TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL POWER AND MECHATRONICS

IMPROVEMENT OF PRODUCTION LINE SYSTEM FOR FINGER JOINTER MACHINE

‘Sõrliite masina tootmisliini täiustamine’

MASTER THESIS

In partial fulfillment of the requirements for the degree of

Master of Science in Engineering in

MECHATRONICS PROGRAM

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Supervisor **Scientist Dimitry Shvarts**

TALLINN 2017

AUTHOR'S DECLARATION

Hereby I declare that I have written this thesis independently.

No academic degree has been applied for based on this material.

All works, major viewpoints and data of the other authors used in this thesis have been referenced.

Thesis is completed under the supervision of **Scientist Dmitry Shvarts**

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Author: ……………………………..

/signature/

Thesis is in accordance with terms and requirements.

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Supervisor: ……………………………..

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Accepted for defence

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Chair of Mechatronics System

School of Engineering

MSc THESIS TASK

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Engineering and economics problems to be solved: Development of special counter for not conformed finger wooden joints due to less amount of glue can be sorted out under the condition set with the help of smart camera and Programmable Logic Controller or electronic counter. To make suitable modification in HMI display and make safety improvements in the production line under the low cost budget.

Further remarks and requirements: Special counter must work under all possible production speed

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EESSÕNA

Käesoleva magistritöö ülesaneks on omandada kirjalik magistrikraad inseneriteadustes kohaldades teooria praktikas. Parim koht kohaldada teooria praktikas on tööstuses nii minu magistritöö aluseks on, kus tööstuse Mehhatroonika sobib kõige paremini. Selles magistritöös üritasin lahendada tehnilised lahendamata probleeme ning konkreetseid ülesandeid aitasid minul lahendada mitmed h;sti haritud inimesed. Esiteks tahaksin pöörata erilist tänu professor Mart Tamrele, Mehhatroonika õppetoolile, kes andis meile võimaluse õppida Tallinna Tehnikaülikoolis. Ta hoiab meid motiveerituna kogu kursuse töö ajal ja aitas mul valida õige minu juhendaja vastavalt tööstusspionaaži teemale.

Samuti tahan tänada oma magisritöö juhendaja, Dimitri Shvarts kes aitab minul palju kirjutada väitekirja õige juhtides mind käigus erineval ajal ja aitas mul lõpetada minu magistrioitöö selle ülesanne. Ilma tema toetuseta oleks mul võimatu olnud lõpetada see töö. Muud kaasjuhendajad selles lõputöös on Asst. Professor Martin Jaanus, Computer Science Institute, ja tööstuse juhendaja vaneminsener Taras Shevencho, JELD-WEN Eesti AS, tegi palju tööd, et aidata lõpetada minu magistritöö ülesandeid.

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PREFACE

The purpose of written this thesis is to acquire Master of Science in engineering degree by applying theory into practice. The best place to apply theory into practice is industry so this thesis is based on industry where the Mechatronics fits best. In this thesis I tried to solve unsolved engineering problems and to achieve this concrete task a number of well educated peoples help me. First of all I would like to pay special thanks to professor Mart Tamre, the chair of Mechatronics, who gave us a chance to study in the Tallinn University of Technology. He keeps motivating us during the entire course work and also helps me to choose the right supervisor according to my specific topic.

I also would like to thank my thesis supervisor, Dimitry Shvarts, who helps me a lot to write thesis in a proper way by guiding me in different course of time and helps me to finish my this thesis task. Without his support it was impossible for me to finish this work. Other co-supervisors involved with this thesis work are Asst. Professor Martin Jaanus, Computer Science Institute, and the industry supervisor Senior Engineer Taras Shevencho, Jeld-wen Eesti AS, who really helps me to choose this topic as a thesis work and supervised me on the field to finish my thesis task

LIST OF ABBREVIATION AND SYMBOLS

HMI	Human Machine Interface
NC	Numerical Controller
LCD	Liquid Crystal Display
EU	European Union
IEC	International Electro-Technical Commission
TF	Touch Finder
PLC	Programmable Logic Controller
FINS	Factory Interface Network
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
CCD	Charge Coupled Device
CMOS	Complementary Metal Oxide Semiconductors
TX	Transmitter
RX	Receiver
ESPE	Electro-sensitive Protective Equipment
OSSD	Output Signal Switching Device
HDR	High density resolution
ISO	International Organization for Standardization
PC	Personal computer
DC	Direct Current
AC	Alternating Current

1. INTRODUCTION

Machine vision mainly deals with image analysis and interpretation and on the basis of result of the image, the quality of the product and manufacturing systems can be improved. Almost every industry uses machine vision technology to produce high quality products and for some semiconductors, electronics, automotive industries machine vision is integral part of their production lines and with the help of machine vision finding flaws, identifying parts, gauging, determining coordinates and collecting statistical data for the process control is very easy even with high speed productions. [1]

Smart cameras are used to apply machine vision technology and smart cameras are capable of analyzing captured images and provide feedback signal after image processing in tenth of seconds to the user interface. [2]

Special counter is based on the machine vision in terms of smart camera that will be used to decide product is confirmed or not confirmed and on the basis of this result special counter will be developed how to achieve this concrete task is a question of analyzing the requirements thoroughly. The main purpose of this thesis work is to improve product quality and machine performances for this purpose special counter will be developed to sort out not confirmed products from confirmed products under the limitation of allowed not confirmed products in one specific length of piece that is plank. The safety system will be selected for the danger areas in order to prevent incidents.

1.1. Problem Statement

This was required to produce quality products because glue applicator sometimes does not apply proper glue to the fingers joint therefore the length piece of wood remains unclamped when checked by the quality inspection keeping these reasons in view the management of the company decided to develop machine vision based technology to overcome this problem.

There are number of other reasons to improve the line production like safety system at assemble section to prevent accidents. The task is to develop a special counter for not confirmed products. The control should be developed by using smart camera and control system as per the international standards and also should make some improvements in the production line as and where necessary and should make electric scheme for all improvements.

1.2. Significance of work

This development and improvement work for finger jointer machine will provide author a great understanding of machine vision applications and will enhance the ability to control complex circuitry and to make programs on PLC and to build electric drawings on PC schematic.

1.3. Objectives and Goals

- The development of vision based smart camera system
- Development of particular software for PLC
- Development of special counter
- Enhancement of safety system in the machine
- Overall quality improvement of the machine

1.4. Scope and Limitations of the work

The scope of the work is to design and develop special counter and improvement in the finger jointer machines in such a way that quality and productivity improves simultaneously. The other aspect of the scope is to make machine safer to work with and make the machine secure from preventing unwanted incidents.

The mechanical work such as piping, making frame, making posts, putting screws, making threads, doing drill, hanging sensor beams, mounting sensors, mounting and designing panel box and their drawings are not covered in this thesis work although they are integral part of the machine.

The performance of the electronic devices is beyond author control and the implementation of all improvements of all the machine are beyond author control as it all depends on the manufacturer of the machine. Wear and tear of all moving parts of the machine is beyond author control.

Author is only responsible for automation work and cannot be responsible if system does not work properly due to any interference or noise or vibration.

MACHINE DESCRIPTION

2.1. Background

Finger jointing is a technique which is applied to joint wood to make a plank or a length of wood. There are many types of joint in wood but finger joint is more popular and stable joint among others. Finger joint just interlock the fingers like human hand at a 90 degree and appears to be a part of the wood not a joint. Finger jointing machine is like a bone of wood industries.

Figure 2.1 Finger joint [3]

2.2. Finger Jointing Machine

Finger jointing technology currently focuses on the precision with maximum production speed and quality joints. No matter how well manufacturer design the machine but still there is always possibility remains for modification and improvement for engineers to work on.

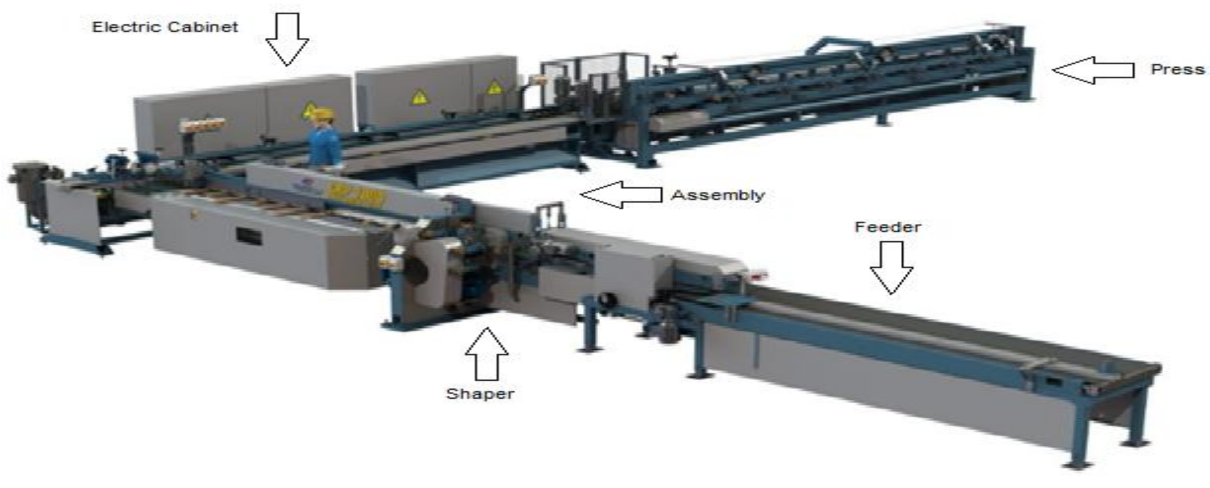

Figure 2.2 finger jointing machine. Arrow pointing the each sections [4]

2.2.1. Structure of the Machine

The machine mainly consists of four sections (refer to figure 2.2) described below:

1. Feeder Section
2. Shaper Section
3. Assembly Section
4. Press Section

2.2.2. Modes of the Operation

The machine has three modes of operation.

1. Automatic
2. Semi-Automatic
3. Manual

2.2.3. System of Machine

At first the wooden pieces are feed in the feeder section through a conveyor then the conveyor take those pieces to the shaper sections where the pieces are shaped by using saws and then the pieces are cleaned with the brushes mounted just after the saws. After cleaning the finger pieces are sent to the pre-assembly area where the glue applicator applies the glue by using comb and then the pieces are assembled in the main assembly sections with the help of chain conveyor, side chains and top wheels tensors. Then the hydraulic press process further to tighten the finger joints and trim the planks according to the defined sizes and deliver to the pallets.

2.2.4. Problematic section of the machine

The problematic section of the machine is the pre-assembly unit where the glue applicator is mounted is discussed in detail in the section 2.3 and the main assembly area where the safety lacks a lot.

2.3. Glue Applicator

The most important and problematic part the machine is glue applicator. It keeps applying glue to the fingers of the block and some time it cannot apply proper glue to the fingers due to freezing of glue on the tip or some dust particles can block glue from some part of the applicator. In figure 2.3 glue applicator is shown with the red direction arrow and some frozen glue is also visible.

Glue comb is fitted to the glue applicator valve and number of glue combs is available according to the knife profile of the cutter in other words glue comb must have as many tips as cutter have. The position of the glue comb should leave 0,5 mm clearance between the shape of blocks and comb.

Figure 2.3 Glue Applicator photo taken on the field the arrow is pointing the applicator

2.4. Specification of machine

Some useful information is given in table 1 to understand the machine and to apply modification on the machine as it will later be required to develop special counter specifically the varied speed is under consideration.

Table 1 Machine Specifications

Nr	Description	Unit	Min to Max
01	Block length	mm	115 to 900
02	Block width	mm	38 to 200
03	Block thickness	mm	16 to 63
04	Plank Length	mm	115 to 6500
04	Lugs speed	Per minute	30 to 180
05	Electrical Supply	voltage	415 to 460
06	Electrical Current	Amperes	40

3. LITERATURE REVIEW

3.1. Special Counter

Special counter is special because it is used for special purpose basically it works like an electronic counter that counts up to a pre-set value and stop. This counter will take digital signals from the smart camera and counts good or bad signals and if three consecutive bad signal comes it must stop the machine and if one or two pulses will come from the smart camera then it will reset the counter itself.

Before developing this counter it is necessary to review various literatures and on the basis of those literature review devices should be selected. Economically the system should be cheap and efficient because prototype project should not cost much. Some important devices have been discussed through literature and selected the possible pros and cons of the machine are given below in the sub sections.

3.1.1 Advantages of the special counter

- Quality improvement and assurance
- Enhance productivity
- Automatic inspection minimize physical check up hence reduce labor cost
- Overall efficiency of the machine increase
- Reduce significantly down time

3.1.2. Disadvantages of the special counter

- cleaning is required
- Care is needed

3.2. Smart Camera

There is no proper definition of smart camera but in general it can be defined as an embedded system consisting of video sensing, processing and communicating within a device.

Smart cameras are capable of performing numerous of tasks such as motion detection, object measurement, number and pattern recognition, even human gestures with the help of embedded microprocessor and pattern recognition algorithm.

The basic function of smart camera is to capture image, analyze to the known data, process information, and make decisions. Those decisions are utilized with the help on automation or intelligent systems.

The basic purpose of smart cameras is to compare image with the quality and make decision and then utilized with control system which is based on automation. [5]

The fields of applications are very vast in almost all types of industries. For example it is useful to check components defect in electronics or production defects of small products in large industries or material production without stopping the production line or detecting surface shape, variations, dirt and damages if any in packaging and logistics etc.

It was never easy to judge and choose the best manufacturer product. As there is not suitable radiation from the object and camera built in lighting is not good enough to see glue therefore need suitable external lighting. Lighting is one of the main conditions to get sharp image. The second condition is the light must be uniform and the third condition is the larger the image from the object the better the quality. Sensor converts the radiation density into a suitable form for future density. Machine vision system usually has 2 dimensional arrays but this camera has scanning system. Three most important parameters for machine vision system are filed of view, size of the camera sensor and number of the pixels and with the help of those parameters focal length can be determined. All the important parameters have been taken into account while selecting this smart camera. [6]

3.3. Selection of smart camera

Choosing the correct camera for an application is not a simple task. Different applications have different requirements and these requirements impose constraints that effect the requirements and price. It is a long debate which technology is better that is CMOS or CCD. Every technology has certain advantages and disadvantages but both apply to all applications. The selected camera has CMOS technology. Smart camera FQ2 series is made by Omron, a well reputed company in the field of automation and control, has been selected for this purpose. It consists of high speed image capturing, high speed digital signal processor, powerful lighting, and adjustable lens. It has many other features like water resistant, flexible cables for both input/output and Ethernet connections and smart click connectors. Only need to select camera according to the field of view and installation distance from the series of FQ2 cameras. This camera is suitable for crystal clear images, edge detection, area inspection, direct part mark, and color difference and deviation. It can also compensate 360 degree position and can eliminate patterns in measurements [7]

Figure 3.1 Smart Cameras FQ2 [8]

3.3.1. Camera Hardware

The smart camera has 1.3 Megapixels CMOS sensor that maintain the both precision and accuracy and also provide a wider field of view. Processing time is as fast as 20 inspection items per second. With optical double reflection technology high brightness and efficiency is achieved. A 24V DC power supply is required to start the TF and Camera. [8]

The camera specification is provided in detail in Appendix 3.

(I).Explanation of I/O Cable

With reference to Appendix B the Brown is connected with +24V DC and Ground is connected with Blue. Pink is connected to the output from photoelectric sensor. From IN1 to IN5 are the command inputs while OUT0 (OR) is the judgment output signal and OUT1 (Busy) output is the processing or busy signal and OUT2 (Error) output signal. These signals are all by default and can be changed to Run and Ready signals.

(II) Ethernet Cable

Ethernet cable is used to connect camera with TF so that communication with camera make possible. The provided Ethernet cable is standard registered jack RJ45. [8]

3.5. Programmable Logic Controllers

PLC is the integral part of automation and control. PLC was implemented in the early 1970s when microelectronics achieved high reliability and performance that was necessary to fulfill demands of industrial applications. Now PLC is playing key role in all the areas of automation. [9]

PLC uses multiple programming languages which includes Ladder Diagram, Sequential Function Charts, Functional Block Diagrams, Structured Text and Instruction List. Every language has its own benefits but widely used language is LD because it is simple to put relay logic technique in the form of ladder to achieve specific tasks. All PLCs can work on LD but there are modern PLCs available that can be worked with all languages at a time. [10]

The basic purpose of invention PLC was to replace hard wired system and to replace relay logic system which occupied plenty of space and time to build and figure out the problems if occurred. PLC has made things easy to perform complex tasks and if faults occur can easily be traced out.

3.6. Selection of PLC

Although there are many smart cameras compatible PLCs are available to connect with by using Omron’s exclusive FINS/TCP communications interface. The FINS/ UDP protocol is an OMRON protocol that is used by a PLC to transfer data and perform other services by using Ethernet connection. [11]

This PLC logo is available in the company stock and author would like to utilize the resources which are available in the company to avoid unnecessary cost. This small PLC consists of LCD display and eight inputs and four outputs. It has electronic pulse counters, timers, relays output with set, reset and impulse functions that is required in this project. [12]

3.6.1 PLC Limitations

The PLC is capable of programming by keypad and by using EASY Software which can easily be downloaded. The PLC is capable of performing those automated tasks in which markers, relays, timers, push buttons, counters, and jump function, and text involves but this PLC has certain limitations. It only works from left to the right in the rung and operates in the cycle from first to the following in a sequence until jump function is used then it jumps to the selected rung and after performing execution it resumes from the same sequence from where it jumps. It never works when wired back word in ladder diagram setup. When more than three contacts are wired then marker relay must be used. The digital input signal should be at least 20 milliseconds of duration whereas for AC input signal the on delay should 80 milliseconds for 50 hertz.

This PLC should not be used in a burner controls, crane controls and emergency stop controls. PLC must not be used in safety control circuits specifically two handed safety controls. Programming of PLC requires skills and must not be used by unskilled persons as active components like motor or pressure control can cause the system damage or the person might be at risk. There are certain regulations for electromagnetic compatibility (EMC) that needs to comply with before installations. [12]

3.7. Photoelectric Sensor

Photoelectric sensor is a device that detects the presence or absence of an object by using a beam of light. This technology replaces the inductive type proximity sensors. [13]

3.7.1 Selection of Photoelectric sensor

This photoelectric was available in the company stock so author decided to use the available resources. This redial type photo sensor as shown in Figure 3.2 is especially designed for non-stop machines. This series E3FA not only provide reliable sensing in a robust and waterproof housing and can withstand high pressure cleaning but also high EMC protection and light immunity and up to 20 meter distance object can be detected. There are two types of lighting indicators that shows operation and output in the form of stability. There is one knob which is used to adjust the sensitivity by which user can adjust the distance between the sensor and the object to be sensed to get stable output.

The response time of the output is as fast as 5 micro seconds for that reason this sensor is suitable for high speed machining and for that reason the sensor is suited well for the task.

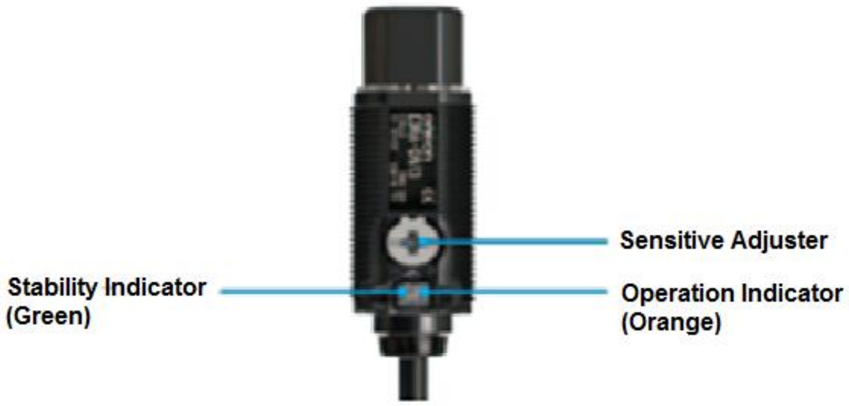

Figure 3.2 Omron E3FA series photo sensor

4. STRUCTURE DEVELOPMENT

Structure development is the first part for the achieving of the desired task physically. For this purpose drawing has been created of each part and then sent for approval. How the each part is manufactured is discussed separately in section wise.

4.1 Camera Stand

First of all the stand of camera is constructed with the help of Solid works software. Different parts are manufactured separately and then assembled all the parts. The dimensions are shown in inches in the figure 4.1. The camera mounting plate is made in a bit flexible way so that camera can focus the object easily. The post on which the camera plate is mounted extrude able in order to adjust the height according to the height of the object. A hexagonal bolt is provided so that it can fix the adjusted height by tightening the bolt. The base plate is provided to fix the camera stand on the ground firmly to avoid vibration and tighten on the ground by using bolts. For more detail of each part see Appendix 1.

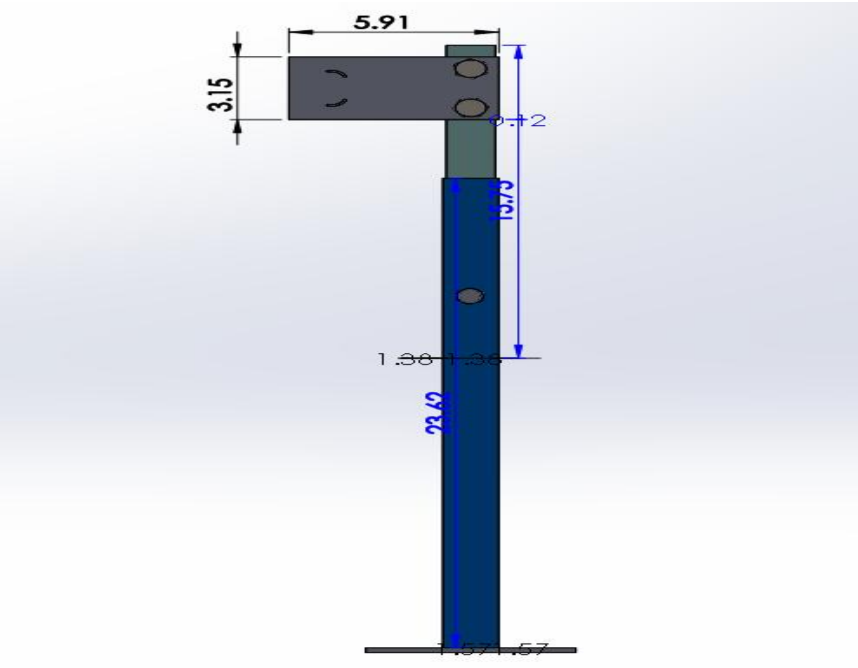

Figure 4.1 Camera Stand with base plate

4.2. Lighting Box and Lighting

The external lighting box is designed and external lighting has been selected before installation as shown in figure 4.2. The proposed box will have two lamps and both lamps will be installed inside of the box and the lighting beam will focus the objective. The chosen lamp will have uniform lighting with high color rendering index so that illumination effect on the object can be improved.

The lamp is of 20 watts and safe for the eyes. It produce uniform light beam without using ultraviolet or infrared lighting and free from flickering and humming. High lumens intensity is desired for smart camera and proposed light has the required lumens as many as 1900 lumens. Power factor is near unity that makes the product ideal for this purpose.

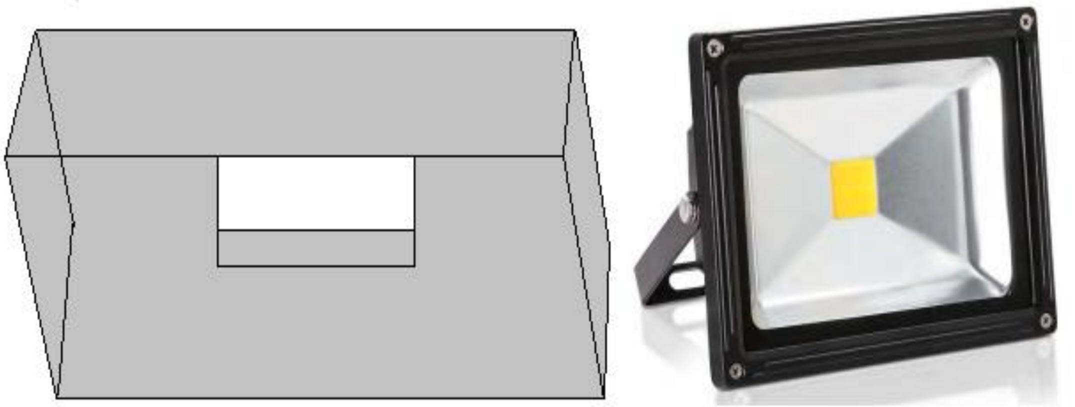

Figure 4.2 Lighting box and external lamp

4.3. Assembling Parts

At first a metallic box is made to house suitable lamps in order to provide better illumination to the camera and then hang a photoelectric sensor with the help of an L type metallic strip. This sensor is used for trigging camera when wooden piece passed through it and initiates the camera to take a picture. In figure 4.3 the metallic box and housed illumination can be seen. Camera is also visible in the picture that is placed at a suitable distance from the wooden piece so that it can take clear picture.

Figure 4.3 Installation of Box and accessories

Figure 4.4 shows the camera stand at which camera is hang so that it can be adjusted in such a way that it can go up and down with the help of screw and bolts as shown. Affixed metallic is made in such a way that it can also be adjusted in terms of angular position at some extent. This design makes the camera more flexible. The camera stand is made in extruding way that can go up and down as and when require so and then 6 mm thread has been made so that it can be stop at certain height and then can be bolted. At the bottom a metallic plate is welded at exactly 90 degree and then bolted on the ground so that vibration can be minimized. This work was the difficult part for author to make.

Figure 4.4 Camera stand with external lighting

Camera stand is placed at 600 mm from the object so that maximum field of view is obtained because the larger the field of view the better is the image as shown in figure 4.5

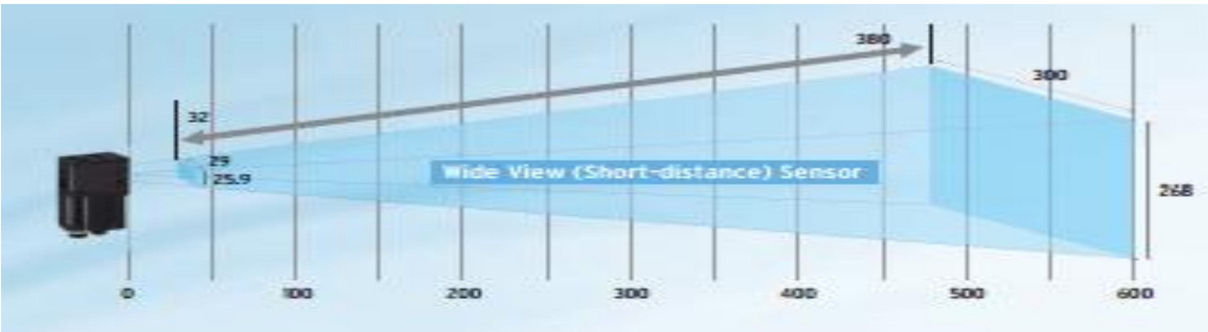

Figure 4.5 Field of view and distance

4.4. Control and Power Connection

A plastic box has selected for mounting PLC and Touch Finder and for this on more metallic plate has been made for mounting this box as shown in figure 4.6. Ethernet cable is connected between smart camera and TF. Electrical power, input and output from camera is being connected to the TF and PLC respectively. All control wires have been numbered as per the EU and IEC standards and also the ground to chassis has been connected for the safety purpose. DC power has been taken from the Finger jointing machine and also the 2 wires has taken from the nearby emergency switch button in series in order to stop the machine.

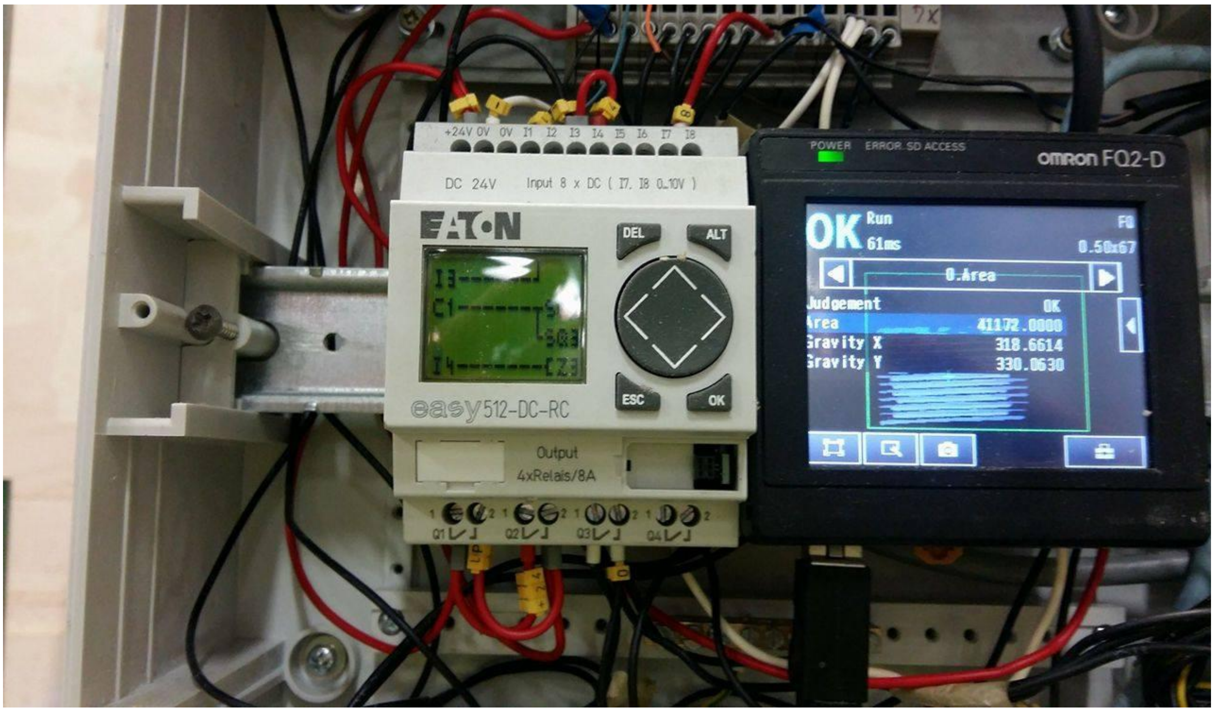

Figure 4.6 PLC and TF power and control wiring

4.5. Electrical Standards

All electrical standards has been followed by keeping power cabling for PLC and TF distinguished as White for negative and Red for positive power supply as a DC voltage 24 volts. All the control cables are distinguished from power as blue with 1mm cable gauge. Also Lugs has been placed with the cable to prevent from loose wiring. 220 volts also distinguished with brown for phase and blue for negative. A drawing has been made on PC schematics which is shown in the figure 4.7

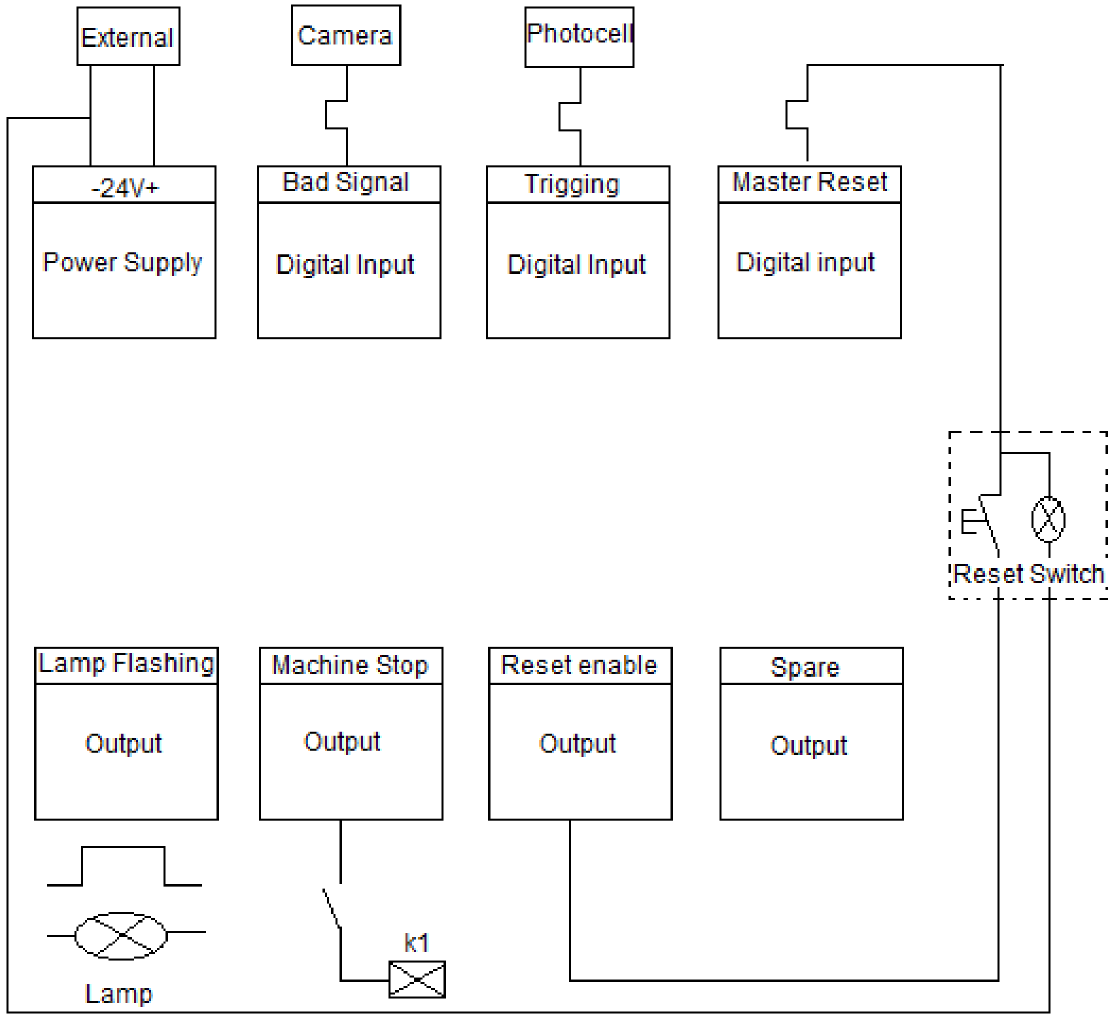

Figure 4.7 Connection Layout for safety system

4.6. Compact Design

The complete Design has been shown in the figure 4.8. A flashing light is also mounted that enable operators to see not confirmed piece of wood with the flashing. There are different standards sizes which are mentioned on the screen with the help of stickers. Start button and different size selection selector switches are also mounted for the operators easy size selection.

Figure 4.8 Complete automation systems

5. PROGRAMMING

Programming part will be discussed in this chapter thoroughly which is a very crucial part of the special counter it has many aspects and approaches to reach the final design. This will be the initial phase for developing the idea and background of the work.

5.1. Process Flow Chart

At first proximity sensor will see the wood piece and then trigger the smart camera to take a picture. After taking picture the camera process and made decision and on the basis of the decision output signals are generated and goes to the input of the PLC. This is the basic algorithm of the task that will be used to construct PLC program.

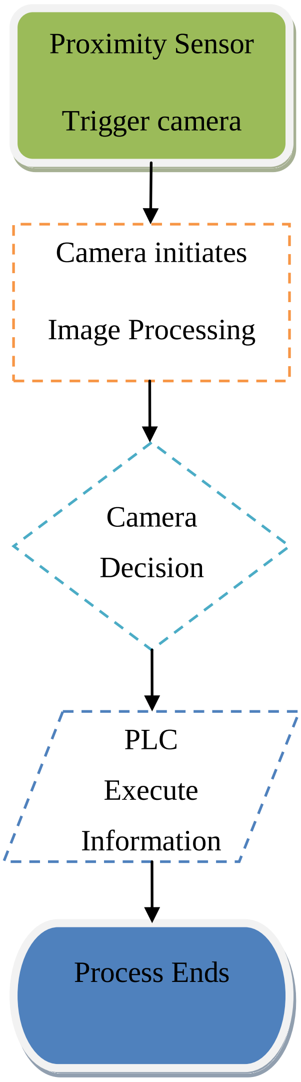

Figure 5.1 process flow chart

5.2. PLC Flow Chart

PLC flow chart is created so that a clear picture of flow chart can help to make a suitable program as shown in figure 5.2. It works if bad signal comes from camera then PLC built in counter can count up and also shows this bad signal in the form of Flashing Lamp to the operator. If no successive bad signals arrive at PLC input then it should reset the counter and if successive bad signals arrive at the input of the PLC then the counter should set the output relay and hold the lamp so that operator can understand that the inspection system has work. A master reset button is also provided in order to rest manually.

This is the initial idea to make PLC program with the help of PLC and this idea has been provided to the management so that it can be implemented on the production line.

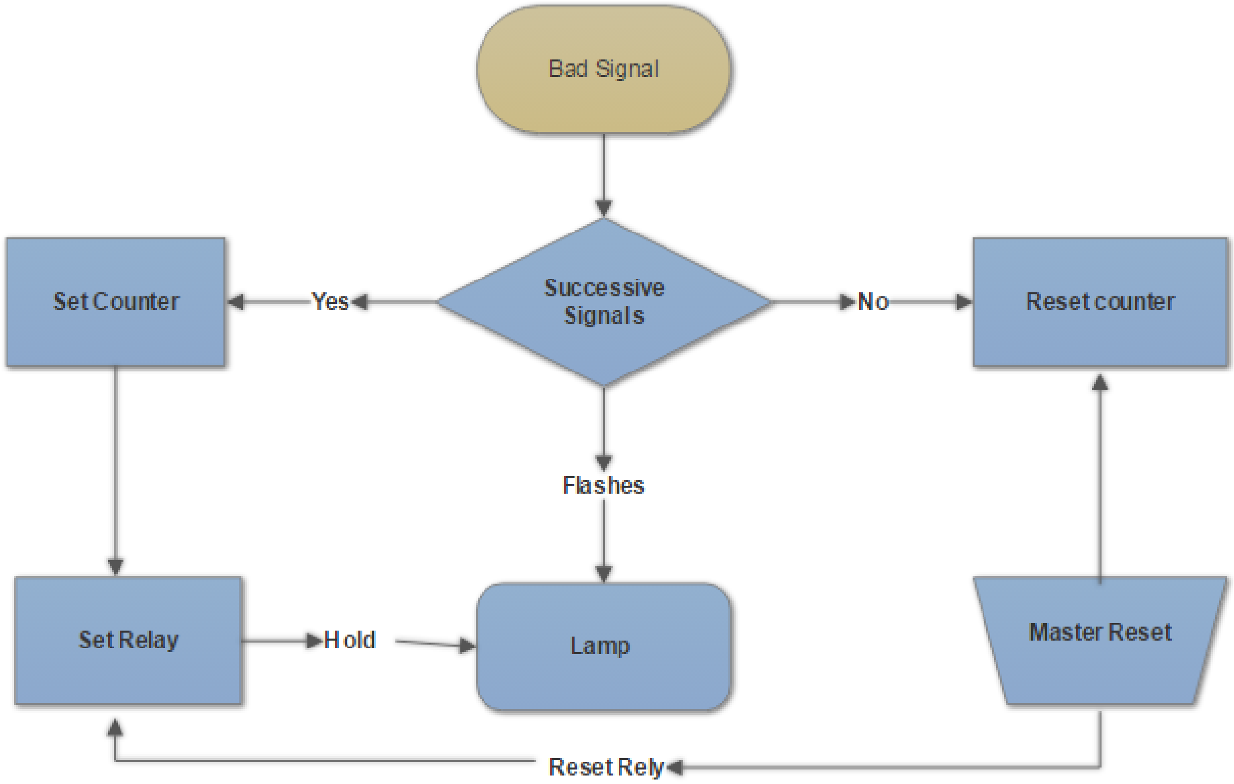

Figure 5.2 PLC algorithm

5.3. PLC Program Development

PLC program has been created with the help of Eaton's Easy Software. This software is designed to create Ladder Logic programs on MFD controllers and displays. It enables users to select menus and functions like drag and drop that helps to build simple circuit diagram. Simulation tool is provided to test the program before commissioning even offline this tool works. Multiple PLCs can be connected at one time when EASY-NET is selected. [10]

Figure 5.3 shows the software and related program in ladder logic.

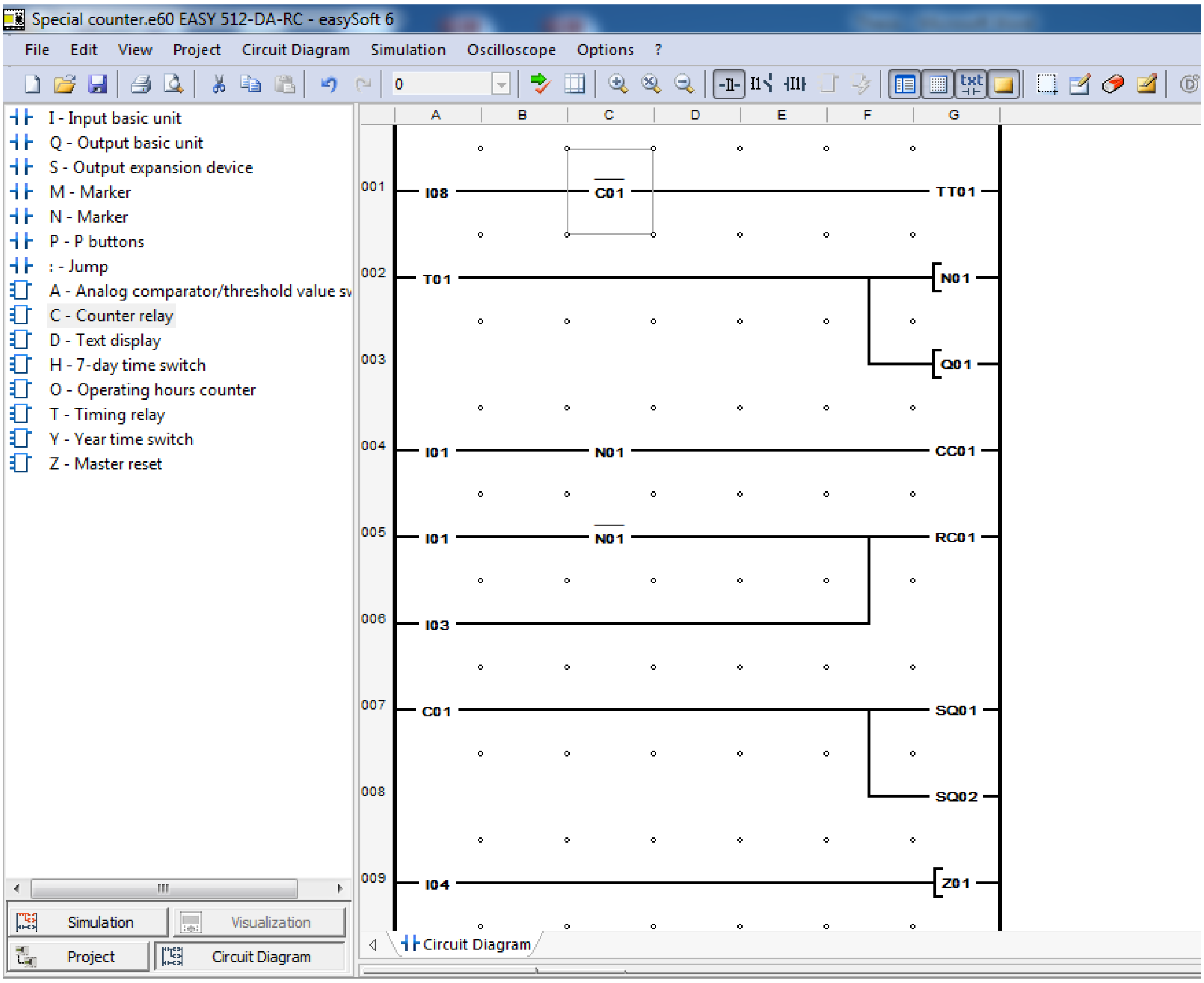

Figure 5.3 PLC Software and program

5.4. Explanation of PLC Program

PLC program (refer to figure 5.3) is made in such a way that a suitable delay is provide so that we can get stable signal and a marker relay is used to get stable output from the signal as an output from the on delay timer and an output contactor coil Q1 is placed in parallel to get flashing signal for the lamp. Two different inputs have been taken I8 as a bad signal and I1 as a good signal. Now an AND logic has been applied to get counter up if both are equal and if one of the signal is missing then an inverted or normally closed contact is used to reset the counter.

When pulse counter counts till set value then the normally open contact of the counter will become normally closed that will set the contactors Q1 and Q2 on respectively. Contactor Q1 set function will hold the lamp keeps lighting and contactor Q2 will stop the machine.

I3 and I4 are used in parallel to reset counter and master reset all the set contactors to their initial position back. These I3 and I4 are used in parallel and on pressing one push button this all process will restart again. Normally closed contact of the counter is used to prevent from any other bad signal from the smart camera while machine stops because it takes few seconds to stop the machine because of frequency inverter deceleration time which is set a bit higher. The program will be implemented on the testing and results chapter of this thesis.

5.5. Camera Setup and measurement Process

The flow chart in the figure 5.4 describes the configuration, setup and measurement process.

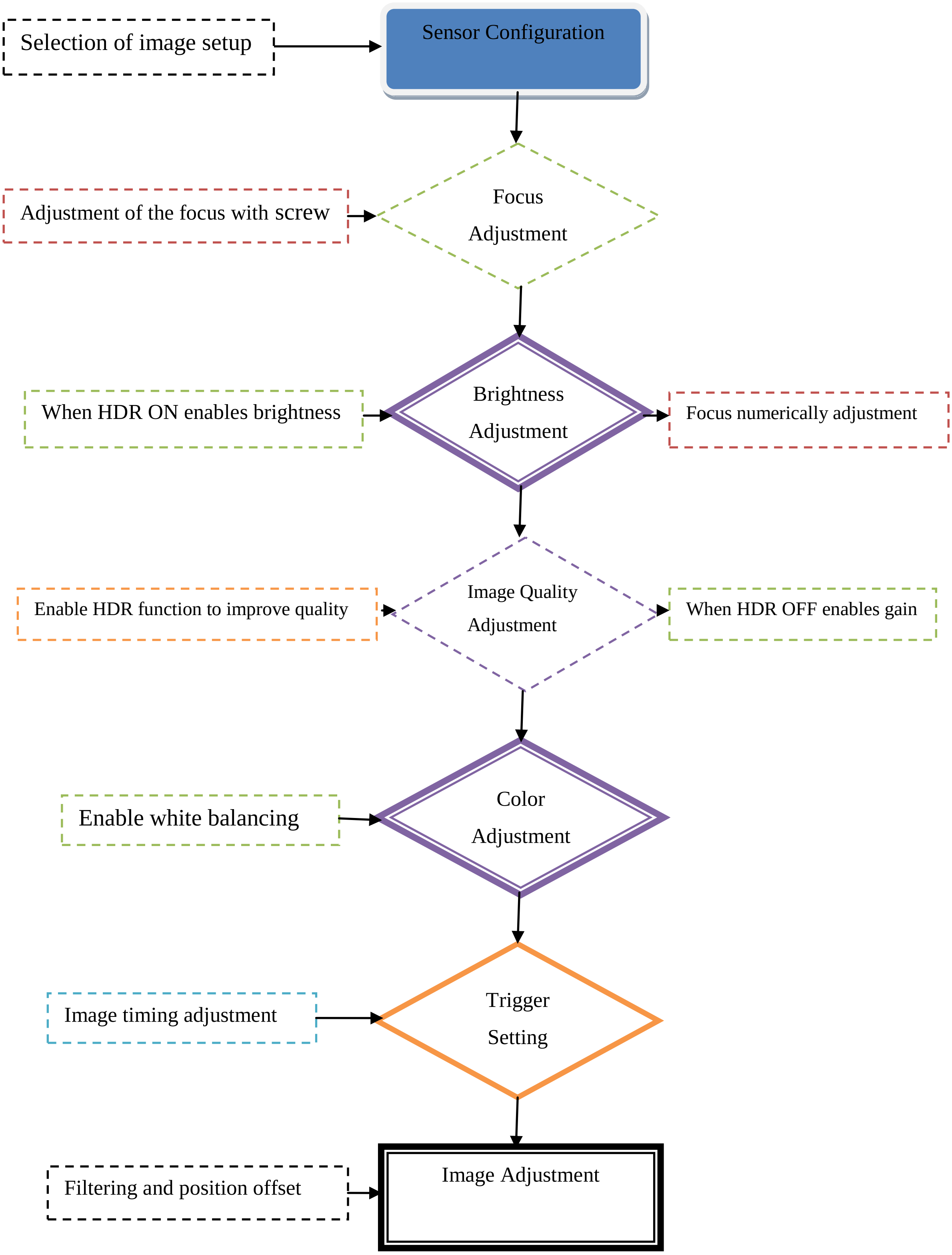

Figure 5.4 Camera setup flow chart

5.5.1. Setup procedure

The first screen appears on the touch finder is start up display as shown in figure 5.5

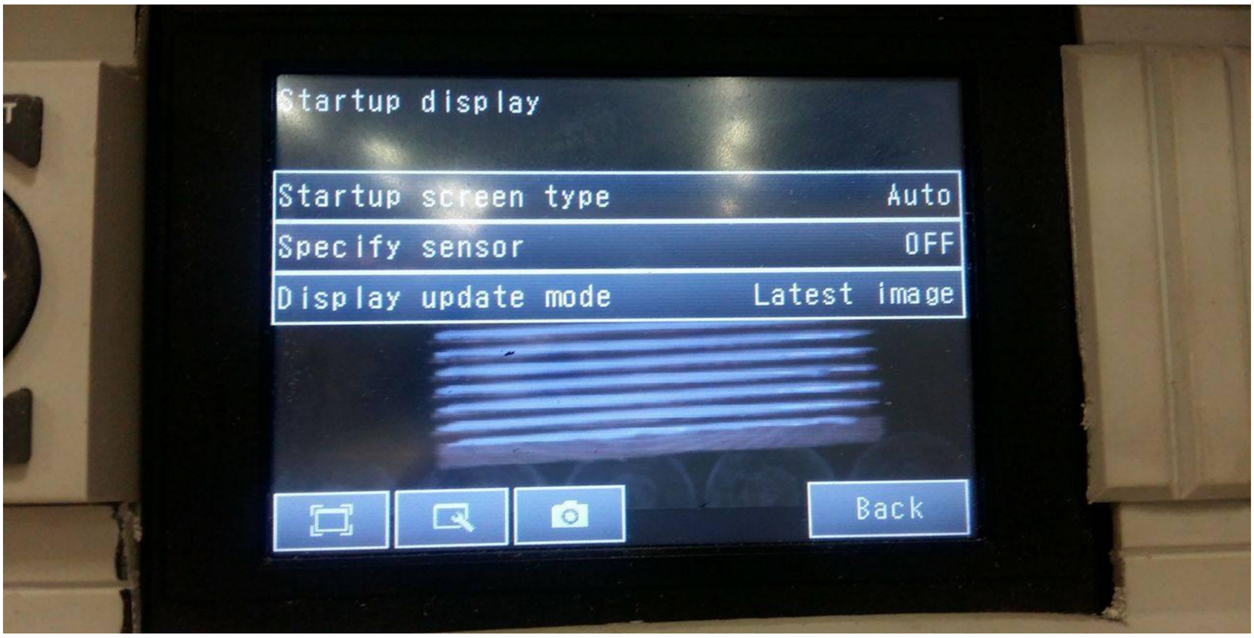

Figure 5.5 Startup display on TF

The camera image set up is shown in the figure 5.6 which is further divided in to sub tabs as camera set up, trigger setup and image adjustment.

Figure 5.6 Image setup

Inspection tab is sub divided into inspection tab and calculation tab as shown in figure 5.7.

Figure 5.7 Inspection tab

The output tab is shown in figure 5.8 along with the selection option of them.

Figure 5.8 Output selections Tab

5.6. Inspection Procedure

The FQ2 smart camera has various inspection techniques to judge the objects and those are given below:

- Judgment according to the shape such as judgment of mark
- Detecting position with pattern such as judgment of same color but different patterns
- Detecting the shape for each division separately such as judgment of differences in labels
- Detecting position with offset marks such as a seal of product
- Judgment according to widths such as width of a cable insulation
- Judgment as per feature such as number of pins on the integrated circuits
- Judgment according to colors
- Judgment according to the size of the object
- Judgment according to the quantities such as number of labels

5.6.1. Inspection items configuration and setup procedure

- For adding new items for inspection just go to **setup and processing** item and select **inspection**
- By pressing add an item on the menu it allow to add item numbers
- Added item can be searched from the menu like search, shape search, edge position search etc.
- Added item can also be modified, deleted, copied and renamed
- Inspected can be teach by pressing teach tab and placing item in front of camera
- Judgment parameters can be adjusted in terms of judgment, correlation, position, count and angle
- Accuracy of the position judgment can be increased by selecting **sub-pixel tab** and pressing yes
- Inspection of item can be selection by pressing **sorting method tab**
- Processing speed can be increased from the **measurement region tab** and **model region tab** allow to choose different shapes from the list
- Selected figure can be masked that enable **OR/Not function** (enable/disable) quickly
- Model can be fine tuned from the **model region tab**
- Edge pitch, color data, edge position, area and labeling can be inspected from **Add item tab**
- **Judgment conditions tab** allow user to select the range to be judged.
- The area inspection is being selected for sensing glue area from the **add item tab**.
- Measuring more than one color is also possible from red, black, and white, blue or green [13]

5.7. Test Measurements

Test measurement is done automatically as shown in figure 5.9. The test measurement makes sure that the setting of the camera is fine and producing stable results still fine tuning can be done if required more stable results. A judgment is shown by either OK (all correct) or NG (Not Good).

Test measurements can also be done with the saved samples by pressing the **tab continuous test** from the logging image files. Image input speed can also be increased from the **image input tab** and selecting high-speed. The best judgment of the inspected items can be selected either manually or by automatically from the **continuous test tab.**

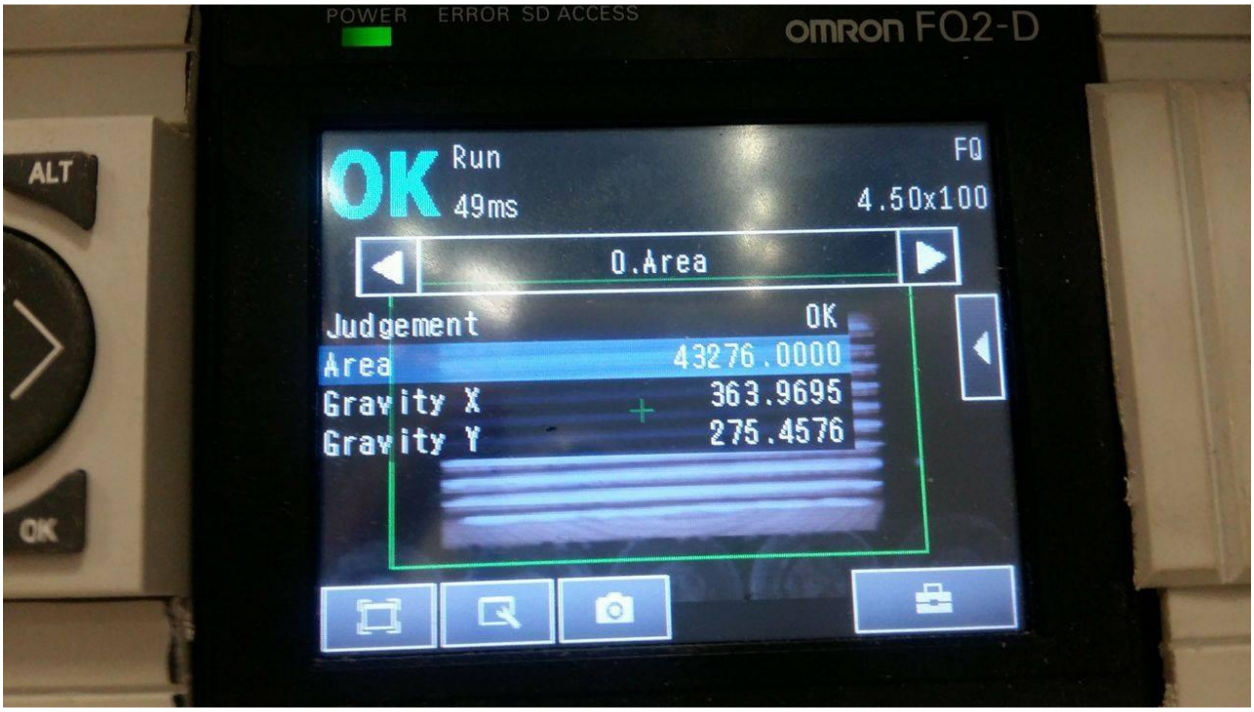

Figure 5.9 Test measurement

Re-measuring of already measured images will allow user to re-inspection to check the system stability and performance. Imaging can be speed up by selecting the region of the image. Pixel sampling can also be applied to decrease the time by selecting image input mode tab. Setting is necessary to save because if not saved then upon power failure the data will be lost. [13]

5.8. Run Mode Operation

After completing the test measurements, the run mode will begin actual measurements. The run mode allows the sensor to take image, process and deliver the judgment to the input and output lines as per the setting. The operation of the camera and monitoring is described in the figure 5.10.

Figure 5.10 run mode operation

Measurement time is the total processing time from the image taking to the judgment as shown in figure 5.10. Here the time is 49 milliseconds. The set up mode can be switched to the run mode by pressing run tab from the menu and just then switch the mode.

Run mode display can further be configured into six different displays as graphics, graphics details, statistical data, trend monitor, histogram and inspection. Trend monitor and histograms display is only allowed when logging setting is turned on. [13]

5.9 Calibration of the camera

Calibration of the camera is a technique to find the quantities internal to the camera that affects the image processing such as position of image capturing, focal length, scaling factors, skew factor, lens distortion etc. and here the calibration is meant to covert camera coordinates into actual coordinates. All the methods were applied before commissioning.

5.9.1. Calibration methods

- Point specification
- Reference
- Parameters

(i) Point specification Method

This method is used to set the pixels coordinates of actual dimensions at any position. Go to setup mode and select calibration data and then specify the points on the screen as shown in figure 5.11.

Figure 5.11 Point specification method

(ii) Reference Method

This method is used for a registered model and then actual coordinates can be set accordingly. Press the camera coordinates to register on the display then a cross mark will appear then enter the coordinates at the specified positions to set the coordinates and then generate parameters as shown in figure 5.12

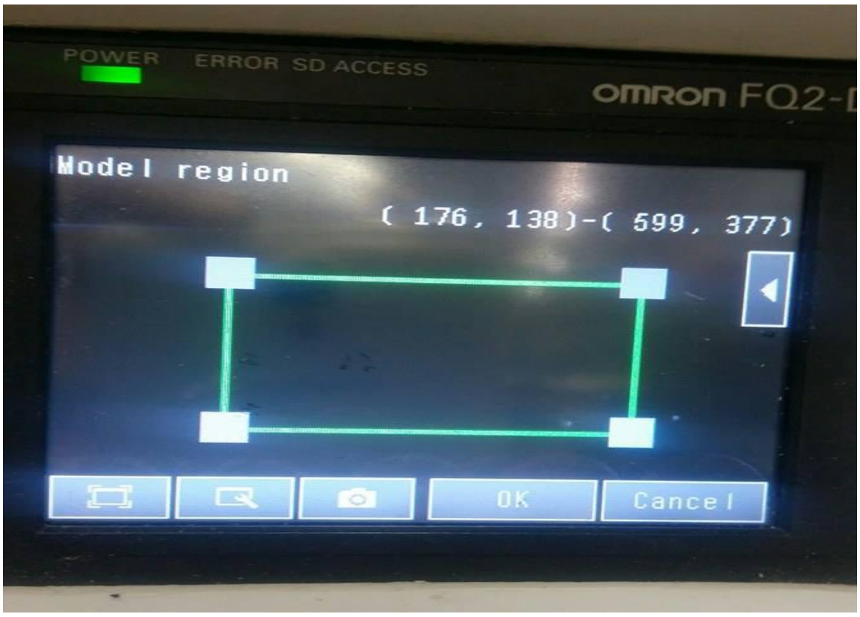

Figure 5.12 Reference method

(iii) Parameters method

In this method the numeric values of the parameters can be entered directly to calibrate the data. Specify the items to convert camera coordinates to actual coordinates. The conversion is done as follows.

$$X' = A \times X + B \times Y + C \qquad (5.1)$$

$$Y' = D \times X + E \times Y + F \qquad (5.2)$$

Where

X, Y is the camera coordinates of measurement position

X', Y' is the converted actual coordinates

A, B, C, D, E, and F are calculated values [13]

Figure 5.13 Parameter coordinate method

5.10 Limitations of Smart Camera

Smart cameras are the new innovation and have limited capacity for interpreting images in the field of machine vision. Therefore the vision system is dependent on PC based image processing system in the field of automation. Usually smart cameras have less processing speed due to its compact design and take time to process complex algorithms which are beyond its scope.

The FQ2 smart camera is a standalone type of smart camera that can be used in general purpose inspection and only capable of limited number of measurements and allowing specific control signals and to connect with data unit in order to expand input and output is not possible. Pixel resolution is limited to 320 x 240 that is 75 dots per square inch (DPI) and the image size appears to be 4,3 inches x 3,2 inches which is too small. Life expectancy is also inadequate i.e. only 50,000 operational hours. Battery life is very low only 300 charging cycles. If it is required to connect with PC then additional accessories are required and specific PC requirements like operating system, RAM, memory and monitor is required. If requires more features then the high resolution type of smart camera is required which cost a lot. Above all most smart standalone types of smart cameras are not easily updateable because of its proprietary hardware and functional range to perform additional tasks.

6. SAFETY SYSTEM

Safety of the machine and operator is the first priority of any industry. Therefore at the assembly section of the finger jointing machine it is necessary to install a safety system because of moving parts of the machine hence this area should be protected. A safety system that can protect body, hand and finger needs to be installed so that safety of the operator can be insured. For this purpose curtain beams has been installed at both ends of the assembly area. The IPF OY32 model has been selected for its robustness and reliability features. These safety light curtains are manufactured to safeguard danger zones for automated systems against possible intervention during operation and therefore prevent accidents.

The IPF has various models for safety light curtains depending on the protection requirement. Three broad categories are finger, hand and body protections.

6.1. Selection Criteria

The selection is made according to three important properties while selecting a safety light curtains. Protected system consists of resolution, height and minimum safety distance.

6.1.1. Resolution

The resolution is dependent on the geometrical properties of the lenses, diameter of the beams and distance between TX and RX. The resolution of the protective system describes the minimum size of the matte object with which the system must be interrupted.

The resolution is denoted by R and can be calculated with the help of following equation:

$$R = I + d \tag{6.1}$$

(Where **R** stands for resolution; **I** specify the distance between adjacent optics and **d** stands for lens diameter) [14]

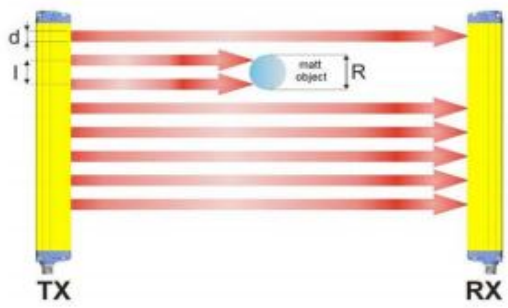

Figure 6.1 Resolution of protective system [14]

6.1.2. Protected Height

The protected height is the height of the entire protected area that is protected by safety light curtains. There is one more term that need to define is the scanning height which is defined as the distance between the first lens and the last lens of the light curtains. The object must be non transparent and should be equal the resolution of the resolution of the light. Figure 6.2 demonstrate the resolution R as a matte body and the protected height is measured from the top lens to the yellow reference mark mentioned on the beams and the scanning height as calculated from top lens to the last lens. [14]

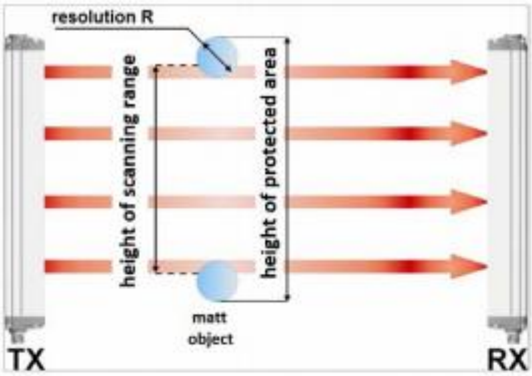

Figure 6.2 Demonstration of scanning and protected heights [14]

6.1.3. Minimum Safety Distance

The minimum safety distance is defined as the distance at which light curtains is to be installed in front of danger area. This is crucial in terms of installation of safety system in practice. The purpose is to protect humans from dangerous moving parts of the machine and machine should stop as soon as the body or the parts of the body is within the danger area. The distance of a safety light curtains depends on the following four factors:

- Response time of the ESPE
- Stopping time of the machine
- Resolution of the ESPE
- Approach speed

The minimum safety distance is calculated with help of following mathematical equation:

$$S = K(t_1 + t_2) + C \qquad (6.2)$$

Whereas

$S = safety\ distance\ in\ milimeter$

$K = Approach\ speed\ in\ milimeter\ per\ second$

$t_1 = Responce\ time\ of\ ESPE\ in\ seconds$

$t_2 = Machine\ stop\ time\ in\ seconds$

$C = The\ distance\ \ of\ a\ body\ enters\ the\ danger\ zone\ before\ the\ safety\ light\ triggers$

The C is calculated as follows:

$$\mathrm{C} = 8(\mathrm{R} - 14) \qquad (6.3)$$

$\mathrm{R} = \text{Resolution of the device according to manufacturere specifications [14]}$

6.2. Operating principle

This safety light consists of a transmitter rail and a receiver rail. The transmitter rail emits infrared beams and the receiver rail received the beams. The receiver evaluates according to the set parameters to determine if the object is in the protection zones then the receiver switches its output. The receiver rail and transmitter rail must be aligned while installation of curtains in order to prevent output instability.

6.3 Connections

The power connections and control connections are mentioned in the figure 6.3. The White cable is used to reset with the help of a button or providing +24 VDC till 5 seconds then the faults from the safety light curtains disappear. EDM is not selected here by connecting it to ground. Manual switch is connected here by shorting with OSSD2 enables manual machine stops. Whereas if manual mode is connected with OSSD1 then automatic restart can be selected [14]

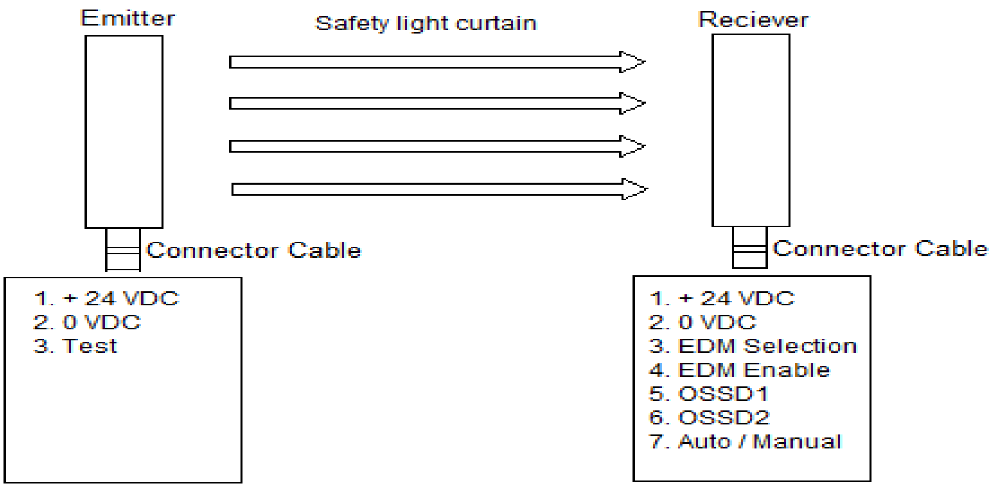

Figure 6.3 Connections of RX and TX

6.4. Safety Relay

A safety relay AO000299 has been selected to synchronize with safety curtains as this relay is designed to use with ESPE. This relay makes sure the safe interruption by cutting off circuit in order to stop the machine. It is simple to install and operate without requiring any sort of service. It has two switches inside the top cover from where manual and auto option can be selected by means switch S1 and switch S2.It has symmetrical and unsymmetrical outputs which can be adjusted with the switch S1 while S2 switch is used to select manual or auto restart selection.

The over voltage and short circuit protection is also provided in this relay. Switches S33 and S34 are used for reset and S33 and S34 are used by OSSD1 and OSSD2 safety light curtains as output for tripping the safety relay. There are three normally open contacts and one normally closed contact in this relay. It works when the power supply of 24 Volts DC is permanently connected. The usage of the relay is very simple provided how well the user understands the control topology. The Block diagram in figure 6.4 demonstrates the use of each function.

The overvoltage protection is provided by using voltage regulator and short circuit is protected with the help of discrete transistors as an embedded circuit.

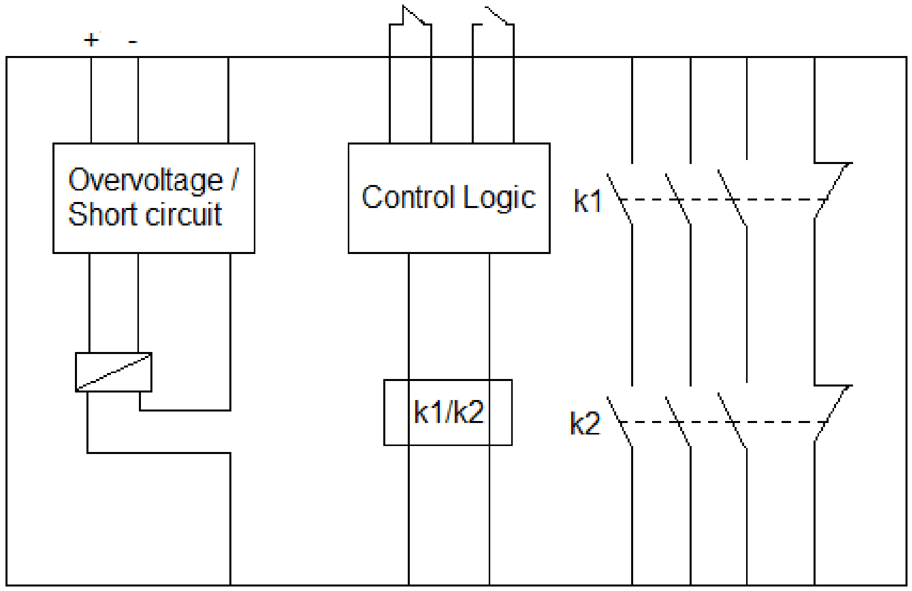

Figure 6.4 Block Diagram of the Relay

6.5. Working of safety system

The working of the safety system on the machine has been tested a number of times before connecting machine stop control function. The control and power wiring has been shown in the figure 6.5. At the current position machine is stop because relay is not working until the reset switch mounted on the rear side of the machine pressed. The Relay is working very fast as soon as it receives a signal from the safety curtains it turns off making the safety of the workers possible.

The normally closed contacts of the relay is used to turn on the lamp inside the re-set button installed on the post whereas the control of the reset button is connected with switches 33and 34. The curtain output signals are connected with the switches 21 and 22 in order to trip the relay. The control of the machine is connected in series of the emergency switch so that it can stop the whole machine when someone enters the protected area. The power supply is provided permanently to make the operation sure.

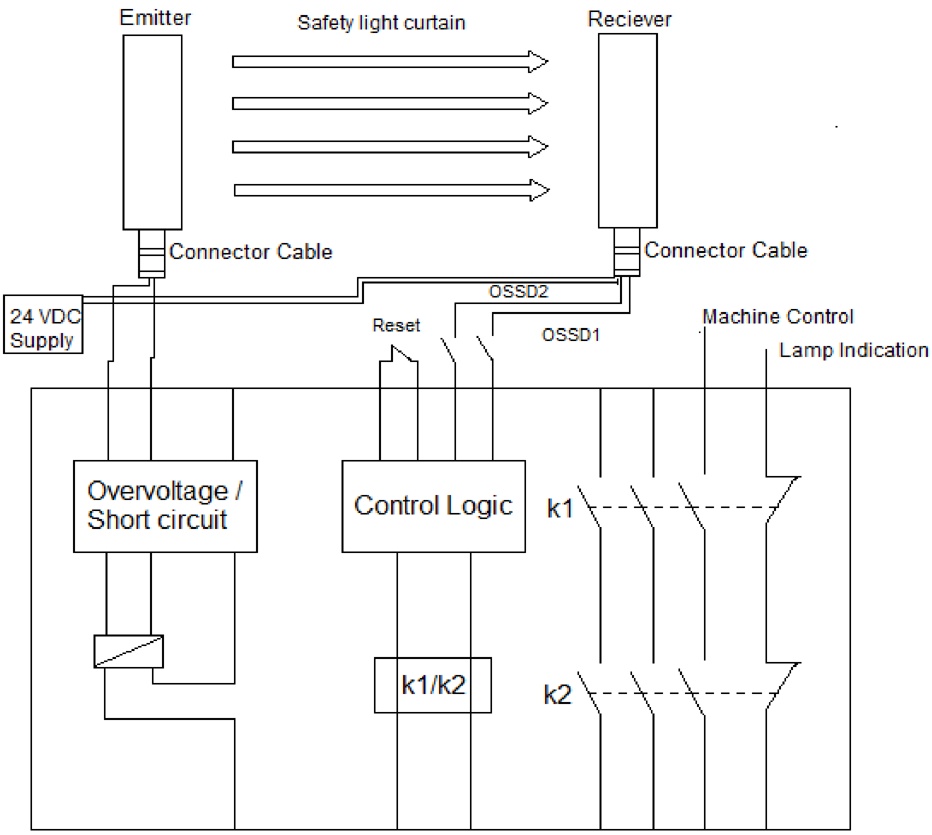

Figure 6.5 Safety system wiring layout

7. TEST RESULTS AND DISCUSSION

The test results of simulation of plc and setup of smart camera and the development of special counter have been discussed in this chapter. The improvement in the machine in terms of quality and production and efficiency of the machine will be discussed.

7.1. Testing Conditions of PLC

PLC program has been tested on the simulator as shown in figure 7.1 by providing both inputs with the help of input I1 and I8 and when both the signals are equal and arrived at the corresponding inputs of the PLC then the counter shows 1 as a count. If one of the signals is missed that is faulty or not confirmed signal then it will reset the counter otherwise continue counting.

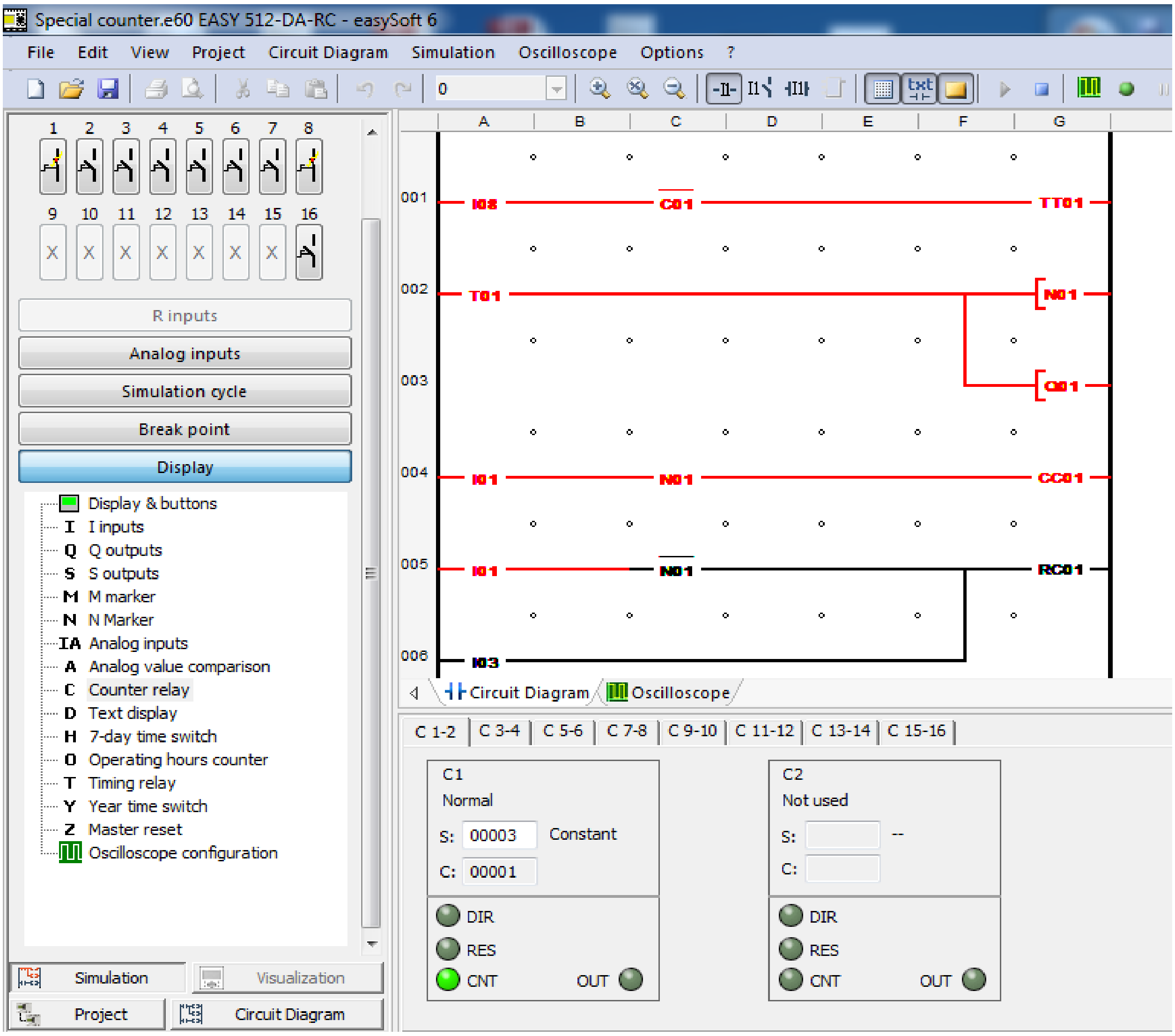

Figure 7.1 PLC simulation of program

7.2. Smart Camera Tuning

The smart camera trigging delay selection is the main part of the program because it takes a lot of time to set as the suitable trigging delay was crucial in this program. The suitable trigging time delay is found to be as shown in figure 7.2. This trigging delay time is working on all possible speeds of the machine. The speed of the machine is varied because of the finger joints length so as the weight due to the variations of length weight of the wood also vary.

Figure 7.2 Camera trigging delay

7.3. Unique Inspection System

The special counter based on vision system is unique in the sense of application and purpose as it is not provided with the machine nor does the manufacturer build this when manufacturing the finger jointing machines. Although many manufacturers have improve their machines in terms of quality, productivity and other modern features by the passage of time but this system still need to capture manufacturer's attention. The top manufacturer those manufacture finger jointing machines are found to be as:

- CONCEPTION RP, CANADA
- WEINIG, GERMANY
- SCHARPF & KOGEL, GERMANY
- NUKUR GROUP, SOUTH AFRICA

All of above manufacturer manufacture finger jointing machines with very advance features and technology but none of them have such inspection system installed on their new and old machines. May be some of them thinking to install but still the author did not find any implementation from them although author went through their newest machines features such as the double of the width, longer plank lengths and the high speed manufacturing.

The author believes that if the manufacturer adopt this special counter system then the quality of the machines would be far better than without having this system/

7.4. Machine Overall Equipment Effectiveness

The overall equipment effectiveness (OEE) and efficiency describe the percentage of the productive time that is improved by installing of inspection system in finger jointing machine.

7.4.1. OEE Formula

OEE is the very important metric which identifies the all losses during planned production and practically calculated as follows:

$$OEE = Availability \times performance \times Quality \times 100\ \% \qquad (7.1)$$

All the losses during production can be demonstrated with the help of a tree diagram as shown in the figure 7.3. There are six main production losses in all and those losses are described with the help of availability, performance and quality. If any of the parameter is declined then the OEE decreases. [14]

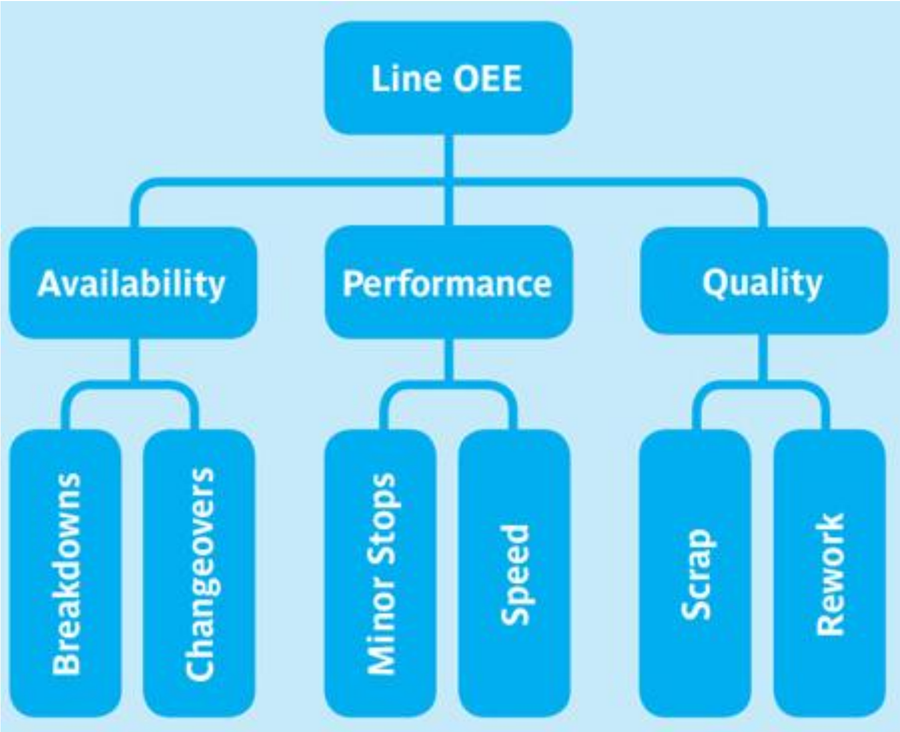

Figure 7.3 Top level losses tree [14]

(i) Availability

The availability defines the percentage of the scheduled time at which the operation is performable. Availability considers all the time losses both the planned and unplanned during operation**.** It is mathematically defined as:

$$Availability = Actual\ Run\ time\ /Scheduled\ Run\ time \qquad (7.2)$$

(ii) Performance

The performance is defines as the actual rate per standard rate of the machine. Performance includes all the factors that cause to slow down production or stoppage of machine.

$$Performance = \ Actual\ rate\ /Standard\ rate \qquad (7.3)$$

(iii) Quality

The quality is the ratio of good units produced to the total units started. The quality loss a very important metric of the OEE and can be calculated as:

$$Quality = Goods\ units\ /\ Total\ units\ satrted \qquad (7.4)$$

OEE can also be calculated with the help of following formula (7.5) but it does not include losses. Therefore all calculations will be made on the basis of first formula (7.1). Although both formulas work well and give equal values after performing calculations.

$$OEE = \frac{Good\ \ Count\ \ \times Ideal\ \ cycle\ \ Time}{Plann\ ed\ Production\ \ \ time} \times\ 100\ \% \qquad (7.5)$$

Whereas,

Good Count = Manufactured pieces without defects

Ideal cycle time = time taken to manufacture one piece

Planned Production Time = Time scheduled for production [15]

7.4.2. Calculations for OEE Parameters

All the calculations are based on an 8 hours standard general shift on finger jointing machine. With 30 minutes lunch break and 80 minutes unscheduled down time because of pause time of 10 minutes in every two hours and 20 minutes for changing sizes and 20 minutes for cleaning. The standard rate of a plank manufacturing is 60 Planks/ hr and in a shift produces 360 planks per shift. The good units are 330 Planks usually.

The OEE is calculated with the help of formula 7.1 as follows:

$$OEE = Availability \times performance \times Quality \times 100\ \%$$

$$Availability = Actual\ run\ time / Scheduled\ run\ time$$

Scheduled time = 480 minutes – 30 minutes = 450 minutes

Actual run time = 450 minutes – 80 minutes = 370 minutes

$Availability = \ 370\ /\ 450 =$ 82.22%

$$Performance = \ Actual\ rate\ / Standard\ rate$$

Available time = 370 minutes

Standard rate = 60 planks / hr

$Actual\ Rate = 360\ planks\ /\ 370\ min /\ 60\ min/hr$ = 58 planks / hr

$Performance =$ 58 planks/ 65 planks = 89 %

$Quality = Goods\ units\ /\ Total\ units\ satrted$

Good units = 320 planks

Total units = 360 planks

$Quality = 320/360 = 88.88\%$

$OEE\ = Availability\ \times performance \times Quality\ \times 100\ \%$

Putting all the values gives

$OEE\ = 0{,}82.89.0{,}89.100 = 64{,}95\%$

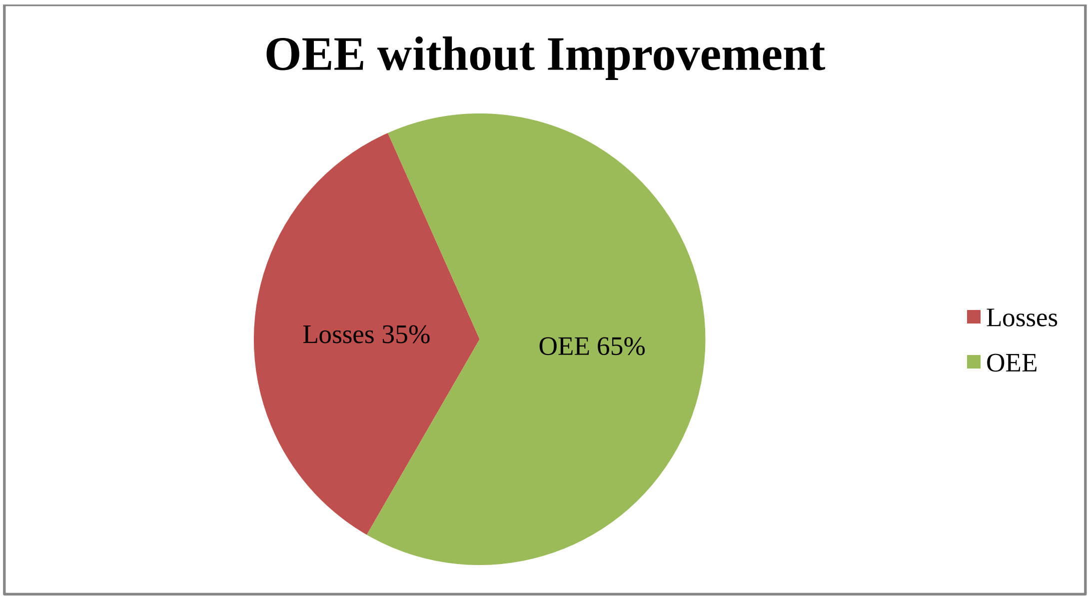

Figure 7.4 Pie Chart for OEE calculations

The OEE score of 100% represents perfect production; a score of 85% represents world class, a score of 60% represents typical and a score of 40% is considered low. Every industry wants to achieve world class quality of their products so that they can lead the market and minimize their production losses.

7.4.2. Quality Improved OEE Parameters

With the help of inspection system the quality of the product is improved and the OEE metric also improved. The improvement is shown with the help of re-calculations of the quality below:

$Quality = Goods\ units\ /\ Total\ units\ satrted$

Good units = 355

Total units = 360

Quality = 355/360 = 98, 61 &

OEE = 0,82.89.0,98.100 % =72%

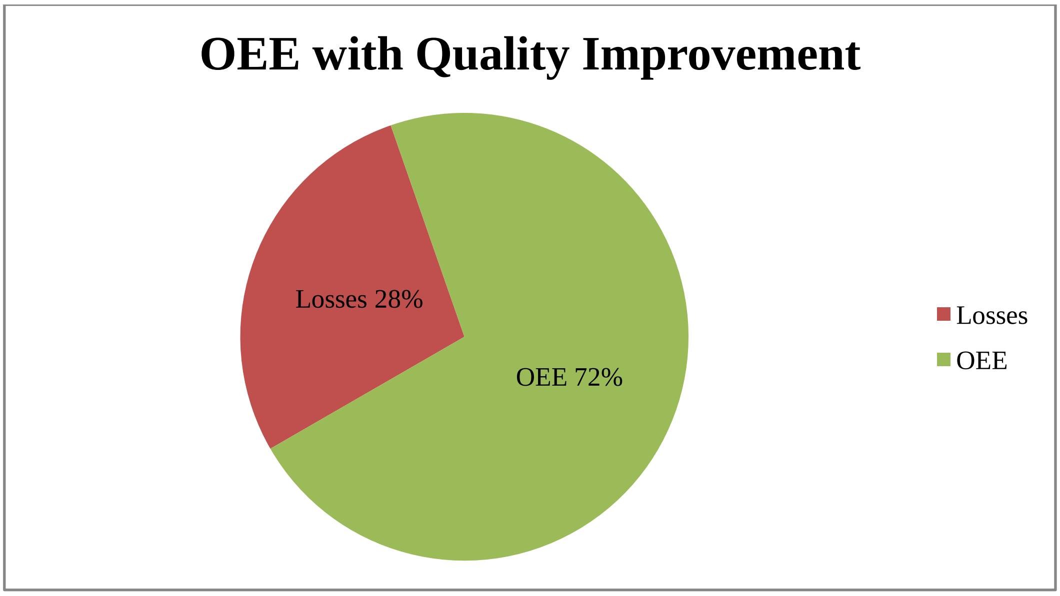

Figure 7.5 Pie Chart with quality improvement

On comparing figure 7.4 and figure 7.5 we can see the significant increase in the OEE values that shifted from 64, 95% to 72%.

(i) Efficiency

Efficiency is the comparison of actually produced goods and the consumed resources i.e. money, time, labor etc. the efficiency of the manufacturing system describes how well the system transfers the input to the out puts.

8. CONCLUSION

The object of developing the special counter for inspection based system has been achieved during this thesis task which was assigned by the company in order to improve the quality. A useful and suitable smart camera and programmable logic controller literature and their user manuals have been studied and applied in order to implement PLC Easy Soft program is learned and then a suitable logic is made feasible by means of simulation and then smart camera has been set up according to the requirements and then tested on the run mode.

Different trigger time has been selected in order to adjust the suitable time delay that can work on all speeds with perfection. The system is tested on all possible speeds initially without controlling the machine stop and then controlled the machine stop. The work was done in the work shop of the company and installed on the production line.

The customized design and automation work needs to be perfect while the installation and commissioning of such equipments on the production machines because if something is wrong with the system then the machine stop times increased so for avoiding such problems one selector switch is provided to select camera inspection or disabled.

The feedback of the inspection system is taken from the production supervisor about the vision inspection system every now and then so that improvements can be made but the feedback from the supervisor all the time positive and now the system is working in 24 hours and 5 days in week without any complete except cleaning of the external lights and camera and photo sensor eye.

This system is going to be adopting by the other machines in order to improve the machine performance and above all the product quality.

The only known disadvantage of the system is the quarterly replacement of the external lamps because of the presence of dust, wood and glue particles which are in abundance. Cleaning is done on regular basis but do not take much time. The safety system is put on the assemble area because of the moving parts that may cause an incident and has been tested.

In this thesis work the author developed automation and control skills along with making drawings on different tools and customizing and tuning smart camera. Mechanically building the stands and box for lighting is state of the art technology which is experienced by the author.

9. FUTURE WORK

The future work is to connect multiple cameras on the different sections of the machine as a distributed cameras network and monitored as a cascaded system so that the quality can be improved from the beginning to the end of the process that is from feeder to the hydraulic press and to replace existing HMI and PLC with the latest available model because they are too old and causing problems and creating unnecessary break down of the production. The PLC often requires replacement of the transistors because of short or open circuit between them and sometimes missing the output switching as well therefore the future work is to replace both of them.

The other work in the finger jointing machine is to replace air pipes because of leakage of air and the chain blocks responsible to moving blocks are damage with wear and tear on the conveyor.

The gear boxes of the main and auxiliary motors are required massive overhauling and the ball bearings of the motors making slight sounding so those bearings will be replaced as well.

The frequency inverters that control the speed require massive service because of visible traces of dust on the heat sink and causing unnecessary heating.

Those works are proposed to do in the summer holidays as we have three week long holidays in the month of July and during these holidays all the proposed work are planned to be done.

10. SUMMARY

The thesis topic was assigned by the company to the author as a proposed possible improvement work under the limited resources and the timeframe. The author took this opportunity as a challenge work. First of all the machine has been studied and then some background studies is carried to understand clearly the reason behinds proposed research work. For the purpose of possible improvements of the machine performance and quality the literature review has been made so that the knowledge and scope of the work can be broaden enough to design the system perfectly or at least near to the perfection as margin of error in the industries are kept very low in order to meet the quality standards which are regulated by ISO. To make special counter on the basis of inspection system was laborious work but was very interesting right from the beginning of the work. The first thing to start with is the selection of smart camera that was done by considering features, requirements and the price as per the theory of machine vision. Then the utilization of available stock was the first priority by avoiding unnecessary cost. The PLC and all other related items were chosen from the company stock. The mechanical parts were made from the raw materials in the form of metal sheets and angles. The prototype model has been created in order to demonstrate the work to the management of the company for the approval before installation on the machine. The power and control wiring has been carried out according to the applicable standards of IEC and EU. Taking all the safety measures during installation and commissioning on the production lines because of nonstop production. Similarly the installation of safety system which was of paramount importance has been carried out as per the applicable standards. Every component that is used in this task has certain limitations which has been discussed

The outcome of the research is that the quality is improved by approximately 10 percents of the total production and the laborious work to check quality is no longer needed. The metric that describes the quality of production that is OEE is raised by 7 percents from the previous. The satisfaction of the operator and the line supervisor is achieved in the form of positive feedback and less defective production sheets

Every system has certain advantages and disadvantages regardless how well the system performs. Similarly this system has also pros and cons but advantages are far better than disadvantages. The system may be required up gradation by the passage of the time. The author believes that the contribution of improvements and making the systems easier to the user is the first task of the engineers of Mechatronics field which is the back bone of the industries.

11. KOKKUVÕTE

Lõputöö teema oli pakutud autorile ettevõtte poolt kui ettepanek parandada piiratud ressursside ja aja jooksul ole masolevat lahendust. Autor võttis väljakutse vastu. Kõigepealt tuli uurida masina tööd ja lisaks teha muid tausta uuringuid antud uurimustöö eesmärkide paremaks mõistmiseks. Masina töö ja kvaliteedi parandamise võimalda miseks sai uuritud olemasolevat kirjandust. Selle abil üritas autor laiendada oma teadmisi piisavalt selleks, et ko nstrueerida võimalikult täiuslik süsteem, kuna tööstuses üritatakse veamarginaalid hoida võimalikult madalad va stavalt ISO kvaliteedinõuetele. Spetsiaalse loenduri konstrueerimine kontrollsüsteemi põhjal oli väga mahukas, aga ka huvitav kohe algusest peale. Alustuseks tuli valida nutikaamera mis sai tehtud hinnates kaamera omadusi, hinda ja nõudmisi kaamerale masinnägemise seisukohalt. Kulude kokkuhoiuks tuli proovida kasutada olemasol evaid vahendeid. Nii PLC kui ka muud asjad said valitud firma laos olemasolevate vahendite hulgast. Mehaanilised osad said tehtud lehtmetallist ja nurgikutest. Masina prototüüp ehitati demonstreerimaks masina tööd firma juhtkonnale enne selle installeerimist. Toite ja juhtimise kaabeldus on teostatud vastavalt IEC ja EU standarditele. Ka turvasüsteemide paigaldus, mis on väga oluline, sai läbi viidud vastavalt olemasolevatele standarditele. Kõikidel antud töös kasutatud komponentidel on teatud piirangud mis on töös välja toodud.

Uurimistöö tulemusel on tootmise kvaliteet paranenud umbes 10 % ja mahukas käsitöö kvaliteedi kontrollimiseks ei ole enam vajalik. Mõõdik mis kirjeldab tootmise kvaliteeti (OEE) on paranenud eelmisega võrreldes 7 %. Nii operaator kui tootmisliini järelvaataja on rahul ja on andnud positiivset tagasisidet, samuti on esinenud vähem defektset toodangut.

Igal süsteemil on teatud eelised ja puudused olenemata sellest, kui hästi süsteem toimib. Ka sellel süsteemil on oma head ja vead, aga eelised on palju paremad kui miinused. Võimalik et süsteemi tuleb aja jooksul uuendada. Autor usub, et süsteemide parandamine ja kasutajale hõlpsamaks muutmine on Mehhatroonika valdkonna inseneride peamine ülesanne, see teeb tööstuse tugevamaks.

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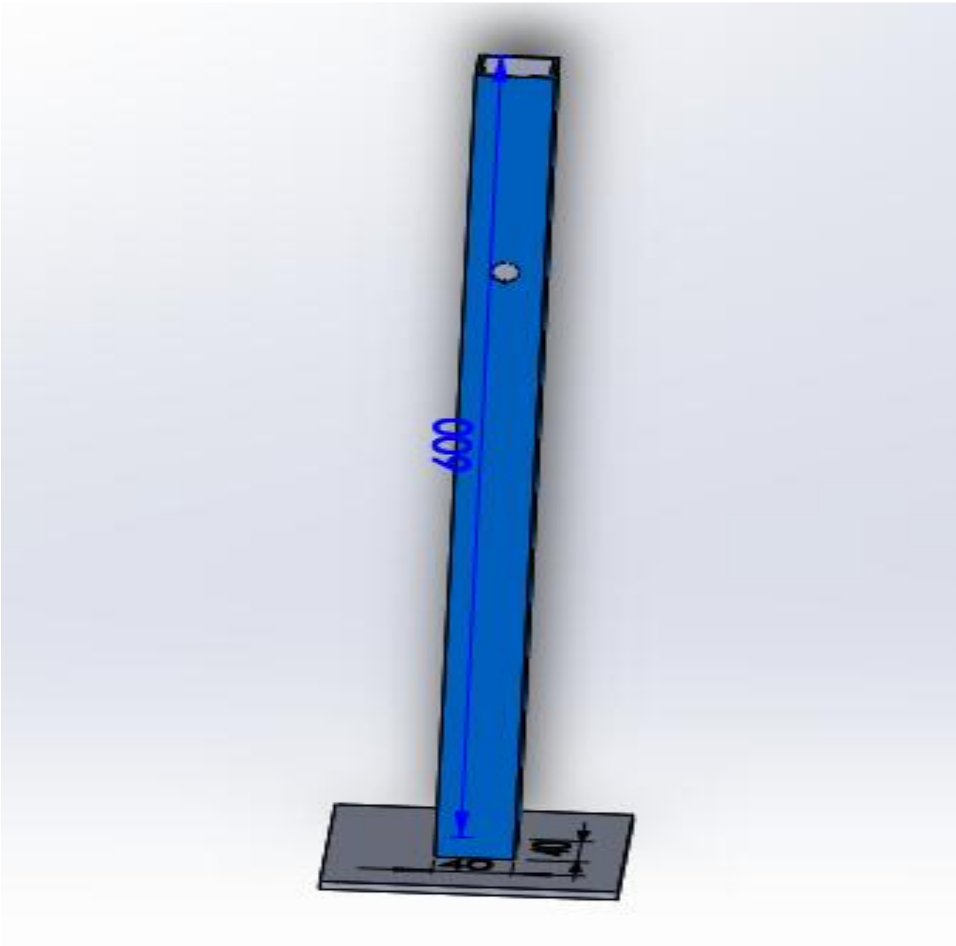
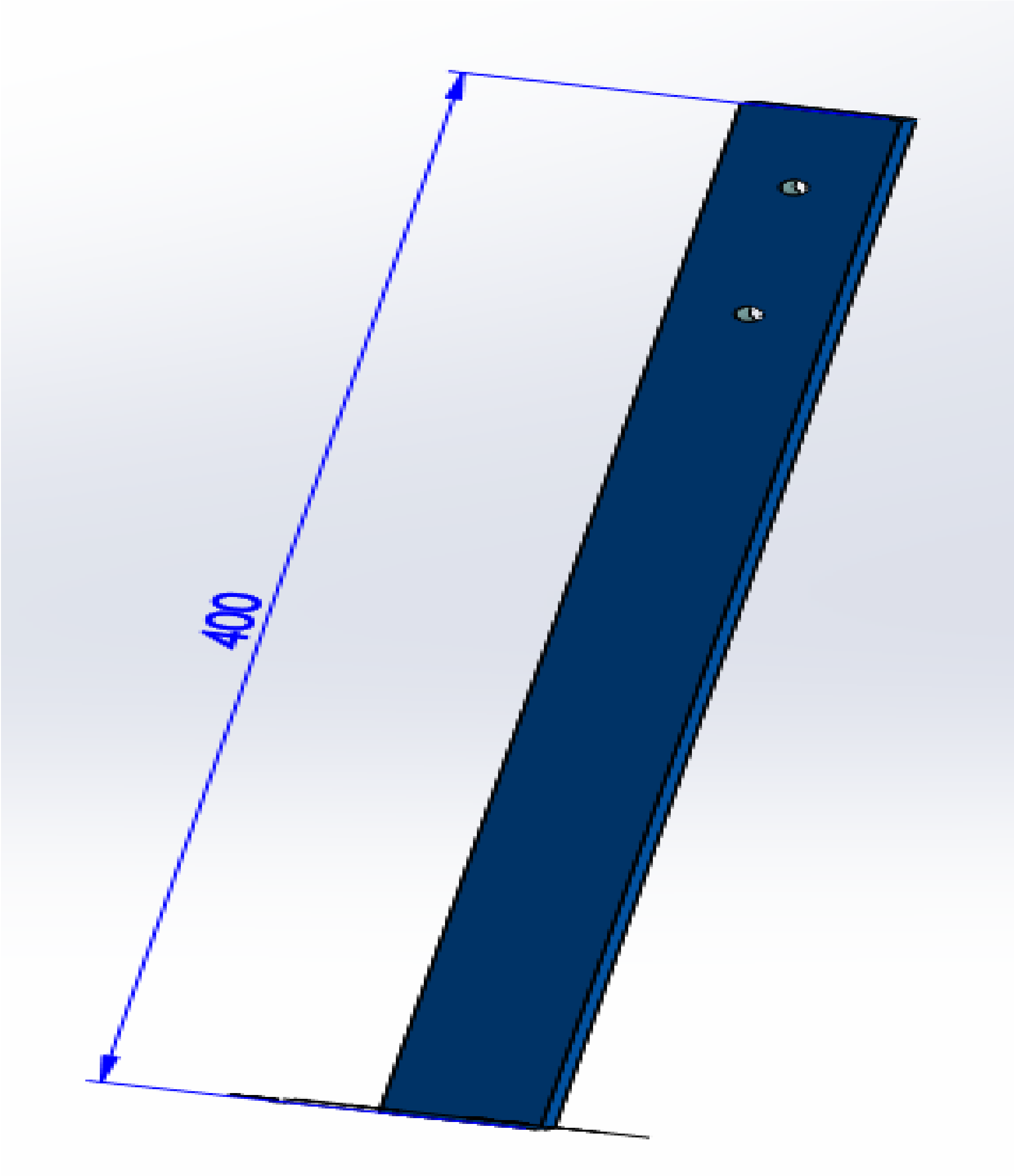
Appendix 1: Camera stand design parts

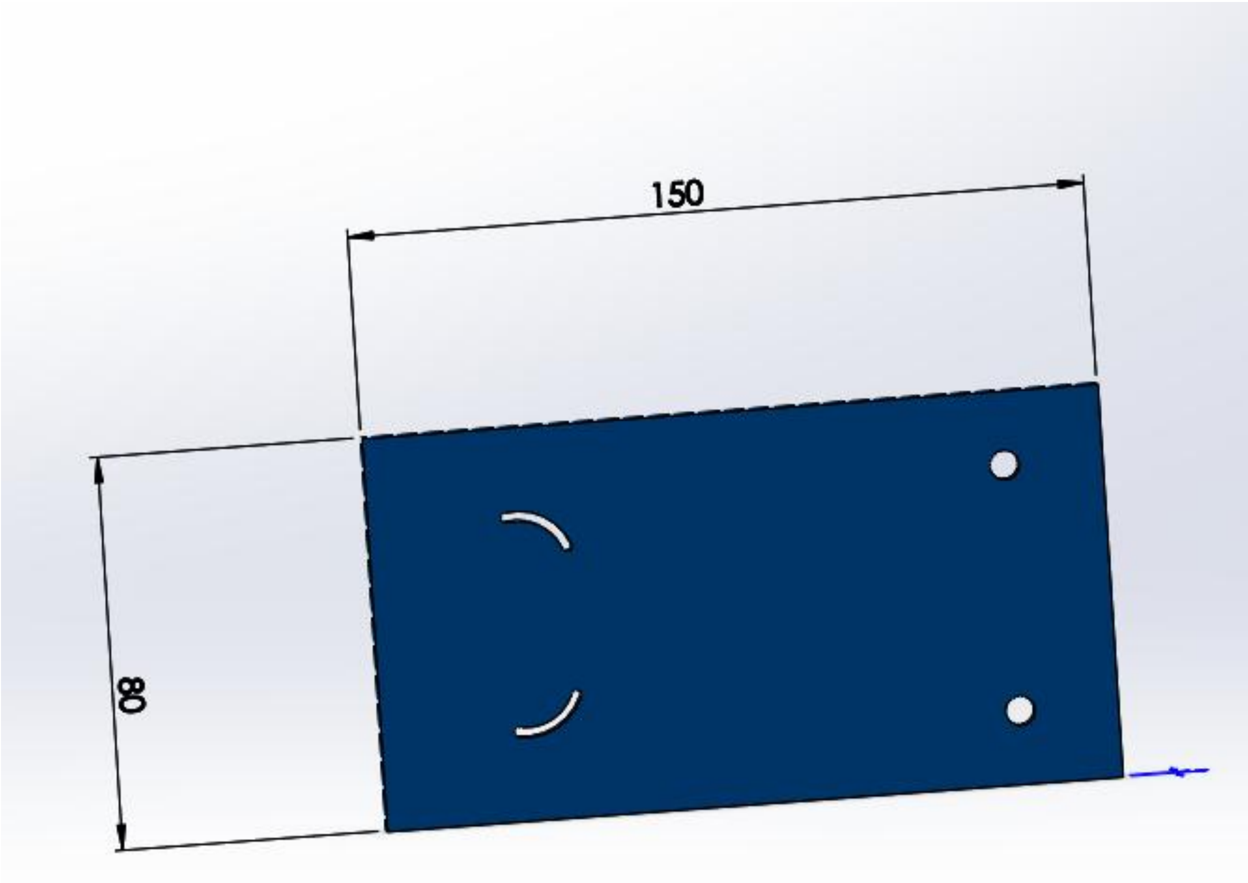
Appendix A1.1: Camera stand



Appendix A1.2 Extrude able Rod



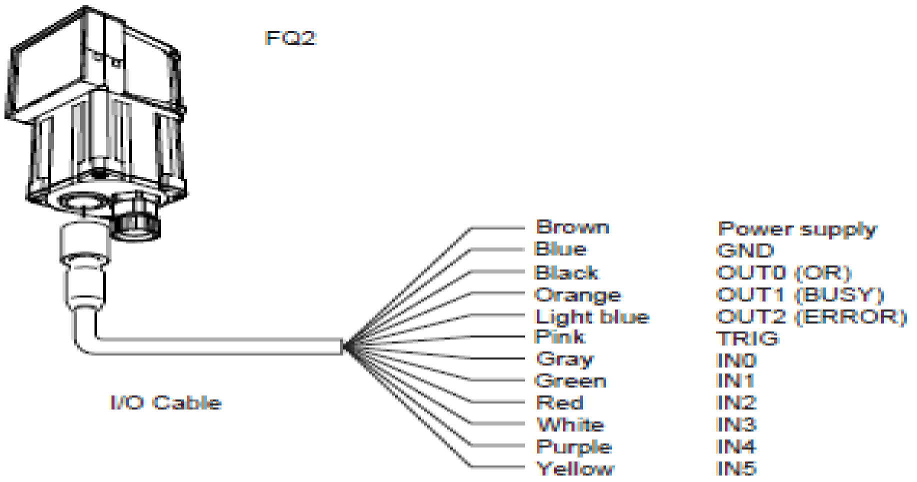
Appendix A1.3 Camera mounted Adjustable plate



Appendix 2 Camera input and output cable

Wiring the Sensor

Connect the I/O Cable to the I/O Cable connector located at the bottom of the Sensor.



Appendix 3: Camera Specification

No.	Name	Description
01	Type	Standard function
02	Model	FQ2-S1/CH
03	Field of view	300 mm
04	Installation distance	600mm
05	Inspection Items	Sensitive search, area, color data, edge position, labeling
06	No. of simultaneous measurements	32
07	No. of registered scenes	32
08	Position compensation	360 degree model/ edge position compensation, Linear correction
09	Calibration	Supported
10	Image Processing method	Real colors
11	Image filter	HDR, image adjustment (color gray filter, dilate, erosion, median etc.) and white balance with brightness correction
12	Shutter speed	Built in light on: 1/250 to 1/50000 seconds Built in light off: 1/1 to 1/50000 seconds
13	Processing resolution	928 x 828
14	Lighting method/color	Pulse / white
15	Measurement data	1000 items in sensor with Touch finder and SD card
16	Images	20 images in sensor
17	Auxiliary function	Statistical data, test measurements, I/O monitor, password function, simulation, history, calibration
18	Measurement trigger	External trigger (single or continuous)
19	Input signals	7 signals Single measurement input (TRIG) and control input (IN0-5)
20	Output signals	3 signals outputs Control (BUSY), Overall judgment (OR) and Error (ERROR)
21	Power voltage / current	24 VDC / 2.4 A
22	Ethernet specifications/ Type	100 Base – TX/10 Base-T / RS-232 C