CHAPTER 2

FRUITS CONVEYOR SYSTEM

2.1 INTRODUCTION

In an on-line sorter, the conveyor system physically moves large quantities of fruits along the process line for sorting, grading and packing either manually or automatically (J.A. Throop and G.E.Rehkugler 1986, M.Recce, et al., 1998, H.K.Purwadari and I. W. Budiastra 1997). In general, the conveyor is required to move the fruits at constant speed along the process line for quality inspection. In systems using machine vision for inspection, the conveyor is additionally required to fully expose the fruits for imaging over their surface area.

Choice of a conveyor system depends on the type of fruit and the specific application requirement. Four types of conveyor systems are in use commercially. The first type of conveyor system uses a number of parallel rollers, which rotate concentrically at a constant speed without lateral movement. This is the most common design employed for conveying many varieties of fruits. The second type of conveyor uses specially designed fruit holder, which physically grabs a fruit with its two specially designed arms. The holder holds the fruit firmly and moves laterally to its destination. The third type uses specially designed cups to hold and carry fruits, one fruit in each cup.

This arrangement is more suitable where the fruits are sorted by weight. The fourth type employs a number of specially designed bi-cones, which rotate concentrically but without any lateral movement, to transport the fruits. This mechanism not only moves the fruit laterally but also aligns the fruit to its stem and calyx axis. This is the most popular conveyor system particularly for implementing machine vision based sorting and grading. However, this arrangement does not guarantee adequate contact of the fruit's surface with the cone. This may cause slip in the fruit's rotation and may create difficulties in synchronising image capture with the fruit's movement.

Considering the above, an improved conveyor system is designed and developed which provides a better overall performance in terms of improved surface contact between fruits and rollers, improved orientation efficiency and easier interfacing to the imaging system.

This chapter discusses the design, fabrication and performance evaluation of a new robust and unique conveyor system for sorting and grading of fruits like apples. Section 2.2 describes the development of two new types of orientation mechanisms. Section 2.3 describes the integration of the conveyor system using a fruit feeding, singulation and the newly developed orientation mechanism.

2.2 ORIENTATION MECHANISM

Orientation mechanism plays an important role in the fruit conveying specially for on-line sorting of fruits based on size, shape, colour and defect identification using machine vision technology.

A normal conveying system moves the fruit at constant speed while optionally rotating it concentrically. However for machine vision applications the orientation of the fruit also becomes important as it controls the portions of the fruit available for imaging. For many fruits the stem portion may be mistaken for bruises (J.A. Throop et al 1997, J.A., Throop et al., 1995). The stem and some of bruises will reflect light of the same wavelength and thus create problems in isolating bruises. For this reason, proper orientation of the fruit to stem and calyx axis is preferable.

The orientation mechanism orients the fruits to stem and calyx axis starting from any random orientation. The fruit is rotated around the stem-calyx axis and multiple images are collected for evaluation. This orientation avoids the stem portion from appearing in the images. In spite of this orientation, the captured images may still include portions of stem for fruits with longer stems. However, in this case, the stem portions will appear at either of the stem or calyx ends of fruit's image. Hence, it will be easier to detect and eliminate the stem portion by suitable software algorithms (E.Molto, et al.,1996). Two mechanical systems for orientating apples are designed namely, vertical orientation unit and horizontal orientation unit.

2.2.1 Vertical Orientation Unit

The vertical orientation unit contains an orienting wheel, apple supporting 'O' ring and apple seating 'O' ring as shown in Figure 2.1. The electrical diagram of the unit is shown in Figure 2.2. The setup uses a three phase electrical motor driven by a programmable frequency converter (Siemens Make, Micro master vector model) for setting the motor at different speeds. The apple is placed in a random position within the apple supporting 'O' ring.

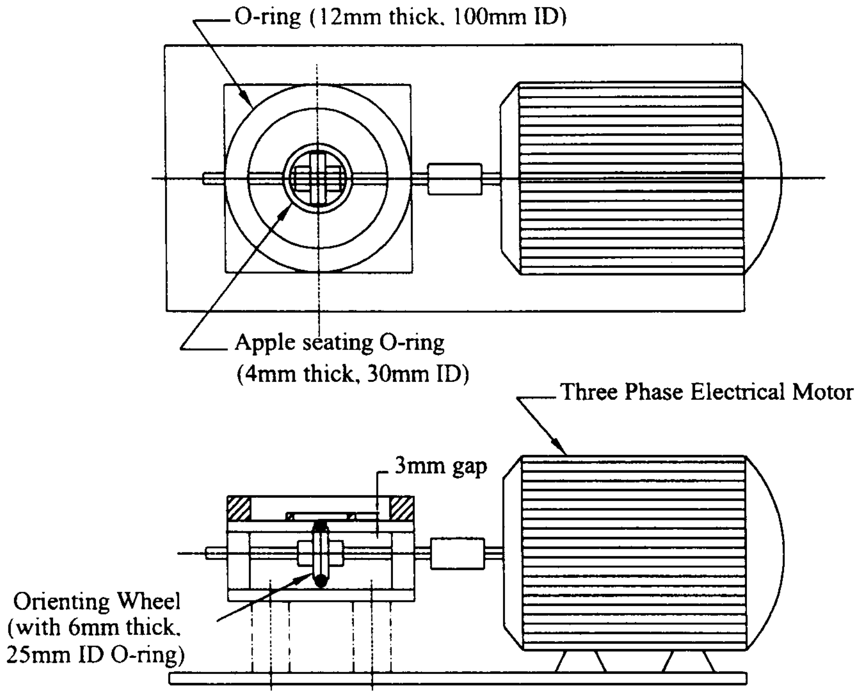

Figure 2.1 Vertical Orientation Unit

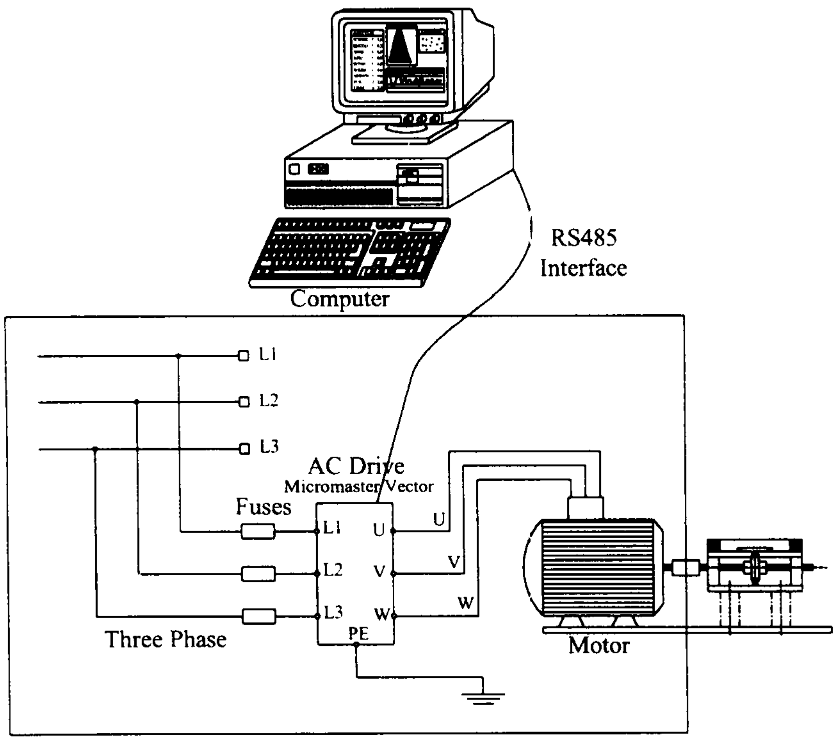

Figure 2.2 Experimental Setup

The motor spins the orienting wheel and hence the apple at pre-determined speed. However, when the apple gets oriented vertically to its stem-calyx axis, the apple ceases to rotate. This is because the orienting wheel does not touch the apple's surface anymore due to the presence of a dip on the apple's bottom and specific gap maintained between orienting wheel and the apple seating 'O' ring. After considerable experimentation, this specific gap is optimised to be 3mm.

The unit is evaluated using four varieties of apples each containing 100 sample fruits. The evaluation used three common Indian and one imported apple varieties. The experimentation is aimed at determining the orientation time which is the time taken for completely orienting an apple starting from any arbitrary orientation. During experimentation, the motor is set to different speeds to determine the optimum speed for all varieties. It is found that an orienting wheel speed of 204 revolutions per minute is optimum for all the apple samples. Using the optimum speed, the orientation time for each fruit is measured. The measured data is analysed statistically to obtain orientation time for different success rates expressed in terms of standard deviation. The results indicate that Fuji (imported), Golden smith, Red delicious and Golden delicious apples require a maximum time of 9.00 sec, 2.31 sec, 8.82 sec and 5.18 sec respectively for orientation with 100% success rate. Table 2.1 shows the orientation time taken for different success rates for each apple variety. Figure 2.3 shows the time versus percentage success relationship for the apple varieties.

Table 2.1 Qualification of success rate for Vertical orientation

Success	Golden Smith (Sec)	Fuji (Sec)	Golden Delicious (Sec)	Red Delicious (Sec)
σ (68.06%)	1.19	1.58	2.38	1.80
2σ (95.44%)	1.94	4.81	4.56	4.34
3σ (99.73%)	2.31	8.85	5.18	6.08

Although the vertical orientation unit is found to be very efficient for orientation function, it exhibits the following drawbacks for integration into an on-line conveyor system.

a) Apple is required to be automatically placed on to the orienting wheel setup by suitable mechanism.
b) Apple does not move laterally during the orientation operation, which seriously affects the sorting throughput.
c) A separate motor and its interface system may be required to operate the orienting wheel, which will increase the cost of on line sorter system.
d) Apple does not rotate after orientation, which will pose difficulties in imaging apple's entire surface.
e) The 'O' ring supporting the apple reduces the surface area available for imaging.

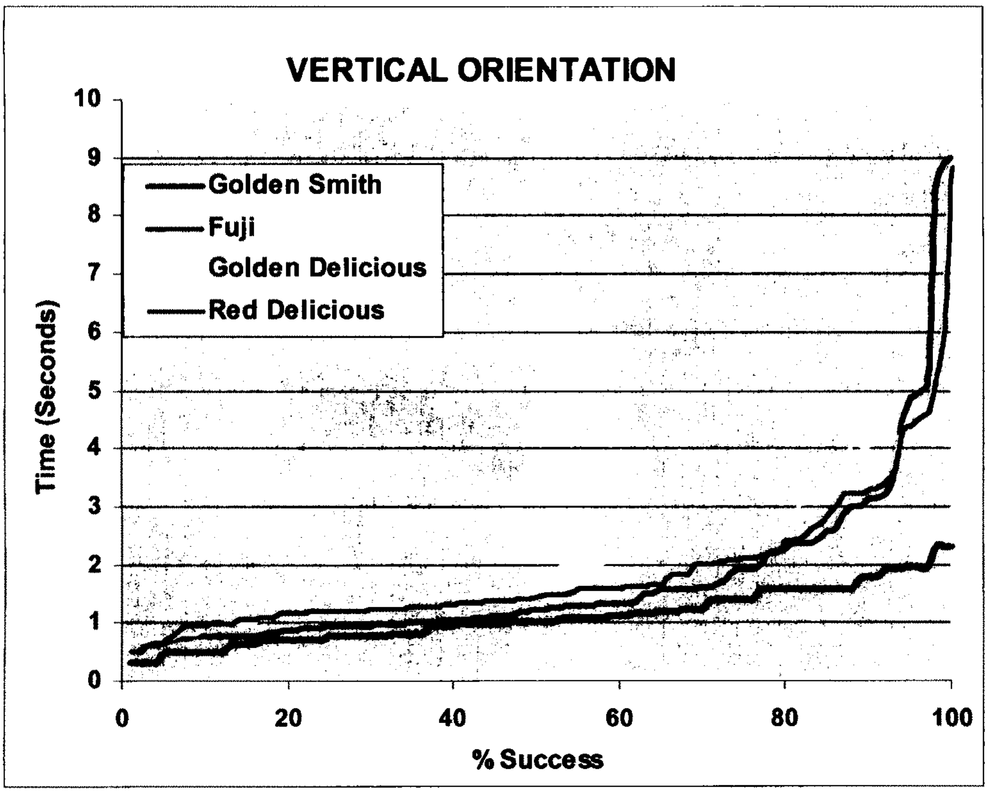

Figure 2.3 Performance of Vertical Orientation unit Time versus Percentage success

To overcome some of the above shortcomings, an "Horizontal orientation unit" is designed and developed as described in the following section.

2.2.2 Horizontal Orientation Unit

The horizontal orientation unit orients the apple horizontally to its stem and calyx axis starting from any arbitrary orientation. The mechanical drawing of the unit is shown in Figure 2.4. The unit is made up of a rubberised aluminium roller and a spring-loaded nylon hyperbolic-contoured roller coupled to a nearly flat nylon disc.

The rubberised roller, driven by a friction belt drive with a tensioning mechanism, rotates the fruit. The friction belt drive coupled with two end rollers moves at the programmed speed from a motor coupled to a frequency converter. The motor driven by a programmable frequency converter (Siemens Make, Micro master vector Model) moves the endless belt through end rollers. The motor's electrical connections are same as shown in Figure 2.2.

The shape of the hyperbolic contoured roller is tailored to suit the common shape of apple varieties. Both the hyperbolic roller and the nylon disc are spring loaded. This allows them to slide sideways along their common shaft to accommodate different sized fruits. A nylon arrestor is placed between the hyperbolic roller and the nylon disc to provide suitable spacing for the minimum sized apples. The contours of hyperbolic roller and nylon disc are so designed that the fruit aligns horizontally to its stem and calyx axis even when it is introduced in a random orientation.

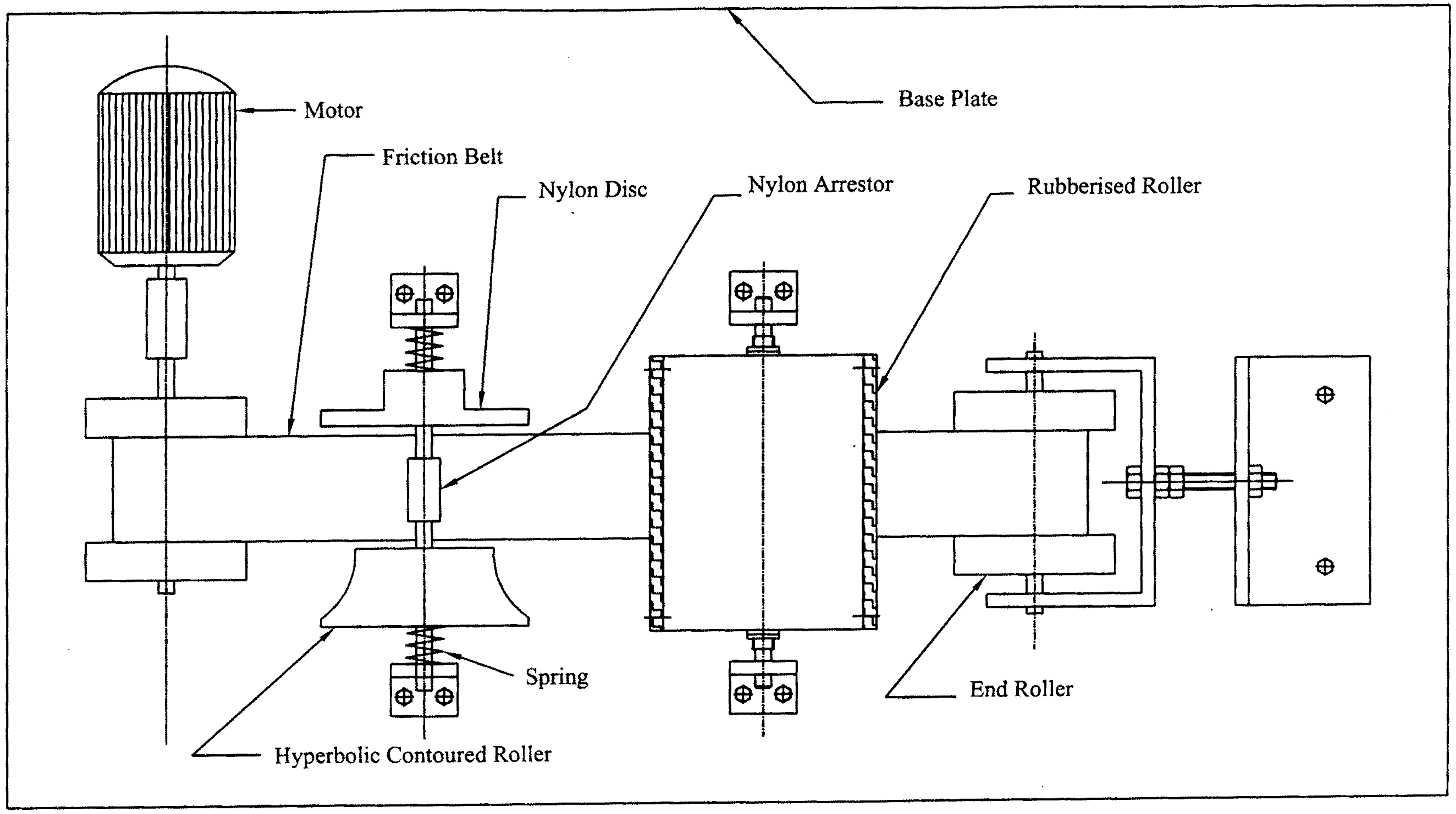

Figure 2.4 Horizontal Orientation Unit

The apple is placed in a random position between the rubberised roller and the combination of nylon disc–hyperbolic roller set. The unit is evaluated using four varieties namely, Fuji (imported), Golden smith, Red Delicious and Golden delicious apples, each containing 100 fruits, as done for evaluating the vertical orientation unit. The measured data is analysed statistically to obtain orientation times for different success rates in terms of standard deviation. Optimum rubberised roller speed is found to be 96 RPM. Table 2.2 shows the orientation time taken for σ, 2σ ***and*** 3σ success rate for each apple variety. Figure 2.5 shows the time versus the percentage success relationship for the apple varieties.

Table 2.2 Qualification of success rate for horizontal orientation

Success	**Golden Smith (Sec)**	**Fuji (Sec)**	**Golden Delicious (Sec)**	**Red Delicious (Sec)**
σ **(68.06%)**	2.32	2.12	1.62	1.94
2σ **(95.44%)**	8.21	5.0	3.34	4.19
3σ **(99.73%)**	∞	6.13	3.97	∞

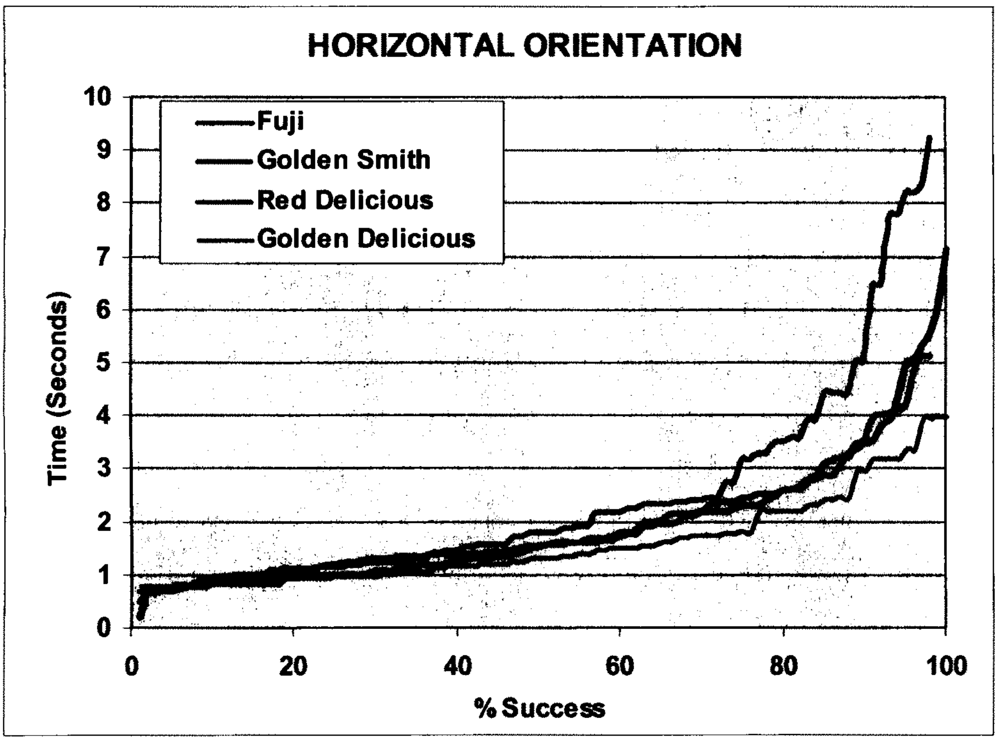

Figure 2.5 Performance of Horizontal Orientation unit Time versus Percentage success

2.3 DEVELOPMENT OF INTEGRATED CONVEYOR

An integrated conveyor system is designed and implemented for automatic apple sorting. Figure 2.6 shows the mechanical assembly of the system that contains three sections namely, fruit feeding and singulation section, fruit orientation section and fruit conveying section. Figure 2.7 shows the photograph of the developed system.

2.3.1 Fruit Feeding and Singulation

The apple feeding section shown in Figure 2.8 consists of a tapered open bin where the fruits are dumped for sorting. These fruits are then carried by means of rolling fingers, which are driven by sprocket chain conveyors. The sprocket chain conveyor gets its drive from the main drive motor, which transports and orients the apples. The rolling fingers and the bed on which the apple moves are covered with soft food grade rubber so that the apples are not damaged during transportation. A baffle plate guides the fruits one after another at a defined speed and the fruits are further guided to the orientation section by a singulating drum. The baffle plate can be adjusted so as to accommodate different sizes of the apples for sorting. The singulating drum is provided with pockets where the apples from the feeding bin enter one after another. The speed of the singulating drum is synchronized with the speed of the feeding chain drive and the main conveyor drive speed for free transportation of the apples.

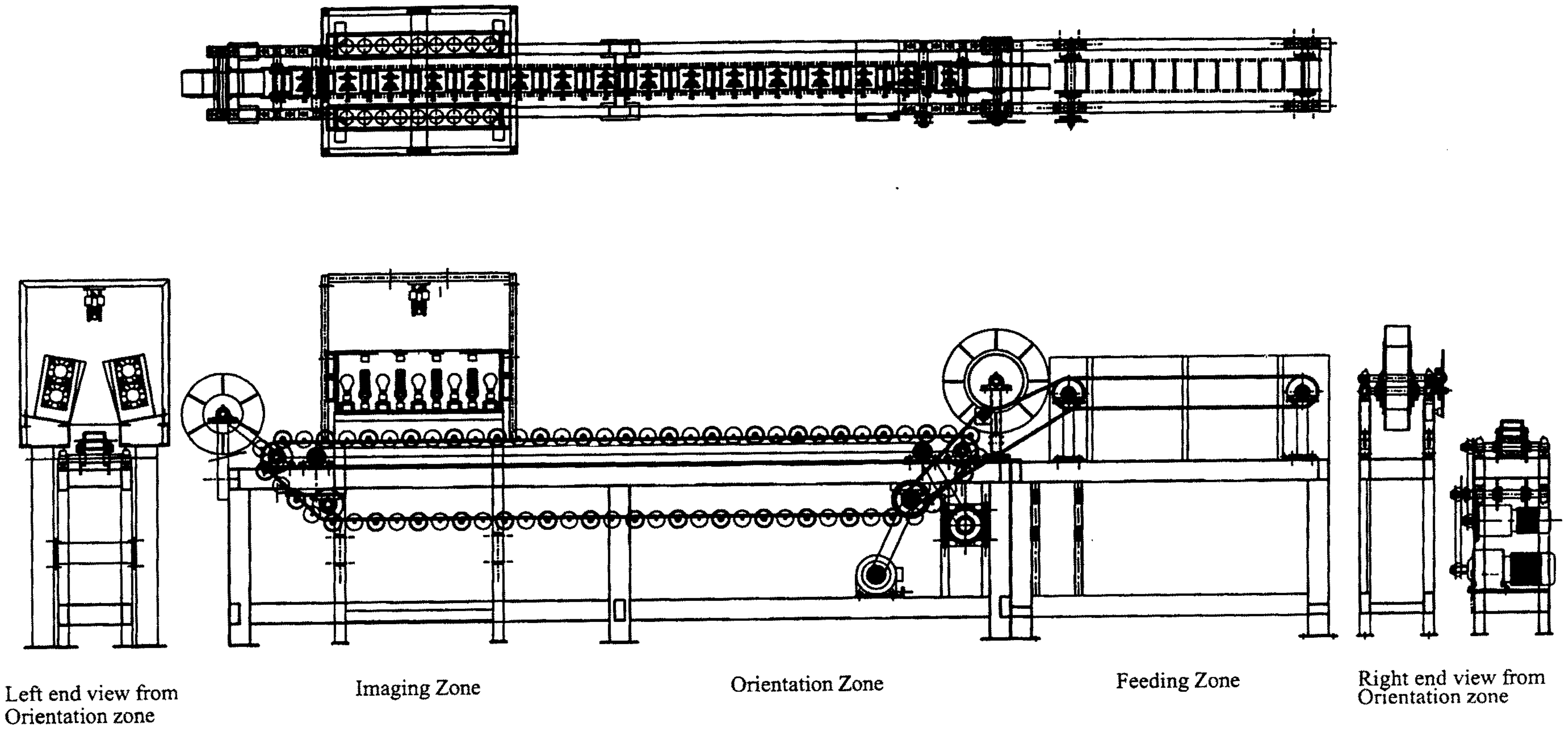

Figure 2.6 Mechanical Assembly of Fruit Feeding, Orienting and Conveying Sections

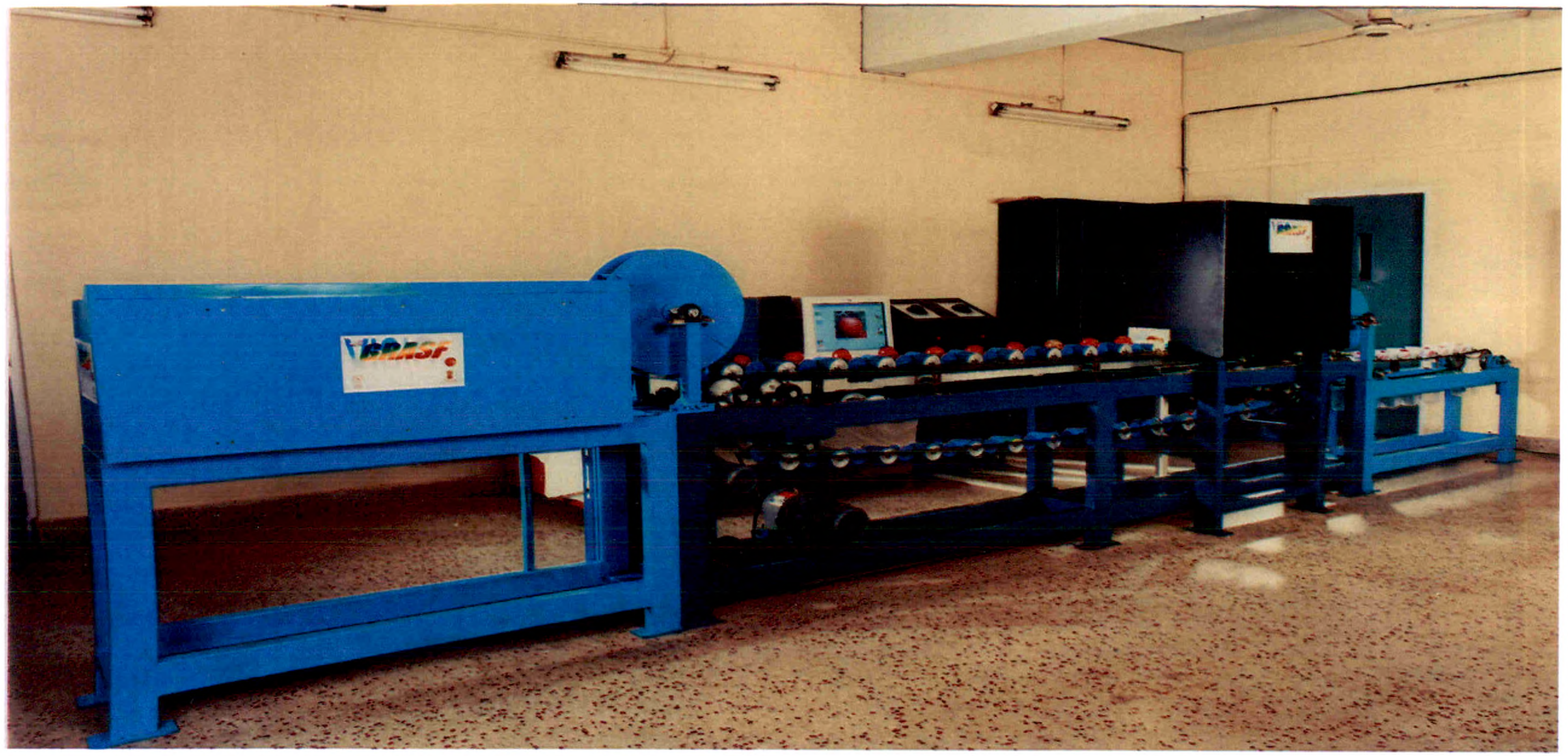

Figure 2.7 Photograph of the conveyor System

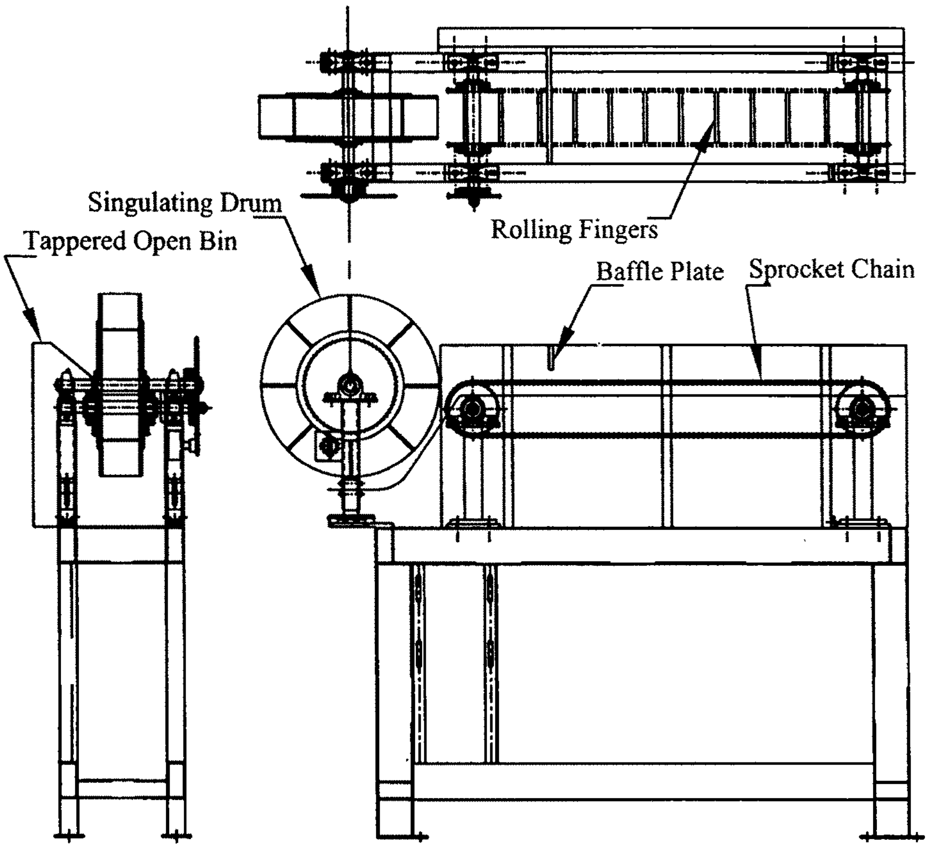

Figure 2.8 Apple Feeding Section

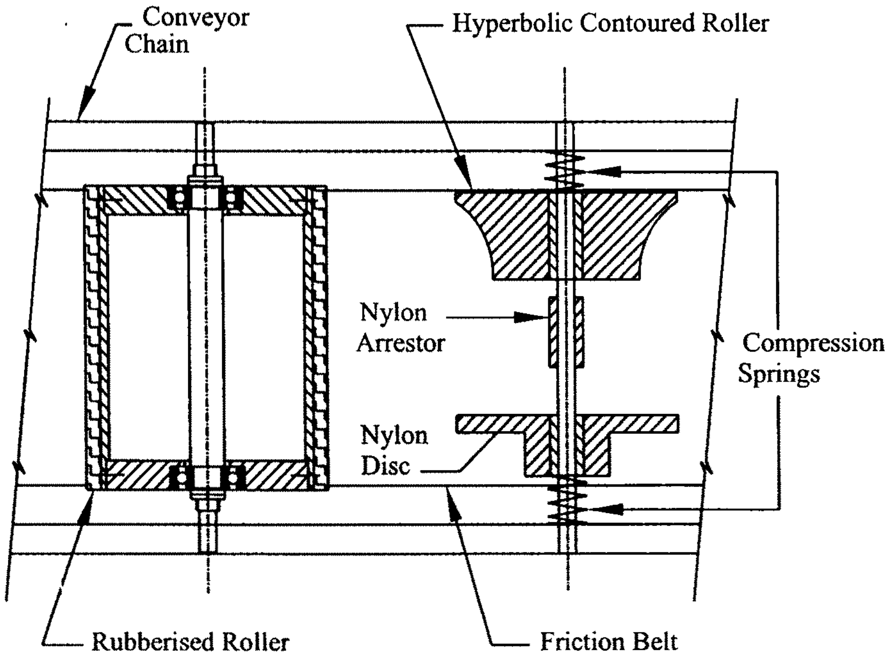

Figure 2.9 Apple Orienting Rollers Assembly

2.3.2 Fruit Orientation

The fruit orienting assembly is same as the horizontal orientation unit described in section 2.2.2. The detailed diagram indicates the integration of the unit with the conveyor assembly as shown in Figure 2.9

The rubberised rollers are rotated due to the frictional contact with a flat belt running below the roller assembly The speed at which the rubberised rollers rotate depend on friction belt speed and the conveyor speed. Hence, the speed of the motor driving the friction belt is set in relation to the conveyor speed. The hyperbolic roller and nylon disc rotate independent to each other but depending on their contact with the fruit's surface. The friction belt drive is provided with belt tensioning mechanism for keeping it under proper tension. The chain conveyor system with built-in and moving orienting rollers adds to the weight of the conveyor and may produce chain sagging. An aluminium support is also provided below the belt to prevent sagging.

2.3.3 Conveying

The fruit conveying section shown in Figure 2.6 employs a chain conveyor. The chain assembly consists of sprocket and attachment chain, which are tension adjusted with dovetail slides, the attachments being fitted at a pitch distance of 10.16 cms. Stainless steel axles are mounted onto these attachments. Seamless rubberised aluminium rollers rotate freely about their axes on these axles. Individual 3 phase AC motors operate the main chain drive assembly and the frictional belt drive assembly. The speeds of these motors are set through the computer programmed frequency converter units. The feeding section gets its drive from the main conveyor drive motor. The drive for the main chain drive assembly is taken from the motor through fibreglass reinforced timing belt to avoid any slip due to varying loads.

2.3.4 Design Considerations

Two considerations namely friction belt speed and component colour are specific to the design of on line fruit sorting system, apart from regular mechanical and electrical design considerations.

2.3.4.1 Friction Belt Speed

The rubberised roller's speed, responsible for the fruit's rotation, is the resultant speed of friction belt speed and the chain conveyor speed.

The following are assumed.

L = Length of field of view (fruit's pass line) in mm

C_S = Conveyor speed in mm/sec

T_S = Time taken by the fruit to travel through 'L' in sec

= $\left(L/C_S\right)$ sec

S_C = Rubberised cylinder speed in revoutions/sec

D_C = Rubberised cylinder diameter in mm

D_A = Typical apple diameter in mm

For one rotation of cylinder, the apple rotates by $360\left(\frac{D_C}{D_A}\right)$ degrees

Therefore, for a conveyor speed of C_S, the apple rotates by an angle ϕ

$$\phi = 360 T_S S_C \left(\frac{D_C}{D_A}\right) \text{ degrees}$$

For the present system,

C_S = 1016 mm (for 5 apples/sec), L = 700 mm, D_C = 86.2mm

Therefore, $T_S = \left(L / C_S \right)$ = 700/1016 = 0.69 sec.

A typical apple's average diameter D_A is assumed to be 85mm.

On experimentation the orientation performance is found to be better for a cylinder speed S_C of 96 RPM. Using the above parameters, ϕ is computed to be 397.5^0. Here, ϕ refers to the total angle of rotation by the apple as it passes through the imaging zone. Since, ϕ is greater than 360 degrees, it is ensured that the entire surface of the apple is covered during imaging.

The rubberised cylinder speed is controlled by the linear speed of the chain conveyor (V_1) and the friction belt speed (V_2). If V_C is the linear speed of the cylinder, then

$$V_C = V_1 \pm V_2$$

$$D_C N = D_1 N_1 \pm D_2 N_2$$

where D_1 = **Pitch circle Diameter of main conveyor chain drive sprocket**

D_2 = **Diameter of friction belt drive drum**

N = **RPM of the rubberised roller**

N_1 = **RPM of the main conveyor chain drive sprocket**

N_2 = **RPM of the friction belt drive drum**

The algebraic sign in the above equations depends upon the direction in which the friction belt is operated for maintaining the padded cylinder speed of 96 rpm to achieve the given throughput.

2.3.4.2 Component Colour

The CCD camera captures images of the rotating and moving fruit at specific locations on the fruit's pass line lying within its field of view. The collected image also contains other machine parts like rubberised roller, friction belt, hyperbolic roller etc. in the background. The image is required to be segmented for extracting only the apple images and eliminating all other portions. In general, this may call for complicated and time-consuming algorithms to extract the apple images.

After analysing HSI spectrums of many apples of different varieties, it is found that all the apples exhibit very low 'blue' colour component intensity. Based on this it is felt that apple segmentation will become simpler if all the other image components have high 'blue' colour component. Hence all the machine parts, which fall under the above category are coloured 'blue'.

2.4 CONCLUSIONS

An improved conveyor system is designed and evaluated. The system contains fruit feeding and singulation unit, improved orientation unit and conveyor system. The orientation unit offers quick and efficient orientation of apples along stem and calyx axis and provides higher throughput. The system offers increased contact of fruit's surface with rubberised roller to result in lower slippage and better imaging efficiency compared to the bi-cones arrangement. The design accommodates many different sizes of apples for grading.