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# Design and Development of Orange Fruit Grading Machine

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**Abstract:** Size basis grading of oranges is an important requirement of fruit market and quantifying the fruit shape gives value addition to it. Proper grading of oranges is beneficial for both consumers as well as producers. Therefore, any system which performs the grading operation will be of great value. The main objective of this paper is to design and development of orange fruit grading machine which is capable of grading oranges on size basis.
In this work, the grading of oranges is performed by passing it through the gap formed between two endless expanding opening conveyor belts. This machine grades the oranges in six different grades. Successfully designed system consists of feeding hopper, grading unit and collecting tray.
**Keywords:** Orange Grading Machine,Design, Size basis, Expanding.

## I. INTRODUCTION

Grading is nothing but the sorting of fruit into different grades according to the size, shape, colour and volume. Aim behind grading is to fetch up high price in market. Orange is the most common among citrus fruits grown all over the world. The high value fresh agriculture product such as orange must be carefully handled and graded in order to meet customer demands and quality standards. Considering Vidarbha, it is main producer of oranges all over the country. So, majority of orange growers of the country are present in this region. But profit earned by farmers during the season of oranges is not convincing. This is the main reason for grading (TOI, 2015). Even though grading is an ancientprocess but the techniques which modern farmers are using is causing problems to them. So, innovations are always made to avoid these problems. Recent techniques developed for grading are based on micro-controllers, sensors and lasers. But these machines are of high cost and available only at market place. Hence grading of oranges could be possible only at market place. For selling, market accepts only top-grade orange fruits sorted out by machine. Hence orange growers suffer a loss of low-grade orange fruits sorted by machine which is not accepted by market for selling. It is difficult for rural background to work with this type of machines considering the environment where grading has to be done.

Further, Orange basically is citrus in nature and has a soft skin covering and highly perishable fruit. Due to its nature, handling of such fruits must be done with utmost care. Moreover, degradation of oranges and bruising is the main problem associated with it. Accordingly, an innovation for Orange grading for growers is necessary which should be robust in construction and could be easily handled by growers. Oranges can be simply graded by expanding belt principle according to their sizes. This machine is free from sensors, microcontrollers and lasers. Proposed orange grading machine can be effectively installed and operated at domestic level.

## II. PROBLEMIDENTIFICATION

Maha-Orange, which is a federation of Orange growers, is facing sever the problem of grading of oranges. Orange growers from different regions bring their product to Maharashtra State Agri-Produce Marketing Board (MSAMB) for selling their products. However, as grading is not introduced; these oranges are directly introduced to markets, where the prices of oranges ultimately come down in spite of product being of superior quality of product. Due to these oranges are getting same price in markets in spite of difference in qualities.

Also, for the orange growers it is very hard to determine prices according to grades. Hence grading of oranges is the primary need for MAHAORANGE and hence for orange growers. Consequently, Maha-Orange decided to grade the oranges on size basis in following way:

- Grade A – Superior quality only for exports
- Grade B – Medium Quality.
- Grade C – For food processing Industries

Due to this grading and sorting of oranges, prices of the fruit can be fixed according to the quality of fruits. Maha-Orange thus needed simple and robust ORANGE GRADING MACHINE**,** which should be able to grade the oranges on size basis. Moreover, it should be portable in nature so that Orange Growers can grade the oranges in their respective farms and so that superior quality and inferior qualities should be determined and accordingly prices can also be determined. Maha-Orange finally approached Mahatma Gandhi Institute of Rural Industrialization (MGIRI), Wardha, for finding the solution to grading problems. MGIRI accepted the request and fabricated machine in REI.

## III. OBJECTIVES

The objectives are,

- To perform grading of oranges on size basis and grade them into different categories
- To Design and Fabricate an Orange Grading Machine which should be directly suitable for farm level installations.
- To support, upgrade and accelerate the process of development of Orange Growers in Vidarbha andprovide a supporting hand to commercialization of oranges.

## IV. PRESENT ORANGE FRUIT GRADER AVAILABLE

The economic status of Indian farmer had improved by small extent by adopting the horticulture crops. The horticulture crops are of great demand when they are in superior in quality. Actually, fruit commercialization is the main purpose of fruit grading. Fruit of the same tree differ in quality such as feature, taste because their growth is affected by many environmental factors. Also, the fruit from different orchard differ significantly in size and quality. Grading may not only standardize fruit product but also promote management of fruit tree in orchard and product quality (San Francisco, California . Patent No. 399799, 1989). Fruit are very difficult to grade exactly and rapidly because of their significance and difference in feature such as size, shape and colour as a result of changeable condition of natural environment and manual factor. All these factors state the need of grading in rural area.

These mechanical types of fruit grading machines studied and available in market is given below:

- Roller fruit grader
- Expanding opening double fruit grader

### 4.1 Roller Fruit Grader:

The main objective of this mechanism is to provide grading of fruits by means of rotating of cylinder which is made up of slats of varying area on size basis(San Francisco, California . Patent No. 399799, 1989). The machine operates as the fruit is fed at the end in the cylinder barrel in which the spaces between slats or bars have least width. The main cylinder or barrel being rotated, the fruit is carried along from one end to the other by means of the spirally arranged flanges. The fruit of a proper size arrives at a place where the space between the slats wide enough it drops through, and the sorting or grading is thus continued throughout the length of the cylinder or barrel.

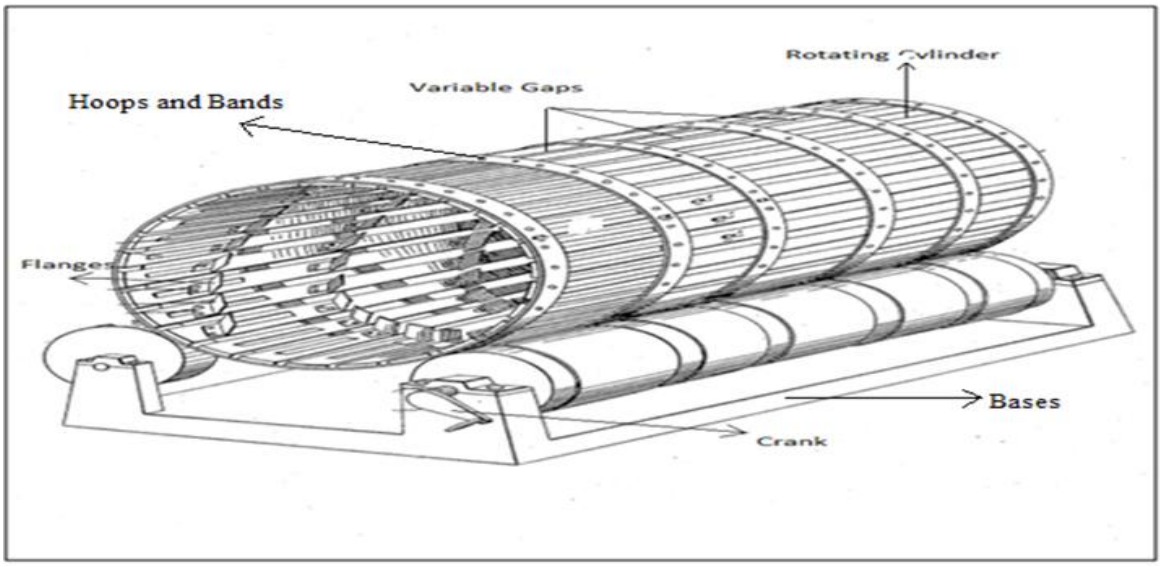


**Figure 1: Roller Fruit Grader**

**4.2 EXPANDING BELT FRUIT GRADER:**

The grading of fruits is performed by passing the fruits through the gap formed between the two endless expanding opening inclined conveyor belts(Jacob, 2012)**.**The distance between the two belts mounted on roller sets is increasing along the length and the belts are inclined to the vertical by 30 to 45 degree to hold the fruits. The ungraded fruit is fed from the end having smallest opening. Fruits get singled and get held in the space between the belts and move along the direction of motion. Small size fruits get graded by passing through the small opening near the feeding end. The fruits having larger size are passes further and fruits having smaller size get drop down. The medium size fruits get graded by passing through medium opening and big size fruit get graded by passing through largest opening near the far end of belt. The medium size fruits get graded by passing through medium opening and big size fruit get graded by passing through largest opening near the far end of belt.

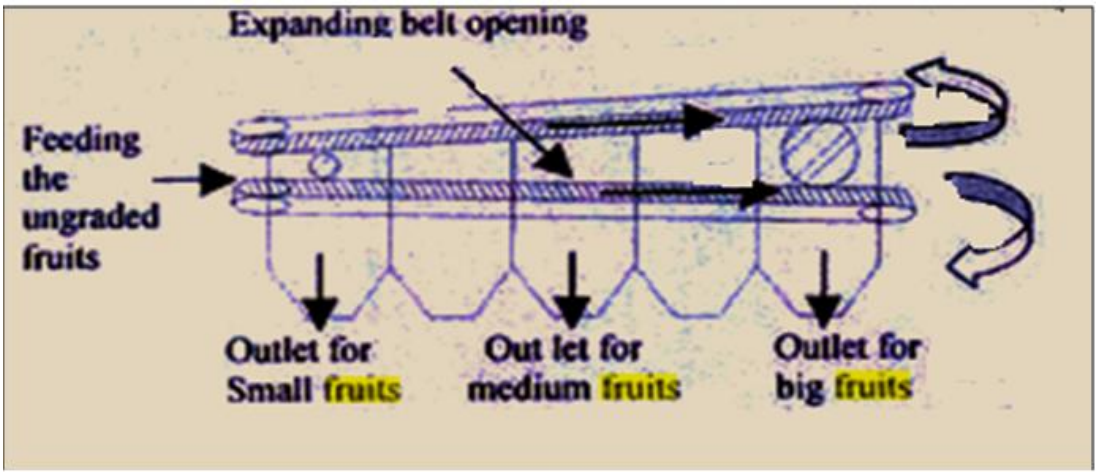


**Figure 2: Expanding Belt Fruit Grader**

## V. COMPONENTS OF ORANGE GRADING MACHINE

Overall structure of the grading machine, the complete machine can divide in 3 parts:
5.1 Feeding Hopper.
5.2 Main Frame (Conveyor Belt System).

**5.1 FEEDING HOPPER:**

A feeding hopper is a storage container which is mainly used to control the mass flow rate of oranges over the conveyor system. For this, machine feeding takes place with the help of gravity. Through the feeding hopper, a discharging chute is made which is inclined to horizontal plane of conveyor bed and through this chute oranges fall over the conveyor belt.

**5.2 MAIN FRAME (CONVEYOR BELT):**

- Pulleys.
- Permanent magnet DC motor (PMDC).
- Adjustable frame.
- Conveyor belt.
- Pedestal bearing.
- G.I. rectangular hollow section pipe main frame for conveyor belt.
- Stainless steel sheets.
- V-belt.
- V-grooved pulleys.
- Nuts, Bolts and Washers.

There is a main frame which is made by G.I. rectangular hollow section pipe and this complete frame is joined by welding process which forms the base of construction. There is adjustable frame through which the tension is provided to conveyor belt which is attached to the main frame by means of nuts, bolts and washers. Over this secondary frame, shaft is placed with the help of pedestal bearing which are bolted to the base in horizontal manner as the diameter of shaft is 1 " pedestal bearing of 1" diameter (P205) is used.

## VI. DESIGN SPECIFICATIONS

### 6.1 MAIN BED FRAME:

As this machine has its applications in rural areas and in fields of oranges, complexity of problems associated with the design of components required for this machine is always minimized. So, as suggested, priority was only given to use the components which are easily available in the markets and can be easily replace if required. All the components, which are used in this machine, are suggested by scientist, as availability being the primary criteria.

Main frame mainly supports the horizontal conveyor system which consists of pulleys, shafts, power transmission systems. As complete load of machine falls completely on the main frame, it is made to meet all the needs of loads of machine. Thus, considering the availability of materials, cast iron is completely used. Hollow rectangular pipes of Cast Iron of dimension (2"×1") are used to make main frame. As complete length of frame was much higher hence supporting members were placed to maintain rigidity of frame. Thus, due to supporting members and hollow section of bars, a complete robust construction was possible. Complete dimensions of frame are mentioned below:

Length = 100"
Height = 10 "
Breadth = 15.5 "Cross Section = 2"× 1".

### 6.2 Design of SHAFT:

Given: - P= 220.8 Watt. N = 200rpm
Dc= 5" = 127 mm. AC = DB= 88.9 mm
Angle of contact $\theta = 180^0 = \pi^C$
$\mu$=0.3
Material of shaft is mild steel.
Permissible shear stress = $\tau_{max}$ = 42 Mpa
Max. bending stress = $\sigma_b$ = 63 Mpa

**Design Criteria:**

As this shaft is completely under rotation so shear stress produces twisting moments. Also, this shaft is under continuous loading of pulleys. This total weight is balanced by bearings at support. Hence bending stresses are induced in shaft. So, for determining diameter of shaft we are considering shaft under combines bending & twisting moments only.

We know that torque transmitted by shaft:

$T=\frac{9\times60}{2\pi N} = \frac{220.8\times60}{2\pi\times200}$

*A.* T= 105.40 N-m
T= 10540 N-mm .....Eqn. (1)
Let $T_1$= Tension in tight side
$T_2$= Tension in slack side
$\therefore \frac{T_1}{T_2} = e^{u\theta}$
$T_1$= 2.56 $T_2$ .... (2)
But,
T= Net torque = ($T_1$-$T_2$) x Rc
$\therefore$ 105. 40x$10^3$= (2.56 $T_2$-$T_2$) x 63.5
$\therefore$ 105.40x$10^3$= 1.56 x 63.5 x $T_2$
$\therefore$ $T_2$= 106.40 N
Using equation (2) $T_1$= 272.38 N
As the motion of belt is in horizontal plane hence the shafts are subjected to horizontal loading only. On the other hand, pulleys are exactly same in size so net horizontal load upon shaft remains same.
By Wc= $W_D$= $T_1$+$T_2$
$\therefore$ Wc = $W_D$= 378.8 N
For moment: -
$R_A$ + $R_B$ = $W_C$+$W_D$
$\therefore$ $R_A$+ $R_B$ = 756 N ..... (3)
Also, taking moment about point A
$\therefore$ 378.8 x 88 + 378.8 x (330+ 88.9) = $R_B$ x 510
$R_B$ = 375. N
$R_A$ = 375 N ..... from (3)
B.M. at C = 375 x 88.9 = 33412.21 N-mm

B.M. at D = 375 x 88.9 = 33412.21 N-mm
Hence, T= 10540 N-mm
M= 33412.21 N-mm
Equivalent twisting moment = $\sqrt{T^2 + M^2} = \sqrt{(10540)^2 + (33412.21)^2}$
$\therefore$ Te = 35035 N-mm
As for ductile material,
By applying maximum shear stress theory
Te = $\frac{\pi}{16} \times \tau \times d^3$
$\therefore$ 35035 = $\frac{\pi}{16}$ x42x$d^3$
$\therefore$ d= 17 mm
Equivalent bending moment = $\frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$
= $\frac{1}{2}[33412 + 35035]$
Me =34223.5 N-mm
By Maximum normal stress theory
Me = $\frac{\pi}{32}$ x$\sigma_b$x$d^3$

$$\therefore \frac{34223.5 \times d^3}{\pi \times 63}$$

$\therefore$ d= 18 mm ..... (B)

Hence from eqn. (A) & (B) maximum value of diameter is 18mm. As suggested the shaft used hence is of 25 mm diameter because of its easy availability and is of standard size which fits in pulleys.Hence, this design is much safer and satisfies all rupture criteria. As 25mm is standard size of shaft size used in rural industries which is easily available in all the markets. Also, standard boxes of flat belt pulleys completely match the diameter of shaft which we have used. In this way, above analysis the diameter of shaft is much safe and correct which can withstand under various twisting of bending loading conditions.

**6.3. EXPANDING BELT FRAME:**

1. Frame:

i. Main frame of expanding belts is made up of hollow rectangular GI pipe of 2"×1" in cross section. Whole frame is of hollow pipes, as the function of pipes is only to hold the two idlers.
ii. This frame remains on plane which is exactly perpendicular to the ground. This frame is mounted with adjustable nut and bolt arrangements on the horizontal plane. Main function of the adjustable arrangement is to form the expanding gap through which grading takes place.

2. Expanding Belt:

i. Width: Expanding belts made up of reinforced plastic polymer are used. As main function of this type of belt is to provide the expanding gap for grading. Width of belt is of 4" so that when oranges enter over the conveyor belts, they will not roll over the expanding belt and fall in grading zones.

**Length:** Process of grading completely takes place with the help of expanding belt. Six types of grades should be graded over this length. As the topmost grade is graded at the end of belt, in all total length it must be divided into 5 equal parts. In which 2 feet of length is sufficient for one grade. Hence, total length of belt used in this system is of 10feet.Frame of expanding belt is providedwith two sections as given below:

**6.4 DESIGN OF EXPANDING GAP**

As suggested by scientists' number of grades is required are in the following manner:
Grade 1: - 76mm to 80mm: - grade A
Grade 2: - 71mm to 75mm: - grade B
Grade 3: - 66mm to 70mm: - grade C
Grade 4: - 61mm to 65mm: - grade D
Grade 5: - 56mm to 60mm: - grade E
Grade 6: - 50mm to 55mm: - grade F

From the above data, minimum diameter of orange was found between 50mm and maximum was 80mm. So, size variation of diameter was clearly from 50mm to 80mm. Hence slope of expanding belt is increasing from 50mm to 80mm.As designed by scientist, top grade of 76-80 mm is graded at last by passing over a complete length of conveyor. This grade is carried over complete length which is passed over pulley from where it falls down.

Hence 5 types of grades are graded with the help of gap between the conveyor belt and expanding belt. Total length available for grading is 100". So, a length of 20" is provided for each grade. So, the gap between expanding belt and conveyor belt increases by 5mm for 20" of length. Adjustable arrangement, for increase or decrease in slope of expanding belt is provided to the belt. This arrangement is shown in following picture. As shown in Fig. 13 the arrangement is made up of nut and bolts that can be fitted to various holes provided over the angular CI rod. Due to this type of arrangement, the slope can be varied as according to size of oranges. This machine is designed for the above-mentioned grades, but this gap can be varied which shows the availability over a large extent.

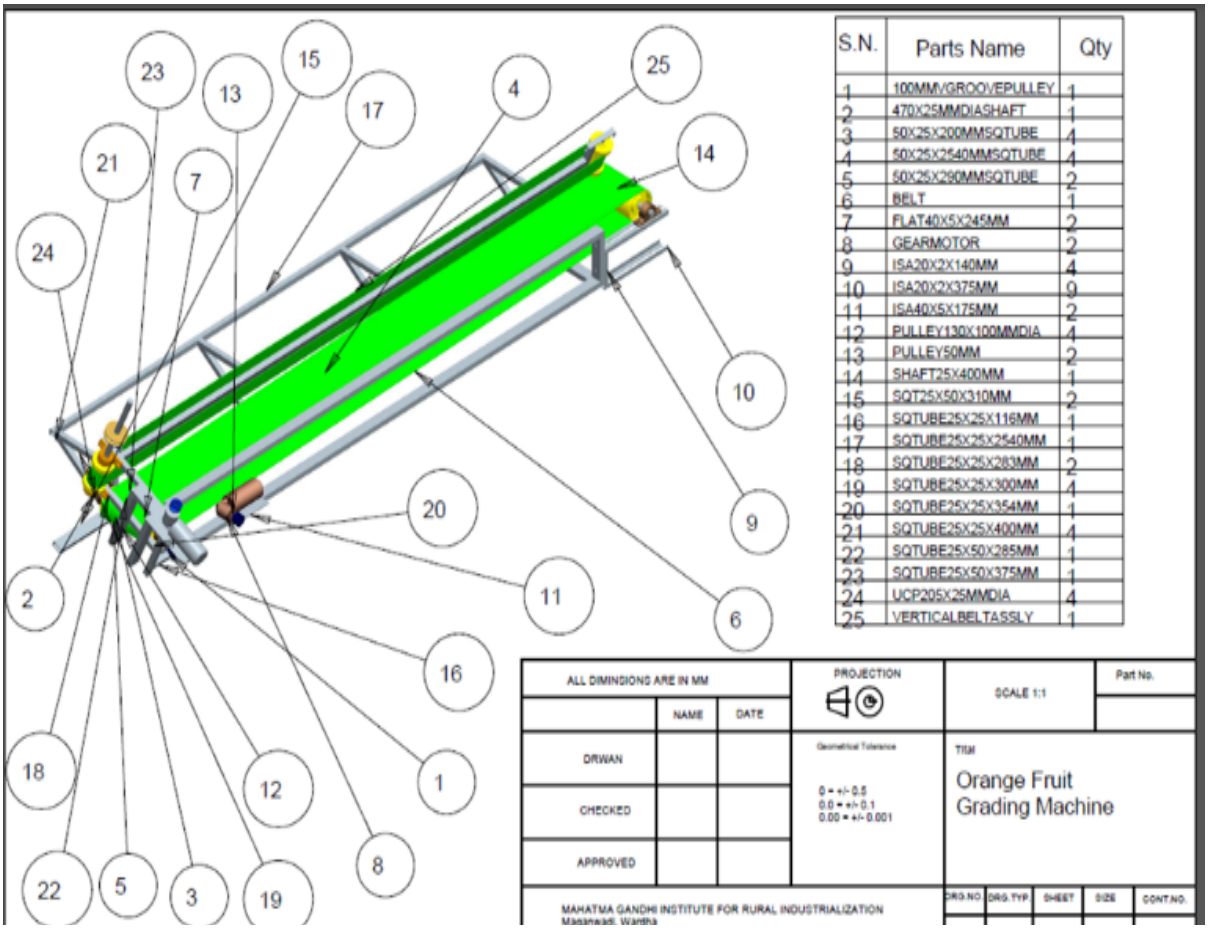


**Figure 1: CAD Model of orange Grading Machine**

## VII. WORKING

Working of proposed machine follows the same principle as that of existing P.T.M. In P.T.M grading of fruits is performed through the gap formed by the expanding belt and the horizontal conveyor belt. Working of this machine can be explained as follows: -

**Feeding System:**

In this section, the main role-playing element is hopper situated at the top in left side of the machine, where the gap between the conveyor belt and expanding vertical belt is very less. After that the hopper is filled with ungraded oranges, in which the oranges from the hopper pass through the discharge chutes and then passing from chutes make entry over conveyor belt.

**Role Of Conveyor Belt:**

After passing through the feeding system, oranges arrive at conveyor belt which is continuously moving in direction of grading.

i. On this bed, conveyor belt is the main part which is mounted on 4 pulleys. For providing support to the conveyor belt a stainless-steel sheet is provided in between the belt and on the upper surface of frame.

ii. When the motion of belt is started in direction of grading, oranges move in same direction along with conveyor belt. As inclination is provided to the horizontal bed of machine, oranges always remain in contact with expanding belt.

iii. The gap between the expanding belt and conveyor belt is continuously increasing from 50mm to 75mm. As belt is 10 ft in length 5 sections of grade are formed over the conveyor belt. As per consequences, grading of oranges into 5 categories is possible. $6^{th}$ grade of orange is allowed to pass over pulleys at another end and is allowed to get collected in tray.

iv. When grading takes place over the conveyor bed, the stainless-steel plate which is mounted over the main frame acts as platform for graded oranges and gives them a guide for collecting tray.

v. As separate power sources are provided to different belts, arrangements are made to maintain the relative velocity of zero between the two belts. As this relative velocity is zero, the grading efficiency increases. Each grading tray is kept in each grading division, so that respective oranges can be collected in the trays and hence separation is possible.

Following data explains about the no. of grades and sizes of oranges.

**Grades Of Oranges: -**

Basically, there are six grades which are accepted by the market as follows: -

Grade 1: - 75mm to 80mm: - grade A
Grade 2: - 70mm to 75mm: - grade B
Grade 3: - 65mm to 70mm: - grade C
Grade 4: - 60mm to 65mm: - grade D
Grade 5: - 55mm to 50mm: - grade E
Grade 6: - below 55mm: - grade F

As mentioned above 6 grades are the grades of orange fruit which are graded on the basis of diameter of orange fruit. The grading of fruit will take place at equal distance of 2 feet, and thus after the graded fruit get fall down in the caret (i.e. collecting tray) which is placed below the conveyor belts.

**Figure 4: Orange Fruit Grading Machine**

## VIII. APPLICATIONS

**1. Maha-Orange:**

As mentioned earlier, main problem of grading was faced by Maha-Orange, indirectly it was faced by orange growers in Maharashtra. Due to this machine, problem can be sorted out to great extent and ultimately helps Maha-Orange to make supply chain of Oranges. Thus, this machine is boon for farmers as it is bringing oranges to different commercial zones of market.

**2. Farm level installations:**

As proposed machine is portable and robust in construction, it can be readily used at farm level installations and thus it saves the transportation cost of farmers. Prices of oranges are fixed according to grades,

Orange growers will be more concerned regarding prices and thus, this will increase the transparency in system of growers, markets, customers, etc. which would attract more farmers towards Maha-Orange.

**3. Small & micro industries:**

It is used in small scale industries which produces fruit juices and soft drinks. It is useful for the farmers who have small scale production.

**4. Fruit markets:**

These machines can also be installed at Maharashtra State Agri-Product Marketing Co-operations at their respective district headquarters to enhance the grading process of oranges and this will again give benefit growers. Responsive market demands a greater emphasis on quality and quantity resulting in the greater need to improve grading practices for fruits.

## IX. CONCLUSION

An Orange grading machine which works on principle of expanding belts was designed, fabricated and developed. This machine was tested for grading orange fruits into six grades. During testing of machine, successfully six grades of oranges were obtained. This makes the machine perfect of orange grading on size basis, with some slight modifications. As this machine is designed with the help of parts which were easily available in markets, this makes the machine much more suitable for orange fruit growers from rural areas. This machine is completely robust in nature and absolutely fit for rural background. Also, it supports farm level installations due to which grading are performed at farm level. Orange grading machine completely solved the problem of Maha-Orange by grading oranges on size basis. Due to this sorting of oranges, prices of oranges can be fixed according to quality of fruits. This fixing of prices of oranges for Maha-Orange ultimately helps the commercialization of oranges and this machine provides a moral base for grading of oranges.

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