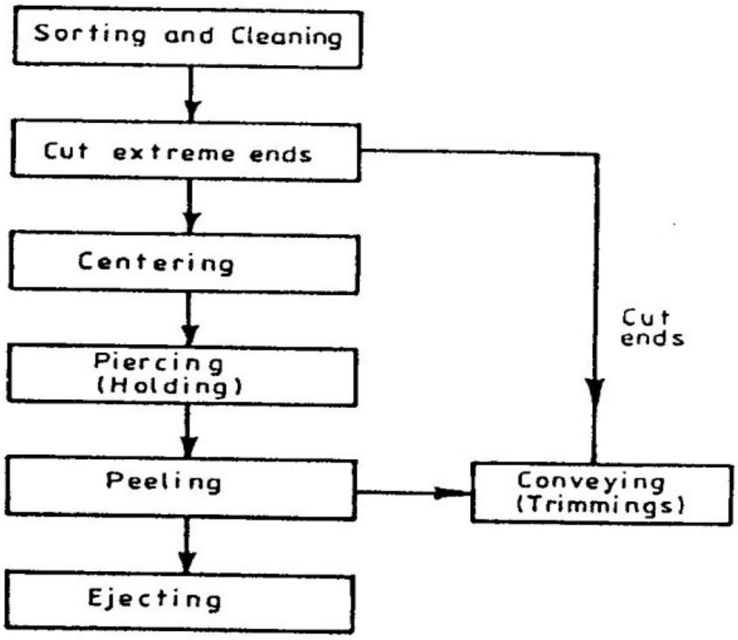

Fig. 6 Processing flow chart.

i) Sorting and cleaning

Harvested pineapples are initially sorted out in order to remove those whose pattern and geometrical properties do not match with the design parameters. For example, pineapples having irregular shape which is outside the control settings. Furthermore, the pineapples are graded according to size ranges and maturity level. The latter allows for peeling in batches, each with a specific control setting. After sorting, the fruits are cleaned to remove any dirt that might have accumulated during the harvesting and transport.

ii) Loading

Pineapples of a specific batch are loaded or lined up in a channel prior to subsequent processes.

iii) Cut extreme ends

Before peeling, the extreme ends of the pineapples are removed. Removal of extreme ends allows for the fruit to be held in place while peeling.

iv) Centering

The centering of the pineapple while peeling has a vital role as it reduces centrifugal forces. Eccentricity (or rotating off centre) may also affect cutter control with the use of springs. Centrifugal forces cause changes in radial displacement of the springs. This change may distort the spring response and in some cases the resulting vibrations may lead to resonance.

In the current design, centering is achieved by the use of top and bottom springs; with pre-determined pre-compression.

v) Holding

The holding process is achieved by employing a spear like device which is pierced into the central portion on the core. This process follows the centering process as explained above.

vi) Peeling

In the peeling process the pineapple is subjected to two degrees of freedom motion namely; axial displacement and rotation, as illustrated in Figures 1 and 2. With the axial displacement, the pineapple allows for longitudinal feeding against the cutter. Further, the rotational motion of the fruit provides for the circumferential feeding against the cutter. The rotational motion of the cutter along the radial axis executes the shearing action whereas the radial displacements (to and fro) determines the depth of cut at each point along the axis of the pineapple, defined by the surface profile. In addition, the machine has two provisions to peel the pineapples. The first set-up allows for peeling without removing the eyes while the second allows for the eyes to be removed.

vii) Ejection

The ejection of the fruit from the holder is done automatically, during the return stroke of the spindle (Fig.2).

viii) Removal of Trimmings

In the final stage of the operation, the trimmings are removed through a screw conveyor to the bi-product section.

CONCLUSIONS AND RECOMMENDATIONS

A new prototype of a pineapple peeling machine has been designed, manufactured and tested. The test results show that the prototype has a peeling rate which is relatively fast compared to existing models. Furthermore, the prototype has improved volumetric efficiency due to small cutting forces.

Based on the tests, it is evident that the prototype requires further modifications. For example, the peeling process can be improved by replacing the spring controlled cutter control by a hydraulic or pneumatic unit. The latter would be particularly suitable for design of a mass production unit.

The operation of the prototype machine is currently being studied for further modifications before being considered for commercialization. The proposed modifications and the final prototype shall be reported in a subsequent publication by the authors.

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Appendix: Study of the Pineapple

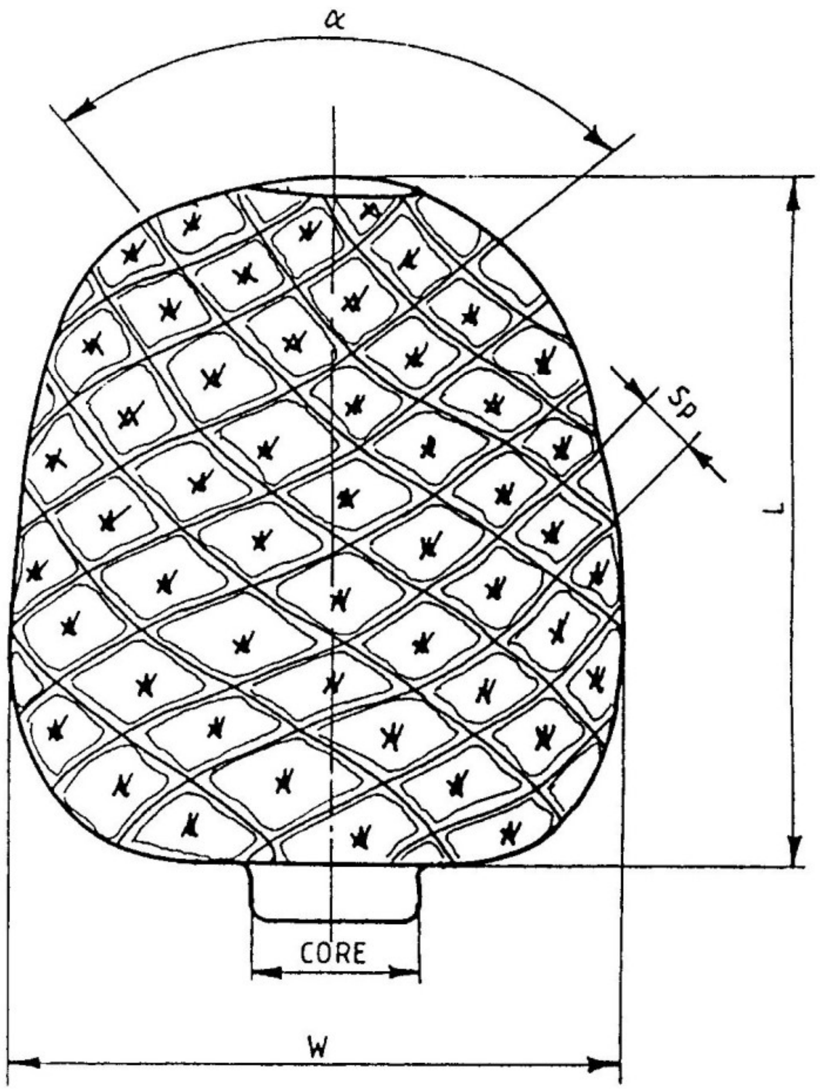

Table A1. Main Dimensions of the Samples

Sample	L	W (mm)	Sp (mm)	α(deg.)	Loops	Core (mm)
1	140	120	25	100	8	25
2	160	100	22	95		20
3	180	120	26	98		30
4	150	100	20	95		30
5	144	110	24	95		20
6	160	120	20	102		20
7	170	130	25	96		25
8	166	100	25	95		30
9	142	100	22	95		28
10	150	110	22	98		20
11	150	120	24	98		20
12	152	95	22	95		20
13	160	100	25	102		25
14	152	120	25	100		24
15	140	120	25	95		20
16	138	110	24	95		20
17	180	130	28	102		30
18	138	100	25	100		25
19	136	110	25	100		20
20	170	120	28	90		28
21	168	120	26	95		30
22	164	125	25	95		25
23	144	110	25	100		25
24	160	120	26	100		30
25	162	110	26	95		31
26	182	135	28	96		28
27	190	140	27	100		36
28	140	100	22	100		25
29	132	100	20	102		20
30	150	110	20	95		20
31	148	100	25	100		25
32	150	90	25	98		24
33	150	95	25	100		25
Σ	5,118	3,690	802	3,222		819

Table A2. Statistical Analysis

	MEAN	SAMPLE STD σ_{n-1}
L	155	15.00
W	112	12.60
Sp	24.3	2.28
x	98	2.96
CORE	25	4.3