ABSTRACT

Grading and sorting of fruits is widely done using conventional mechanical sorters as well as the more advanced machine vision based fruit sorters. Typical mechanical or machine vision based fruit sorting systems consist of mechanical handling subsystems for fruits singulation, conveying and sorting operations. Throughput of a fruit sorter mainly depends on the mechanical design of the fruit handling subsystems. The present paper describes some novel configurations for mechanical handling subsystems used for fruit singulation, conveying and sorting operations suitable for online mechanical or machine-vision based fruit sorting systems. Some of the proposed subsystems for conveying combine the imaging and sorting sections and thus minimize the fruit transfers.

Keywords: quality inspection, machine vision, sorting and grading, mechanical design, fruit handling.

INTRODUCTION

As both the market and the technology are constantly evolving, fruit grading and sorting machines are being continuously developed ensuring careful product handling as well as achieving uniformity of grading. The development of good fruit handling system added with image processing technique will help in the automation of such industries. Instrumentation based on image processing with effective fruit handling systems offers solutions for implementing automatic grading to provide accurate, reliable, consistent and quantitative information. This has resulted in growing trend towards automation.

Machine vision plays a large part in grading and sorting of fruits providing quality assurance so that the fruits get added value for their worth. These machine vision systems also have a higher throughput compared to manual sorting and are more consistent. The general arrangement of any machine vision based fruit handling system is shown in Fig.1.1 [1]. The major handling requirements are singulation of objects for inspection, conveying for inspection and sorting, presentation for imaging and control action based on inspection criteria. These sub-modules play an important role in influencing the overall performance of any fruit sorter. Over the decades, lot of advancement has taken place in each of these sub modules of the sorting/grading system of fruits. Whether it is a mechanical or machine vision based fruit sorting, mechanical handling subsystems play a major role on the overall performance in terms of throughput and safe handling of fruits.
2.0 Literature Survey:
Exhaustive literature survey on the various techniques and related equipments on fruits sorters and graders [1] reveals that a few industries abroad are manufacturing and selling a variety of fruit sorting and grading equipments, but all of them are very costly which cannot suit the pockets of small scale industries existing in developing countries.

In many of the preceding research work, one or several methods were employed, to acquire image features for food quality evaluation, yet little or no explanation of the reason for using such methods was given by the researchers [2], [3]. There is still lack of a universal method that can be proposed to obtain the most appropriate handling method for the inspection while facing the infinitely diverse nature of food products. All these factors increase the difficulty and complexity of inspection using computer vision for the fact that it is difficult to decide the optimal method for handling. Therefore, a review was done on the fruit handling methods available to propose design alternatives.

From the internet survey it was found that there are a number of sorters and grader equipment manufacturers abroad who manufacture systems for online sorting and grading of fruits and vegetables. Only few of them who are pioneers in this field were considered for the study, viz., Colour Vision systems (CVS) - Australia, PSF equipments - Australia, Aweta - Netherlands, Autoline - USA, Greefa – USA, Compac – USA, Unitec – Italy and Farmco Inc. – USA. The type of fruits and vegetables handled by these companies and the inspection parameters handled by them are listed under Table 2.1 and Table 2.2 respectively. Some of the patents related to the fruit handling system (Table 2.3) were studied for understanding the various fruit handling mechanisms.

3.0 Proposed Mechanical Handling Subsystems for Fruit Sorting:
The literature survey given in Section 2.0 indicates that fruit sorting systems are mainly based on either machine vision or mechanical control. Based on detailed study of available literature including patents, commercial systems and based on experience, we propose some novel mechanical handling subsystems for singulation, conveying and sorting of fruits suitable for implementation in mechanically controlled or machine-vision based fruit sorters. The design configuration and operation of the proposed subsystems are described using schematic diagrams.

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Table 2.1: Types of fruits and vegetables handled by some companies.

<table>
<thead>
<tr>
<th>Name of sorter &amp; grader equipment manufacturer</th>
<th>Apple</th>
<th>Mango</th>
<th>Citrus / Orange</th>
<th>Grapes</th>
<th>Tomato</th>
<th>Potato</th>
<th>Cucumber</th>
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<td>Unitec, Italy</td>
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</table>

Table 2.2: Inspection parameters handled by some companies.

<table>
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<th>Name of sorter &amp; grader equipment manufacturer</th>
<th>Colour</th>
<th>Weight</th>
<th>Size</th>
<th>Shape</th>
<th>Volume</th>
<th>Density</th>
<th>Brix</th>
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Table 2.3: Patents related to fruit handling system.

<table>
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<tr>
<td>US5339963</td>
<td>Method and apparatus for sorting objects by colour</td>
<td>patented method for sorting objects by colour</td>
</tr>
<tr>
<td>US5751833</td>
<td>Apparatus and method for inspecting articles such as agricultural produce</td>
<td>patented apparatus for inspecting agricultural produce</td>
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<tr>
<td>US5799105</td>
<td>Method for calibrating a colour sorting apparatus</td>
<td>patented method for calibrating a colour sorting apparatus</td>
</tr>
<tr>
<td>US6401913</td>
<td>Conveyor device for products, in particular fruits, for feeding a unit for sorting said products</td>
<td>conveyor device for fruit sorting</td>
</tr>
<tr>
<td>US770111</td>
<td>Apparatus for sorting fruit according to colour</td>
<td>patented apparatus for fruit colour sorting</td>
</tr>
<tr>
<td>US553628</td>
<td>Method and apparatus for sorting objects by colour including stable colour transformation</td>
<td>patented method for stable colour transformation</td>
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<tr>
<td>US5791497</td>
<td>Method of separating fruit or vegetable products</td>
<td>patented method for fruit separation</td>
</tr>
<tr>
<td>US66252188</td>
<td>Sorter for agricultural products</td>
<td>patented fruit sorter</td>
</tr>
<tr>
<td>US6888082</td>
<td>Analizing method and device for automatically sorting products such as fruit</td>
<td>patented method for fruit sorting</td>
</tr>
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</table>
3.1 Proposed configurations of singulators:
Presently V-troughed twin belt singulators running at differential speed [4],[5] and drum type singulators with flat baffle plates [6] are being used by most of the commercial systems. Here, few other alternative configurations of singulators, have been proposed which can serve the purpose: (a) Singulator drum with concave felt material (food grade) [Fig.3.1.(a)], (b) Singulator drum with inflated rubber tube (food grade) [Fig.3.1.(b)] and (c) Singulator drum with nylon bristles (food grade) [Fig.3.1.(c)].

![Fig. 3.1: Proposed singulator drum with (a) concave felt material, (b) inflated rubber tube, (c) nylon bristles.](image)

3.1.1 Singulator drum with concave felt material:
From experience it is observed that, in the case of a singulating drum having flat baffle plates cushioned with padded material, when fruits enter into the drum, they are subjected to some impact load as it get hits on all sides during motion. Instead, it is proposed that if the baffle plates are replaced with curved soft food grade felt material having sufficient cushioning [Fig.3.1(a)], may offer a smooth transfer with negligible impact, as the curved profile will adapt to the shape of the fruit being transferred. Fruits will not hit the sides.

3.1.2 Singulator drum with inflated rubber tube:
The proposed configuration uses an inflated rubber tube, as shown in Fig.3.1(b), which gently presses on fruits providing cushion effect and carry them to the next section one by one. This method offers absolutely no impact to the fruits. The transfer rate can be controlled by varying the drum speed.

3.1.3 Singulator drum with nylon bristles:
This is similar to the singulator drum with inflated rubber tube but the rubber tube is replaced by nylon bristles of appropriate diameter as shown in Fig.3.1(c). Function wise it is similar to the inflated rubber tube type. As the drum rotates, nylon bristles wrap the fruits to be transferred and gently transfers to the next section one by one.

3.2 Proposed design configurations of conveyors and sorters:
The study reveals that colour, size and shape inspection are done by rotating rollers and any other parameters like weight measurement is done with specialized trays or cups [1]. In most of the cases, the fruits are finally sorted by central dropping of the fruit carriers [7] or by side tilting of fruit carriers [8].
Here we have proposed some additional mechanical design configurations to sort fruits based on size, weight or combination of such quality parameters.

3.2.1 Collapsible roller type sorter:
The proposed collapsible roller type sorter is a size-sorting conveyor. The principle of this conveyor is that when fruits are placed and conveyed over the rollers connected to a high pitched continuous chain link conveyor and if by some mechanism if the gap between the rollers can be expanded or contracted, the fruits will get dropped into the gaps depending upon their size, and get collected into bins. The proposed model is as shown in Fig.3.2. The expansion and contraction of the chain links can be controlled using suitable mechanical control devices (tie rods) or electrically operated control devices. A number of sections can be provided along the conveyor length for sorting of fruits according to their size ranges.

To every alternate end of the successive chain links, a fruit carrying roller with guide bearings and a stub axle with freely rotating bearings are fitted. Two structural guides are provided, one at the top for guiding the rollers such that the roller guide bearings roll on the top of this guide and the other for guiding the stub axle bearings such that the bearings roll below this guide. The position of the guides, over which the stub axle bearing rolls can be controlled using a vertical height adjusting tie rods, which can be manually adjusted and kept at fixed positions depending upon the gap size to be opened for a particular range of fruit size to fall. These tie rods can be positioned at intervals depending upon the range of sizes of fruits to be sorted. These tie rods can be connected to stepper motors and their height can be precisely adjusted for the required expansion or contraction of the chain links. When the bearings move from one section to the next section it passes over a gradual taper provided in the structural guide. The bearings after passing over the entire range of guides, are smoothly brought in level with the rollers, i.e., the roller axes and the stub axle bearing axes will
come in one plane and then enter into the chain return path via the drive sprocket. The chain sprockets can be driven by an AC motor. The speed of the motor can be controlled using a variable speed drive.

**Fig. 3.2:** Proposed collapsible roller type sorter.

The advantage with this type of conveyor is that the gap variations can be dynamically controlled and hence useful for sorting any size of fruits. The limitation in this method is that when the bearing rolls from one section to another section on a gradual taper, the gap between the rollers will get altered and there are slight chances of next higher sized fruit to get sorted in the earlier bin.

**3.2.2 Dual roller type sorter:**

The proposed dual roller type sorter is a general sorting conveyor, which can be used for sorting fruits for any combination of surface quality parameters. One of the dual rollers is a floating roller (or swing roller) as shown in Fig.3.3 that carries the fruit along with the main roller. Swing roller has a drag pin or pinch roller which moves over a guide. On reaching a sorting station, the floating roller swings into the gap, created in the fruit path by a solenoid operated pneumatic actuator, and the fruit falls down.

**Fig. 3.3:** Proposed dual roller sorter in dropping position.

The main roller when running under the imaging station can be rotated by means of a friction belt provided at the bottom so as to expose the full surface of the fruit to the imaging unit. The swing roller running on the guide does not touch the friction belt and it gets the drive from the main roller via the fruit as the fruit rests on both the main roller and the swing roller. Both the rollers can be curved at the centre to ensure seating of the fruits centrally without floating. Speed at which the fruit is rotated depends upon conveyor speed and the friction belt speed. The advantage of this type of sorter is that there is no need to have separate conveyor for imaging and sorting, thus eliminating the transfer problem. The same conveyor can be used for carrying the fruits for imaging and for sorting. A number of sections can be provided along the conveyor length for sorting of fruits according to the combinations of user defined surface quality parameters.

**3.2.3 Inclined bed type sorter:**

The proposed inclined bed type sorter is an improvement over the mechanical size-sorting conveyor. The principle of this conveyor is that when the fruits roll down along the gently tapered conveyor, depending on the size of fruits, they get into the preset gaps provided by the adjustable rollers at the sloping end (Fig.3.4). The gap heights presently controlled using mechanical control devices can be replaced with electrically operated control devices. In existing sorters, the adjustable rollers are positioned and their heights are controlled...
by tie rods placed at intervals depending upon the size range of fruits to be sorted. In proposed sorters, these tie rods can be connected to stepper motors and the rollers can be precisely adjusted to obtain the required gap heights.

3.2.4 Plunger type sorter:

The proposed design configuration (Fig.3.5) is as an improvement over the weight-based sorter. The conveyor is a general fruit carrier conveyor, which can be used for sorting the fruits for any combination of surface quality parameters. In existing weight based sorter, depending upon the preset weight of the balancing weigh scale, the scale tilts and the fruit carrier drops down. In the proposed design configuration, the counterweight is replaced with a pneumatic actuator, for sorting fruits based on multiple parameters. On receiving the signal from the processor (controlling sorting computer), the pneumatic actuator will be operated to push the weight scale up and create a gap at the other end of the scale for the fruit carrier to fall down, dropping the fruit.

![Proposed inclined bed type sorter](image1)

**Fig. 3.4:** Proposed inclined bed type sorter.

![Proposed plunger type sorter](image2)

**Fig. 3.5:** Proposed plunger type sorter.

3.2.5 Push type sorter:

The proposed push type sorter (Fig.3.6) is a general sorting conveyor, which can be used for sorting the fruits for any combination of surface quality parameters. This type of conveyor can be provided with simple plain cylindrical padded rollers. Here, the fruits are pushed sideways using pneumatic cylinders actuated by solenoid valves positioned at different places at the sorting station. On reaching a sorting station, the pneumatic cylinder is actuated and the piston pushes the fruit to the side and makes it to fall into the sorting bin. The piston ends can be provided with cushion pads so as to avoid damages to the fruit. Push-on fittings with polyurethane tubes can be used in the pneumatic circuit. Fig.3.6 shows the fruit in sorted condition.

3.2.6 Blower type sorter:

The proposed blower type sorter is a general sorting conveyor, which can be used for sorting the fruits for any combination of surface quality parameters. This is similar to the plunger type sorter where instead of pneumatic actuators, air nozzles actuated by solenoid valves are used for blowing the fruits at sorting stations. On reaching a sorting station, the air nozzle is actuated and the blown air pushes the fruit to the side and makes it fall into the sorting bin. A number of air nozzles can be positioned in line at intervals, depending upon the number of grades of fruits have to be sorted. On receiving the signal from the processor (controlling sorting computer), corresponding air nozzle will be actuated by the solenoid valve. Push-on fittings with polyurethane tubes can be used in the air circuit. Fig.3.7 shows the fruit in sorted condition. The same conveying rollers used for imaging can be used in the sorter section thereby eliminating the transfer problem. The limitation is that the correct type of air nozzle should be selected such that the air blown should not damage the fruits. The air should be blown such that it wraps the fruit gently and pushes.
3.2.7 Cleated belt type sorter:

The proposed cleated belt type conveyor is a general sorting conveyor, which can be used for sorting the fruits based on surface quality parameters. The conveyor is made up of nylon belt, which is partitioned into a number of pockets using cleats. The fruits are placed in these pockets and moved under the surface inspection system. Depending on the number of grades of fruits to be sorted, a number of cleated conveyors can be assembled in line in stages. At the end of each conveyor stage, spring controlled hinged flaps and pneumatic cylinders operated by solenoid valves are provided. Depending on the grade, the corresponding flap is opened and the fruit falls into the bin. If it is of different grade, the flap does not open, and the fruit passes on to the subsequent section. This process continues till the fruit reaches the correct sorting bin.

The conveyor assembly is shown in Fig. 3.8. The fruit spilling at the sides is avoided by pasting corrugated cleats at the edges of the belt. The inspection system is placed above the conveyor belt in the first section. The advantage of this type of sorter is that multiple lanes of fruits can be graded and sorted. A number of sections can be provided along the conveyor length for sorting of fruits according to the features desired.
4.0 Conclusion:
This paper has reviewed the mechanical handling subsystems in commercially available machine vision based and mechanically-controlled fruit sorting systems. A few novel configurations of mechanical handling subsystems suitable for mechanically-controlled and machine vision based fruit sorting systems have been described using schematic diagrams. The design feasibility of few configurations for singulating, conveying and sorting has been discussed. Some of the proposed design configurations are totally new ideas and some are improvement over the existing design configurations. All the proposed configurations are required to be fabricated and tested for fine-tuning of their design.

Acknowledgement
The authors wish to thank the Director, CSIR-CEERI, Pilani and the Scientist-in-charge, CSIR-CEERI Chennai Centre for their encouragement and valuable support.

References
4. Colour Vision systems (CVS), Australia – Product catalogue
5. Greefa, Newzealand – Product catalogue
6. PSF equipments, Australia – Product catalogue
7. Aweta G&P, Netherland – Product catalogue
8. Compac, USA – Product Catalogue