Design of an Automated Pill Weight Checker System for Pharmaceutical industry

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Abstract

Quality control is an essential operation of the pharmaceutical industry. Drugs must be marketed as safe and therapeutically active formulations whose performance is consistent and predictable. It not only protects the manufacturer against compensation claims but also guarantees the patient a safe and effective product. In this work official, an inline quality test for solid dosage in the form of pills or capsules are discussed. The weight of the articles (solid dosage) is measured in this paper to ensure the uniformity of the weight as prescribed by Indian Pharmacopeia. To avoid packing of the articles which has a surface defect or any dimensional defect, visual inspection is carried by image processing. The proposed device uses a load cell for weight measurement. These quality tests are carried out at high speed using a Programmable Logic Controller.

Keywords: *Automation, Image processing, Load cell, PLC, Pharmaceutical, Weight checker.*

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Introduction

Quality is the best business plan. There are many institutions formed around the world in the last few decades to derive a set of instructions, standards to maintain the quality of the product manufactured. The manufacturer needs to inspect the manufactured goods and to assure that articles are within tolerance limits as prescribed by the standards. In the pharmaceutical industry, a quality check is a sophisticated problem because the modern-day tablet manufacturing process can manufacture hundreds of tablets per second also the size and weight of the article made the process more difficult. The major drawback exists in its manufacturing. If any minor problem occurs during their manufacturing, then the whole batch of the unit should be discarded. Also, an inspection of tablets is very important to avoid any sort of defective drug content from the packaging. Riaz et al. [1] discussed that mass production results in various production issues. The issues like under dose or overdose due to the difference in weight of tablets, foreign particles etc. Risk associated with manufacturing high quality tablets can be addressed with artificial intelligence. In 2004, the Food and Drug Administration (United States of America) introduced a Process Analytical Technology (PAT) initiative [2], which encourages the pharmaceutical industry to employ new in-line and on-line quality measure techniques to measure critical process parameters with the purpose of quality assurance and better process understanding. Since then, many PAT techniques have been developed and applied to the pharmaceutical industry. For example, digital imaging techniques have been successfully used for measuring the coating thickness of the pellets during the coating process and for the automated visual inspection of tablets during the tablet coating process.

Haritha [3] discussed different quality tests where the aspects of the tablets like size, shape, hardness, friability, weight, and weight variation, etc. are inspected. Out of various characteristics weight is considered to be an important characteristic in tablet inspection. In existing methods strain gauges were used to find the tablet weight. Furtwaengler et al. [4] suggested generating an error signal which alters the punch-pressure or stroke-height to affect the formation of tablets depending upon the data obtained from strain gauges in the lever arm of the upper and lower punches of tablet compression station. Doerman et al. [5] suggested using laws of conservation of momentum by using a load cell and velocity sensor to measure the weight of several objects in succession without stopping the flow of the moving conveyor. He achieved it by shooting tablets on a curved surface and determining the weight by loss in momentum. Bawuah et al. [6] used terahertz transmission pulse delay measurements to determine porosity and weight. Various studies support that to determine the size and shape of an article image processing and machine learning can be used. Možina et al. [7] discussed a system that is capable of testing 100 articles per second by using image processing. At present, a few types of equipment are available in the international market for weight checking or dimension checking at medium to moderately high speeds. But both dimensional measurement and weight measurement cannot perform in a single machine this obstacle will increase the price of the device. In addition to that in-process quality check is carried out in this current paper. This paper aims to provide a weight measurement and dimensional check device. The device discussed in this effort is relatively autonomous and capable of handling a very high rate of articles/hour

A medicine filling machine was designed by Kohashi [8] which included suitable quality checks like weighing of empty and filled liquid medicines bottles. It was done by a rotating platform having multiple filling systems. This machine included a conveyor belt transporting the empty bottles which are loaded into the filling station by rotating C-grooves having the size of bottles. After filling it is similarly unloaded by rotating C-grooves. At the weighing station sensors were used to sense a bottle on the belt at the entry and exit of the weighing system. Le [9] designed a simple conveyor type machine for measuring weights of static objects

like oysters, pharmaceutical tablets, etc. It contained three conveyors running at different speeds which are coupled by downward sloping ramps. This design, although effective, is not compact and is suitable for one type or the same dosage. A compact high-speed tablet sorting machine was designed by Mayer & Broders [10]. This machine contained a hopper to load the tablets into the turntable via a chute. The Turntable surface was made rough to generate friction to hold the tablets. As the turntable rotates, a curved deflector guides the tablets to pass through an opening at the top and aligns them along the circumference of the turntable in a single row. As each tablet passes through the capacitance sensor there is a change in capacitance which can be linked to the measure of the weight of the tablet by certain equations. Then defective and good tablets are sorted and sent along the different paths. Mayer [11] resolved the problem of non-uniform tablet blocking. Evans & Oestreich [12] proposed a device measuring the capacitance of tablets of different shapes and sizes. The tablets move between the plates of a capacitive sensing device. The system comprises a lower disk made of aluminum and an upper disk (with silicone rubber coating), and resilient clamp, Burns Automation [13] designed an Automatic Weighing System that determines efficiently the weight of tablets, capsules, and other solid dosage forms during or after the production process. It contains a feeder to separates tablets into individual pieces and a channel to guide tablets to a weighing disk with cavities for tablets.

A drug weighing and drug metering machines which monitor the weight of gelatin capsules with powdered drugs was proposed by De & Ansaloni [14]. This design has an empty capsule feed device, feed unit, weighing systems, transfer drum, and a metering unit. Empty capsules fed by the feeder to the drum are captured at slots by suction and fed to the first weighing unit that measures the weight of empty capsules. Empty capsules are directed to the metering unit where capsules are filled. Further, filled capsules weight is measured by the second weighing unit. Tsukamoto Katsura [15] proposed a device capable of checking the weight of tablets, soft capsules, hard capsules, and a variety of oral solid drugs, with a capacity to check 100000 units per hour with an accuracy of ±2 mg. According to the design, the pharmaceutical product of proper quantity is placed into a hopper and a suction drum sucks and transfers in tablets one at a time to a transfer roller and then placed on the electromagnetic weighing balance. This electromagnetic balance has high accuracy and mostly maintenance-free. The device has flaps that discard defective drugs. The design given by IMA Group PRECISA, [16] is an extremely compact and 100% weight checking vertical setup containing a hopper, feeding channel to guide tablets in multiple single lines feeds. Each tablet is loaded onto slots in a rotating drum, which in turn transfers each tablet to the weighing unit. Tablets of correct weight are separated from underweight/ overweight tablets through a sorting channel. A compact vertical weighing machine was created by Klopfenstein et al. [17] which segregates the product into discrete quantities and combines several discrete quantities into a group that closely approximates a target weight. Seidenader Maschinenbau GmbH [18] designed another machine that sorts the tablet according to a size having a capacity of 1000kg /hr. This design involves a hopper and vibrating V-channels which spreads tablets in single lines and fed to sorting rollers where oversized and undersized tablets are removed. The system is quite precise and fast and the size of tablets is set by rotating wheel and setting distance equal to tablet width with an accuracy of 1/100 of a millimeter. From this Literature review, it can be concluded that there are various types of machines and mechanisms for tablet sorting and weighing. Each of these machines has a complex mechanism and complexity increases with the control compatibility. However, in each case, there is a deficiency and there is a requirement for improvement. Simple sorting and weighing machine with a less complex control system having higher sorting speeds and low cost is the current day requirement.

Design Schematic of the Pill Weight Checker System

Basic Layout

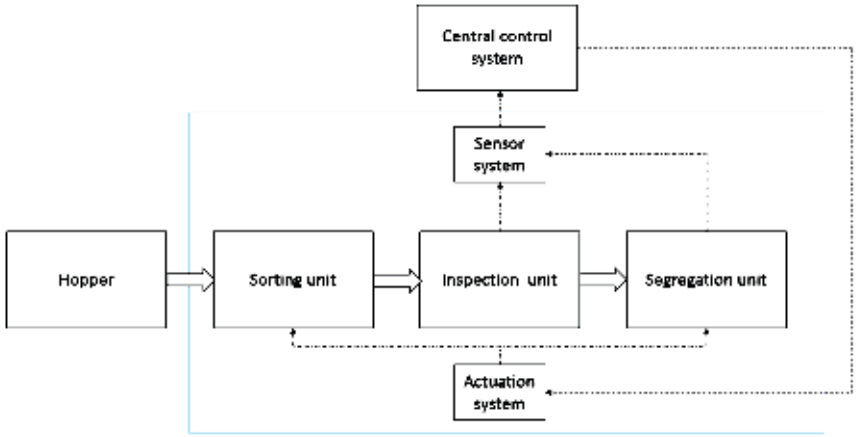


Figure 1. Layout of Automated Pill Weight Checker System for Pharmaceutical industry

Figure 1. shows simple layout of the work discussed in this paper. The entire design of the current paper is divided into six different parts acceding to their working. Those sub-parts are

I. Sorting Unit
II. Inspection Unit
III. Segregation Unit
IV. Central control system for autonomous operations and data logging
V. Sensor system
VI. Actuation system

The sorting unit is used for aligning the articles which will go through quality tests on the inspection unit. Actuation system drive motors on the sorting unit and segregation unit. Apart from the sensors used for quality test, capacitance sensors are used to measure the articles.

Physical Construction

Aligning the articles is important to prevent troubles like multiple pills entering, pills clogging, and pills damage. William [19] created a system where the articles aligned in conveyor and inspected by visual inspection. Two Charged –Couple Device (CCD) is used to inspect the top and bottom parts of an article. Yamatomo et al. [20] used two different rotating cylinders so that articles can be arranged according to the position of slots on the cylinders which in turn prevents the articles from slipping. The bottom of the table consists of a weight measuring sensor. But this model cannot be used for different shapes of articles. The current investigation provides an improved model to overcome the obstacle described before.

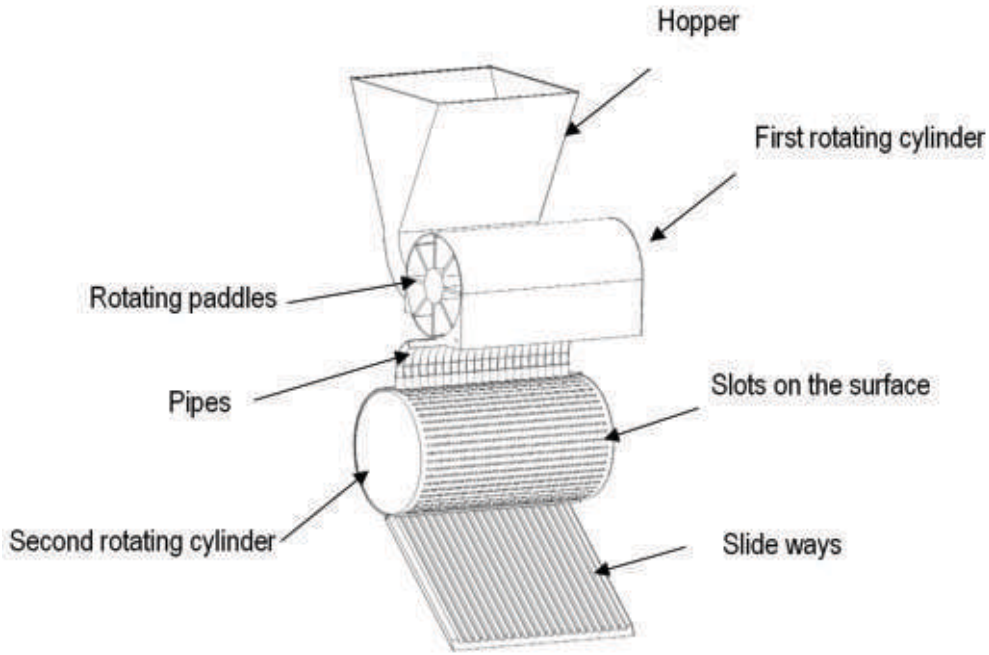


Figure 2. Concept model

In quality check, a set of the load cell is used to measure the weight of the articles. For dimension measuring image processing method is used. Another method GO-NO GO gauge method cannot be used. In the GO-NO GO method, the surface contact between the article and the gauge surface is high so it may lead to surface damage of the article. Image processing is also used to find defects on the surface of the articles.

The concept model of the device described in this effort is shown in Figure 2. A hopper is provided to store the articles which need to be tested and two different rotating cylinders are connected by pipes to align the articles and aid to conduct quality tests.

Sorting Unit

To align the articles one-hopper, slotted guideways, and a rotating cylinder with paddles are used to align the articles used in this paper. In this paper one-hopper, slotted guideways, and a rotating cylinder with paddles are used to align the articles. The hopper is used to store the articles which need to be inspected. Hopper is connected to the closed rotating cylinder as shown in Figure 2. The first cylinder consists of three important parts, they are hollow cylinder where the articles are transferred, one roller with a paddle, and a slotted plate. One roller with paddles like in will rotate inside of the cylinder will make move the articles randomly. These paddles will rotate in less rpm to avoid the damage of articles. One plate with holes is placed inside the cylinder so when articles aligned to the holes it will fell and enter the bottom opening and transported to the second cylinder. To transfer the articles a set of small pipes is used. Inside those pipes, the articles move due to gravity only no other external force is applied. The pipes used to transport the articles are narrow so the articles will be aligned thereby clogging is avoided. The number of holes on the slotted plate and no of pipes used to transfer the article are the same in number also they are the same

number as at a time how many articles can be inspected. The inner surface of the cylinder and pipes are having a polished surface to reduce the friction which may cause a surface defect of the articles. The plate with the hole is connected inside of the first cylinder. For different shapes of articles, no need to change the entire setup, as only this plate needs to be changed. Once the articles pass through the pipes it enters the second rotating cylinders. In the back of these plates, a separate division is provided which prevents an article from colliding with an adjacent article. The clearance level on the plate will be very less so only one article will enter at a time. The gap between the plate and paddles and the rotating roller is very less. The assembly of the second cylinder has a slotted surface plate and a rotating cylinder. Slotted on the surface hold the article which needs to be inspected. The slotted plate can be changed for different kinds of articles. This changeable plate has an extension on the inside which matches with grooves inside on the rotating cylinder. This second rotating cylinder rotates anti-clockwise while the roller in the first cylinder rotates in a clockwise rotation.

One curved cover plate is placed left side of the second rotating cylinder so the article will not slip from the cylinder due to gravity. Also, a transparent section is provided on the top of the curved plate so the visual inspection can take place. At the end of the cover plate, the weighing scale is placed so the weight measurement can take place.

Inspection Unit

Basic principle

For weight measurement, a series of the load cell is used instead of a single unit to achieve a high speed of measurement. The load cells are working based on the Electro-Magnetic force compensation principle. The main advantage of this load cell is low response time and high accuracy.

For dimension measuring an image processing module is provided right side of the second cylinder. This image processing unit will take pictures of the articles in a second rotating cylinder then compare it with user input and send the final output to the central control system(CCS).

Dimension check:

The visual inspection module will take an image of articles through the transparent window given in the curved cover plate. In a single image, the visual inspection module can analyze a set of articles for that edge detecting algorithm pre-feed into the visual inspection module. From the top surface image, the area of the article will be found. The thickness of the article is calculated using weight and volume relation as the length and width of the article are already measured by the visual inspection module and the density of the article is known. Figure 3. shows a simplified functional block diagram of how the process of dimension measuring is executed. From the visual inspection, any defects present on the surface of the article also will be noted. Once the inspection is done visual inspection module will send the signal to the (CCS) and the CCs will decide whether the article can be accepted or not.

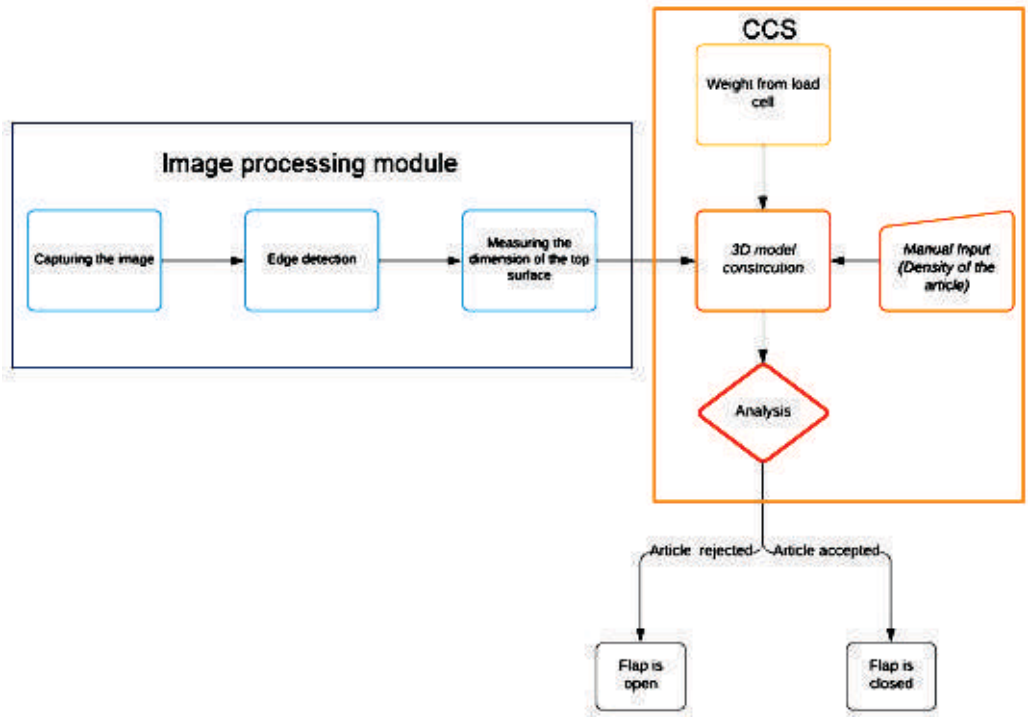


Figure 3. Functional blocks for image processing

Weight measurement

For quality control on solid dosage, the weight measurement is the main test. Verma et al. [21] emphasize the importance of tablet or capsule weight variation, content uniformity, and homogeneity. Uddin et al. [22] gave the tolerance level for weight measurement of articles as per Indian Pharmacopeia standards. The second rotating cylinder places the article on the series of load cell incorporated at the end of the curved plate. Each load cell sends the measurement value separately in terms of current or voltage to the CCS. In CCS it's already programmed to convert this output of the load cells in terms of either current or voltage into numerical numbers according to the program fetched in the CCS the input from the user is compared against the converted numbers. After the quality test, the articles are pushed into the slideways by the second rotating cylinder.

Table 1. Tolerance limit for tablet prescribed by Indian Pharmacopeia

Threshold Limit	Average weight W_{avg} of pill (IP/BP)
±10%	W_{avg} =< 80mg
±7.5%	80mg < W_{avg} <250mg
±5%	W_{avg} >=250mg

Filtering Defective Pills

Series of slideways are placed in a way the articles will slide after the quality test. These slide ways are inclined and the articles are delivered by gravity. In Each slideway, one servo controlled deflecting flap is mounted. The servo motor of this flap will get a signal from CCS. If the article is defective the CCS will send the signal to the servo motor to open the flap so the defective article will be segregated. Capacitance sensors are mounted at the end of the slide way and near the defective collector bin. The signal from the capacitive sensor will be sent to CCS so the number of articles accepted and rejected is stored.

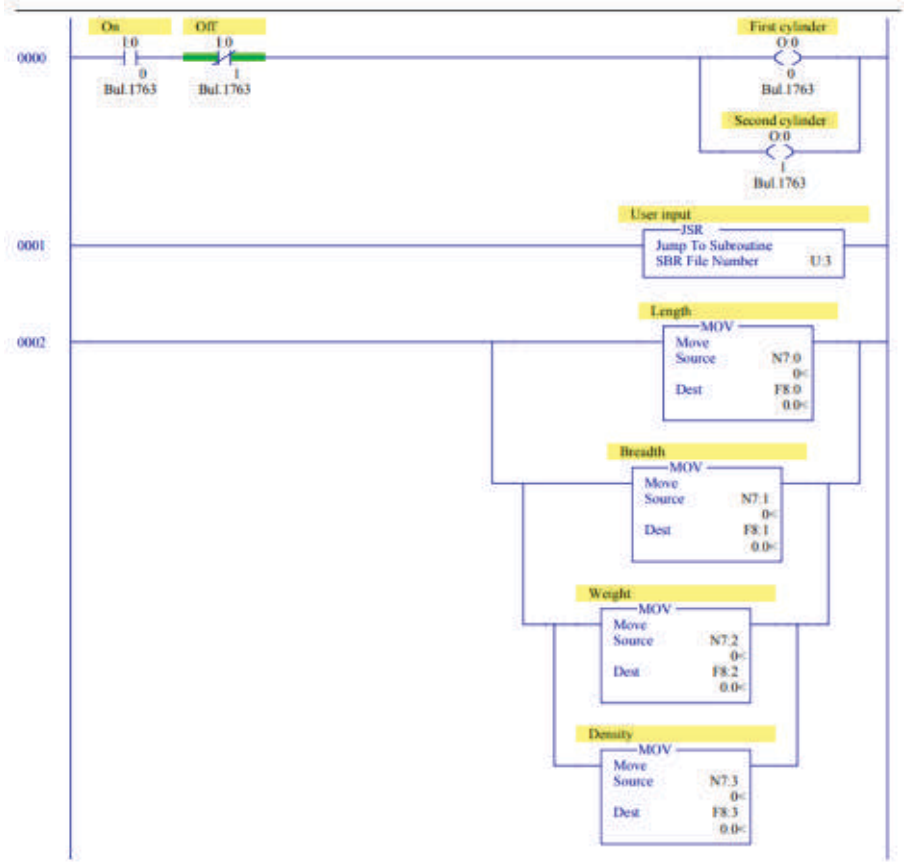
Control Logic for Pill Separation and Data Acquisition

By reducing human interference in quality check reduces the errors. Also fully autonomous is the only solution to test many articles in a small amount of time. Complete autonomous operation requires a CCS with high processing power and processing speed. In the current paper, the number of inputs and outputs are high. So among many options for automation Programmable Logic Control(PLC) is used as a master controller. Another advantage of using PLC as CCS is, it's reliable and easy to configure, and also additional modules can be incorporated in the future for more input, output. To connect users and CCS, Human Machine Interface is used. This HMI is used for real-time monitoring and insert user input to CCS. A separate Personal Computer is communicating with PLC so the data can be stored in PC and can be used for further analysis and comparison.

Simple Programme logic with Ladder diagram

PLC LOGIC

Program structured text, Functional block diagram, and ladder diagram are the way to program the PLC. Among those, Ladder logic is the more convenient and reliable method of programming. A basic ladder logic for the PLC used in this shown below Figure 4.



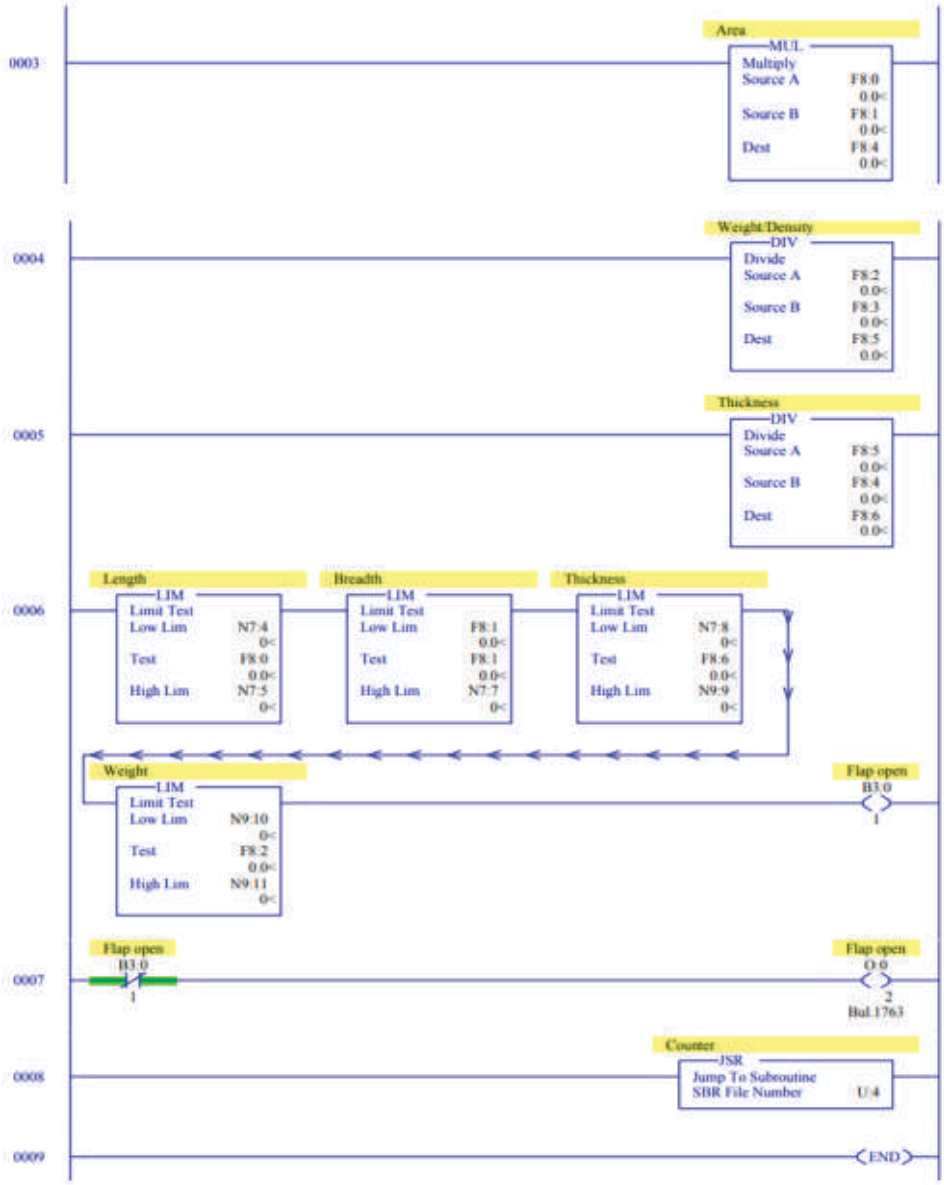


Figure 4. Ladder logic created in Rslogix 500

Rung 0000 : Start and stop the operation of first and second rotating cylinders
Rung 0001 : Jump to subroutine to get user input from HMI
Rung 0002 : The user inputs values will be converted into an integer in subroutine 1 and that integer values are moved to float values
Rung 0003 : The top surface area of the article is found by multiplication of length and breadth of the article
Rung 0004 : Weight/ Density (Volume) is calculated
Rung 0005 : Thickness is calculated by diving the volume by the area
Rung 0006 : The limit condition is verified against the user input and tolerance level
Rung 0007 : The servo motor attached to the deflecting flap will get respective signal
Rung 0008 : Jump to subordinate to count the number of defective and non-defective articles

Apart from the main ladder subordinates will transfer the user data and convert that into respective integer value and crate necessary data table for real-time monitoring

Conclusion

The need to measure the quality of articles (solid dosage) and the difficulty in the quality assessment process is briefly discussed in this investigation. The quality test conducted in this paper validates the content uniformity and homogeneity of the articles. In current work, the articles are fed to the hopper and transferred to the sorting unit to align the articles with the help of load cell and image processing unit weight and dimension quality tests are carried and the data is sent to CCS. In CCS the PLC is directly connected to every sensor and actuators and communicating with the image processing module, PC, and HMI. PLC will give respective signals to the actuator according to the input got from sensors and HMI. The current design makes sure uniformity of weight in all articles and sorts out the defective and non-defective articles. Automation incarnated using PLC in this design enables the high speed of operation of each unit in this system.

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