Development of Manually Operated Orange Peeling Device for Domestic Use

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Abstract
Orange a very rich source of vitamin C is a perishable fruit that can only be stored unpreserved for few days before its biological degeneration. When processed to juice, the chemical preservatives that are usually added coupled with the contaminations by its back skin fluid instantly change its natural flavor. This has made many consumers to still prefer freshly peeled fruit to its processed juice. As a solution to laborious hand peeling process that is highly prone to injury due to the sharp tools used several devices have been developed for its peeling. Each of these has its own technical, economic and other shortcomings. This work designed and fabricated a manual orange peeling device with a capability of processing oranges for a domestic family household. The device incorporated a rotary handle through which power was introduced into the system, power screw, spur gear train mounted on a base and cutting blade that performed the peeling function. The fabricated device was operated and assessed to have a peeling efficiency of 97%, generated 2.6% over peeled and damaged oranges and a capacity to peel about 140 oranges per hour as compared to hand peeling that can produce 32 peeled oranges per hour. It is robust, simple to operate and maintain, had good aesthetics and light weight of 619g due to transparent light but strong plastics used to construct the frame and base.
Keywords: Orange, peeling, device, household, juice.

1.0 INTRODUCTION

An orange is a type of citrus fruit that is eaten by all races of people all over the world. Oranges are round/oval shaped coloured thick back covered fruits that are borne on trees of 1-10meters high initially originating from Asia and now grown in virtually all parts of the world. The inside of orange is divided into segmented lobes with seeds called pips; all bounded by tough shiny back covering skin. The outer covering skin and inside segments are separated by white stringy stuff called pitch. In most types of oranges, the back skin can be peeled off the pitch and the segments pulled apart with human finger. For instance, with mandarin orange species, the skin, pitch and segments can easily be pulled apart. In some other types this manual separation of orange back skin called orange peel, pitch and segments is not readily possible. The fruit of citrus sinensis, called sweet orange to distinguish it from citrus aurantium, bitter orange is the species of orange mostly consumed today because of its good source of many vitamins especially vitamin C, which is one of the essential minerals needed for good human health (www.abecitrus.com:Br/process.html).

Orange trees are widely cultivated in tropical and sub-tropical climates of the world where they are reported to grow well and yield fruits abundantly for commercial and industrial purposes, such that over 68.5 million tones of oranges were reportedly produced in Brazil, United States of America in 2008 (www.ehow.com, 2013). Orange is used in many industrial/commercial forms like; dehydrated orange juice powder used as flavour, colour, nutritive additives in many bakery and other products, orange grated peel in flavouring and essential oil in food, soft drink and candy; juice sacks obtained after juice extraction called finisher pulp (dried to less than 10% moisture) is used as emulsifier and binder in food and beverage industries; orange peel oil containing 90-95% lemon content is used as lethal insecticide on housefly, flea, and fire ants and as engines cleaners and waterless hand cleaners in heavy machinery repair shops (www.ehow.com, 2013). Orange is a highly perishable fruit that can be stored for 3-5 months at 11.11-3.89^{0}C; after which it deteriorates due to transpiration, losses of moisture in peel/pulp (www.storagewest.com/orange.htm). In order to prevent abundant after harvest wastages oranges are processed into juices, concentrates, fruit powder e.t.c, packaged in industries for sales and human consumption. However, due to taste modification by chemical preservatives and contamination during processing, many people still prefer freshly peeled fruits (Cailliot S., 1990).

Peeling oranges is not an easy task as there are several problems that can be encountered during the process. One of the problems is that orange has round shape meaning that it must be tightly gripped to prevent it from rotation during peeling. The thick outer skins of oranges demand that it can only be peeled with sharp tools like knives, making the process prone to injury to hand. Another problem associated with orange peeling process is breakage of cellulose juice bearers leading to lose of juice. Because of the bitter and unpleasant fume/juice that oozes out of the outer skin called rind, oranges yield sweeter, better and more hygienic juice when properly peeled before it is consumed. The most common way of peeling orange is by use of bare hand and sharp knife though frequently resulting to injury. Apart from problem of injury, this manually based process is limited to low productivity per period. Orange peels when properly removed can be supplied to industry for use as raw material for added economic value. Several mechanized peeling devices have been developed in different parts of the world to enable people who desire fresh unpreserved juice for their tastes. A Chinese-Canadian concept developed in Quebec created an adjustable robotic arm that can handle fruits and vegetables of any sizes with ease but was a bit complicated and expensive for individual or household use due to its discriminating tendency in respect of ripeness, firmness, shape, blemishes e.t.c. of the fruit to be peeled (www.orangefiles.com:Orange history/how-to-peel-an-orange).

The art of peeling orange is complicated by the physical transformation that different parts of orange pass through with time as this affects ease of separation of the inside segments from outer covering. When orange is unripe its peel is very smooth on outside, somewhat thinner and tougher. As oranges become riper, the peels get thinner but not much stronger and the inner rind becomes rougher. There are physical pockmarks in orange or some other form of texture. As orange gets older, it dries out as some of the juice inside evaporates and it shrinks due to lose of juice, but the peel remains the same size making inside segment pull away from peel (Http://www.freepatentsonline.com/4771682.html). To solve these complications with orange peeling associated stress, high injury risk, contamination and tendency of disease transmission through blood stain on peeled orange from injured peeler; a robust and effective peeling device is needed to solve the problems. This work is therefore aimed at the development of a robust, simple and manually operated orange peeling device of low cost for an individual or family use. The objectives of the work are to estimate the average shear stress required to peel outer back of orange; design a mechanical device that is simple to operate and maintain based on proper stress analysis and fabrication with carefully selected materials using standard workshop facilities. The significance of the device when developed are that lovers of fresh orange juices would be availed with it through the use of a device that hygienically peels orange within a minimal period.

2.0 MATERIALS AND METHODS

2.1 Preliminary design concepts

The orange peeling device was conceived to have multiple components that are expected to perform the following functions.

2.1.1 Machine base: The base will bear and provide structural support/housing for all the component members of device including a set of spur gears that connect a threaded shaft to lower arm spindle. .

2***.1.2 Machine column:*** It would house the threaded power transmission shaft, provide support for the cutter arm, upper arm and the rotary handle.

2.1.3 Upper and lower fruit holders: The two holders would function as arms that hold and support the orange to be peeled. The lower arm will be mounted on a fixed position while the upper arm will perform the needed vertical displacement along the vertical column. The lower arm will be directly connected to a system of spur gears mounted on the base, while the arm is connected to the column in a way that it can perform vertical up and down motions to adjust and support different sizes and shapes of orange that may be mounted on the system.

2.1.4 Cutter arm: The cutter arm is designed such that it is two ended. One end is shaped into a threaded nut that interlocks with the thread of the shaft while the other end is rounded off to stabilize its operational motion. The cutter arm performs a vertical motion along the column when the shaft is rotated as a result of the effort applied to the rotary handle of the device.

2.1.5 The cutter blade: This would be made of a stainless steel so that it does not quickly corrode as it shears through the orange peel and get wetted by fluids oozing from outer orange skin. It will be a thin edged flat flexible razor-like metal sheet that can readily bend and curve into assorted shape and contours as dictated by the body shape of the orange mounted on the device for peeling. As orange is mounted on device between the upper and lower holders, it gets rotated as the rotary arm is manually rotated and orange rubs against the razor sharp cutter edge which acts as the cutting tool by shearing through orange skin to effect peeling. Provision is made for easy removal and replacement of cutter blade whenever it skips, jams up, clogged with peels or gets worn out and blunt.

2.1.6 The rotary handle: This is the component through which external manual force is applied to rotate and peel orange. The handle is mounted on top of device to make it very convenient to apply a force to rotate the upper handle of device. As human hands rotate this handle, torque is applied and the rotary motion is transmitted through a threaded power shaft to spindle of the lower arm through a set of spur gear train system mounted at the base of the device. The square threaded power screw that acted as translator screw used to convert rotary motion to translational motion and made possible the vertical movement of the cutter arm bearing and cutter blade. The square threading of shaft enables power transmission in either direction for maximum efficiency with minimum radial/bursting on nut. By the technicality of peeling process, it will be much easier to use cutter blade rather than taps and dies just as it is more practical for single point tool in lathe machining technology.

2.1.7 Set of spur gears: The spur gears system serves as intermediary transmitter of motion between the shaft and spindle of the lower arm of device. The spur gear train performs the two basic functions of transmitting power and motion as distance between the driver and follower is very small to enable use of belt drive and achievement of desired definite velocity ratio as the device is expected to be precision equipment by avoidance of rope drive. Three spur gears of same size were combined into the system of gear train One of the gears directly connects the shaft, the second one directly connects the spindle to the lower arm; while the third gear connects the threaded power shaft gear to the gear connected to spindle known as gear 1 and gear 3 such that both rotate in same clockwise direction while the connector gear known as gear 2 rotate in anticlockwise direction.

2.1.8 Operation of the machine linkages: By the arrangements of the machine component linkages, one revolution of the shaft and lower fruit holder take place at same time, the cutter arm fixed in a position on the shaft is calibrated to move down along the column through a distance of 3mm; which is the pitch of the threaded shaft. An orange mounted on lower handle performs another revolution with the cutter blade mounted on the cutter arm held in fixed position. The cutter arm moves down at a distance of 7mm which corresponds to the pitch of shaft and the process is repeated continuously from top to base of orange until it is completely peeled and removed from device. The orthographic views of the proposed device with its major components are shown in figure 1 (David et al., 2002).

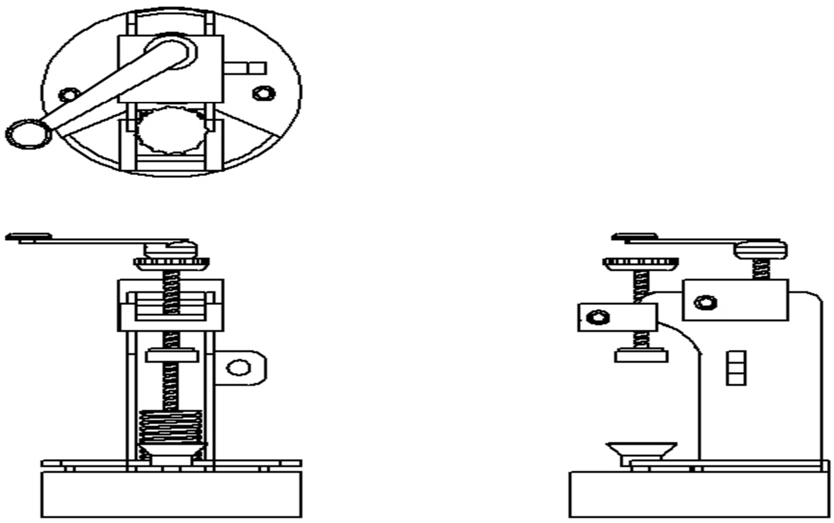


Figure 1:- An orthographic view of the conceptual design of the proposed orange peeling device

2.2 Theoretical Analysis

2.2.1 Preliminary design parameter evaluation:-The orange peeling machine design analysis was initiated based on average stress required to shear thin film-like orange skin. Biologically, there are different species of sweet orange are available not only in a country but many human settlements due to ecological modification. Thus the experimentally evaluated average shearing stress was needed to be used as a basis for analyzing the stress that is required to be overcome by peeling/shearing blade. This is determined analytically by equation 1 (Khurmi R. and Gupta J., 2003; Hall et al., 1982).

$$\delta = \frac{F}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where δ = shear stress; F = Force to initiate a cut on orange skin.

Six oranges each of which was carefully selected to represent a most common species of orange fruit consumed in Minna town of Nigeria was purchased from different fruit markets in the town. These were experimentally subjected to peeling with a shear device in Mechanical engineering department of Federal University of Technology, Minna, Nigeria. The average stresses needed to cut through the skins were measured to be in the range 15-40N. Thus, the highest stress of 40N was adopted for the design assuming that the device is to be used to peel oranges with very strong/tight outer skin cover. Therefore; A = Area of edge engaged in cylindrical cutter = Length X width of the cutter

= 25mm X 0.005mm = 0.125mm^2

$$\therefore \delta = \frac{40\text{N}}{0.125\text{mm}^2} = 320\text{N/mm}^2.$$

2.2.2 Average orange shapes and sizes:-Naturally the common profiles of oranges of any species range from spherical to circular shapes. The sizes as measured on the six experimental species used above fall into diametric ranges of 70-230mm.

2.3 Peeling device component design

2.3.1 Shaft Design:-The design incorporated the following:

(a) Material selection: The material selected for the shaft was Nigerian mild steel of grade 40C8 due to its properties that included reasonable strength, resistance against corrosion and torsion and low cost since the device was meant to be affordable by an average household. The shaft will be threaded and also made to act as power screw. This central and critical component of device is as illustrated in figure 2 (Khurmi R. and Gupta J., 2003. From standard materials hand book, the steel has a yield strength of 320mPa and an ultimate tensile strength of 650mPa (Harold A. R., 1985).

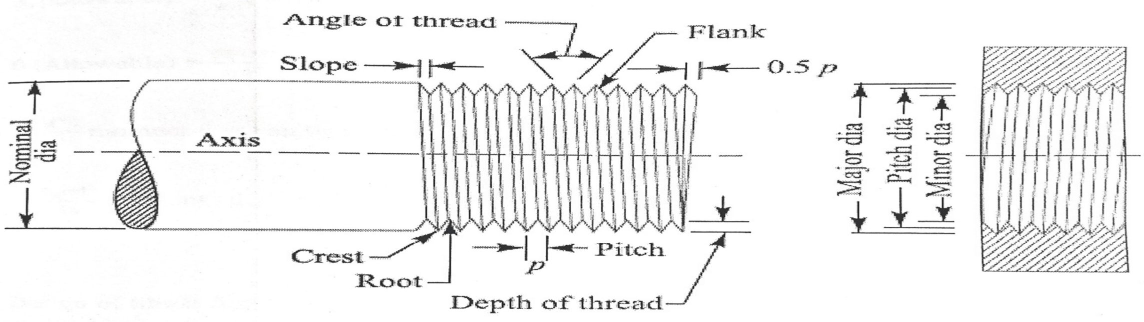


Fig 2: An illustrative sketch of the threaded shaft/power screw

(b) Design Analysis:-The shaft would be subjected to torsional loads and a little axial loading.

Torsional stress $\tau_{xy} = \frac{Mt_r}{J} = \frac{16Mt}{\pi d^3}$ (for solid shaft) …………………………….……………..(2)

ASME code for steel shafting provides S_s (allowable) =800psi for shaft without keyway (55MN/m^2);

Thus; S_s (allowable) = $\frac{16Mt}{\pi d^3}$ (Rober L. N., 2001)……………..……………..…………………….. .(3)

θ (Allowable) = $\frac{584Mt}{\pi d^3}$ ………………………………………………...……………………..(4)

Mt = $\frac{\theta d^4 G}{584L}$ moment that can be transmitted in allowable twist ……………………...……………. (5)

Mt = $\frac{S_s \pi d^3}{16}$ moment that can be transmitted ……………………………………………………… (6)

(c) Design of Shaft for Torsional Rigidity:-This is based on permissible angle of twist. The amount of twist permissible depends on application and it varies about 0.3deg/m for machine tool shafts to about 3deg/m for line shafting. Then from equations (5) and (6);

$$\frac{\theta d^4 G}{584L} = \frac{S_s \pi d^3}{16} \quad \text{……………………………..……………………………….……………. (7)}$$

$$d = \frac{584L \times S_s X \pi}{\theta 16G} \quad \text{…………………………...……………………………….…………… (8)}$$

θ = 3deg/m → angle of twist, deg.
D = shaft diameter, m.
L = 200mm = length of shaft
Mt = Torsional moment, MN
G = Torsional modulus of elasticity N/m^2
S_s = Allowable stress

$$\therefore d = \frac{584 \times 0.2 \times 55 \times 10^6 \times \pi}{3 \times 16 \times 80 \times 10^9} = 5.256\text{mm}$$

As the shaft would also be used as a power screw and to rule out failure completely, we decided to fix the nominal diameter of the shaft to be 8mm (Stepin P., 1969).

2.3.2 Design of the small spindle shaft spindle:-This was assumed to be subjected to torsional load and the weight of orange on pan. Using equation (7) and taking the length = 55mm, then;

$$d_s = \frac{584L \times S_S X\pi}{\theta 16G}$$

$$d_s = \frac{584 \times 0.055 \times ss \times 10^6}{3 \times 16 \times 80 \times 10^9} = 1.446\text{mm}$$

This shows a very slender shaft. The diameter is therefore, raised and fixed at 3mm to avoid failure.

2.3.3 Design of the Rotary Handle:-This was under the sub-sections;

(a) Material selection: Cast aluminum alloy was selected because of low cost, lower tensile strength than wrought alloy and good corrosion resistance (Smallman R. E. and Bishop R. J., 1999).

(b) Design analysis: The twisting moment or torque required to turn the shaft was given as:

$$\frac{T}{j} = \frac{\delta}{r} \quad \ldots\ldots (9)$$

Where: T = twisting moment (or torque) acting upon the shaft.

J = polar moment of inertia of the shaft about the axis of rotation

δ = Shear stress

r = distance from neutral axis to the outermost fiber $= \frac{d}{2}$ where d is the diameter of the shaft.

For a round solid shaft, polar moment of material is given as:.J = $\frac{\pi}{32} \text{ x } d^4$ …………………… (10)

Equation (9) may be written as: $\frac{T}{\frac{\pi}{32} \text{ x } d^4} = \frac{\sigma}{\frac{d}{2}}$………………………………………….. (11)

From equation (11) T = $\frac{\pi}{16} \text{ x } \delta \text{ x } d^3 = \frac{3.14}{16} \text{ x } 320\text{N/mm}^2 \text{ x } 8^3\text{mm}^3$ = 32174N/mm .... (12)

2.3.4 Gear Design:-A set of spur gears was selected based on the expected functions in the device.

(a) Material Selected**:** For the spur gears plastic material was selected because of the low torque on the component, low cost, low friction and high corrosion resistance of the plastic. The plastic is made of acetic resin and it has a good bending strength, anti-organic properties and low noisiness (Smallman R. E. and Bishop R. J., 1999)..

(b) Design Analysis:-(i) Design theory: The beam strength and load carrying capacity of toothed gears are determined from Lewis equation based on the illustration in figure 3 (Rober L. N., 2001).

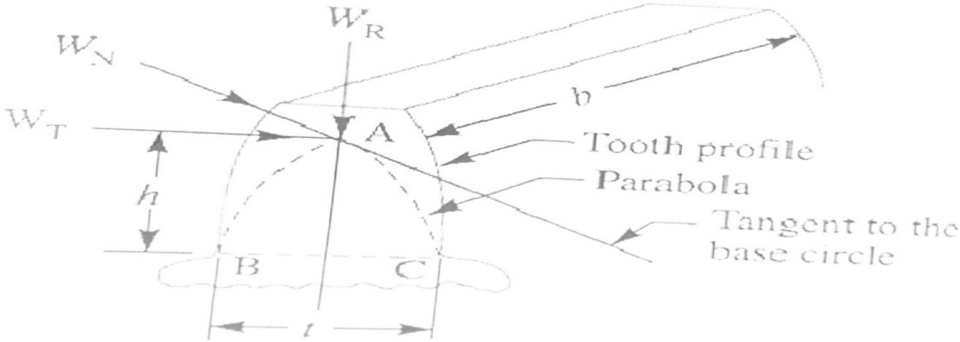


Figure 3 Tooth of a gear and its design parameters.

By the theory, consider each tooth as cantilever beam loaded by normal load (W_N) as shown in the figure resolved into two components; as tangential component (W_T) and radial component (W_R) acting perpendicular and parallel to centre line of tooth respectively. The tangential component (W_T) induces a bending stress that tends to break tooth. The radial component (W_R) induces a compressive stress of relatively small magnitude and therefore, its effect on the tooth is neglected. In the parabola A, B and C in figure 3, section BC is the critical section of maximum stress. Maximum permissible working stress at the section BC is given by equation 13.

$$\delta = \frac{My}{I} \quad \ldots\ldots (13)$$

Where; M = maximum bending moment at the critical section BC = W_T X h

W_T = tangential load acting at the tooth; and h = length of the tooth.

y = half the thickness of the tooth (t) at the critical section BC = $\frac{t}{2}$

I = moment of inertia about the center line of the tooth = $\frac{b.t^3}{12}$

b = width of gear face.

P_C = circular pitch = $\frac{\text{circumference}}{\text{no of tooth}} = \frac{\pi d}{T} = \frac{3.142 \text{ x } 40}{42} = 3\text{mm}$

Substituting the values of M, y and I in equation 13, gives:

$$\delta_w = \frac{(W_T \text{ x } h)\frac{t}{2}}{\frac{b.t^3}{12}} = \frac{(W_T \text{ x } h) \text{ x } 6}{b.t^2}$$

Or that; $W_T = \delta_w \text{ x } h \text{ x } \frac{t^3}{6h}$ ……………………………………………………………….(14)

In equation 14, the parameters, t and h are variables that depend upon the size of the tooth (i.e. the circular pitch) and its profile.

Let t = $x \times P_c$, and h = k × P_c; where x and k are constants.

Thus; $W_T = \delta_w \times b \times \frac{x^2.Pc^2}{6k.Pc} = \delta_w \times b \times P_c \times \frac{x^2}{6k}$.

Substituting $\frac{x^2}{6k} = y$ (as another constant), gives equation 15 as:

$$W_T = \delta_w.b.Pc.y \text{ ………………………………………………………………… (15)}$$

The parameter, y is known as the Lewis form factor and parameter, W_T (which is the tangential load acting at the tooth) is called the beam strength of the tooth.

Since y = $\frac{x^2}{6k} = \frac{t^2}{(Pc)^2} \times \frac{Pc}{6h} \times \frac{t^2}{6h.Pc}$ ……………………………………………………….…. (16)

The value of y in terms of the number of the teeth is expressed as; y = 0.154 – $\frac{0.192}{T}$ for 20^o full depth involutes system. Where T = number of teeth = 42; y = 0.154 – $\frac{0.912}{42}$ = 0.1323

(ii) Permissible tooth stress:-The permissible working stress (δ_w) in Lewis equation 13, depends upon the material; for which an allowable static (δ_0) is determined. The allowable static stress is the stress at elastic limit of a material. According to Barth formula , the permissible working stress is given as:

$$\delta_w = \delta_o \times C_v \text{ ………………………………………………………………………… (17)}$$

δ_o = Allowable static stress = 56N/mm^2 for a plastic material; and C_v = Velocity factor

$C_v = \left(\frac{0.75}{1+v}\right) + 0.25$ (for non-metallic gears)

Where v = pitch line velocity = $\frac{\pi DN}{60}$ (m/s) ……………………………………………….(18)

D = Pitch Diameter = $\frac{PcT}{\pi}$ ………………………………………………………………………… (19)

Where Pc = circular pitch = 3mm; T = number of teeth = 42.

Therefore; D = $\frac{3 \times 42}{3.142} = 40\text{mm}$

From equation (12), where N = 120rev/min, $v = \frac{3.142 \times 40 \times 120}{60}$ = 251.36mm/s = 0.25m/s

From equation (18), velocity factor $C_v = \left(\frac{0.75}{1+0.25}\right) + 0.25 = 0.85$ and from equation (17),

Permissible stress = $\delta_w = 56\text{N/mm}^2 \times 0.85$ and; $\delta_w = 47.6\text{N/mm}^2$

2.3.5 Gear Design Calculations:- Given data; Pc = 3mm, N = 120rpm, T = 42, b = 2Pc = 6mm

(a) Tangential load acting on the tooth:- From equation (15);

$$W_T = \delta_w \times b \times P_c \times y = 47.6\text{N/mm}^2 \text{ x } 6\text{mm x } 3\text{mm x } 0.1323 = 113.4\text{N}$$

(b) Pitch diameter:- From equation (19); D = $P_c \frac{N}{\pi} = 3 \times \frac{42}{\pi} = 40\text{mm}$

(c) Pitch line velocity:- From equation (18); v = $\frac{\pi DN}{60} = \frac{3.142 \times 40 \times 120}{60}$ = 251.36mm/s = 0.25m/s

(d) Dimensional pitch:-This is given by the equation; $P_d = \frac{T}{D} = \frac{42}{40}$ = 1.05mm

(e) Outside diameter D_0:-It is given as; $D_o = T + \frac{2}{P_d} = 42 + \frac{2}{1.05}$ = 44mm

(f) Pressure angle θ:- It is determined as; θ = $\cos^{-1}\left(\frac{D}{D_o}\right) = \frac{40}{44}$ = 25^o

(g) Base circle diameter D_b:- It is determined as; $D_b = D\cos\theta = 40 \times \cos 25^o$ = 36.3mm

(h) Base pitch P_b,:- It is given by the equation; $P_b = P_c\cos\theta$ = 3 cos 25^o = 3mm

(i) Tooth thickness T:- It is determined as follows:- T = d = $\frac{P_c}{2} = \frac{3}{2}$ = 1.5mm

2.3.6 Bearing Analysis:- The rating/service life of ball/roller bearing is given as follows:

L = $\left(\frac{C}{W}\right)^k \times 10^6$ revolutions Or C = $W\left(\frac{L}{10^6}\right)^{\frac{1}{k}}$ (Khurmi R. and Gupta J., 2003)……..… (20)

Where L = Rating life; C = Basic dynamic load rating; W = Equivalent dynamic load

K = 3 for ball bearings = $\frac{10}{3}$ for roller bearings

The total life expected for the bearing is 20 x 10^6 revolutions at 95% reliability.
According to Wiebull (Rober L. N., 2001), the relation between the bearing life and reliability is as:

$$\log_e\left(\frac{1}{R}\right) = \left(\frac{L}{a}\right)^b \text{ or } \frac{L}{a} = \left[\log_e\left(\frac{1}{R}\right)\right]^{\frac{1}{b}} \quad \ldots (21)$$

Where L is the life of the bearing corresponding to the desired reliability R
a and b are constants whose values are a = 6.84 and b = 1.17
if L_{90} is the life of a bearing corresponding to a reliability of 90% (i.e. R_{90}) then,

$$\frac{L}{L_{90}} = \left[\log_e\left(\frac{1}{R_{90}}\right)\right]^{\frac{1}{b}} \quad \ldots (22)$$

Dividing equation (21) by (22), gives; $\frac{L}{L_{90}} = \left[\frac{\log_e\left(\frac{1}{g}\right)}{\log_e\left(\frac{1}{R_{90}}\right)}\right]^{1/b}$ ……(23)

If L_{90} = life of the bearing corresponding to reliability of 90%
And L_{95} = life of the bearing corresponding to a reliability of 95% = 20 x 10^6 revolution

$$\therefore \frac{L_{95}}{L_{90}} = \left[\frac{\log_e\left(\frac{1}{R_{95}}\right)}{\log_e\left(\frac{1}{R_{90}}\right)}\right]^{1/b} = \left[\frac{\log_e\left(\frac{1}{0.95}\right)}{\log_e\left(\frac{1}{0.90}\right)}\right]^{1/1.17} = \left[\frac{0.0513}{0.1054}\right]^{0.8547} = 0.54$$

$$L_{90} = \frac{L_{95}}{0.54} = \frac{20 \times 10^6}{0.54} = 37 \times 10^6$$

From equation (20), Dynamic load rating C = $W\left(\frac{L_{90}}{10^6}\right)^{\frac{1}{k}}$

Taking equivalent dynamic load = 2KN

$$C = 2\left(\frac{37 \times 10^6}{10^6}\right)^{1/3} = 6.66\text{KN}$$

2.3.7 Bolt Design:-The bolt design included the components:

(a) Material Selected:-Mild steel was selected for production of the bolt due to its high strength, resistance to torsional vibration and low cost (Smallman R. E. and Bishop R. J., 1999). The steel is of grade 40c8 with an ultimate strength of 620mPa and yield strength of 320mPa.

(b) Design Analysis:-The upward force acting on cylinder cover is given as follows (Stepin P., 1969)

$$P = \frac{\pi}{4}(D^2)P \quad \ldots (24)$$

This force is resisted by the number of bolts and nuts provided on the cover
Therefore, resisting force offered by n number of bolts is given as

$$P = \frac{\pi}{4}(d_c)^2 \times \sigma_{tb} \times n \quad \ldots (25)$$

Where D = diameter of the cylinder; P = pressure in the cylinder; d_c = core diameter of the bolt
n = number of bolts; σ_{tb} = permissible tensile stress for the bolt material

Taking diameter of cylinder as 150mm and pressure acting on its cover as insignificantly as 1N/mm^2.

Therefore, from equation (24); $P = \frac{\pi}{4}(D^2)P = \frac{3.142}{4}(150)^2 \times 1$ = 17673.75N.

Assuming a bolt of nominal diameter 8mm is used; from dimensions of bolts and nuts in accordance with Indian Standard:4218 (Part 111), corresponding core diameter (d_c) of bolt is 8.16mm.

Thus, the resisting force offered by n number of bolts (equation 25),

$$P = \frac{\pi}{4}(d_c)^2 \times \sigma_{tb} \times n = \frac{3.142}{4} \times (8.16)^2 \times 55 \times n = 2876.7n\text{N} \quad \ldots (26)$$

From equation (26); $n = \frac{17673.75}{2877}$ = 6.14 say 7

Taking the diameter of the bolt hole (d_1) as 8.5mm, we have pitch circle diameter of the bolt,

$D_p = D + 2t + 3d_1$ = 150 + 2 x 5 + 3 x 8.5 = 185.5mm (t = thickness of d cover plate = 5mm)

Therefore; circumferential pitch of the bolts $= \frac{\pi \times d_p}{n} = \frac{\pi \times 185.5}{7}$ = 83.3mm

For a leak-proof joint, the circumferential pitch of the bolts should be between $20\sqrt{d_1}$ to $30\sqrt{d_1}$ where d_1 is the diameter of bolt hole in mm.

∴ Minimum circumferential pitch of the bolts = $20\sqrt{d_1} = 20\sqrt{8.5}$ = 58.3mm

And maximum circumferential pitch of the bolts = $30\sqrt{d_1} = 30\sqrt{8.5}$ = 87.5mm

Since the circumference pitch of the bolts obtained above lies between 58.3mm to 87.5mm.

∴ Size of bolt = M8. This size of the bolt that is chosen is satisfactory for the loading and function.

3.0 RESULTS AND DISCUSSION

The design analysis on the individual components of the peeling device carried out above generated sizes and dimensions presented in engineering drawings in figures 4-9. Figure 4 shows orthographic projection of the orange peeling device when looked at from the front showing the top, front and side views. Figure 5 presents another set of orthographic views of the device as generated while looking it from its back side to further reveal some details and dimensions not readily displayed in figure 4. In figure 6, the assembly drawing of the top section of the orange peeling device showing its essential parts and how they are interrelated with other components of device for its fabrication. In figure 7 an assembly drawing of lower section of device is presented showing how the parts are interrelated for fabrication and assemblage. Figure 9 shows the exploded view of device from its back side. Figure 8 shows isometric drawings of device as viewed from back and right hand sides. Figure 10 presents the completed machine in extruded to reveal its pictorial appearances. Figure 10(a) shows the shaded plain form and figure 10(b) the body frame in red coloured form with the major components clearly displayed. The fabricated device is a light portable machine that can be hand held or mounted freely on table top and operated easily. Its total weight was measured as 619g. The lightness was due to the selected materials particularly the machine base and body frame that were constructed with resinous plastic. This provided high structural strength to low weight ratio, corrosion resistance, anti-toxic advantages and gave transparency for sighting device mechanisms and peels accumulated inside the machine base for prompt attention to any issues that may arise during operation.

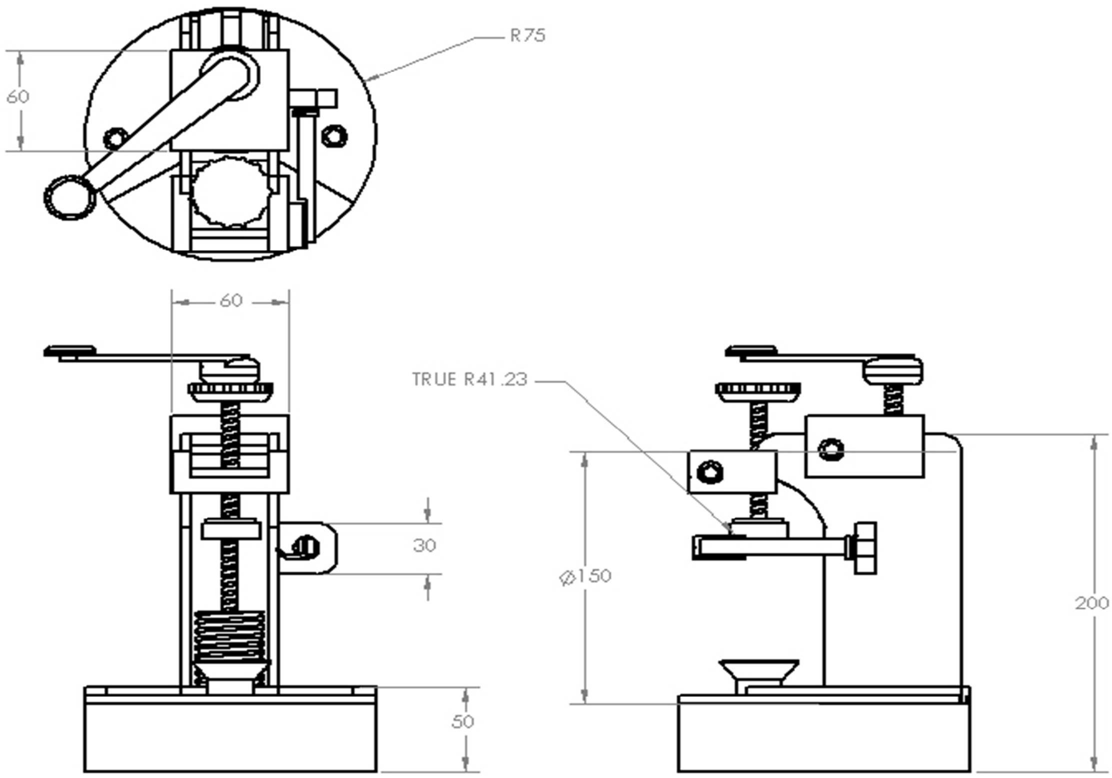


Figure 4:-First angle orthographic projection views of device showing dimensions (in mm).

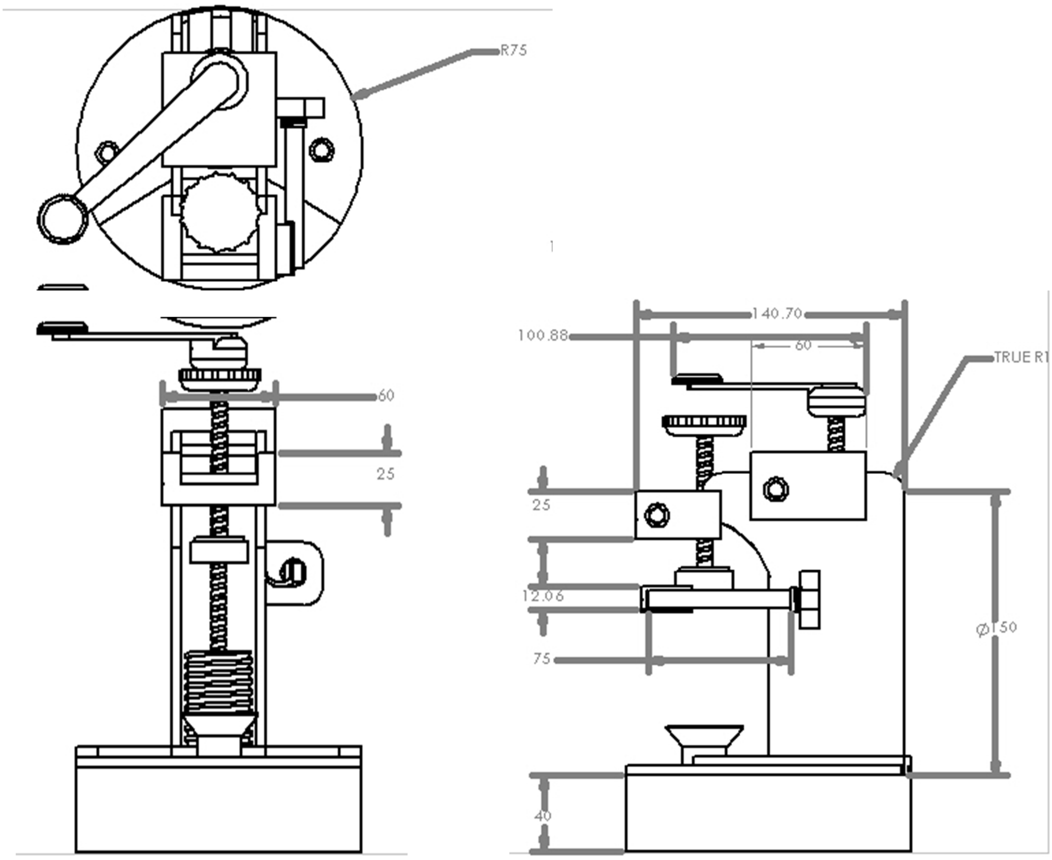
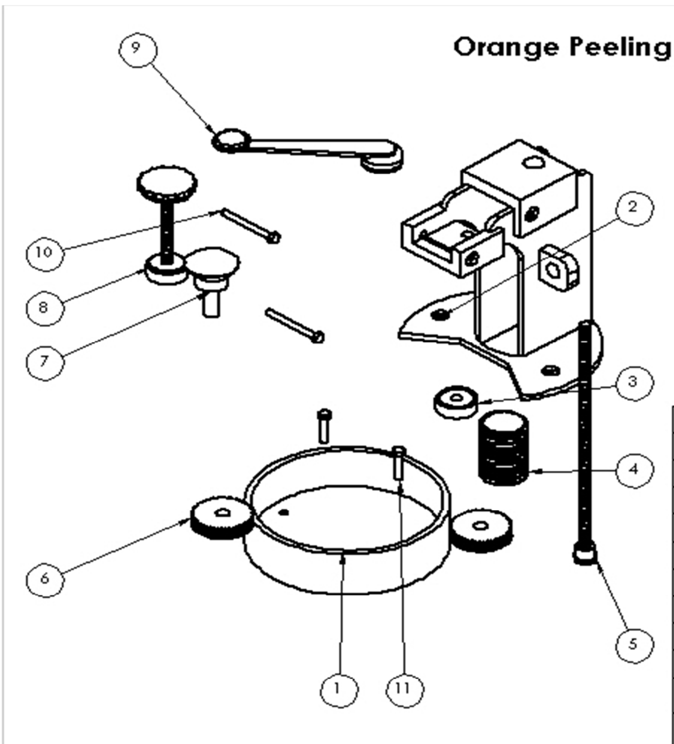
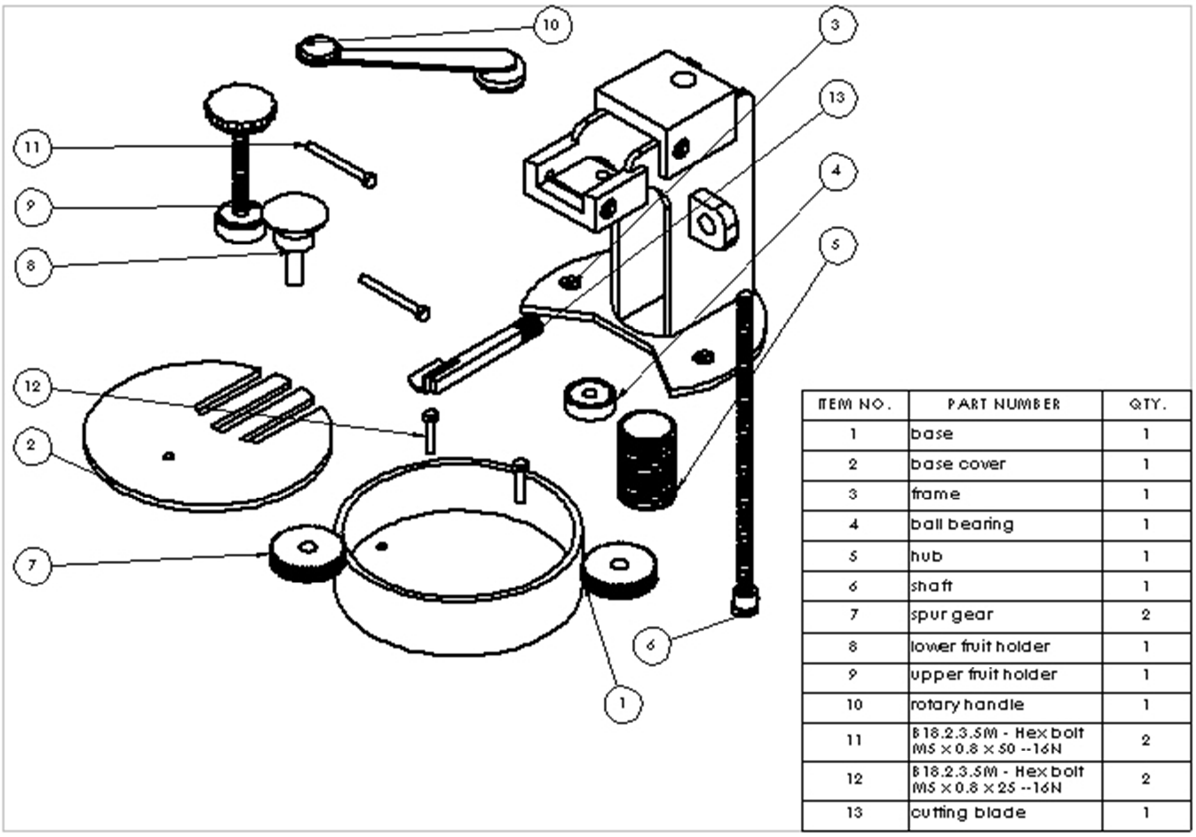


Figure 5:-First angle orthographic projection of the orange peeling device when looked at from the back side revealing some further details and dimensions (in mm).



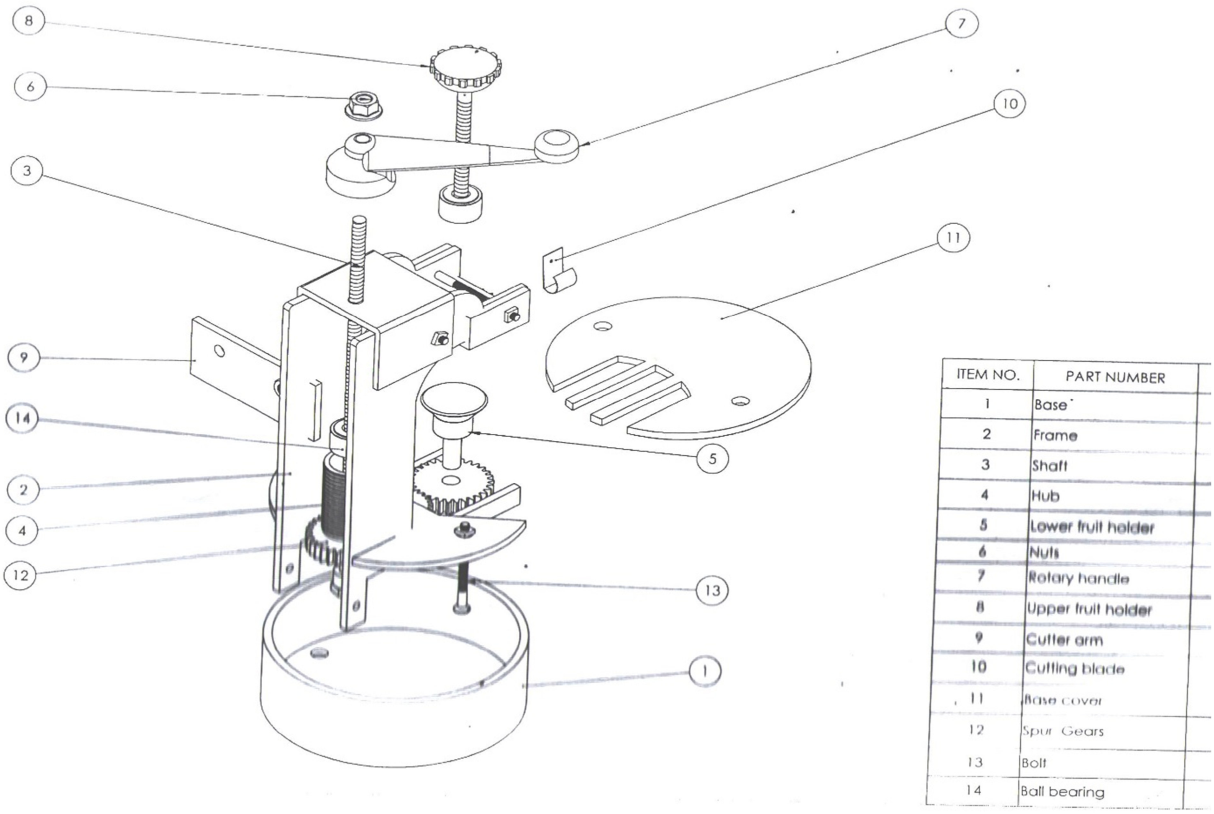
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base		1
2	frame		1
3	ball bearing		1
4	hub		1
5	shaft		1
6	spur gear		2
7	lower fruit holder		1
8	upper fruit holder		1
9	rotary handle		1
10	B18.2.3.5M - Hex bolt M5 x 0.8 x 50 --16N		2
11	B18.2.3.5M - Hex bolt M5 x 0.8 x 25 --16N		2

Figure 6:-Assembly drawing of the upper section of peeling device showing its different parts and interlinkages with the other components.



ITEM NO.	PART NUMBER	QTY.
1	base	1
2	base cover	1
3	frame	1
4	ball bearing	1
5	hub	1
6	shaft	1
7	spur gear	2
8	lower fruit holder	1
9	upper fruit holder	1
10	rotary handle	1
11	B18.2.3.5M - Hex bolt M5 x 0.8 x 50 --16N	2
12	B18.2.3.5M - Hex bolt M5 x 0.8 x 25 --16N	2
13	cutting blade	1

Figure 7:-Assembly drawing of the lower section of orange peeling device showing how parts are related to one another.



ITEM NO.	PART NUMBER
1	Base
2	Frame
3	Shaft
4	Hub
5	Lower fruit holder
6	Nuts
7	Rotary handle
8	Upper fruit holder
9	Cutter arm
10	Cutting blade
11	Base cover
12	Spur Gears
13	Bolt
14	Ball bearing

Figure 8:-Assembly drawing of peeling device showing its exploded view from the back side.

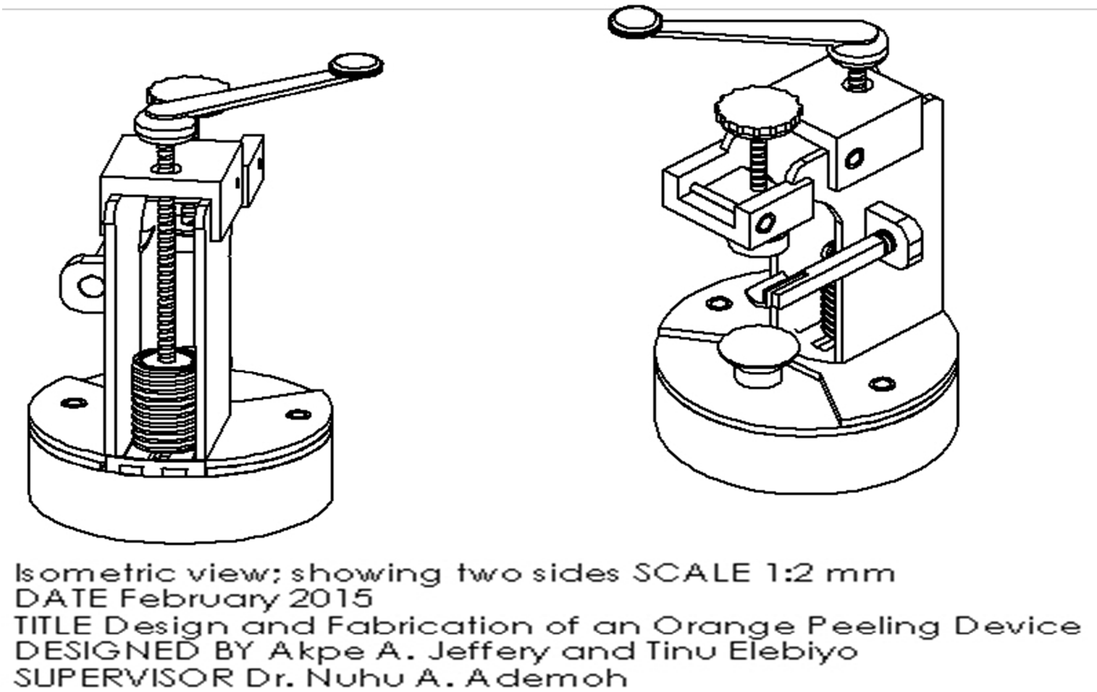
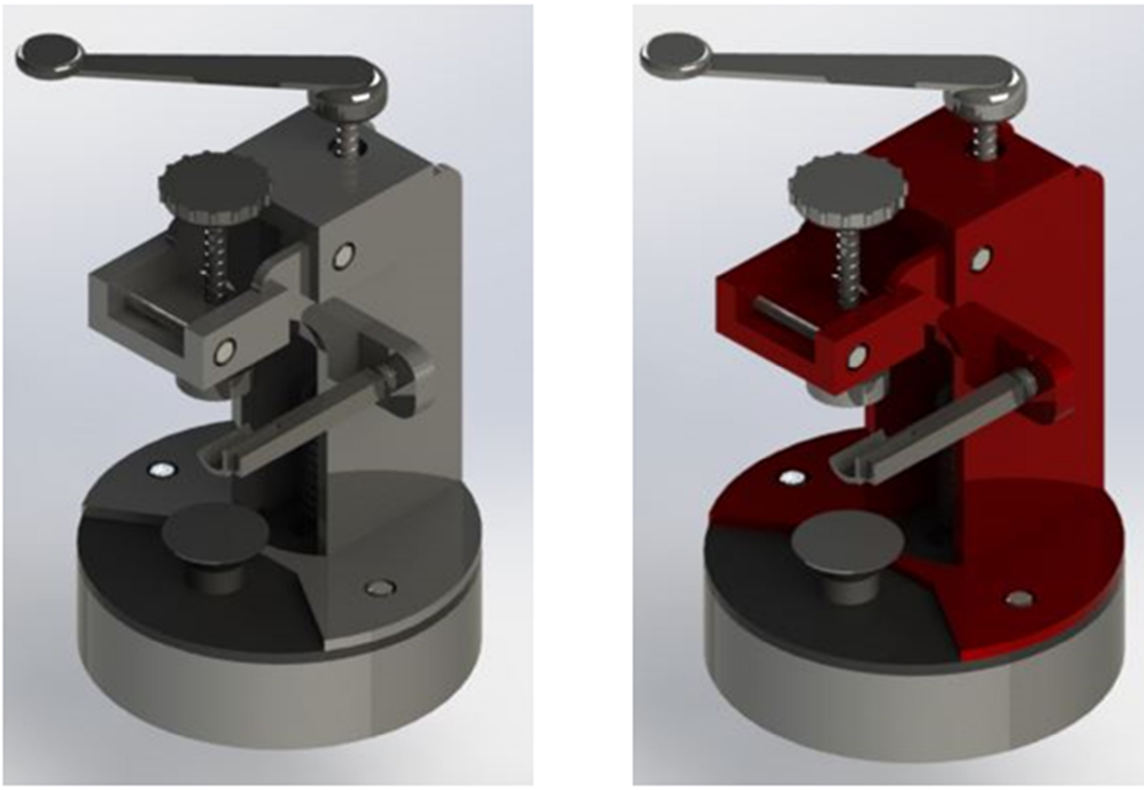


Figure 9:-Isometric drawings of peeling device when looked at from end side and when looked at from the front side.



(a) (b)

Figure 10:-Extruded views of the orange peeling device showing its pictorial presentations in
(a) Shaded plain colour; (b) Red coloured body frame and transparent base.

The device is easy to operate and maintain following very simple procedures. An orange to be peeled is mounted on the lower arm/support while the upper arm is lowered gently to firmly grasp it. Having secured orange in machine using a height adjustment lever, the cutter arm is raised to top of orange. The upper arm is gently pressed on orange and the rotary mounted on it is rotated in a clockwise direction carrying the fruit to rotate in the same direction along the horizontal plane of the machine. When the rotary arm completes a revolution the orange does same and moves vertically downwards by a distance of 3mm which corresponds to pitch of threaded shaft. As fruit and moves down, the cutter blade carried on cutter arm engages back skin of orange; continuously peels it generating a continuous curvilinear and coiled chip of 5mm width and about 3mm thick depending on pressure on rotary arm. On completion of a peeling cycle, the upper arm is gently raised and orange is removed from device. Thicker orange skins will require higher pressure on rotary arm for effective peeling.

Periodically, the base of device is inspected for accumulated peel and emptied to avoid congestion. Experimental trials showed it took 20-25 seconds to peel an orange using this device depending on size. A die patch method of accessing the surface volume of unpeeled orange in relation to that of the peeled orange was used to estimate the peeling efficiency (www.abecitrus.com:Br/process.html). The device was found to have a peeling efficiency of about 97%, with the leftovers being the top and the base of the orange that was gripped by device during peeling. Also over peeling and damage to orange was estimated to be about 2.6%. This showed a better productivity when compared to average of 9-120 seconds taken for hand peeling orange. The device can peel about 140 oranges per hour by when manual process produced 32 peeled oranges. Its maintenance is by periodic application of light machine oil to gear train and threaded shaft to minimize friction and wear of these moving/mating parts. During operation or idle mode, care should be taken not to wipe over its cutter blade to avoid razor sharp cuts/injuries. The device is expected to be durable as it can peel at least 3,000 oranges when carefully handled before first signs of correctable failure in form of worn out thread of power screw/shaft, gear teeth or slackening of tightening bolts/screws begin to appear. Cost of producing a piece of this device was estimated to be about seven thousand Nigerian Naira.

4.0 CONCLUSION

The manually operated orange peeling device hereby developed is quite effective for the purpose of an individual or family household. It can be mechanized by removing the rotary arm and introduction of an electric motor to drive the threaded shaft through which power is brought into the system. Its productivity is commendable and would be increased if mechanized to adapt it for commercial use. The estimated price is low and affordable and can be drastically reduced if device is mass produced for sale. Its aesthetic appearance is quite robust and beautiful due to the materials selected and used for its construction. The beauty and price of device can be further improved with additional weight savings if the threaded shaft/power screw and spur gears made of steel are replaced with aluminium alloy of comparable strength. The rotary arm can also be made with alumunium or polymer material.

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REFERENCES

Cailliot S., (1990). “Appliance for peeling fruit and vegetables”.USA Patent 4972789; Citrus Propagation, Research Program on Citrus Rootstock Breeding and Genetics. Texas Coorperative Extension.

David A. M., James F., Keren A. S. and Turpin J. (2002). “Engineering drawing and design”. 2nd edition; Thompson Learning Company, USA.

Hall A., Holowenko A. and Laughun H. (1982). “Theory and problem of machine design”. McGraw-Hill Inc. Singapore.

Harold A. R. (1985). “Mechanical design systems handbook”. McGraw-Hill Book Company, USA.

Http://www.freepatentsonline.com/4771682.html. Retrieved in November, 2014.

Http://www.freepatentsonline.com/4972769.html. Retrieved in October, 2014.

Khurmi R. and Gupta J. (2003). “Machine design”. Eurasia Publishing House Pvt. Ltd., New Delhi.

Rober L., Norton (2001). “Analysis of Mechanism and machine”. 2nd edition; McGraw-Hill Book Company, USA.

Smallman R. E. and Bishop R. J. (1999). “Modern physical metallurgy and materials engineering”. 6th edition; Reed Educational and Professional Publishing House, Ltd, USA.

Stepin P. (1969). “Strength of materials”. 2nd edition; Peace Publishers, Moscow.

www.storagewest.com/orange.html. Retrieved in November, 2014.

www.orangefiles.com:Orange history/how-to-peel-anorange. Retrieved in December 2014.

www.abecitrus.com:Br/process.html. Retrieved in November 2014.

www.ehow.com (2013). Retrieved in December, 2014.