KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

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Analysis and Modernization of Liquid Filling Process in a Manufacturing Company

Master's Degree Final Project

Supervisor
Assoc.prof. dr. Jolanta Baskutiene

KAUNAS, 2017

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Industrial Engineering and Management (code 621H77003)

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(Title and code of study programme)

" Analysis and Modernization of Liquid Filling Process in a Manufacturing Company“

DECLARATION OF ACADEMIC INTEGRITY

24th MAY 2017

Kaunas

I confirm that the final project of mine, **Vasudevan Ganapathi**, on the subject “**Analysis and Modernization of Liquid Filling Process in a Manufacturing Company**” is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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Approved:
Head of Production engineering Department

____
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Kazimieras Juzėnas
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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Analysis and Modernization of Liquid Filling Process in a Manufacturing Company.

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

To analyze the liquid filling process in a manufacturing company and propose solution to reduce the losses.

3. Structure of the project

1. Literature review
2. Analysis of packaging process
3. Analysis of wastes from the packaging process
4. Reduction of changeover time
5. Other solutions for removal of wastes
6. Analysis of results
7. Conclusion and future developments

4. Requirements and conditions

The packaging process data were obtained from the company's personnel and mainly concentrating on the packaging process. The demand of the product per day was taken as 7000 per day which is the peak value of demand which arises in the company. The time lost for breakdowns were obtained for the month of January and the pareto analysis was done was six months using this data. The software used for plotting the value stream map is " Lean pilot" and the software used for programming the machine is "Cx programmer 9.4".

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 June 9th.

Student	Vasudevan Ganapathi	______________________
Supervisor	Assoc. Prof. Dr. Jolanata Baskutiene	______________________

Ganapathi, Vasudevan. Talpų užpildymo skysčiu proceso tyrimas ir modernizavimas gamybinėje įmonėje. *Magistro* baigiamasis projektas / vadovas doc. dr. Jolanta Baskutienė; Kauno technologijos universitetas, .Mechanikos inžinerijos ir dizaino fakultetas.
Mokslo kryptis ir sritis: Technologijos mokslai, Gamybos inžinerija.

Reikšminiai žodžiai: bendrasis įrenginių efektyvumas, programuojami loginiai valdiklliai, vertės srauto žemėlapis, bendroji įrenginių priežiūra.

Kaunas, 2017. 42 p.

SANTRAUKA

Projekte nagrinėjamas talpų užpildymo skysčiu procesas gamybinėje įmonėje. Atlikus analizę, sudarytas pakavimo linijos vertės srauto žemėlapis, nustatyti pagrindinai proceso nuostoliai Nustatyta, kad pagrindiniai nuostoliai yra susiję su papildomu perderinimo laiku. Siekiant sumažinti perderinimo trukmę, sudaryta programuojamo loginio valdiklio kontaktų diagrama. Kadangi perderinimo laikas sumažėjo sąlyginai nežymiai, sudaryta nauja programa, kuri užtikrino sąlyginai trumpesnį perderinimo laiką ir atitinkamai pagerino įmonės gamybos procesą. Įdiegus atnaujintą programos versiją, galima nesunkiai užtikrinti papildomą produkcijos poreikį vasaros laikotarpiu. Be to, tokiu būdu padidėja ir bendrasis įrenginių efektyvumas. Sumažinta perderinimo trukmė, pasiūlytas pakavimo linijos balansavimo sprendimas. Atlikta Pareto principu paremta analizė įvertinanti nuostolius. Nustatyti pagrindiniai nuostoliai, kurie sąlygoja prastovas. Atsižvelgiant į egzistuojančius nuostolius, sudarytas įrenginių priežiūros planas ir Be to, pasiūlyti sprendimai. Pasiūlyti modernizavimo sprendimai padės sumažinti nuostolius ir avarines prastovas. Suformuluotos ir pateiktos projekto išvados.

Ganapathi, Vasudevan. ANALYSIS AND MODERNIZATION OF LIQUID FILLING PROCESS IN A MANUFACTURING COMPANY: *Master's* thesis Final project/ supervisor assoc. prof. Dr. Jolanta Baskutiene. The Faculty of Mechanical engineering and design, Kaunas University of Technology.

Research area and field: Technological Sciences, Production Engineering

Key words: Overall Equipment Efficiency, Programmable Logic Calculator, Value Stream Mapping, Total Productive Maintenance.

Kaunas, 2017. 42 p.

SUMMARY

The main objective of this Research is to analyze the Liquid filling process in a manufacturing company. By analyzing the process and by perfomring several calculations the main wastes in the process were identified. The wastes were identified by plotting a Value stream map of the packaging line and the map was plotted with the help of the obtained calculation results.The main waste which contributed much was the "Excess Changeover Time". So in order to reduce the changeover time a new "PLC Ladder Logic program" was written for the machine and it was executed using the software. And hence the changeover time was reduced to negligible value. By the usage of this new program there will be reduction of Changeover time which helps to increase the production of the company. Excess demand which usually arises in the summer can easily be met with this update in the program. Adding to this the Overall Equipment Effectiveness value was also increased. After the reduction of changeover time a new line balancing solution was proposed. In the later chapters of the project "Pareto Analysis" involving the losses was made. Main losses which contributed to the breakdown were identified. A TPM plan was designed keeping in mind the losses and the ways of improvement. Using the 8 main pillars the losses were associated and required plans were put up which would help decrease the losses and breakdowns. Finally a TPM master plan was designed.

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List of Abbreviations

- OEE= Overall Equipment Effectiveness
- PLC- Programmable Logic Controller
- TPM- Total Productive Maintenance
- VAT- Value Added Time
- VSM- Value Stream Map
- RFID- Radio Frequency Identification

Introduction

There are a lot of small and medium scale packaging companies in India with budget constraints. But the demand is always increasing. Due to the budget constraints the companies are not able to have great quality in their equipment and hence as a result they face a lot of problems. The problems include breakdowns, excessive set-up times, lack of skilled workers, low productivity. Due to these problems they are not able to meet the demand. It is very important to analyze these problems and propose solutions to meet the demands. But the most important factor which must be kept in mind when proposing solutions are the budget constraints. Since these companies don‘t have enough financing capabilities the solutions which are proposed must be under the budget value which are often fixed by the companies.

There are various methods which can used to solve the problems like excessive changeover time, increased set-up times. Single minute exchange of die (SMED) is an important method which can be used to reduce the excessive changeover time. And there are other line balancing methods like largest candidate rule, kilbridge and wester heuristic, ranked positional weights which are used to balance the lines efficiently. In this project some of the ideal methods are used which are used to solve the various issues surrounding the company.

Aim

To analyze the liquid filling process in a manufacturing company and propose solution to reduce the losses.

Tasks involved

1) To perform analysis of the packaging process using the collected data and perform calculations.
2) To draw a Value stream map of the process using the calculated values and find out the wastes.
3) To perform Pareto analysis and find out the root cause of time lost due to breakdowns.
4) Proposing a solution to reduce the excessive changeover time.
5) Proposing a solution to balance the manual tasks through efficient line balancing.
6) Proposing a TPM master plan to reduce the time lost due to breakdowns.

1. Literature Review

1.1 Introduction to packaging

Packaging is one of the most important industrial process. The packaging process is very broad and it consists of various process, equipment and materials. Packaging contributes to about 9 percent of the product's whole manufacturing cost. So this process is not the one to be ignored [1]. Packaging is usually done with the aid of machines and each machine has its own characteristics. Some of the important functions of packaging include for storage, protection, transport and logistics.

1.2 Types of packaging machines-

There are different types of packaging machines available with each of them having their own functions. Each of the type of the machine have their own characteristics. Below, the various types of machines are listed,

- **Hardware packing machine**- It is used for packing screws, nuts, bolts, plastic products and wooden products.
- **Granule packing machine**- It is used for packing food products such as salt, sugar, detergent powder.
- **Powder packing machine-** It is used for packing powder products like milk powder, cosmetic powder.
- **Counting packing machine-** It is used for automatically counting and packing hardware products like screws, nuts, bolts [2]. Fig.1 shows various types of packaging machines.

1.3 Liquid packaging machine process

Liquid packaging machines take packing standards to a whole new level by also providing a clean and reliable packaging. It also allows easier process handling which allows to maintaining a high level of precision in operations. The latest process technology and experienced manpower involved in the design and manufacturing of these packaging machines helps the customer in getting a high percentage result. Another important factor which contributes to its success is the flawless functioning of all the controls which makes it very resourceful [3]. These liquid packaging machines perform various tasks and there are lot of variety and different types of machines available in the market. These machines are fully automatic and requires to be programmed with the aid of PLC's.

1.4 Tasks performed by the machine

- Weighing
- Filling
- Sealing

(a) Pouch Filling Machine

(b) Vacuum packing machine

(c) Packing tube machine

(d) Bottle packing machine

(e) Cup filling and sealing machines

(f) Pure pack packing machine

Fig.1 Types of Packing machines: (a- Pouch filling machine), (b- Vacuum packing machine) (c- Packing tube machine), (d- Bottle packing machine), (e- Cup filling and sealing machines), (f- Pack pack packing machine)[1]

1.5 Performance and accuracy

Some of the important features that will influence the balancing accuracy and the performance of the packaging machines are given below:

- They are designed to offer high quality of sealing, filling and weighing.
- They make use of quality components effectively.
- They follow a very efficient set of standards which aids to obtain recognition with minimal needs for maintenance.
- These machines exhibit a lot of variety with various options.
- These machines are designed in such a way that it requires very less maintenance needs. In other words it helps to cut down maintenance costs.
- These machines are made in such a way to deliver high standard of sealing support and it exhibits excellent functionality standards.
- These machines also support other sub-processes [4].

1.6 Latest technology support

The current scenario in this packaging industry is the introduction of many latest technologies which aids in increasing the efficiency of the company. But most top technologies are accessible to top companies and many SME's don't have their share of high technology machines. On the contrary there are still many small and medium scale companies who do not have latest technologies equipped in their packaging machines and they still have some low-cost machines due to the budget constraints. Some of the latest technologies which are equipped to the machines are as follows,

- Single/multi tracking operation modes.
- Easier installation interface with relatively long operational lifetime.
- Side sealing and 4 sealing options.
- Machines are available with different speeds to suit the needs of the demand.
- These machines with different speeds also are also capable of handling different maximum roll width, roll diameters, packet length etc.
- Usage of advanced PLC programs.
- Usage of Radio Frequency Identification tags in packaging.
- Usage of advanced PLC programs to control the machine.
- According to the needs the program can be altered and speed of process can be increased or decreased [5].

1.7 Latest development- RFID tags for packaging

The latest development in the packaging industry has seen the usage of Radio Frequency Identification tags. German chemical power-house BASF SE are making fully customized shampoo packaging. The empty bottles which are to be filled are fixed with Radio Frequency Identification (RFID) tags which contains all the information about the product. Main information includes the shampoo flavor, fragrance, size etc. This helps the product to communicate with the production machines and says what kind of size, flavor it requires. And the most interesting thing is that each bottle in the conveyer can be entirely different in its properties. This process is done with the aid of Robotic machines, Conveying system and a private cloud. The most important requirement is the Internet Wireless Network (IWN)[6].

As shown in the fig. 2, Physical resources are the products and the machines and they are connected with the Industrial Wireless Network. Data and information from various products and machines are connected to the Industrial Wireless Network and hence it helps to send all the information from the physical resources to the cloud. The Cloud is basically similar to a storage device which helps to store all the information regarding the product and machines. And all the information from the cloud reaches the terminals for supervision and control which are things like computer, laptop, mobiles etc [7].

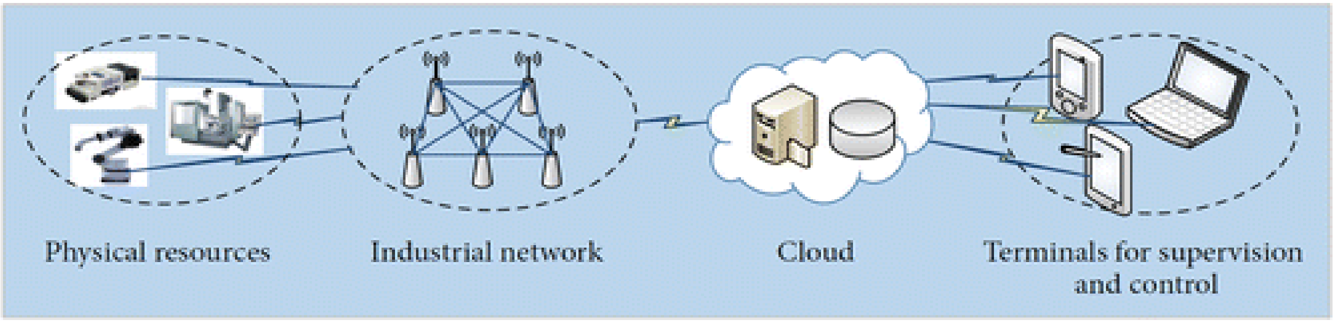

Fig.2 RFID for packaging [6]

1.8 Problems faced by the packaging companies

Excessive changeover time

Changeover time is generally the time elapsed between the completion of one product and the start of the next product. In other terms it can also defined as the summation of the Startup time and Setup time. Changeover time in our case is the time between the start of the new product B and completion of product A. Excessive changeover time will result in many problems like decrease in productivity, not meeting demands, drop in Overall Equipment Efficiency etc. So it is important for all companies to take necessary steps to decrease the changeover time. This is a major problem in-case of many small and medium scale companies who have budget constraints. And it also affects the large scale companies and it could hamper their progress in developing new products.

Impact of excessive changeover time

It is very important for a production line to minimize its changeover time to a lower value as possible. Excessive changeover times can influence a production line in various forms, a case study was conducted by Jessore university of science and technology about production sector with focus on sewing section in garment industries and the results obtained are represented below,

- **Increase in Work-in-process (WIP) stock**

Higher changeover time can easily result in increase of the Work-in-process stock. If the changeover time is high then the next product which is to be produced has to wait for a long time and it results in huge number of WIP stocks which are major wastes [8]. Fig.3 explains the increase in WIP stock due to the increase in changeover time.

- **Increase in production lead time**

Increase in changeover time can result in increase in Production lead time. Because if there is a good chunk of time wasted in changeovers the production cycle has to wait until the changeover over is done and the setup is ready for production. Ultimately there is an increase in production lead time.

- **Increase in defects**

Higher value of changeover time can also result in the increase of defects in the end product [9] as indicated in the fig.4.

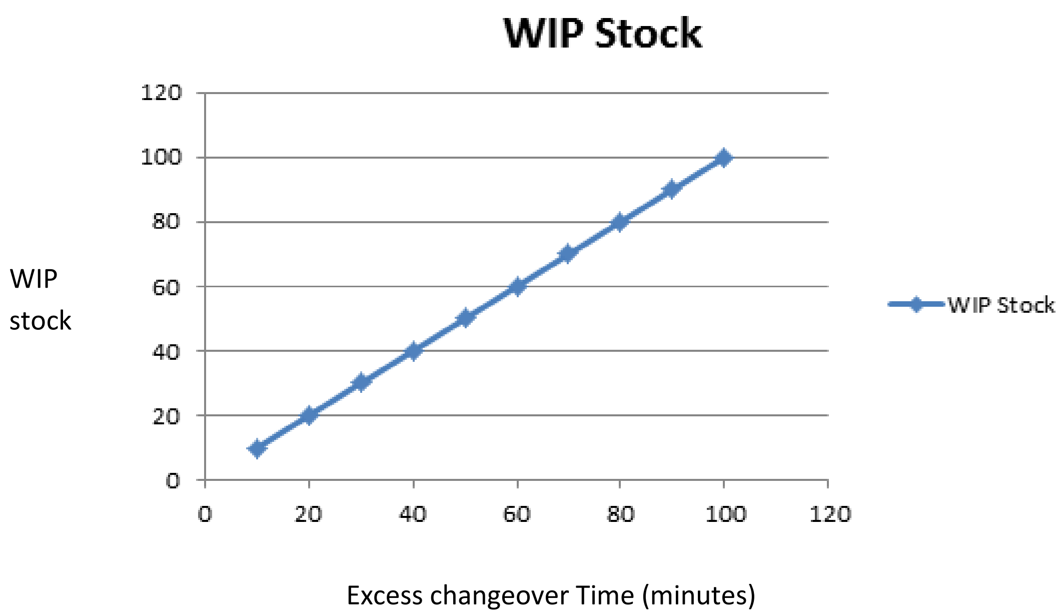

Fig.3 Excess changeover time vs WIP stock [19]

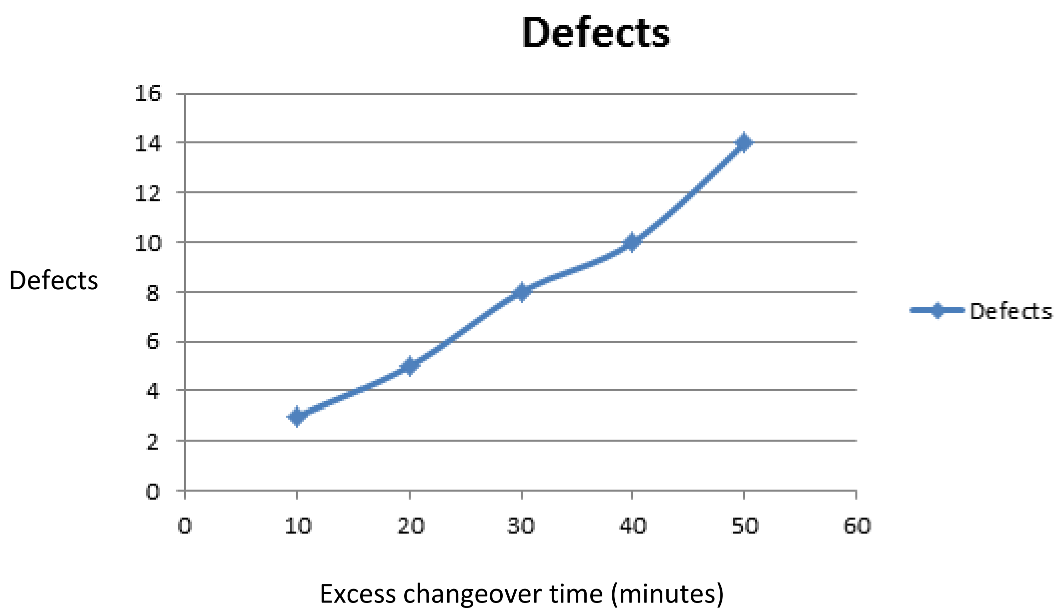

Fig.4 Excess changeover time vs Defects [19]

- **Decrease in production rate**

Production rate can take a heavy toll if there is an increase of changeover time. If a lot of time is wasted in the changeovers then the final products which are produced will be comparatively low as shown in fig.5.

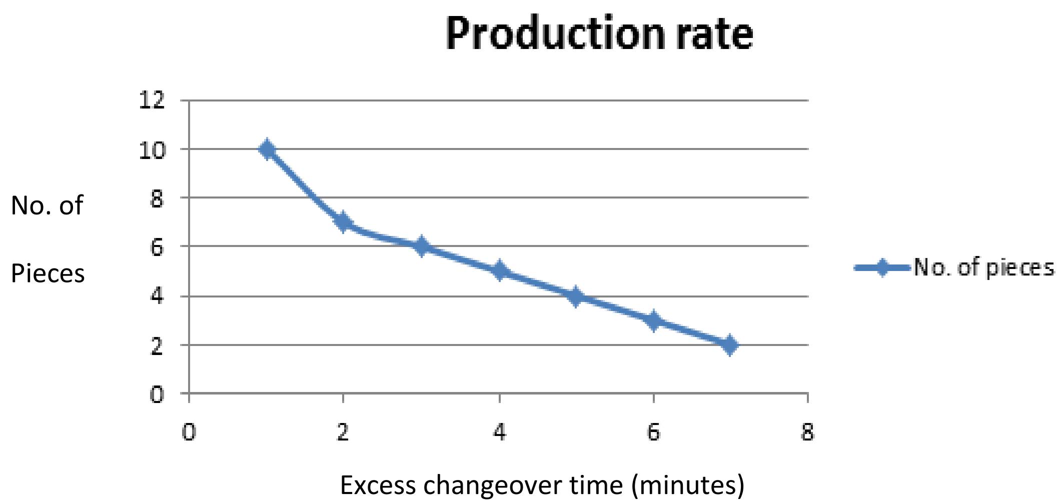

Fig.5 Changeover time vs no.of pieces [19]

SMED

Single-Minute Exchange of Dies (SMED) is usually the most popular method which is used to reduce the changeover time. There are three important steps involved in the SMED process. The first step is separating the internal and external processes. The second step is the analysis of task times in the external and internal processes and convert the internal process to external or even remove them completely. And the final step is the streamlining of the processes. Using this method it is possible to reduce the changeover time to a negligible extent.

Problems faced by Heineken by increase in changeover time

Heineken is one of the leading and popular beer manufacturers in the world. It has been having a successful run all over these years. But now it has been hit with a major obstacle. Over the couple of years there has been a huge drop in beer market and so Heineken must increase its innovation rate to withstand and be successful in the market. This means that there will be a lot of changeovers involved [10]. The increasing number of NPI's means increase in number of changeovers. "Increase in number of changeovers results in negative productivity". So currently there is a research happening in Heineken to decrease the number of changeovers. Not only in heineken, the excess changeover times are a problem for many large and medium scale companies.

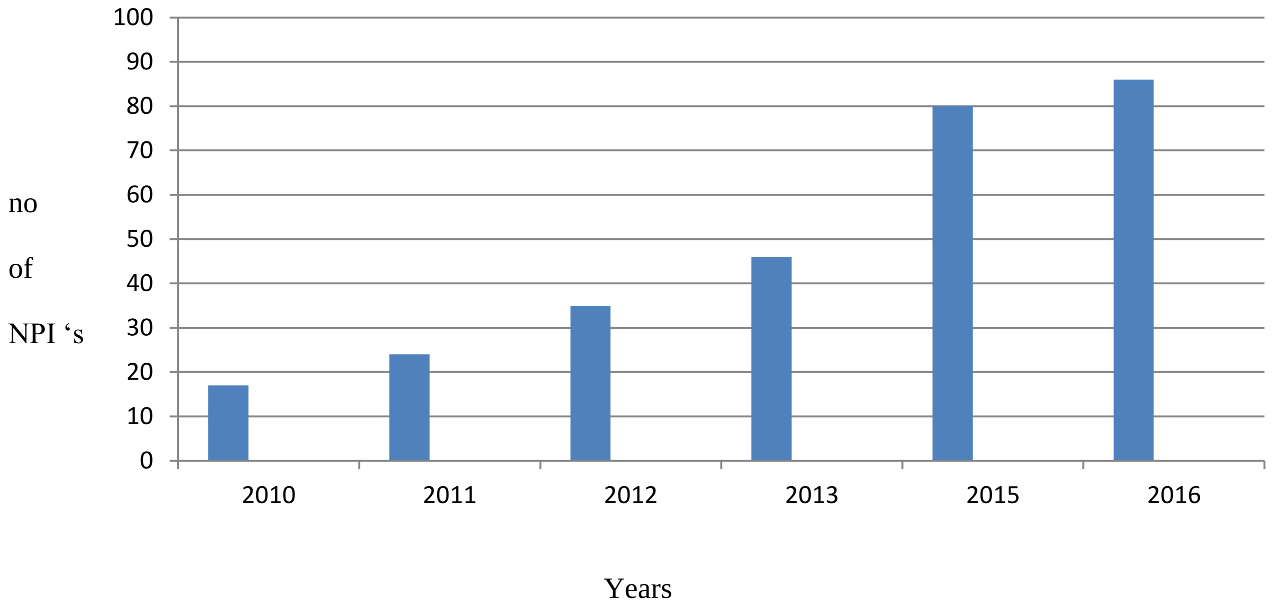

Fig.6 No. of new products innovation vs years [10]

As shown in fig.6 the number of new products innovation has been always increasing. This could have a negative impact if there will be a consistent increase in changeover time. So in order to sustain this increase in number of new products innovation it is important to reduce the time lost due to changeovers.

Conclusion from the chapter

In this chapter the different types of packaging machines were reviewed and some of the latest technologies used in packaging have been explained. Adding to that some of the problems faced by the packaging companies has been reviewed in the later parts of this chapter and some of the methods to reduce the changeover time have been discussed.

2. Analysis of packaging process

2.1 About the company

The company is cavinkare which mainly produces shampoo liquids and some food products. The company is located in the southern part of India. The packaging process is going to be analyzed. This packaging process includes packaging of shampoo packets with the help of PLC's (Programmable Logic Controllers).

2.2 Collection of data

- **Operating hours of the machine**

  The machine is generally operated according to the demand. So generally it is operated around 6-8 hours a day. But if we take it on an average it is to be said that the machine is operated for 7 hours and 30 minutes a day.

  Operating hours= 7 hours 30 minutes per day

- **Cycle time**

  The cycle time defined here is the cycle time of the process.

  Cycle time for Product type A (5ml packet) - 3s

  Cycle time for Product type B (8ml packet) - 4s, Cycle time for Product type C (10ml packet) - 5s.

- **Demand of the product**

  The daily demand varies according to the customer orders. But if we consider at an average the demand can be 7000 per day, product type A- 3000, product type B-2000, product type C- 2000. In which product type A is a shampoo packet containing 5ml of shampoo liquid, product type B -8ml, product type C-10ml.

- **Number of operators**

  The number of operators for this process is two operators.

- **Breakdowns, Changeovers**

  Time lost for changeovers- 40 minutes per day

  Time lost due to breakdowns, technical errors- 4 hours per month.

- **Tasks**

  The tasks involved in the process will include both manual tasks and automatic tasks. For each tasks there is time in seconds and its precedence. Precedence is the order in which the each task would take place. The packaging process is the only automatic task and all the other tasks are manual tasks and are done by the operators. The task times are represented in seconds and it is represented in the table.1 which is shown below,

Table.1 Tasks and time

S.no	**Tasks**	**Time (s)**	**Precedence**
1.	Setting up the machine	90	-
2.	Packaging of product A	(Automatic)	1
3.	Changing of wrapper	240	2
4.	Quality checking (product A)	600	2
5.	Packaging of product B	(Automatic)	3
6.	Changing of wrapper	240	5
7.	Quality checking (product B)	600	5
8.	Packaging of product C	(Automatic)	6
9.	Quality checking (product C)	600	8
10.	Taking the boxes to warehouse	100	9
	Total	2470s	

2.3 Calculations involving the packaging process

- **Takt time**

Takt time can be defined as the time from the start of the production of the product till the time it is delivered to the customer.

Formula for calculating takt time= Available working time per day/ Daily customer demand

Available working time per day = 7 hours 30 minutes

Customer demand= 7000 packets per day

The shampoo packets are delivered to the customers in boxes and each box consists of 250 packets of shampoo. So the demand for a day is 28 boxes.

Takt Time (s) = 27000/ 28 = 964.28=965s

- **Calculation of Value added time**

Value added time can be defined as the time which is used up to produce the right quantities. Value added time can be calculated by determining the number of correct quantities which is produced per day.

Minutes lost due to changeovers = 60 mins per day

Hours lost due to breakdowns, technical errors = 4 hrs per month

On an average it can be said that nearly 10 minutes are lost per day.

So, Value added time = No of right quantities*cycle time [11].

Value added time = (3000*3)+ (2000*4)+ (1536*5) – (4 hours) = 142.82 hours

- **Overall Equipment Effectiveness**

Overall Equipment Effectiveness is a method to measure productivity of a process. It simply says how effectively the production time is used.

OEE= Value added time/ Scheduled time* 100

Scheduled time = Overall time- Scheduled stops

Operating time per day = 7 hours 30 minutes

Scheduled time = 165 hours per month

OEE = 142.82/165 = 0.86%

- **Performance factor**

Performance factor can be defined as the ratio of operating time to the overall scheduled time.

Performance factor = Operating time/Scheduled time

Operating time = 6 hours 50 minutes (40 minutes lost due to changeovers per day)

Operating time = 6.8*22= 149.6 hours

Scheduled time = 165 hours

So, **Performance factor = 149.6/165 = 0.90.**

- **Quality factor**

Quality factor can be defined as the ratio of Value added time of the process to the operating time of the process [12].

Quality factor = Value added time/ Operating time.

So, **Quality factor = 142.82/149.6 = 0.95**

All the calculated data from the packaging process are represented in the table.2 and some of the important values are takt time which is calculated as 965s and the Overall Equipment Effectiveness which is 86%. The time lost for changeovers is 40 minutes per day. It is a value which has to be reduced. Other data include the daily demand which is 7000 per day. The cycle time for each product is also given and it is 3 seconds for product A, 4 seconds for product B and 5 seconds for product C. The value added time is also calculated and it is 142.82 hours per month. The performance factor was found to be 0.90 and the quality factor is 0.95. All these data are represented in the table below, Table.2 Calculated data

Operating hours	7 hours 30 minutes
Cycle time	For Product A- 3 seconds Product B- 4 seconds Product C- 5 seconds
Changeovers	40 minutes
Takt time	965 seconds
Daily demand	7000 per day
Value added time	142.82 hours per month
Scheduled time	165 hours per month
OEE (Overall Equipment Effectiveness)	86%
Performance factor	0.90
Quality factor	0.95

Conclusion from the chapter

The results from the collection of data from the packaging process indicates that there is a necessity to analyze the process, find out the wastes from the process and propose solutions to reduce the wastes and hence contribute to the increase in overall efficiency of the packaging process.

3. Analysis of wastes from the packaging process

3.1 Value stream map of the current process

With the help of the data obtained from the calculations we can plot the Value stream map of the current process as shown in fig.7. Value stream map is a method that is built on Lean management to document, analyze and improve the flow of information or materials needed to produce a required product for the customers [13].

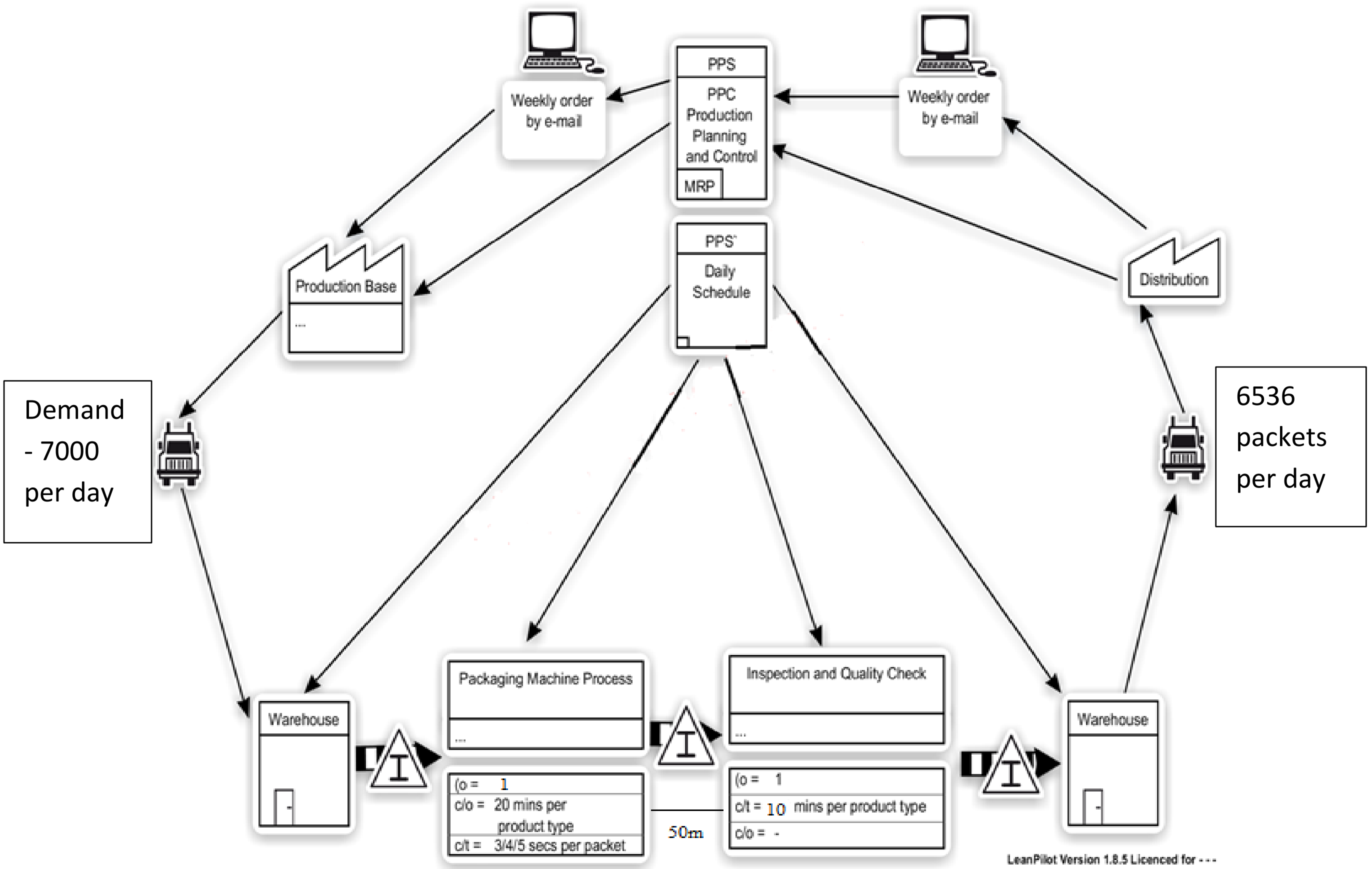

Fig.7 Value stream map of the current process

By carefully analyzing the results from the calculations we can infer some data as follows,

- The Overall Equipment Effectiveness (OEE) of this machine is calculated and the result suggests that it is around 86%.
- From the results it can also note that the daily demand of 7000 packets per day (product A,B and C) is not met. Only around 6500 packets are produced per day.
- Around 40 minutes of production time is affected by loss of time which occurs as a result of changeover time. This changeover time is high because the machine process only one product at a time. There are three types of products namely A,B and C.

3.2 Breakdown of the packaging process

The Value stream map in the figure above clearly describes about the various processes involved and it also clearly explains about the movement and quantity of the product movements. It can be seen that the demand for the day is 7000 packets but the delivery is only around 6536 packets. To analyze the base of the problem, a clear understanding of the breakdown of the process is very important. Table.3 lists the activities or tasks and the respective time taken to complete these tasks. Fig.8 shows the operator's work and times to complete these tasks.

Table.3 List of activities and time taken

S.No	Activity	Time-taken (minutes)	Number of products produced/checked
1.	Packaging- Product type A	2 hours and 30 minutes	3000
2.	Quality checking	10 minutes	3000
3.	Changeover	20 minutes	-
4.	Packaging- Product type B	2 hours and 15 minutes	2000
5.	Quality checking	10 minutes	2000
6.	Changeover	20 minutes	-
7.	Packaging- Product type C	2 hours and 5 minutes	1536
8.	Quality checking	10 minutes	1536

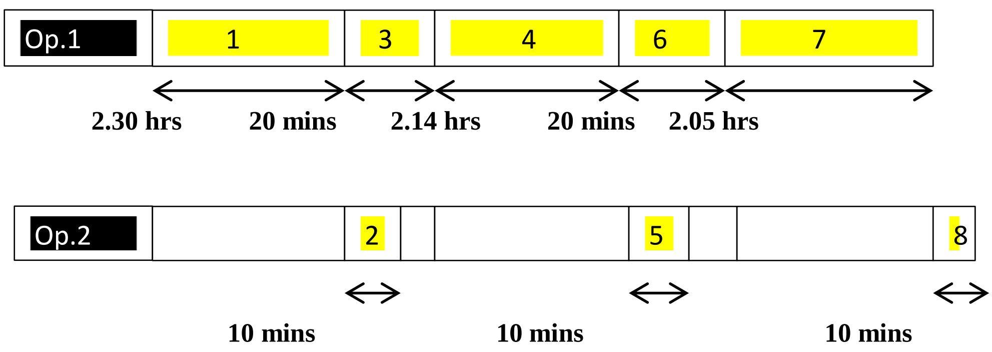

Fig.8 Breakdown of the packaging process time with the operator's perspective

3.3 Identification of wastes (problem identification)

- **Excess changeover time-** The most apparent waste which can be identified from the Value Stream Map as shown in fig.9 is the excess changeover time. It can be seen that the changeover time for each product type is 20 minutes which is a lot of time. So for three products time taken on an average 1 hour is lost every day. This factor contributes to hampering the production rate and efficiency and must be taken care. In-order to deeply analyze the changeover time the breakdown of the changeover time is given below,

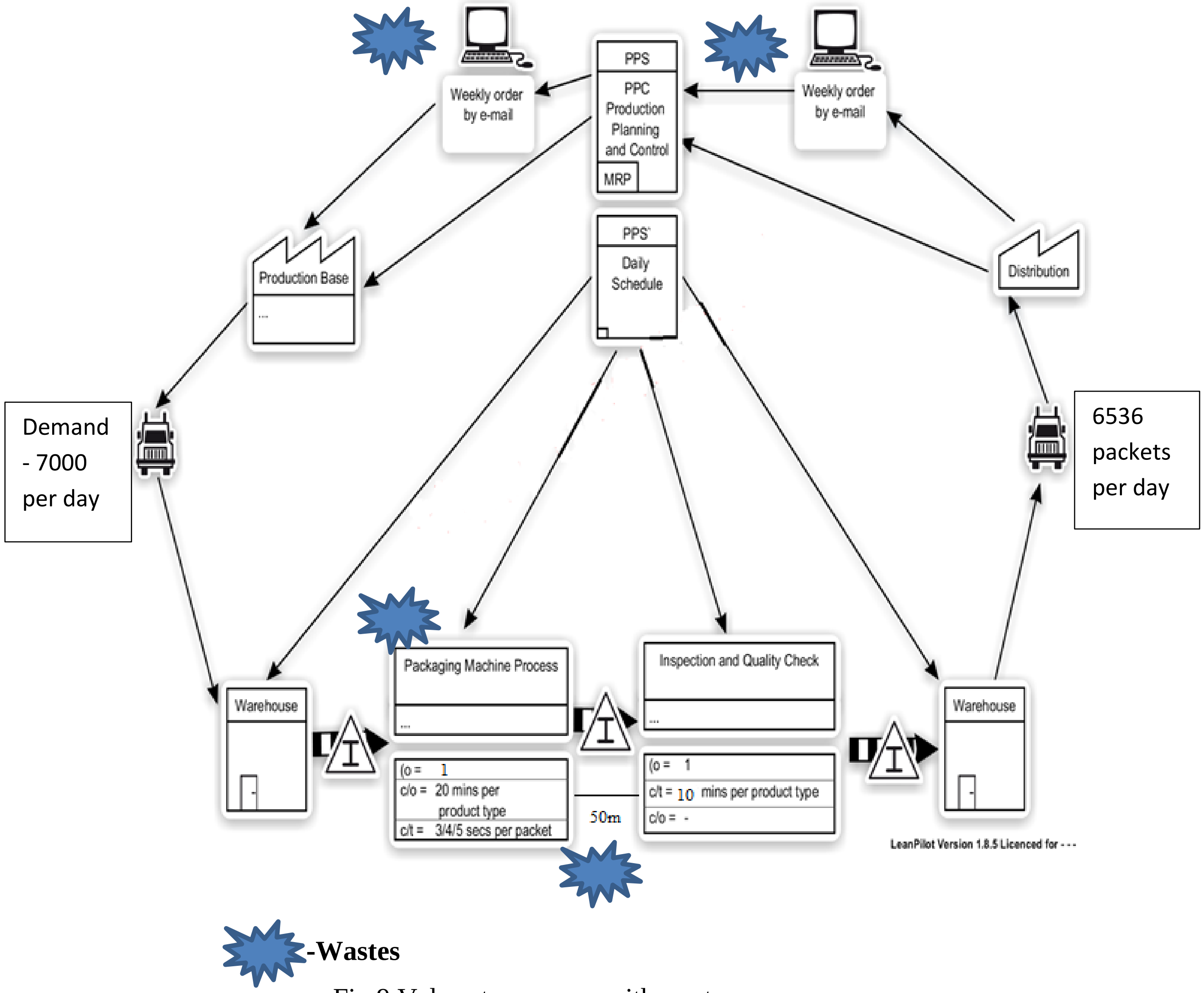

Fig.9 Value stream map with wastes

Breakdown of changeover time (for each product type)

The changeover time can be broken up into two important process as shown in table.4. First one is the equipment preparation which involves connecting the laptop with the PLC and loading the program into the PLC. After loading the process is checked and then after that the machine starts running. This process takes around 15 minutes minimum and 20 minutes maximum. Another important process is the changing of wrapper which takes around 4 minutes on an average. Overall, the changeover time contributes to a total time of 20 minutes.

Table.4 Breakdown of changeover time

S.No	Process	Time taken (minutes)
1.	Equipment preparation (PLC connections and program loading)	16 minutes
2.	Wrapper change	4 minutes
	Total	Average- 20 minutes

- **Information frequency between production planning control and internal stock**

The information frequency between production planning control and internal stock is very low and done only once a week. This is also another waste which can be improved.

- **Distance between workstations**

The distance between the workstations are around 50m and it results in increased task times. It can be reduced to improve the process.

3.4 Pareto analysis

Pareto analysis is a technique that is used to find out the selected number of tasks which contribute to the major defect. It is based on the theory that 80% percent of the problems can be corrected by taking the 20% of the major problems into account. It is an important decision making tool which is used to analyze the causes behind the losses. It is found that nearly 4 hours of time is lost due to breakdowns per month. Using the pareto analysis tool it will be possible to find the causes for those breakdowns. Using those results it is possible to have a very clear picture of the causes for the losses.

Calculation of OEE

With the use of available data the OEE (Overall Equipment Effectiveness) can be calculated for the last six months, Operating hours= 7 hours and 30 minutes

For 6 months= 22 working days*6 months= 132 days

132 days*7 hours and 30 minutes= 990 hours

Scheduled stops= 4 hours per month

Scheduled stops for six months= 4*6= 24 hours per month

Scheduled Time= Operating time- Scheduled stops= 990-24= 966 hour

The OEE data for the last six months were calculated and the results are represented in the table.5. The value added time was also calculated. The OEE was calculated and it is around 88%.

Table.5 OEE data

Produced Units	143792 per month, 143792*6= 862752 for six months
Value Added Time	856.92 hours
OEE	856.92/966= 88%

Analysis of losses

With the usage of the obtained data it is possible to make the analysis of losses. The three main losses in this case are due to changeovers, breakdowns and value added time. From the table 6 it can be seen that the time lost for changeovers is the highest value and it contributes to around 132 hours in the six month duration. The second loss inferred from the table is the time lost due to breakdowns which contributes to around 24 hours in the six month period of operation. As a next step it is possible to use this data of total time lost for breakdowns and find out what kind of factors contribute to the breakdowns. By finding out the factors responsible for the breakdowns it will be possible to make a plan to rectify the losses.

Table.6 Pareto analysis

Changeovers	1 hour per day, 22 hours per month. 22*6=132 hours
Breakdowns	4 hours per month 4*6=24 hours
Value added time	860 hours

Table.7 Data analysis of losses

Cause	Time (hours)	Percentage of losses %
Breakdowns	24 hours	0.15 or 15 %
Changeovers	132 hours	0.84 or 84 %
Total	156 hours	100 %

From the table.7 it is seen that there are two main causes for losses. They are due to breakdowns and changeovers. The time lost due to breakdowns is 24 hours for six months and the overall percentage it contributes to the overall loss is 15%. So it is negligible. The next loss is the loss of time due to excess changeover. The lost due to changeovers is 132 hours and it contributes to 84% of the total losses. So this value is a very huge value and it steps must be taken to reduce this time. This loss contributes to the major loss in productivity for the company.

The three main causes for the breakdowns and stoppages were identified and they are due to the defects caused due to the PLC, the electrical circuit failures and other miscellaneous failures as shown in the table.8. Fig.10 shows the causes for the time lost with the help of a pie-chart.

Table.8 Cause for breakdowns

Cause	Time (h)	Percentage %	Cumulative %
PLC defects	8 hours	33.33	33.33
Electrical Failures	10 hours	41.66	74.9
Miscellaneous failures	6 hours	25	100

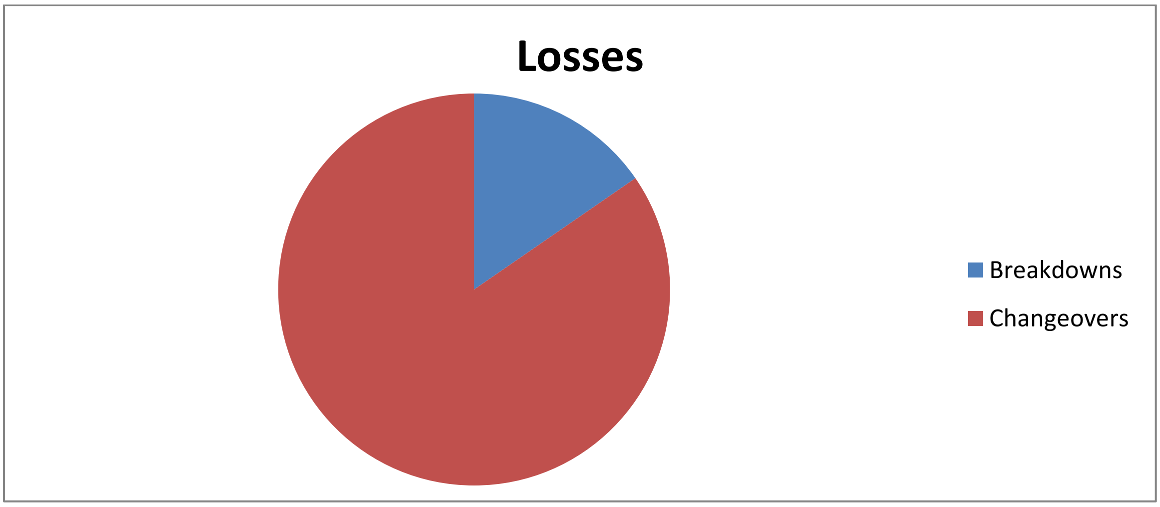

Fig.10 Lost effectiveness by its causes

3.5 Solutions to be proposed

- Reducing the changeover time of the packaging machine process by introduction of updated ladder logic PLC program.
- Proposing a line balancing solution with the design of work stations.
- Proposing a TPM plan based on the losses identified from the pareto analysis.

Conclusion from the chapter

1) The value stream map of the packaging process suggests three important wastes which includes the excess changeover time, long distances between workstations, time lost due to breakdowns.
2) Pareto analysis was performed to find out the cause for the breakdowns and three important causes were found which includes PLC defects, Electrical failures and other miscellaneous losses.

4. Reduction of changeover time using PLC ladder logic program

4.1 Introduction to programmable logic controller

PLC basics

A Programmable logic controller is basically a micro-processor based controller which has multiple number of inputs and outputs. It makes use of a programmable memory which is used for storage of data and instructions and also to perform functions to control machines and processes. PLC is able to perform logic functions of timers, relays, sequences and counters. The major benefits of using a PLC is its low cost and re-programmability [14]. The type of PLC used for this packaging process is described in the annexure 13.

The PLC inputs are typically the sensors and switches. They are usually connected to an input module which depicts the interface between the sensors and the PLC. Fig.11 represents the various types of PLC circuits.

Fig.11 PLC circuits [3]

How it works? In steps

- At first the personal computer or laptop is loaded with the PLC support software.
- The program is built using the software which includes all the controls like sensors, actuators etc.
- This program is loaded into the PLC controller's memory which can be battery based or non-volatile.
- The output from the PLC is connected using wires to the packaging machine.
- PLC's are connected with sensors which is used to sense temperature, pressure which can used to process data efficiently [15].

4.2 Design of the machine

In-order to reduce the changeover time an updated version of the PLC program should be designed. In the annexure 12, working diagram of the liquid filling machine is explained and it consists of various sensors, switches, cylinders for the operation and control of the machine. The whole process is controlled by pneumatic (air) cylinders and not hydraulic.

Important parts

- Single acting cylinder (Pneumatic- S.A.)
- Double acting cylinder (Pneumatic D.A.)
- Sensors, holders and storage tank

4.3 Working of the Packaging machine

In the annexure 12, the schematic diagram of the liquid filling machine is represented and its further working is explained. The process starts with the horizontal/vertical movement single acting cylinder which is activated. As it holds the holder which is incorporated with sticking agent it moves in an upward direction and it comes in contact with the pouch tray and grabs one packet. Now the cylinder is retracted and it moves in a downward direction and it is stationary in its starting position. There are two sensors attached to this cylinder, one is to monitor the forward movement and the other one is to monitor the backward movement. Next to the Horizontal /Vertical movement single acting cylinder there is rotary double acting cylinder attached to it. As it is activated it rotates the cylinder and hence the holder to the right, and hence the packet is set in the right direction and made ready for the filling process. In this cylinder there are two sensors forward and reverse sensors attached to monitor the forward and backward movement. Now the cylinder comes in contact with the holder arms of the opening cylinder.

There is a load cell which is attached to the cylinder below the opening cylinder. The load cell is mainly used to compare the weights and it receives the input from the PLC and hence the required ml of shampoo which is inputted in the program coding is poured into the packet. This upward/downward movement cylinder is activated and it moves the opened shampoo packet upwards. Hence the liquid is poured from the opening tube in the tank. Now the load cell does its job and the exact amount of shampoo is poured into the packet. After this process the two double acting sealing cylinder packets seals the packet and the packet is dropped into a conveyer below. There is flow sensor which is used to monitor the flow and there are also two other sensors placed in the tank namely high level and low level sensor which helps to monitor the flow levels of the liquid. There is an operation panel box attached to the right side of the machine and it consists of a cycle start and a cycle stop button. Next to it there is an emergency switch which is switched on incase of any emergencies when the machine has to be stopped. And finally there is a three way selection switch.

4.4 Current structure of operations in the packaging machine

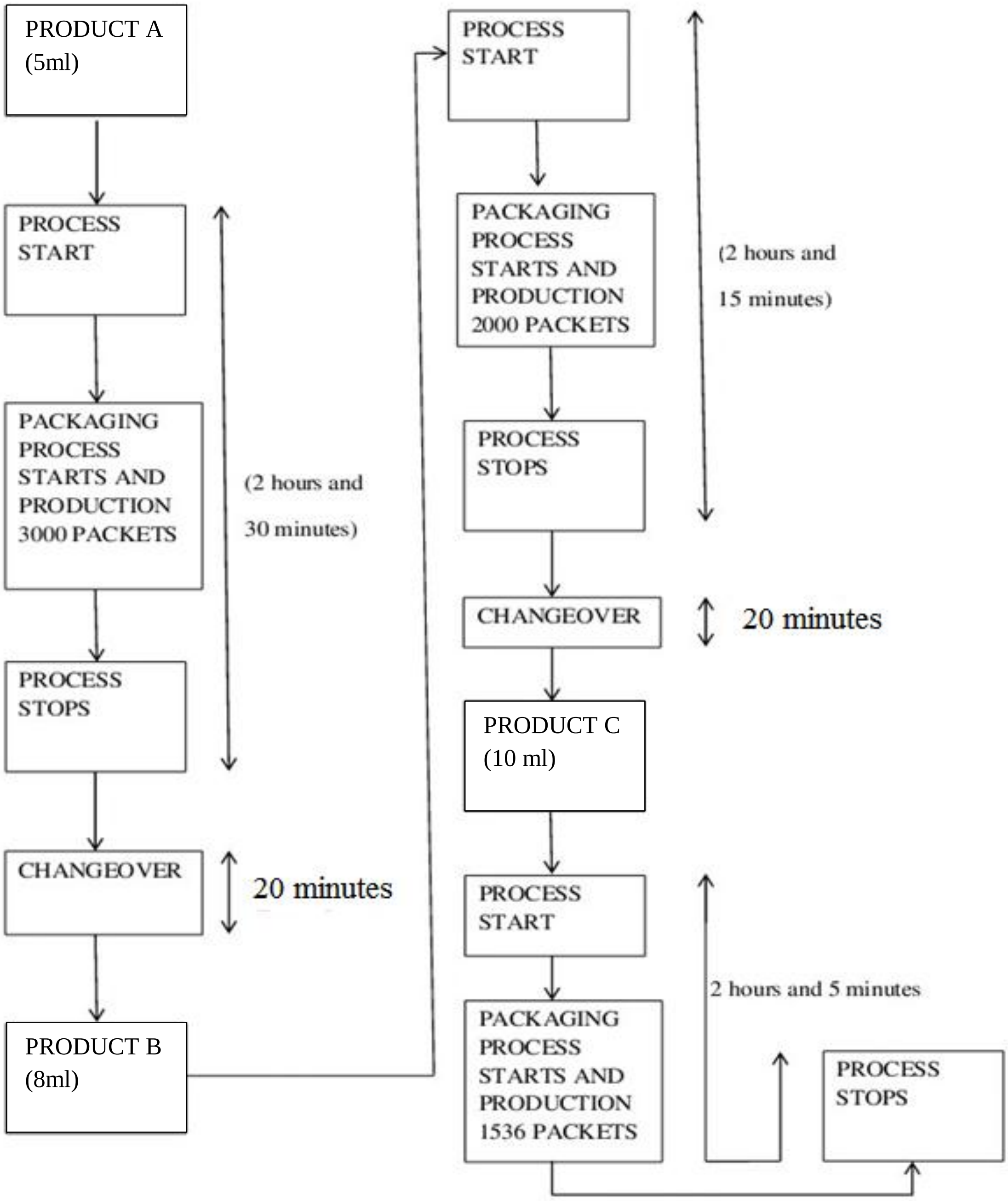

Fig.12 Current structure of operations in the packaging machine

As shown in fig.12 the machine starts by processing of product type of A and then after producing 3000 packets the machine stops for 20 minutes (changeover time). After the break of 20 minutes it starts producing packets of product type B and after producing 2000 packets again there is changeover of 20 minutes. So this changeover time of 20 minutes must be reduced.

4.5 Programming software used for the programming of the PLC

CX-Programmer 9.4 (Omron)

CX-Programmer 9.4 is the software in which the PLC ladder logic program is designed and it is run and compiled. This software helps in effective implementation of various logics for industrial automation. The program is designed according to the requirements and it consists of various forward/reverse sensors and cylinders. The cylinders are also called as solenoids. The whole process runs with the help of pneumatic control and there are a lot of hose pipes all around the machine. A load cell set up is used to measure the exact quantity of the liquid. The load cell input must be given in grams and it will be converted into the required unit of ml.

4.6 Updated structure of operations in the packaging machine

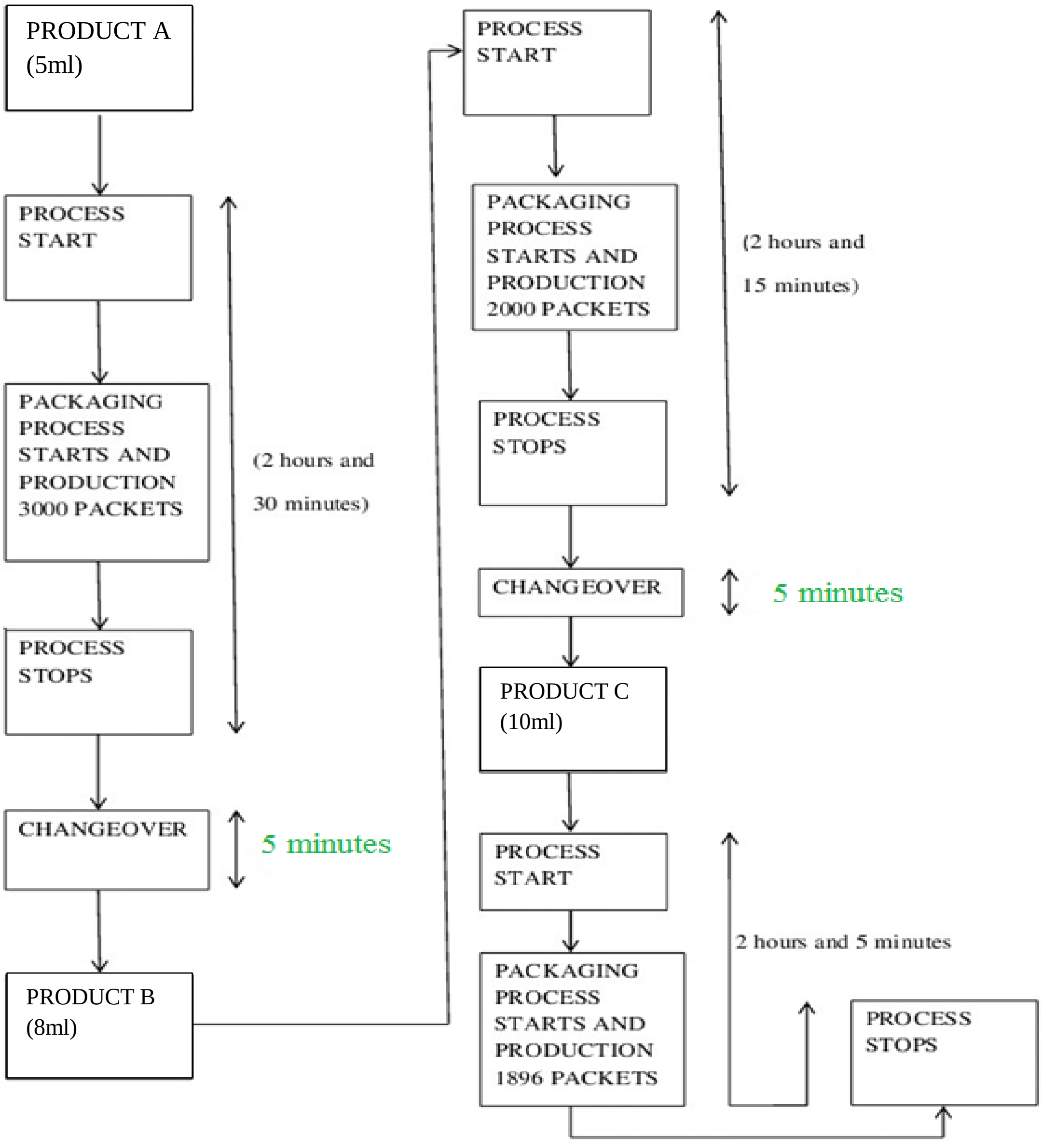

Fig.13 Updated structure of operations in the packaging machine

The PLC programming is done in such a way that the changeover time is reduced to 5 minutes. At first the requirements of the program of the program should be well known in advance. The updated structure is represented in fig.13 and the breakdown of the process in represented in fig.14.

Requirements

- The machine should start and produce 3000 packets of product A. The quantity of product A type packet is 5 ml. And the time taken for the completion of each packet is 3 seconds.
- The machine should stop for 5 minutes after 3000 packets are produced and the approximate time taken to complete these 3000 packets is 2 hours and 30 minutes.
- After the 5 minutes of stoppage the machine should start again and start producing product B.
- Product B's quantity is 8 ml and the machine should run until 2000 packets of product B is produced. After producing 2000 packets the machine should stop. The time duration taken for this is 2 hours and 15 minutes.
- The machine should stop for 5 minutes and after the completion of 5 minutes it should start again.
- The machine should produce 1836 packets and after producing it the machine should stop.
- The program is designed keeping in mind all these requirements and the program is compiled. By executing this new program the changeover time is reduced from 20 minutes to 5 minutes for each product type.
- The machine should automatically stop after the completion of production of all three types of product and the program should be designed in such a way.

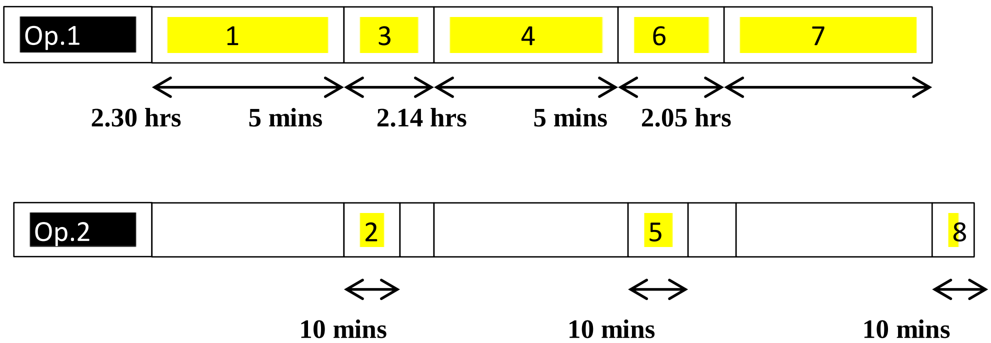

Fig.14 Breakdown of the packaging process time with the operator's perspective

4.6 Re-design of the program

The PLC program has to be re-designed to reduce the changeover time to 5 minutes. The program is written in such a way that the machine stops for 5 minutes after the end of each process. After the packaging of 3000 packets of product A the machine stops for 5 minutes. And then the machine automatically starts after 5 minutes and starts processing packets of product type B. After the packaging of 2000 packets of product B the machine again stops for 5 minutes and then after the 5 minutes of stoppage time the machine again starts and it processes packets of product type C. The whole program is represented in the annexure (1-11).

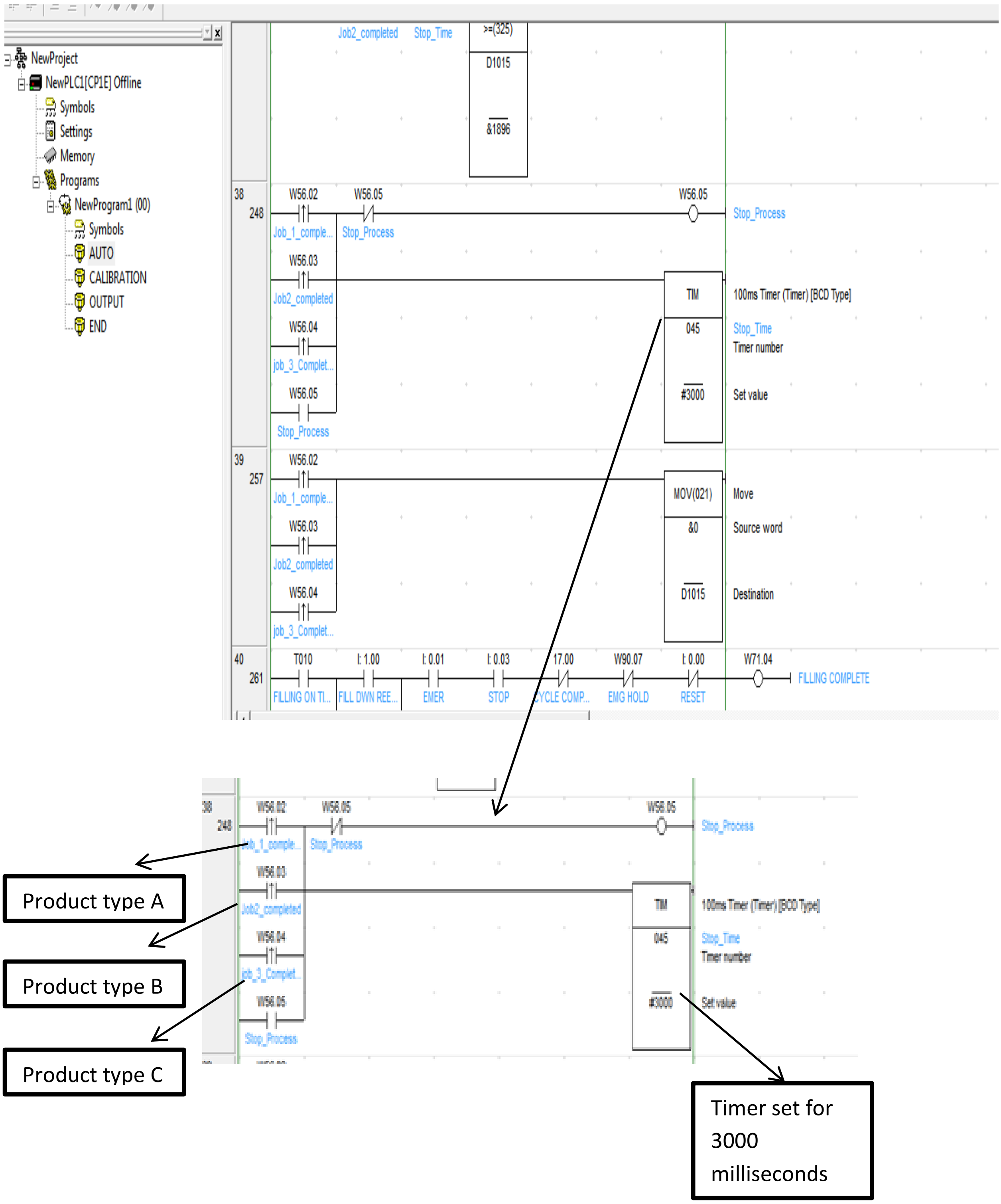

Fig.15 Timer setting in the program

In this fig.15 W56.02 is the output of product type A and as indicated the value given is 3000 which means the machine will produce the 3000 packets. In the next line as the output of W56.02 is received job 2 will start and it will produce 2000 packets and the output of job 2 is W56.03. After job 2 is completed the output of job 2 W56.03 is indicated as the input in the next line and hence job 3 starts and the output of job 3 is W56.04. The timer is set for 3000 milliseconds which is equal to 5 minutes. So after the completion of each product the machine will stop for 5 minutes and after 5 minutes automatically the machine starts.

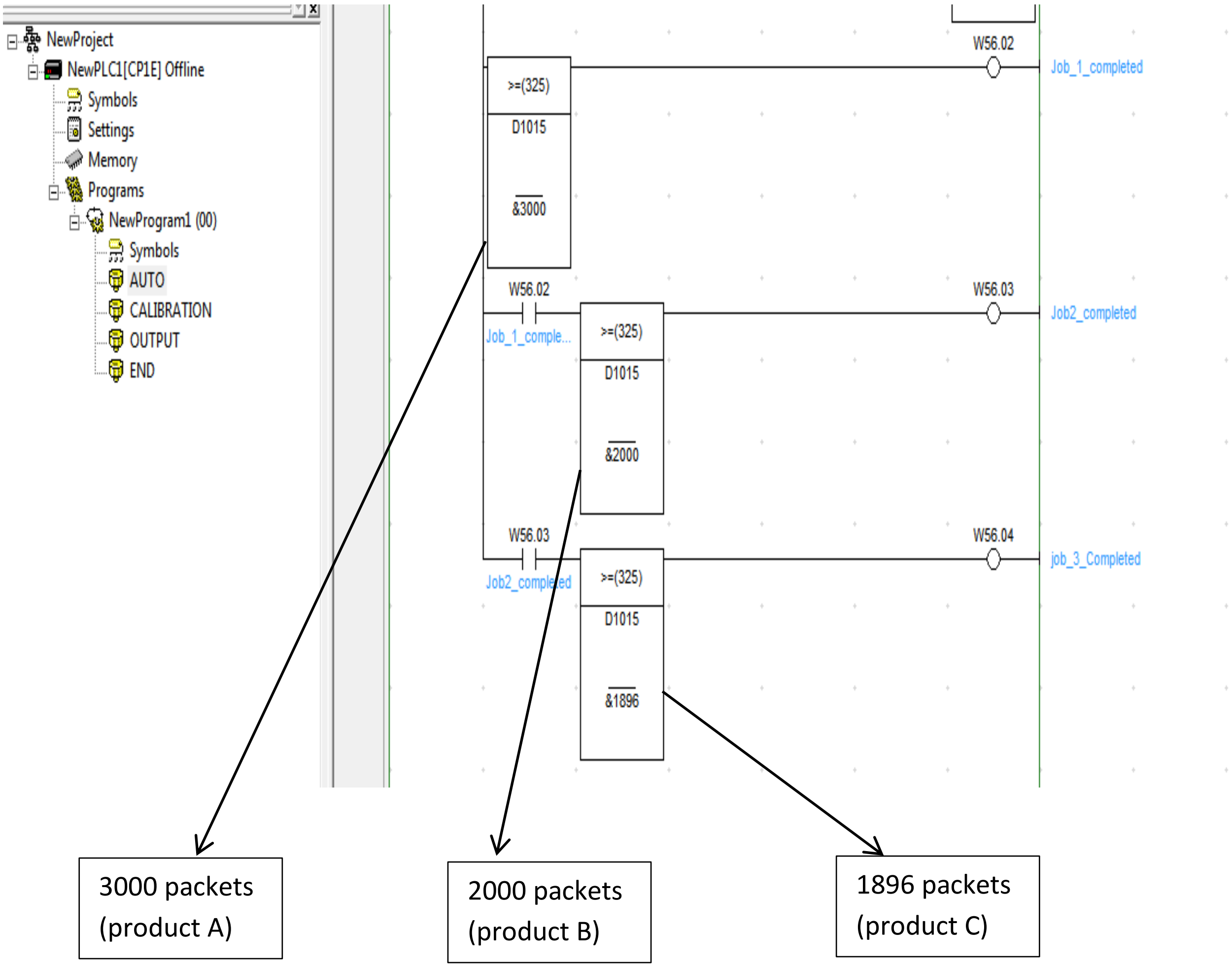

Fig.16 Number of packets input

As shown in fig.16, W 56.02 is the output of product A and it is programmed to produce 3000 packets. W56.03 is the output of product B and W 56.04 is the output of product C and the number of packets produced is 2000 in the case of product B and 1896 in the case of product C. The program written for the whole process is represented in the annexure (1-11). In which annexure (1-5) depicts about the movement of the cylinders and the filling of the packets and annexure (6-11) shows details about the load cell action and the newly edited timer settings.

Conclusion from the chapter

In this chapter a new PLC program was written to reduce the changeover time from 20 minutes to 5 minutes. So after this change it is possible to save around 30 minutes time and this time can be used to produce more packets and hence contribute to the increase in efficiency of the packaging process.

5. Other solutions for the elimination of wastes

5.1 Line balancing

Line balancing is a technique which is used to balance the time taken for completing the tasks in an equal way.

- **Takt time**

Takt time= Overall operating hours/overall customer demand

Overall operating time per day= 7 hours and 30 minutes, (7*60*60)+(30*60)= 27000s

Overall customer demand= (12 boxes for product A)+(8 boxes for product B)+ (8 boxes for product C)= 28 per day, **Takt time= 27000/28= 965s**

- **Manual tasks**

The entire set of tasks including both the automatic and the manual processes are represented in the table.9 and also its respective task time is represented.

Table.9 Task, time and precedence

S.NO	Tasks	Time (s)	Precedence
1.	Setting up the machine	90	-
2.	Packaging of product A	(Automatic)	1
3.	Changing of wrapper	240	2
4.	Quality checking (product A)	600	2
5.	Packaging of product B	(Automatic)	3
6.	Changing of wrapper	240	5
7.	Quality checking (product B)	600	5
8.	Packaging of product C	(Automatic)	6
9.	Quality checking (product C)	600	8
10.	Taking the boxes to warehouse	100	9
	Total	2470s	

- **Precedence diagram**

Precedence diagram is the diagram which is used to identify which tasks depends on which tasks and it is a helpful tool for an efficient line balancing. The line balancing can be done efficiently with the help of precedence diagram and this serves as a tool to identify which each tasks and what it depends on. Fig.17 represents the precedence diagram of the packaging process and table.9 shows the precedence of each tasks.

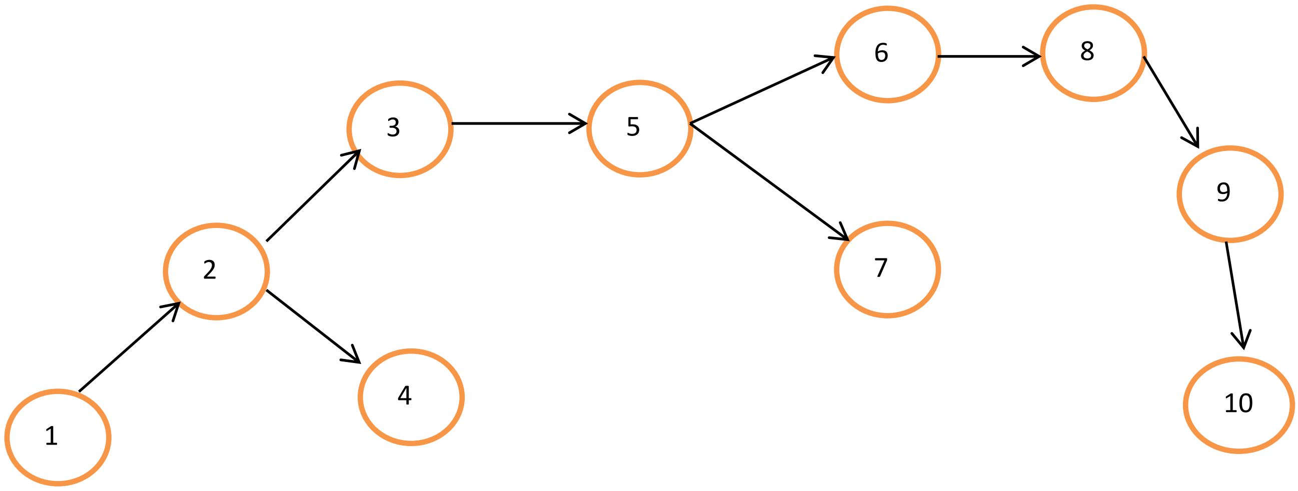

Fig.17 Precedence diagram

- **Minimum number of workstations (MNW)**

The formula for finding the minimum number of workstations is the ratio manual time to the takt time.

MNW= Manual time/ Takt time

MNW= 2470/965= 2.55 can be rounded off to 3.

- **Line efficiency**

The formula for finding line efficiency is the ratio of manual tasks time to the takt time and the product of number of workstations.

Line Efficiency= (Manual tasks time/cycle time*minimum number of workstations)*100

Line Efficiency= 2470/(965*3)= 0.85 or 85%

- **Line balancing of workstations**

Table.10 Station no.1

Task	**Time (s)**	**Aggregate time (s)**	**Available time (s)**
1	90	90	875
3	240	330	545
4	600	930	35

Table.11 Station no.2

Task	**Time (s)**	**Aggregate time (s)**	**Available time (s)**
6	240	240	725
7	600	840	125

Table.12 Station no.3

Task	Time (s)	Aggregate time (s)	Available time (s)
9	600	600	365
10	100	700	265

A solution with 3 stations with cycle time of 930s. The tasks and times for these three workstations are explained in the table.10,11 and 12.

- **New line efficiency**

The formula for finding line efficiency is the ratio of manual tasks time to the takt time and the product of number of workstations.

Line efficiency= (Manual tasks time/cycle time*minimum number of workstations)*100

Line efficiency= 2470/(930*3)= 0.88 or 88%

5.2 Long distances between work-stations

Another important waste which is identified is the long distances between work stations and it results excess task times. In the fig.18 below the work stations and their distances are given below,

The process starts with the movement of materials from the warehouse to the packaging machine. The operator loads the wrappers into the machine and starts the machine. Product type A packets are produced and after that the machine is stopped. The operator from the first workstation collects all the produced packets and moves it to the table 1. The distance between the packaging machine and work station 1 is 50m. In this work station quality checking process takes place and after this process the packets are moved to collection table which is around 150m away.

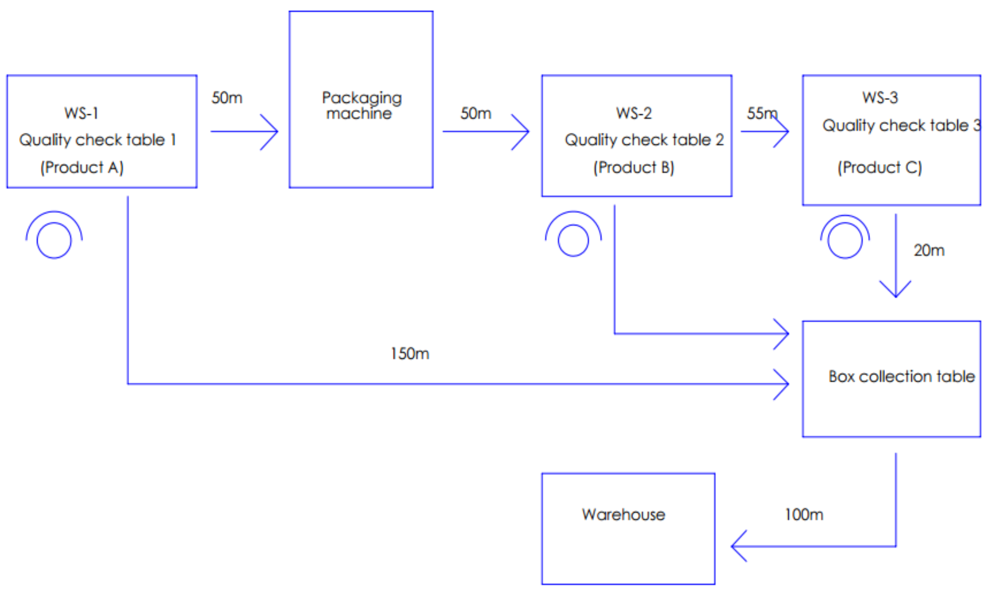

Fig.18 Process workstations of the packaging process

5.3 Design of U-shaped cell

This problem can be rectified by the implementation of a U-shaped cell in which the workstation tables are placed very close to each other in a U-shaped structure. With the amount proximity between workstations the manual task times can be reduced. The movement of material can be reduced from 90s to 60s. The quality checking process can be reduced to 400s mainly because there is no time wasted for the movement of packets from the machine to the workstation. The other task times remain the same. With the reduction of these task times the number of workstation are reduced. Earlier the minimum number of workstations required were three and after the design of the U-shaped cell it is possible to reduce the number of workstation to a value lower than three. With the reduction of number of workstation the efficiency of the line increases and hence a lot of time and money are saved. It also helps to save a lot of time due to which there will be a possibility to increase the productivity and hence meet the demands. This is very effective in small scale companies as they have varying demand with a lot of budget constraints involved. Implementing this U-cell in a small scale company will be very productive to the company's progress and improvement. The task times with the updated changes are represented in table below. The revised task times are represented in the table.13 with the precedence order. It also includes the time taken for automatic tasks and there is no change in that time.

Table.13 Updated manual tasks time

S.no	Tasks	Time (s)	Precedence
1.	Movement of material	60	-
2.	Packaging of product A	(Automatic)	1
3.	Changing of wrapper	240	2
4.	Quality checking (product A)	400	2
5.	Packaging of product B	(Automatic)	3
6.	Changing of wrapper	240	5
7.	Quality checking (product B)	400	5
8.	Packaging of product C	(Automatic)	6
9.	Quality checking (product C)	400	8
10.	Taking the boxes to warehouse	100	9
	TOTAL	1840s	

- **Minimum number of workstations (MNW)**

The formula for finding the minimum number of workstations is the ratio manual time to the takt time.

MNW= Manual time/ Takt time

MNW= 1840/965= 1.9 can be rounded off to 2.

- **Line efficiency**

The formula for finding line efficiency is the ratio of manual tasks time to the takt time and the product of number of workstations [16].

Line efficiency= (Manual tasks time/cycle time*minimum number of workstations)*100

Line efficiency= 1840/(965*2)= 0.95 or 95%

The efficiency value is so high because of the reduction in the number of workstations and hence the workstations are effectively used. There is a possibility to increase the efficiency more than this after the line balancing in each workstation and obtaining a new cycle time value.

- **Line balancing of workstations for the revised task times**

Table.14 and15 represents the workstations for the revised task times.

Table.14 Station no.1

Task	**Time (s)**	**Aggregate time (s)**	**Available time (s)**
1	60	60	905
3	240	300	665
4	400	700	265
6	240	940	25

Table.15 Station no.2

Task	**Time (s)**	**Aggregate time (s)**	**Available time (s)**
7	400	400	565
9	400	800	165
10	100	900	65

We have found a solution with 3 stations with cycle time of 940s.

- **New line efficiency**

The formula for finding line efficiency is the ratio of manual tasks time to the takt time and the product of number of workstations.

Line Efficiency= (Manual tasks time/cycle time*minimum number of workstations)*100

Line Efficiency= 1840/(940*2)= 0.97 or 97 %

5.4 Reduction of number of work stations and increase in efficiency

Due to the proximity between workstations there is a significant decrease in manual task times. With the updated manual task times the line balancing is done. The number of workstations are reduced to 2 and can be seen in fig.19. And hence the efficiency is increased to 97%. And also the distances between the workstations and the delivery table is also reduced so that the time taken for the operator to move the finished products to the delivery table is reduced and hence it contributes to the increase in overall efficiency. The distances between the workstations which were very high around 50m are reduced to 5m and it contributes to the increase in efficiency. And also the distance between the workstations and the collection table is also reduced and it is only around 10m which means the operator has to travel very less compared to the earlier design due to which there was a lot of time lost. And also this implementation of U-cell design is easy and it does not take a huge deal of financial aid for its implementation and it is ideal for small and medium scale companies.

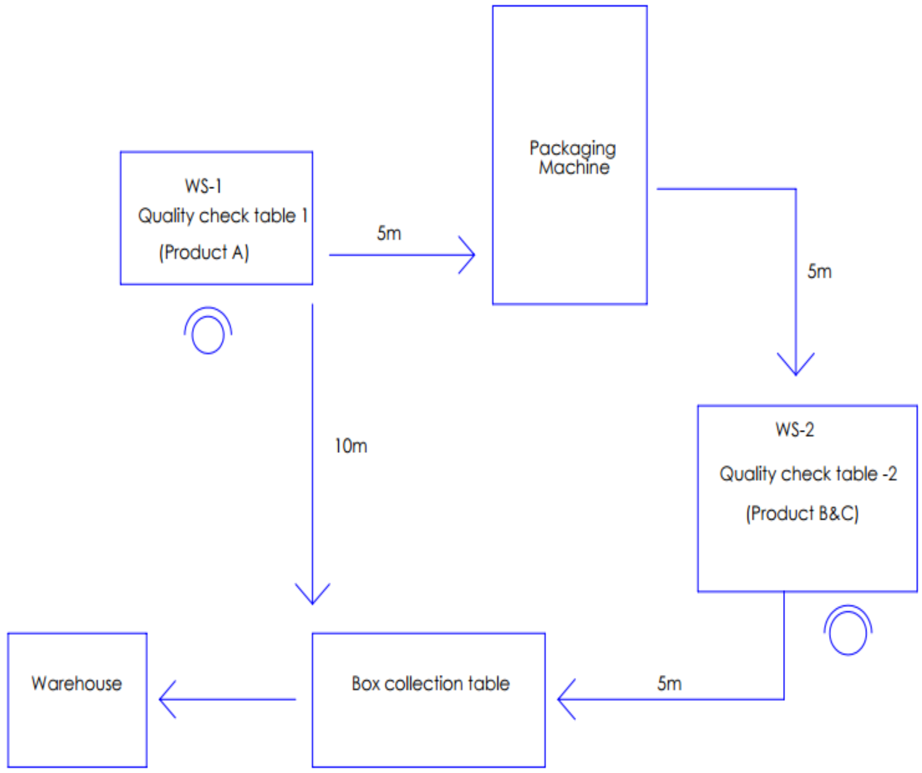

Fig.19 U-shaped cell

5.5 TOTAL PRODUCTIVE MAINTENANCE (TPM)

Total productive maintenance is basically a maintenance program which is designed for the effective maintenance of plants and equipment. According to (Nakajima,1988), "TPM has been accepted as the most promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena". It has proved to be an effective methodology for the maintenance in industries [17].

Benefits

- Avoiding wastes.
- Reducing costs
- Maintenance of quality in production
- Less or no defects.

Organizational structure for TPM implementation

The organizational structure for implementing the Total productive maintenance consists of a responsible plant manager who is the in-charge for all the TPM operations which is to be conducted. The plant manager is responsible for all types of maintenance processes which is done in the company. The structure is designed in such a way that there are 8 main pillar activities around which all the maintenance process takes place. The 8 pillars include activities like autonomous maintenance, preventive maintenance, quality maintenance, planned maintenance, individual maintenance, safety and training people development.

5 S foundation and 8 pillars

The approach to implementation of TPM consists of 5S foundation and 8 supporting activities which are called as 8 Pillars as shown in fig.20. **5S** consists of Sort, Set in Order, Shine, Standardize and Sustain. **The 8 pillars** consist of 8 main activities which helps in the maintenance and improvement of equipment reliability [18].

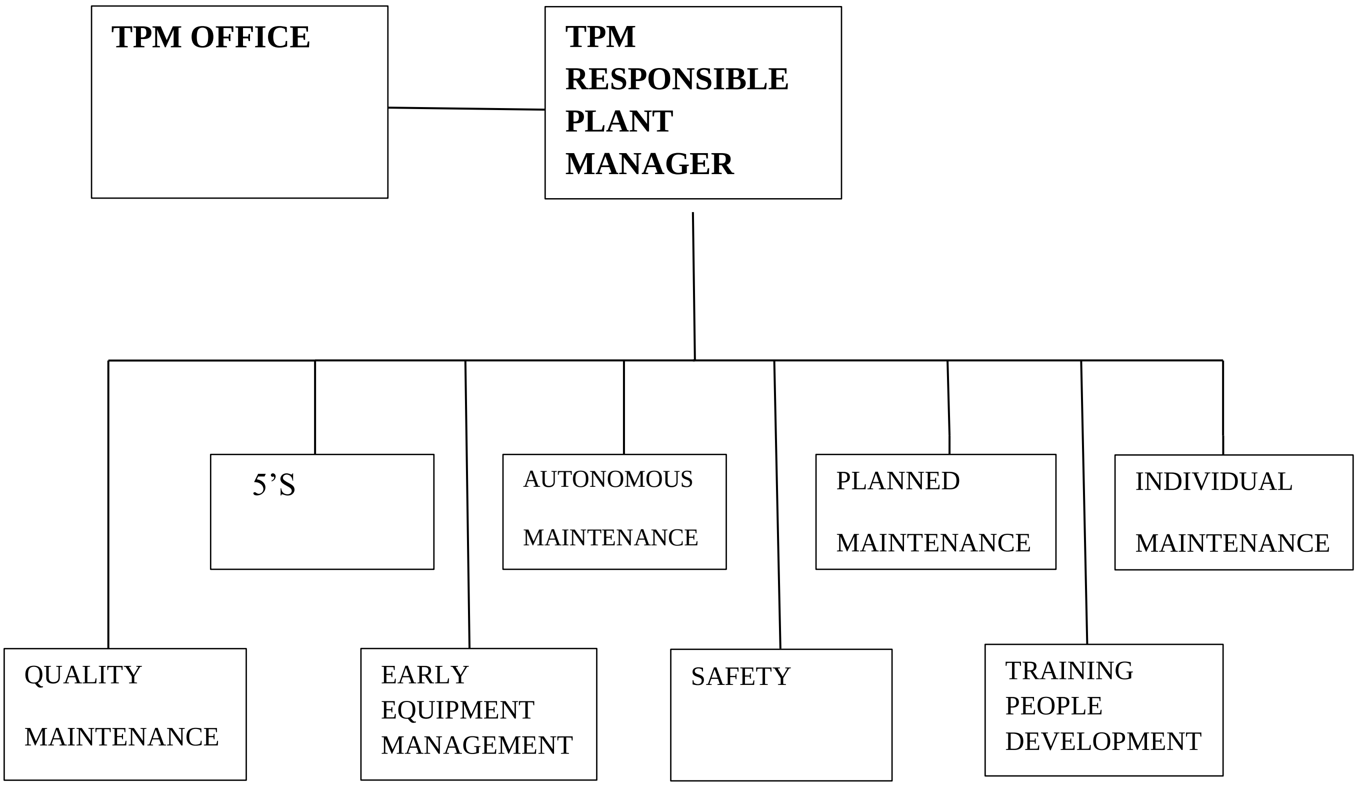

Fig.20- 8 pillars in TPM [Lean Production]

Analysis and TPM implementation

Table.16 Causes of breakdown during the packaging process

Cause	Time (h)	%	Cumulative %
PLC defects	8 hours	33.33	33.33
Electrical Failures	10 hours	41.66	74.9
Miscellaneous failures	6 hours	25	100

Looking at the Pareto breakdown table.16, we have three main causes for failure:

1) PLC failures
2) Electrical failures
3) Miscellaneous

Maintenance staff that do not follow TPM standards does not use to analyze in detail the root causes of a breakdown after the implementation of corrective actions. So, first of all, every breakdown or malfunction should be analyzed in detail using Ishikawa's or 5 whys methods in order to find the root causes. Secondly, preventive measures should be defined in order to avoid the breakdown repeat. Fig.21 explains about the hours lost due to breakdowns and its causes.

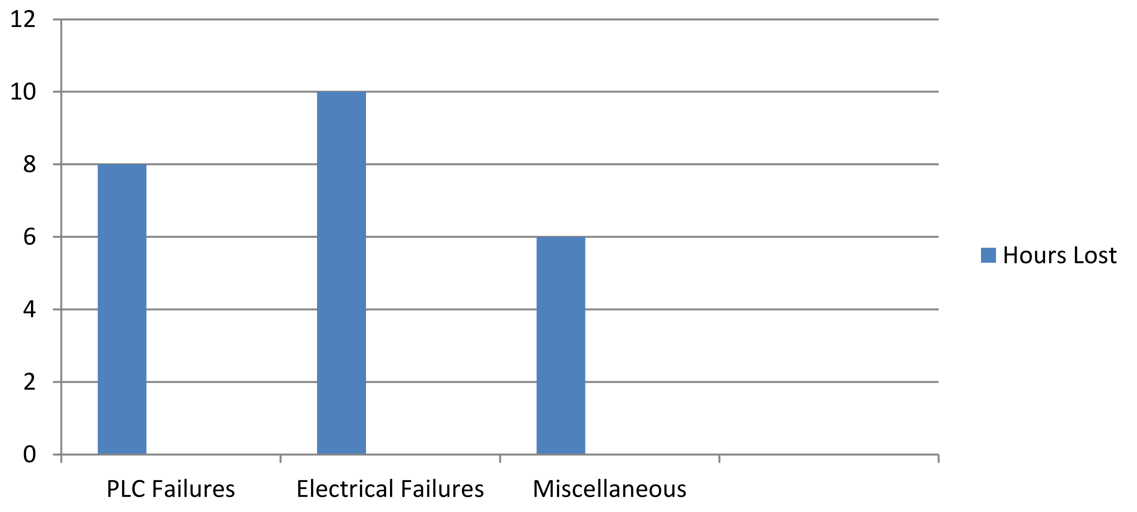

Fig.21 Hours lost and cause

- **Autonomous maintenance**

A plan should be designed by the maintenance staff and implemented by the manufacturing operators in their daily routines. This plan should provide a set of checklists with the schedule to perform perfect maintenance operations of the PLC systems and it should include the frequencies at which this plan should occur. This action plan should reduce dramatically the PLC breakdowns of the transmission systems.

- **Preventive maintenance**

A plan with planned preventive actions should be implemented by the maintenance staff. This is part of a time based maintenance (TBM) strategy in order to check for the main systems of equipment and replace key parts of them before they break. According to the life cycle of any part, it is possible to forecast its reliability and plan for the optimal moment to replace each part, assuming that it is better to replace working parts before they break to avoid major and costly breakdowns. Any new cause of failure identified during the cause analysis of breakdowns may add new actions in the preventive plan as machine conditions change along time.

By implementing these two maintenance activities we can see improvement in the overall breakdown time.

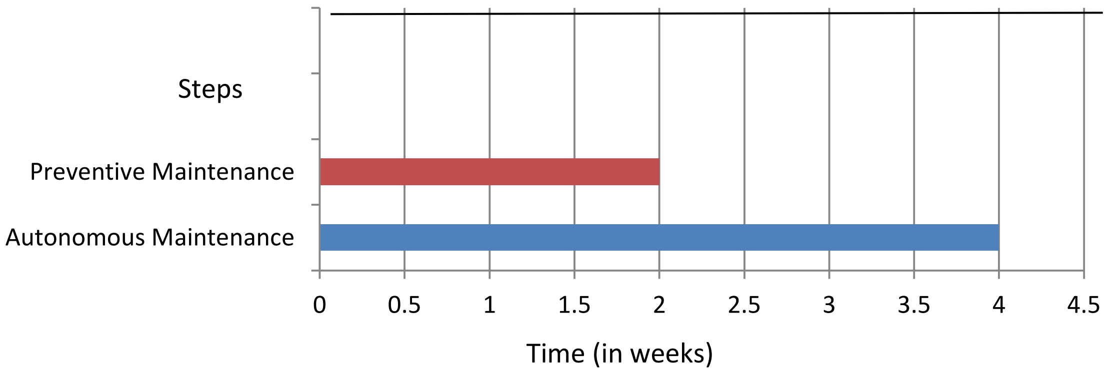

Fig.22 Master plan for TPM implementation

The master plan for implementing TPM mainly consists of two steps as shown in the fig.22 and the time and duration it takes place.

5.6 Improved value stream map

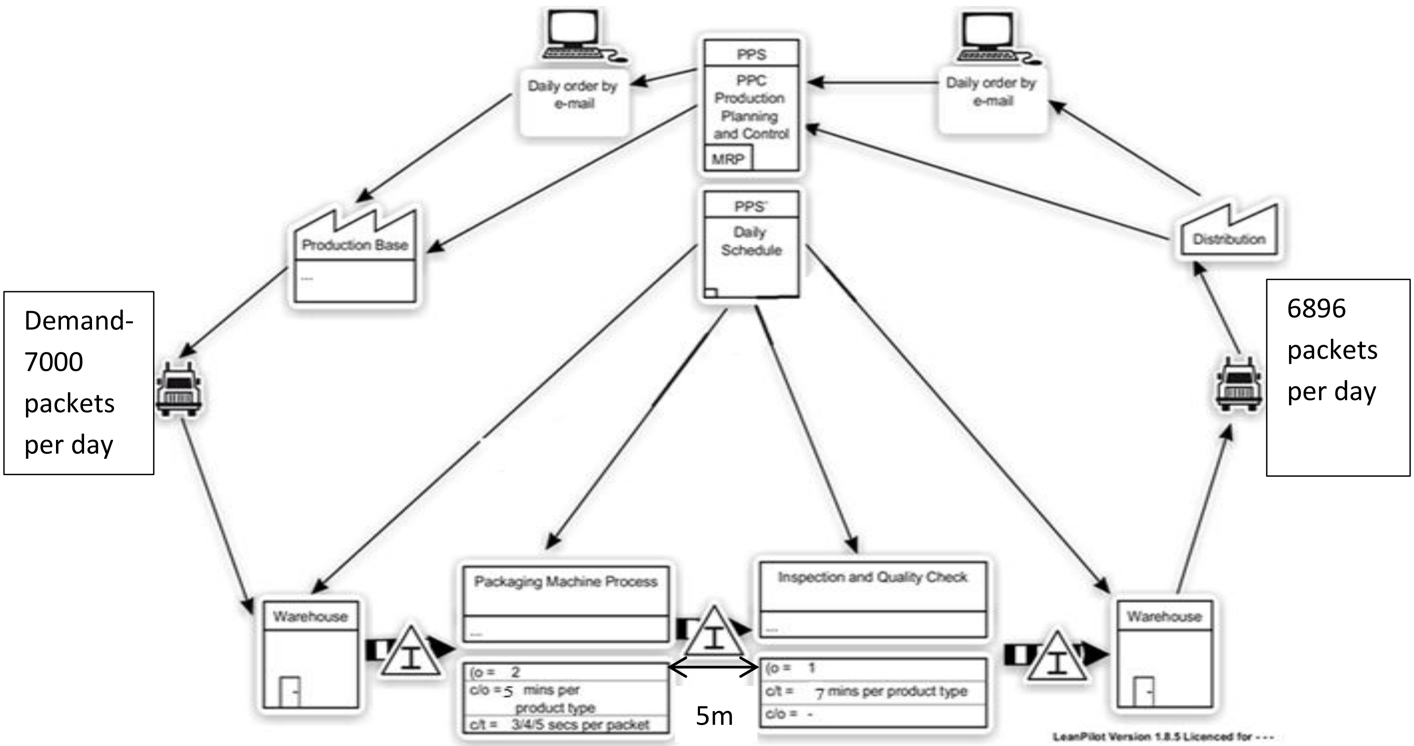

Fig.23 Improved value stream map

After deeply analyzing the wastes in Value stream map several solutions have been proposed. From the improved value stream map as shown in fig.23 it can be seen that the changeover time is reduced to 5 minutes per product type. Due to which the number of packets produced per day has increased to 6896 packets per day. The communication frequency between the production planning and control is improved to happen on a daily basis. Also the distances between the workstations have been reduced to 5m which was 50m earlier and a major cause for the wastes.

Conclusions from the chapter

1) In the initial parts of this chapter the packaging line was balanced into 3 workstations and the efficiency of the line was found to be 85%.
2) The existing line had a problem of long distances between the workstations and hence a U-shaped cell was designed and the distances were reduced from 50m to 5m between the workstations.
3) Due to the reduction of distances between the workstations the manual task times were reduced and the new line was balanced and the efficiency of the line was found to be 97%.
4) In the later parts of this chapter a TPM master plan was designed in-order to reduce the time lost due to breakdowns. The plan included two types of maintenance namely preventive maintenance and autonomous maintenance.

6. Analysis of results after the improvement of wastes in the packaging process

After the reduction of changeover time form 20 minutes to 5 minutes it is important apply this new changeover time and perform calculations using this new changeover time.

6.1 Expected result calculations

- **Takt time**

Formula for calculating takt time= Available working time per day/ Daily customer demand

Available working time per day = 7 hours 30 minutes

Customer demand= 7000 packets per day and 28 boxes per day.

Takt Time (s) = 27000/ 28 = 965 secs

- **Calculation of Value added and Non-Value added time**

Value added time can be calculated by determining the number of correct quantities which is produced per day.

Minutes lost due to changeovers = 10 mins per day

Hours lost due to breakdowns, technical errors = 4 hrs per month

On an average it can be said that nearly 10 minutes are lost per day.

So, Value added time = No of right quantities*cycle time

Value added time = (3000*3)+ (2000*4)+ (1896*5) – (4 hours) = 157.82 hours

- **Overall Equipment Effectiveness**

OEE= Value added time/ Scheduled time* 100

Scheduled Time = Overall time- Scheduled stops

Operating time per day = 7 hours 30 minutes

Scheduled time = 165 hours per month

OEE = 157.82/165 = 0.95 or 95%

- **Performance factor**

Performance factor can be defined as the ratio of operating time to the overall scheduled time.

Performance factor = Operating time/Scheduled time

Operating time = 7 hours 30 minutes (10 minutes lost due to changeovers per day)

Operating time = 7.5*22= 165 hours

Operating time= 165-(4 hours for breakdown)= 161 hours

Scheduled Time = 165 hours

So, **Performance factor = 161/165 = 0.97.**

- **Quality factor**

Quality Factor can be defined as the ratio of Value Added time of the process to the operating time of the process.

Quality Factor = Value Added Time/ Operating time

So, **Quality factor = 157.82/161 = 0.98.**

The results from the calculations of the packaging process are represented in table.17.

Table.17- Expected results after the improvement of the changeover time

Operating hours	7 hours 30 minutes
Cycle time	For Product A- 3 seconds Product B- 4 seconds Product C- 5 seconds
Changeovers	10 minutes
Takt time	965 seconds
Daily demand	7000 per day
Value added time	157.82 hours per month
Scheduled time	165 hours per month
OEE (Overall Equipment Effectiveness)	95%
Performance factor	0.97
Quality factor	0.98
Products produced per day	6896

6.2 Conclusions from expected result calculation

- **Increase in Overall equipment efficiency**

Reduction in changeover time directly impacts the overall equipment efficiency. As the changeover time is decreases from 40 minutes to 10 minutes, there is an increase in overall equipment efficiency. This directly contributes to the increase in productivity. This difference can easily be seen in the graph from the fig.24.

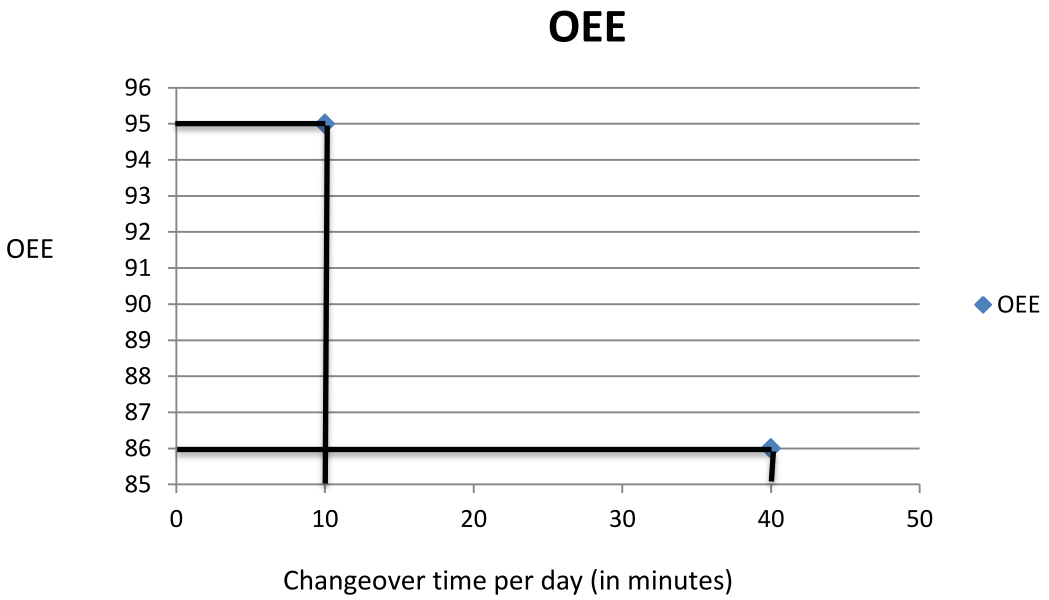

Fig.24 Changeover time vs OEE

- **Reduction in number of workstations and Increase in line balancing efficiency**

Due to the proximity between workstations there is a significant decrease in manual task times. With the updated manual task times the line balancing is done. The number of workstations are reduced to 2. And hence the efficiency is increased to 97%.

- **Increase in productivity**

The decrease in changeover time is inversely proportional to the overall productivity as shown in fig.25. As the changeover time is decreased from 40 minutes to 10 minutes, there is an increase in overall productivity to 6896 packets per day.

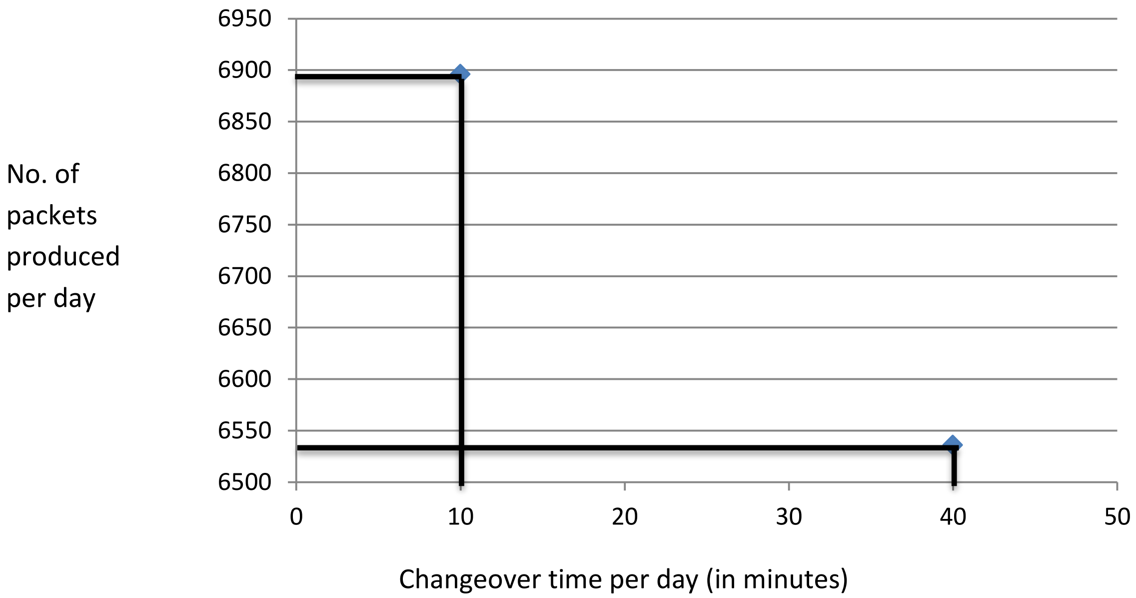

Fig.25 Changeover time vs productivity

- **Reduction in breakdown time**

The time lost due to breakdowns can be reduced to a negligible extent after the implementation of the TPM plan. But there cannot be an exact value of it represented because the exact value of time can be obtained only when this plan is implemented and only after a month or two the values can be obtained. So it is important for the company to implement this plan and measure the improvements.

The results achieved thus reflects an increase in number of products produced per day which will aid in meeting the daily demand and also it helps to increase the Overall Equipment Efficiency of the packaging process.

7. Conclusion and future developments

1. An efficient analysis of the packaging process was done, calculations were performed and some important data values like takt time, OEE, cycle time, quality factor, performance factor were found out. The Overall Equipment Effectiveness of the machine was found to be 86%.

2. Using the values obtained a value stream map was sketched and using that some important wastes involved in the process were identified. The important waste which was identified was the changeover time and it was 20 minutes for one product type.

3. Pareto analysis was also performed and the root causes for the breakdowns were found out and it was the electrical failures which contributed to 41.66% of the overall percentage.

4. PLC ladder logic program was written and compiled to reduce the changeover time from 20 minutes to 5 minutes. Due to which the number of packets produced per day was increased from 6536 to 6896. And the OEE of the machine was increased from 86 % to 95 %.

5. The packaging line was balanced and the distances between the workstations were reduced with the design of U-shaped cell. The manual tasks time were reduced due to the design of U-shaped cell and the number of workstations were reduced from 3 workstations to 2 workstations and hence the efficiency was increased to 97%.

6. A TPM master plan was proposed to reduce the losses due to breakdowns. And by implementing this plan the time lost due to breakdowns which is 4 hours per month can be reduced.

Future developments

For small and medium scale companies it is important to make use of the resources available efficiently. This project is a perfect example for economic as well as an efficient project. This statement can be justified because there is no requirement of huge amount of capital required to implement this project. And also there is a negligible amount of increase in productivity and efficiency. Although there is not a huge deal of increase in percentage of productivity, it is a huge total for small or a medium scale company. And most importantly for these types of companies meeting the demand is the most important condition. And although the demand cannot be met in all seasons this project helps to increase productivity to a reasonable value. The future of packaging will be mainly based on automation and there will be no requirements of human workers. Technologies like machine to machine communication, usage of radio frequency identification tags will be used and hence these technologies will contribute to increase in the overall efficiency of the company.

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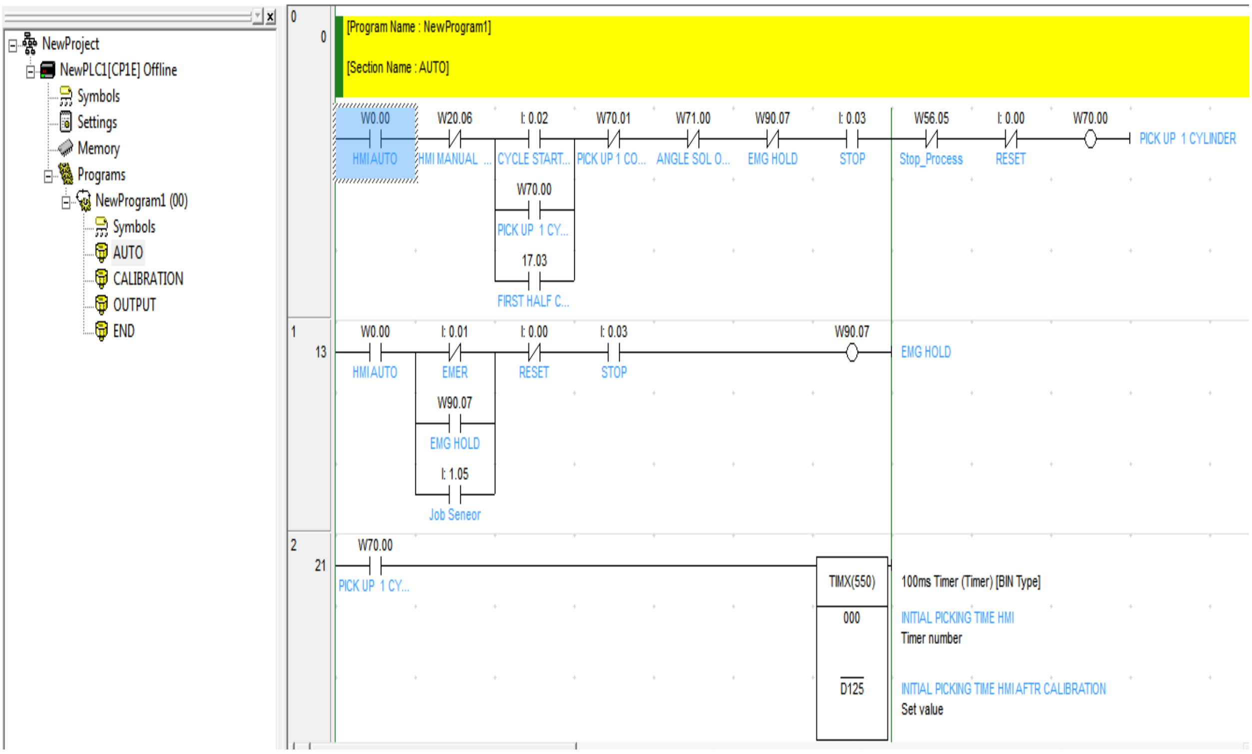
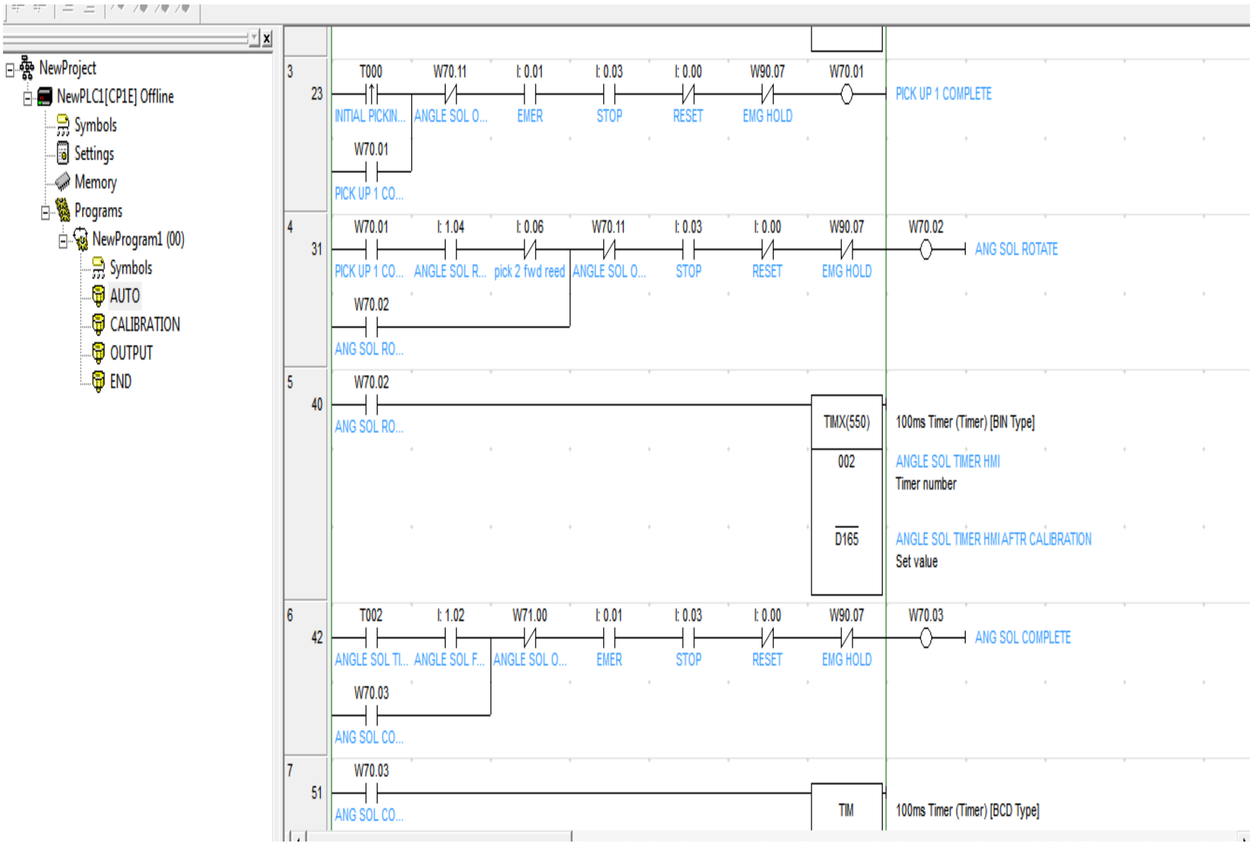
Annexure

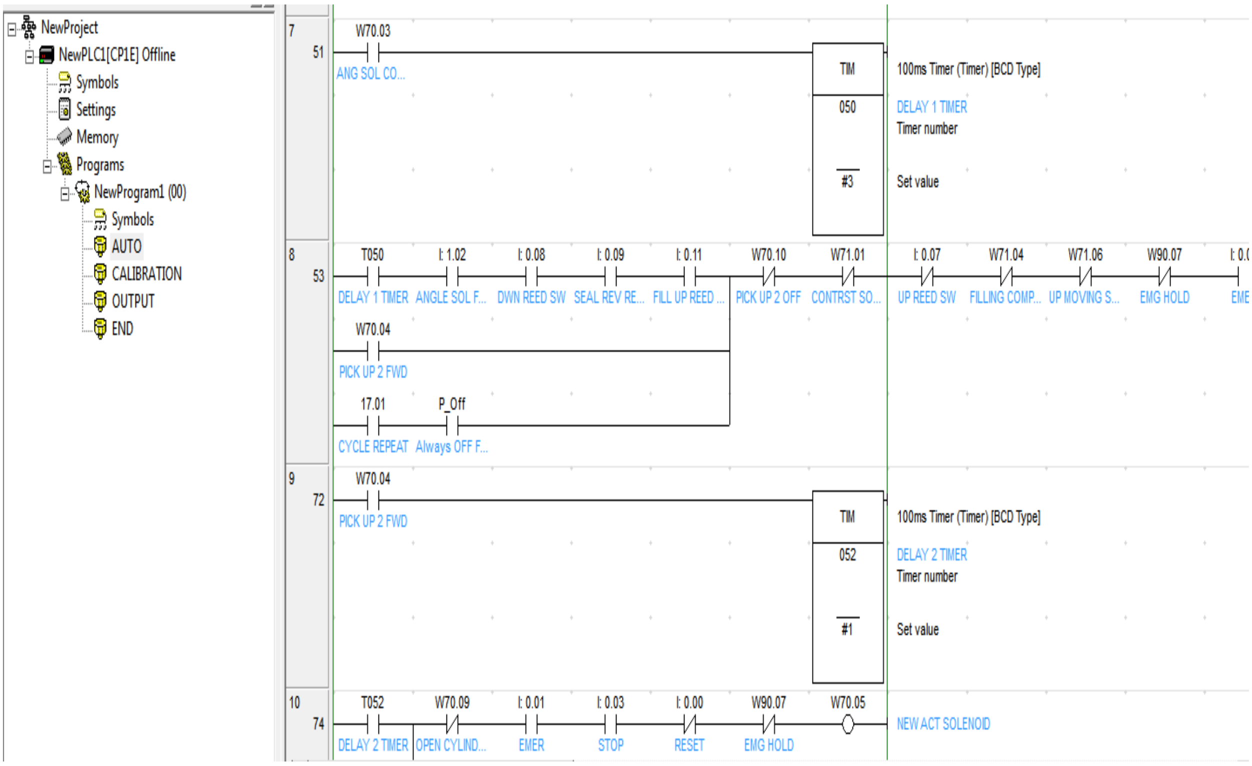
1) **Annexure 1- Initial movement of solenoids for the pick up process**
2) **Annexure 2- Movement and holding process of the packet**
3) **Annexure 3- Opening process of the packet**
4) **Annexure 4- Filling up process**
5) **Annexure 5- Completion of filling process**
6) **Annexure 6- Load cell action**
7) **Annexure 7- Setting timer for the process**
8) **Annexure 8- Sealing process**
9) **Annexure 9- Cycle completion**
10) **Annexure 10- Reset process**
11) **Annexure 11- Final reset process**
12) **Annexure 12- Schematic diagram of the packaging process**
13) **Annexure 13- PLC used**
14) **Annexure 14- Questionnaire**

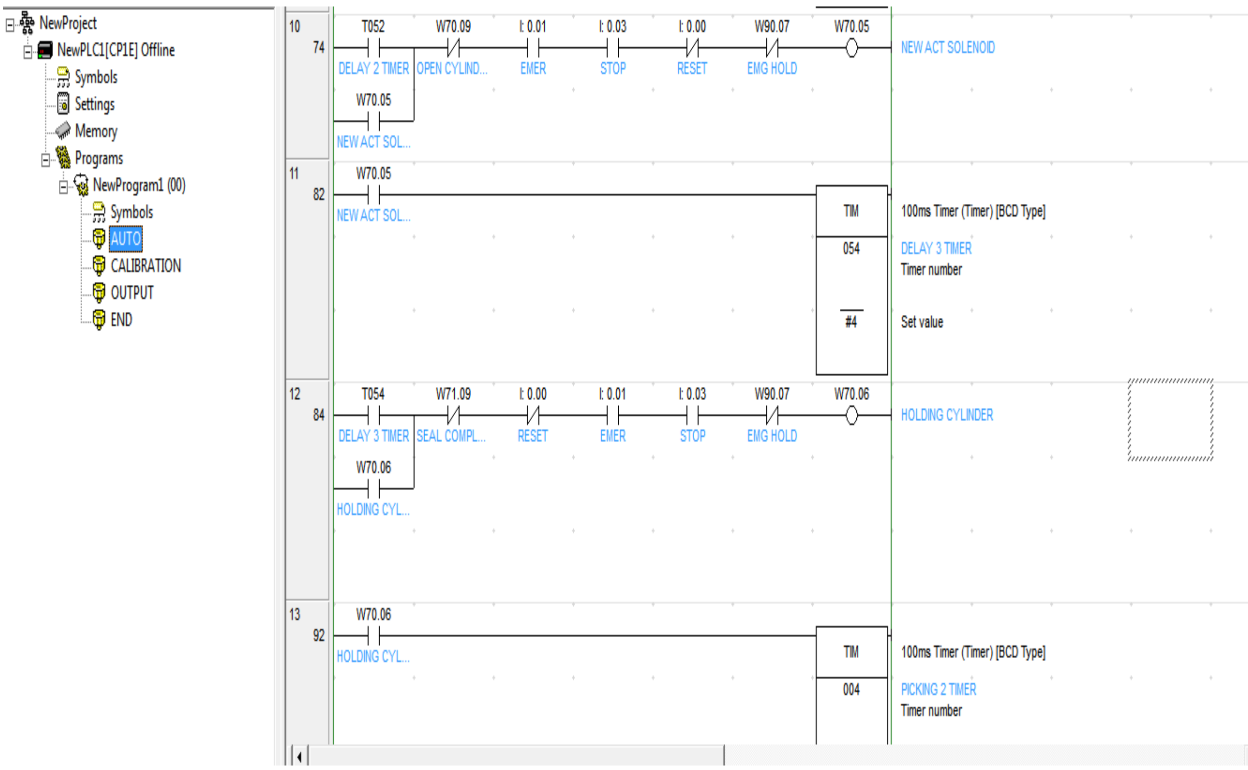
Annexure 1- Initial movement of solenoids for the pick up process



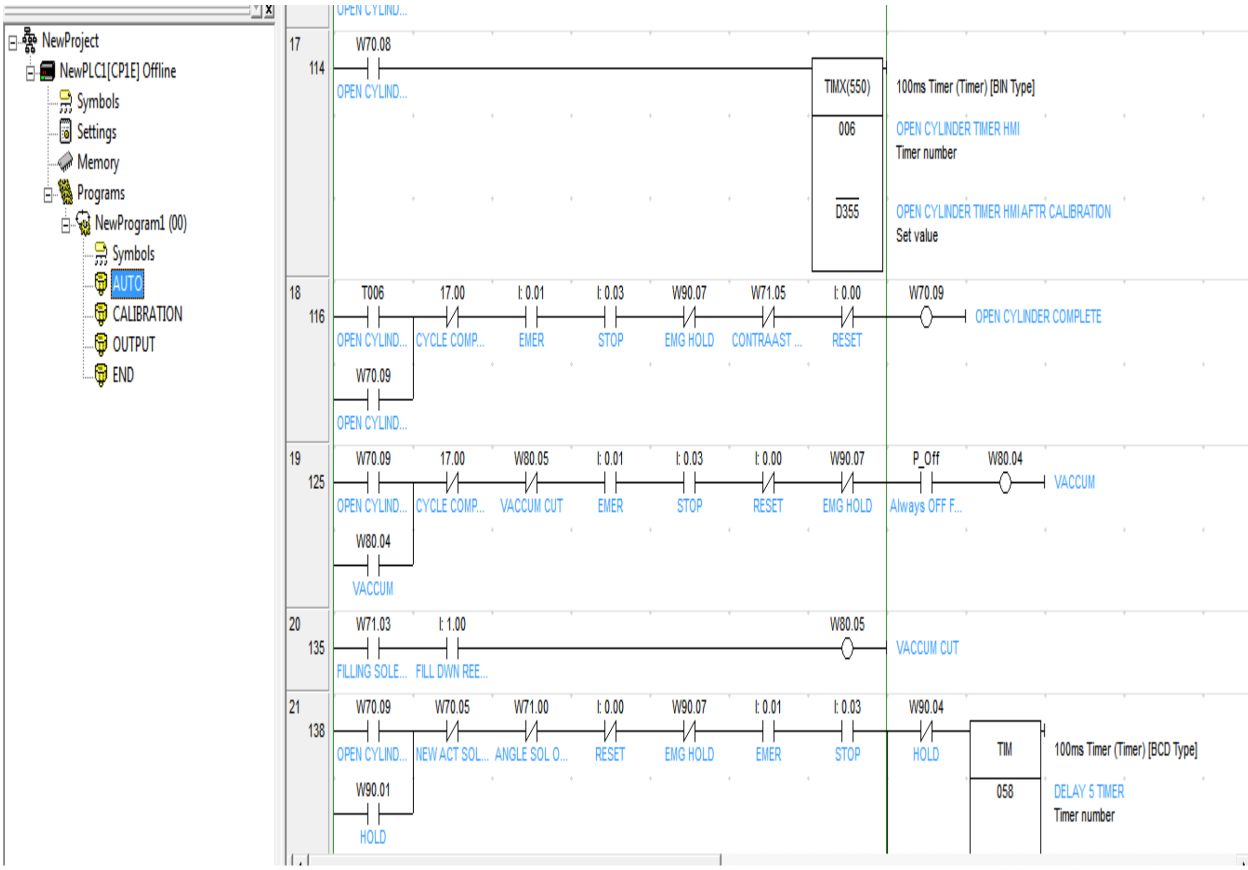


Annexure 2- Movement and holding process of the packet

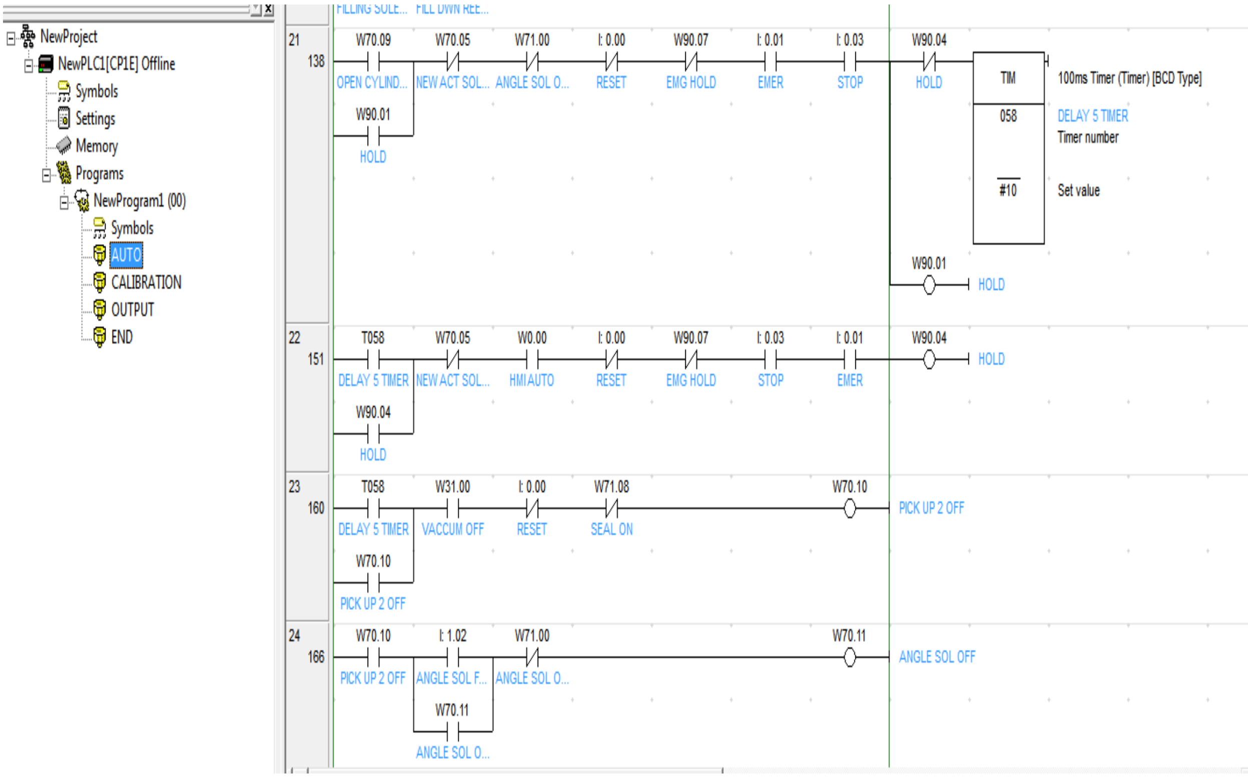


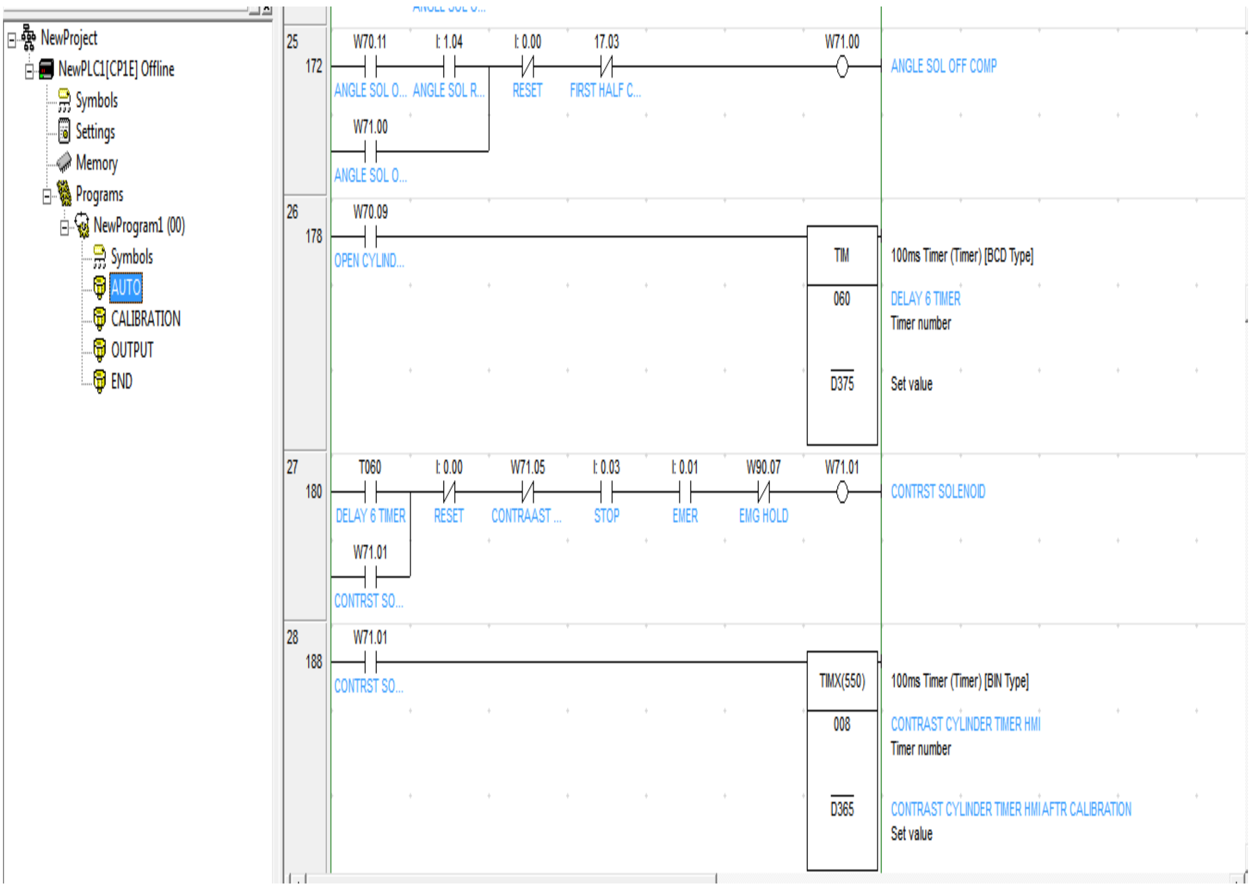


Annexure 3- Opening process of the packet

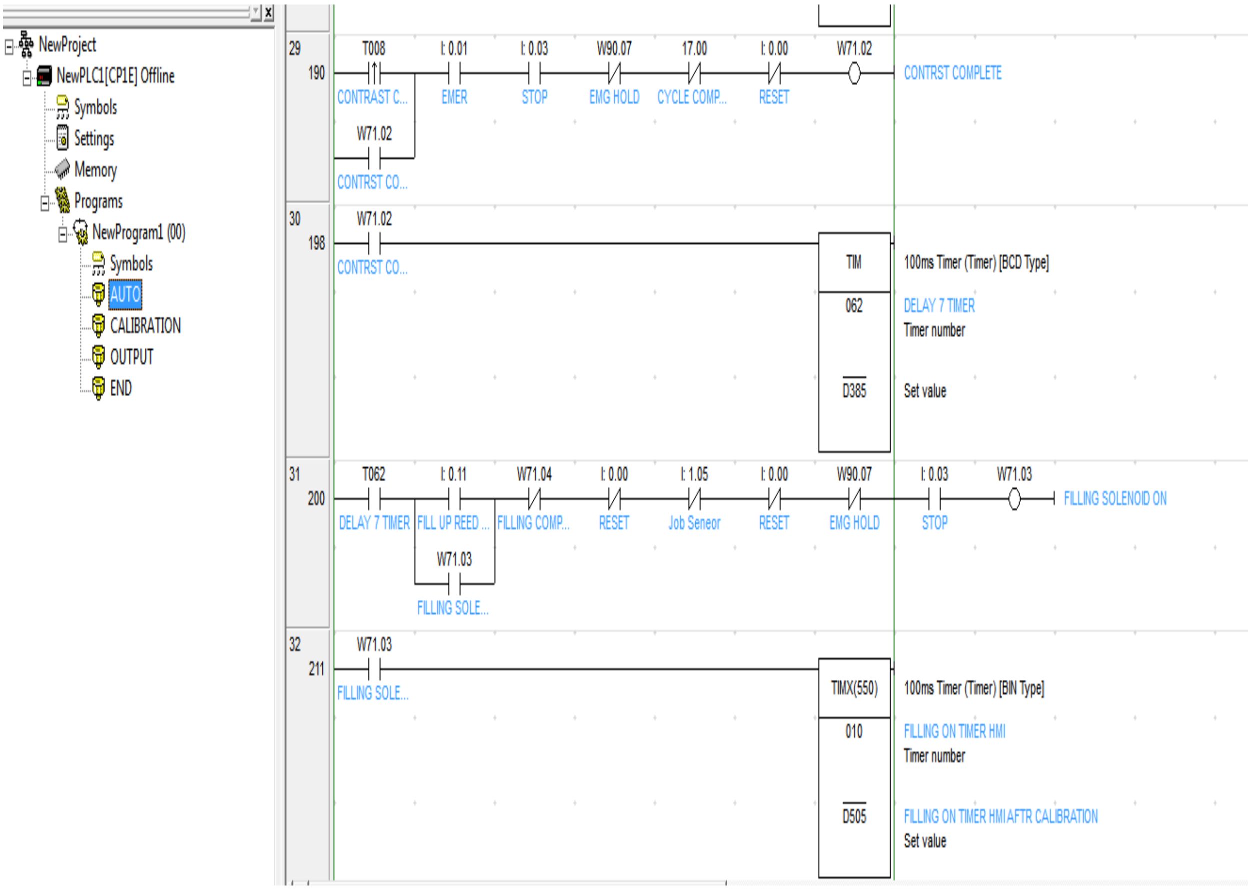


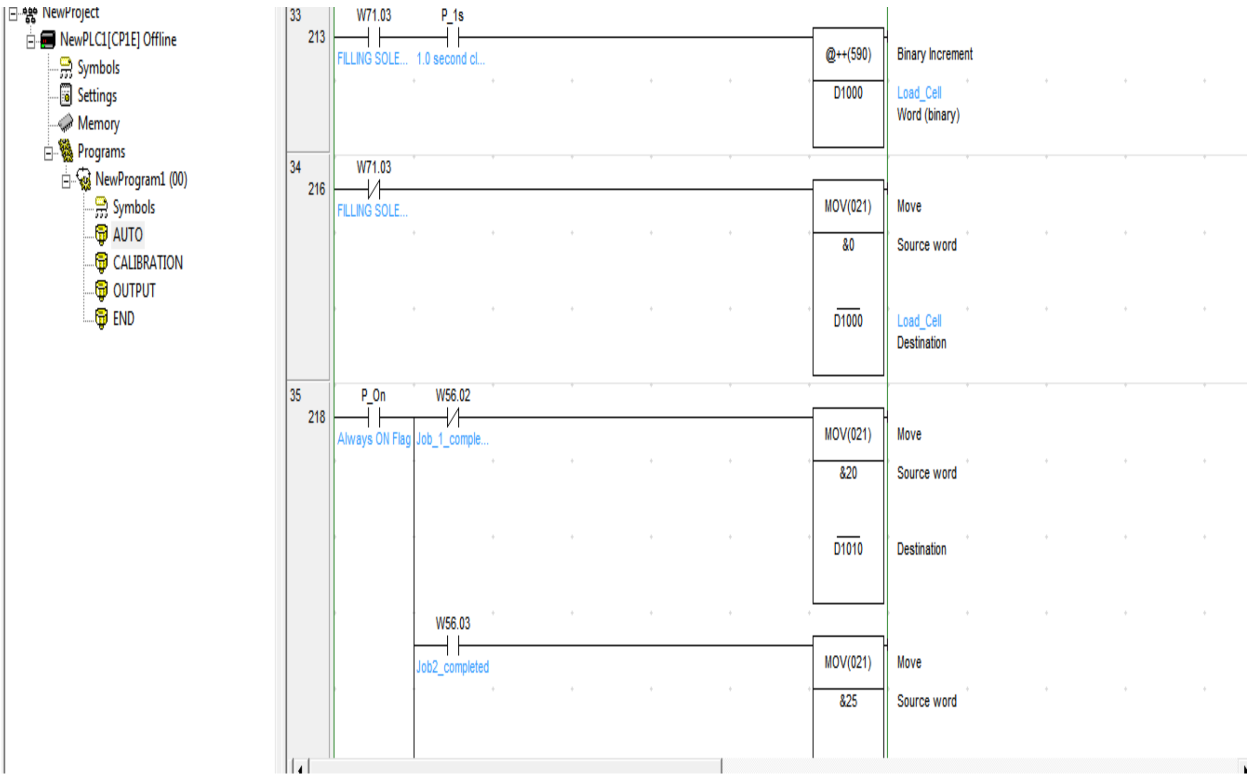
Annexure 4- Filling up process



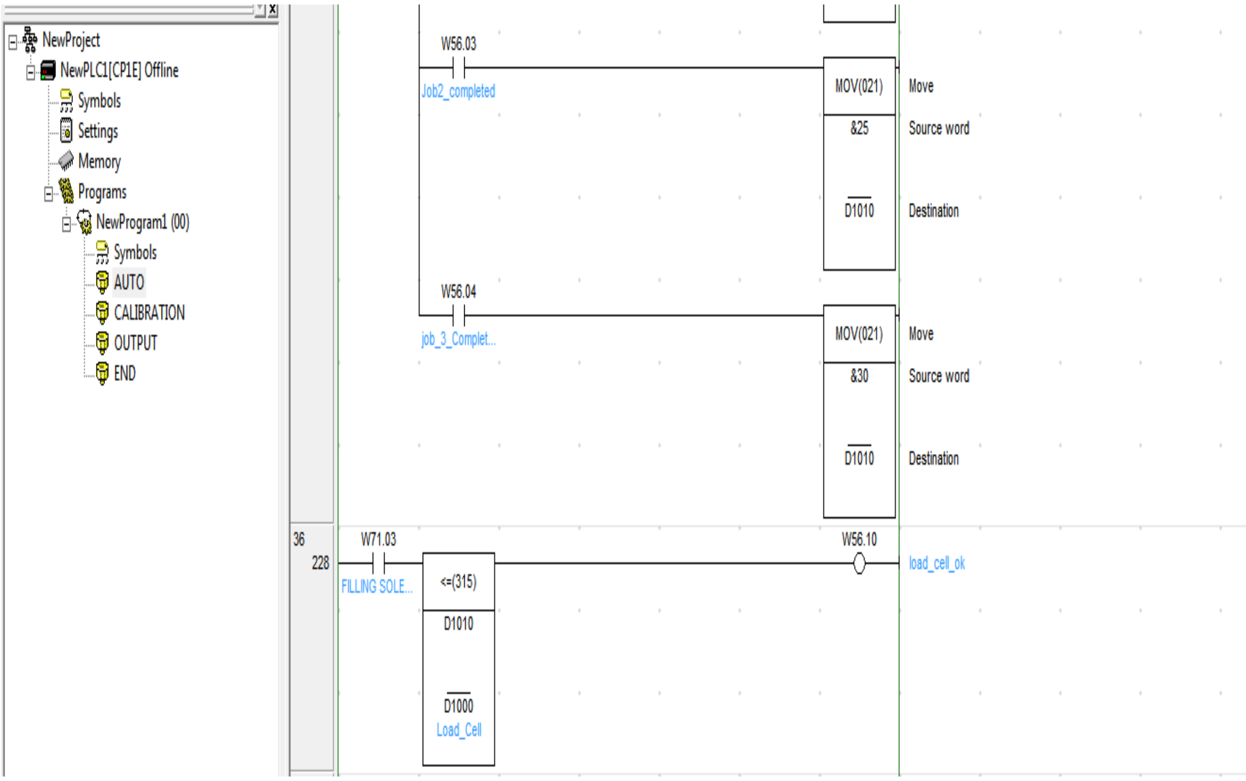


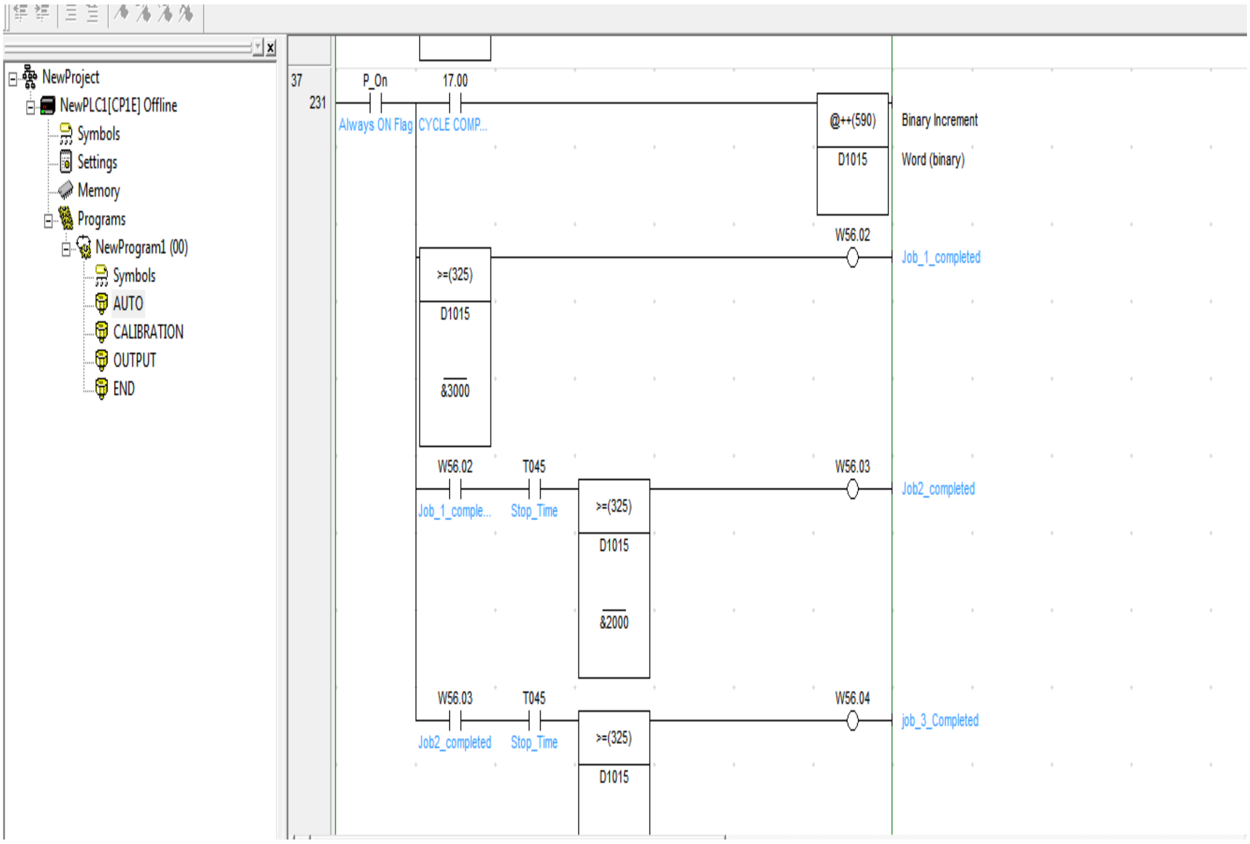
Annexure 5- Completion of filling process



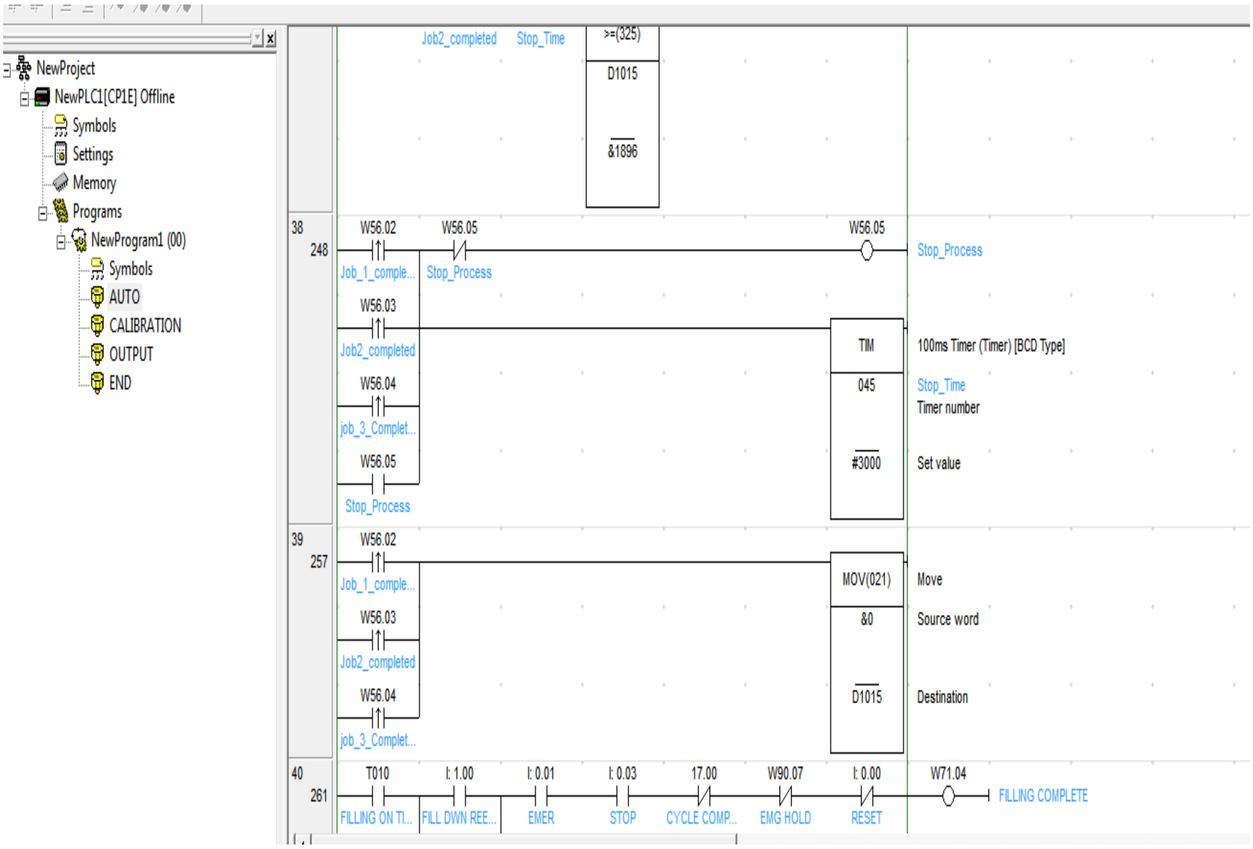


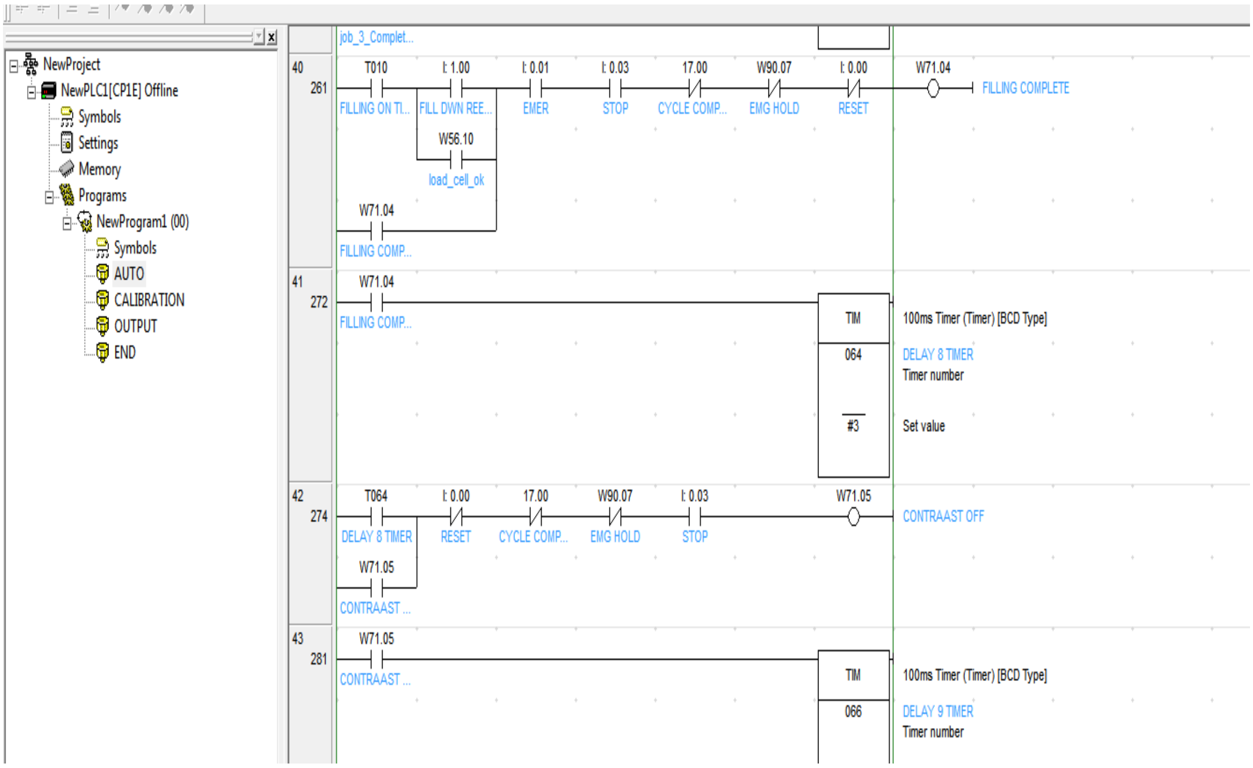
Annexure 6- Load cell action



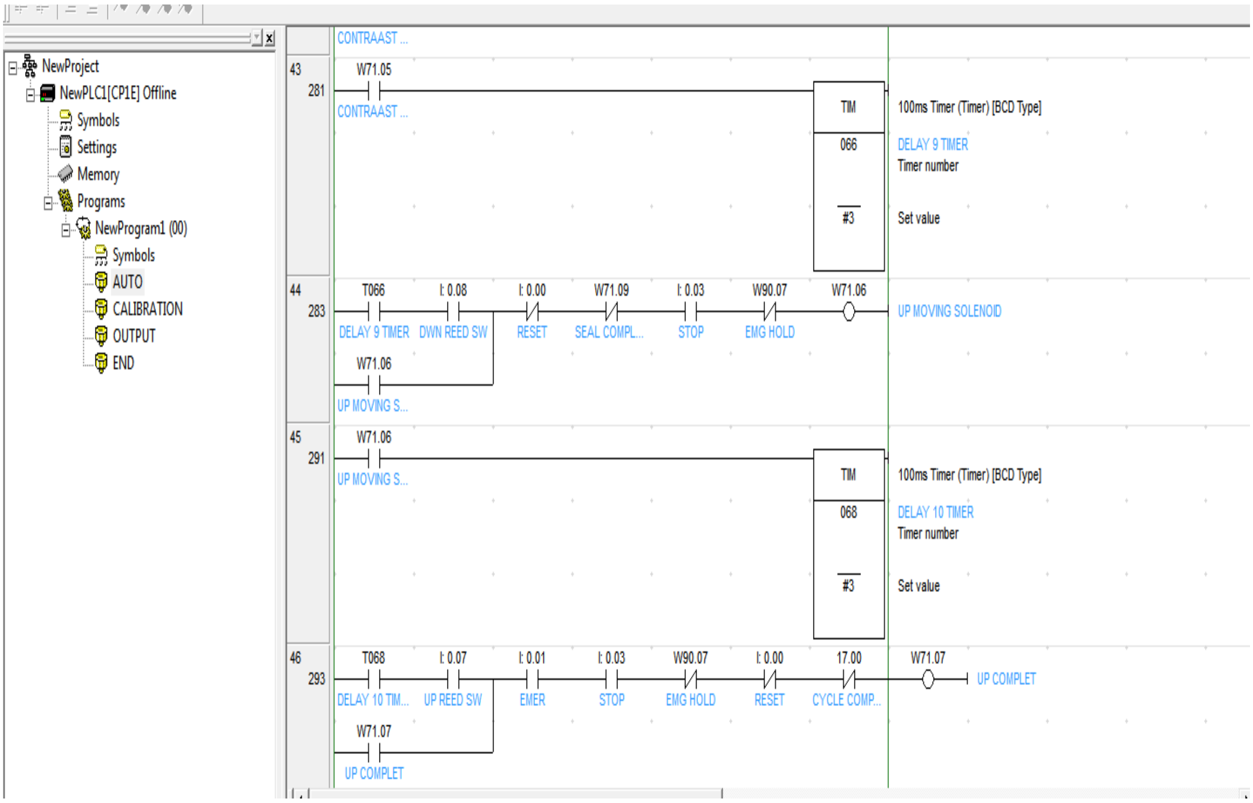


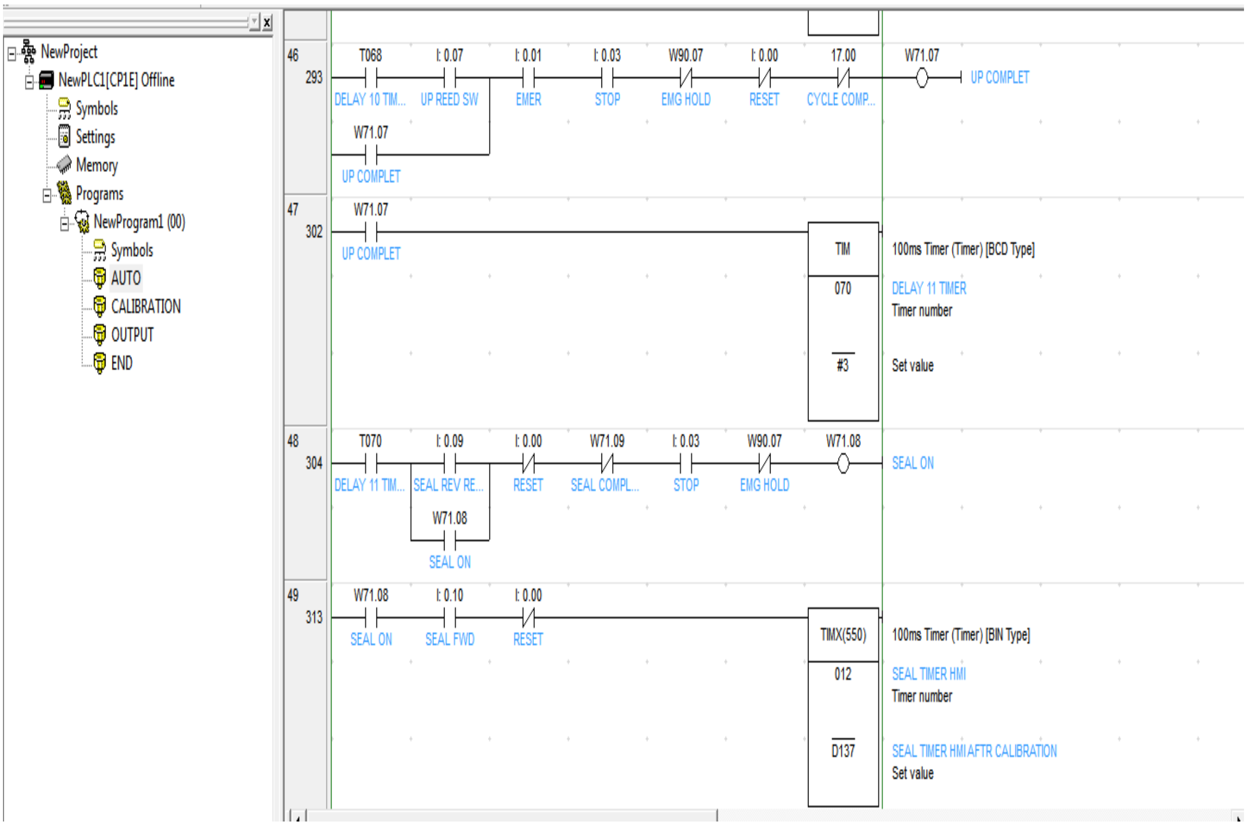
Annexure 7- Setting timer for the process



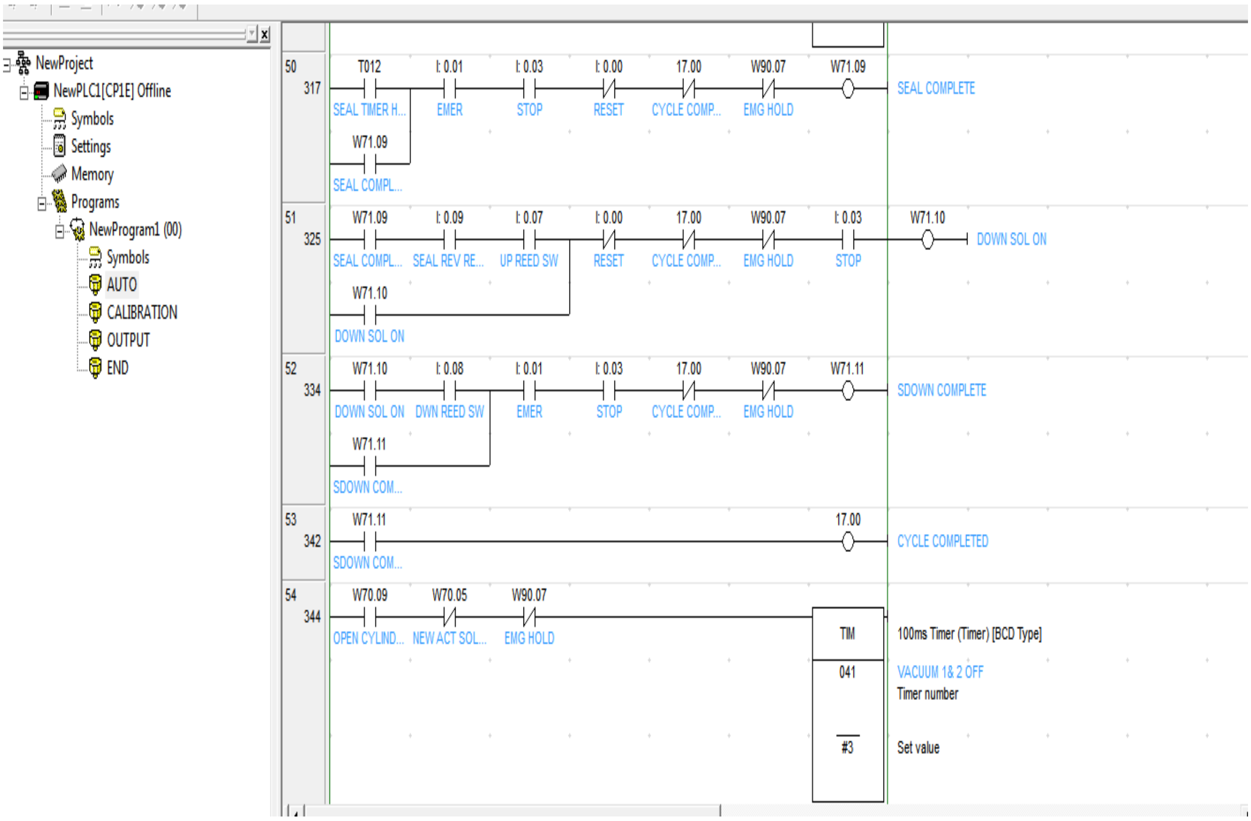


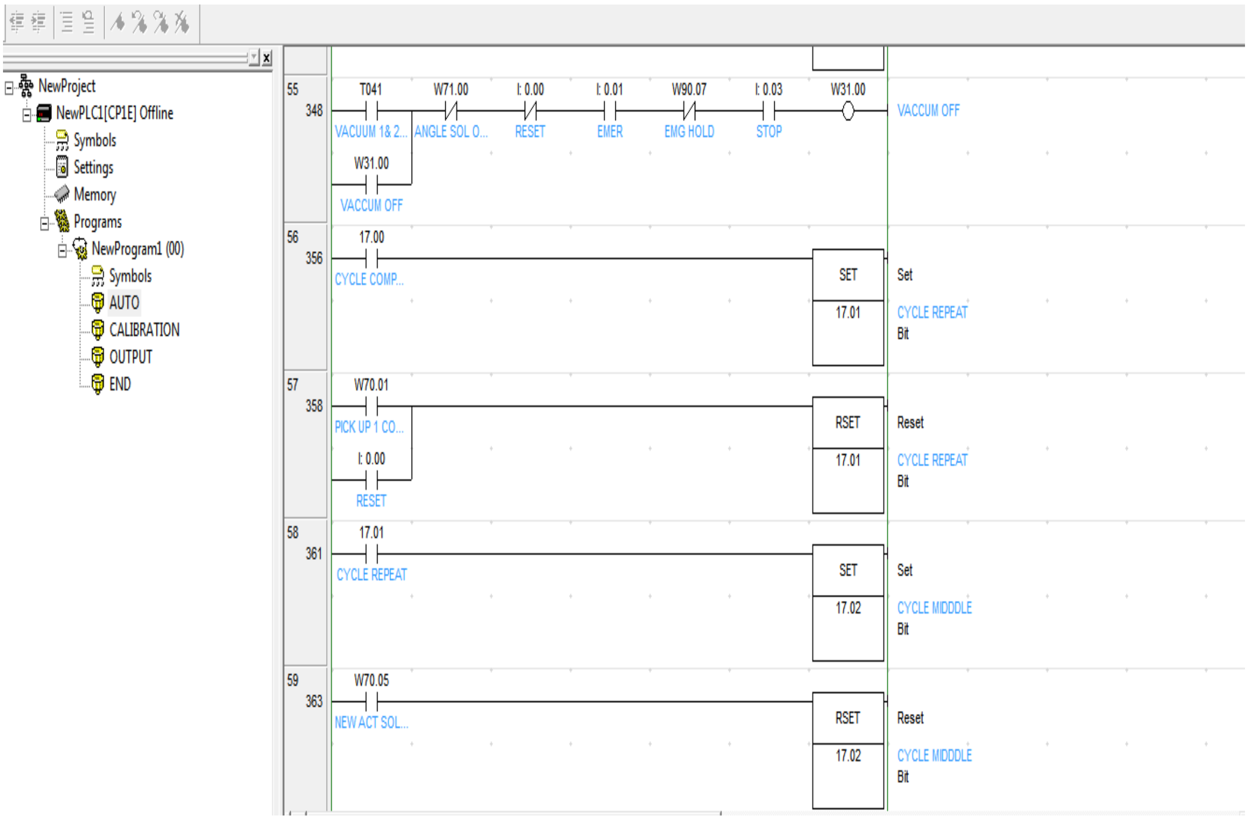
Annexure 8- Sealing process



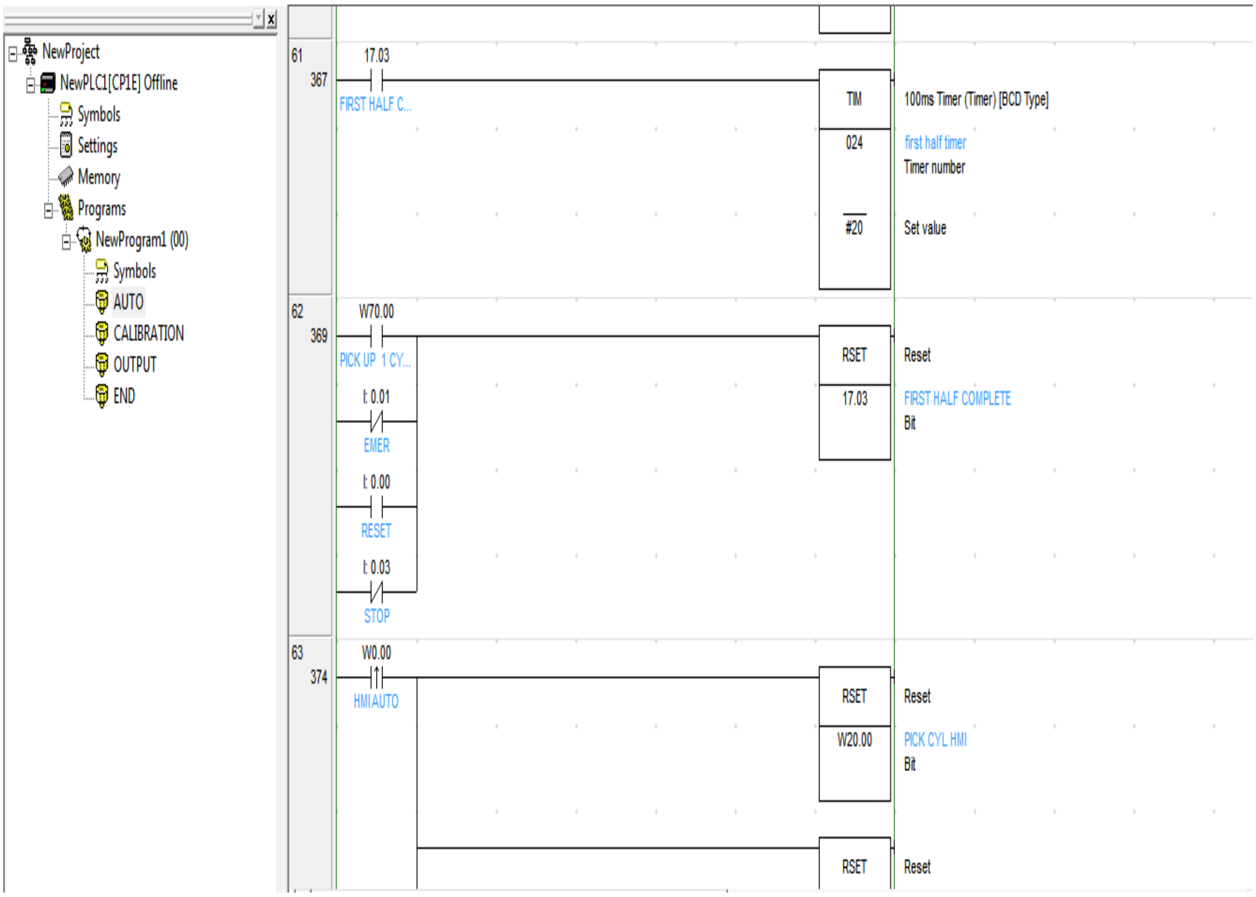


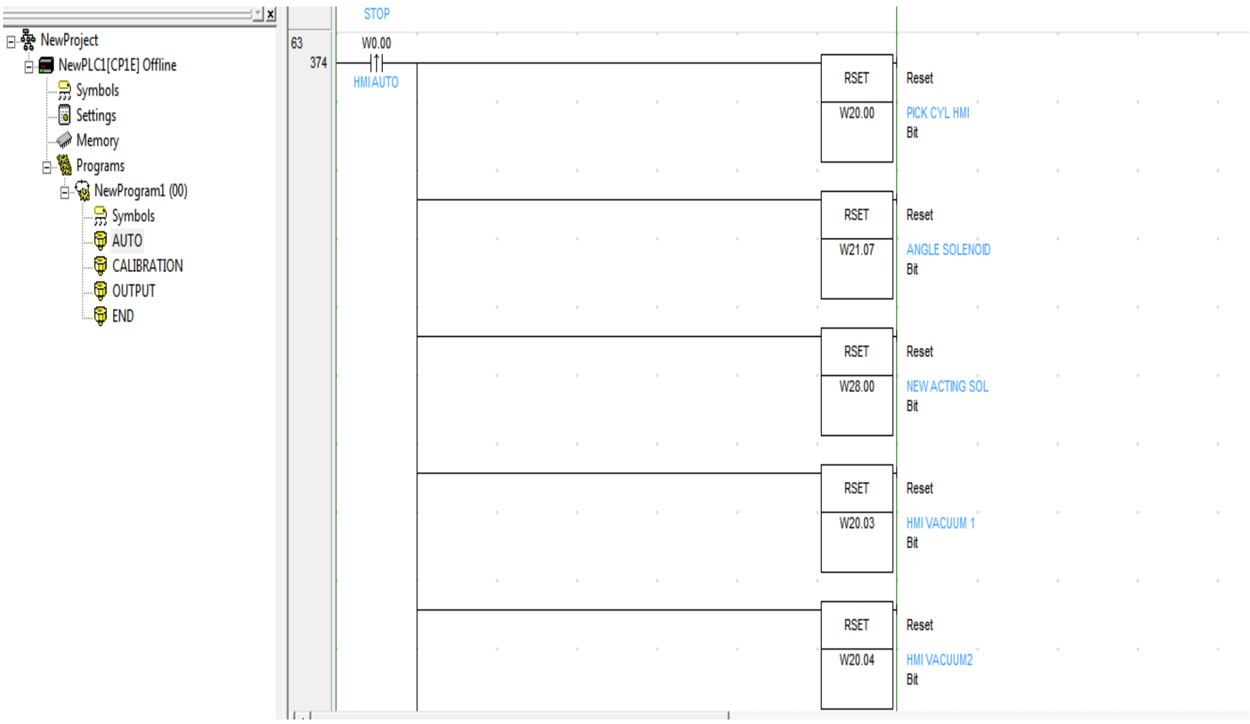
Annexure 9- Cycle completion



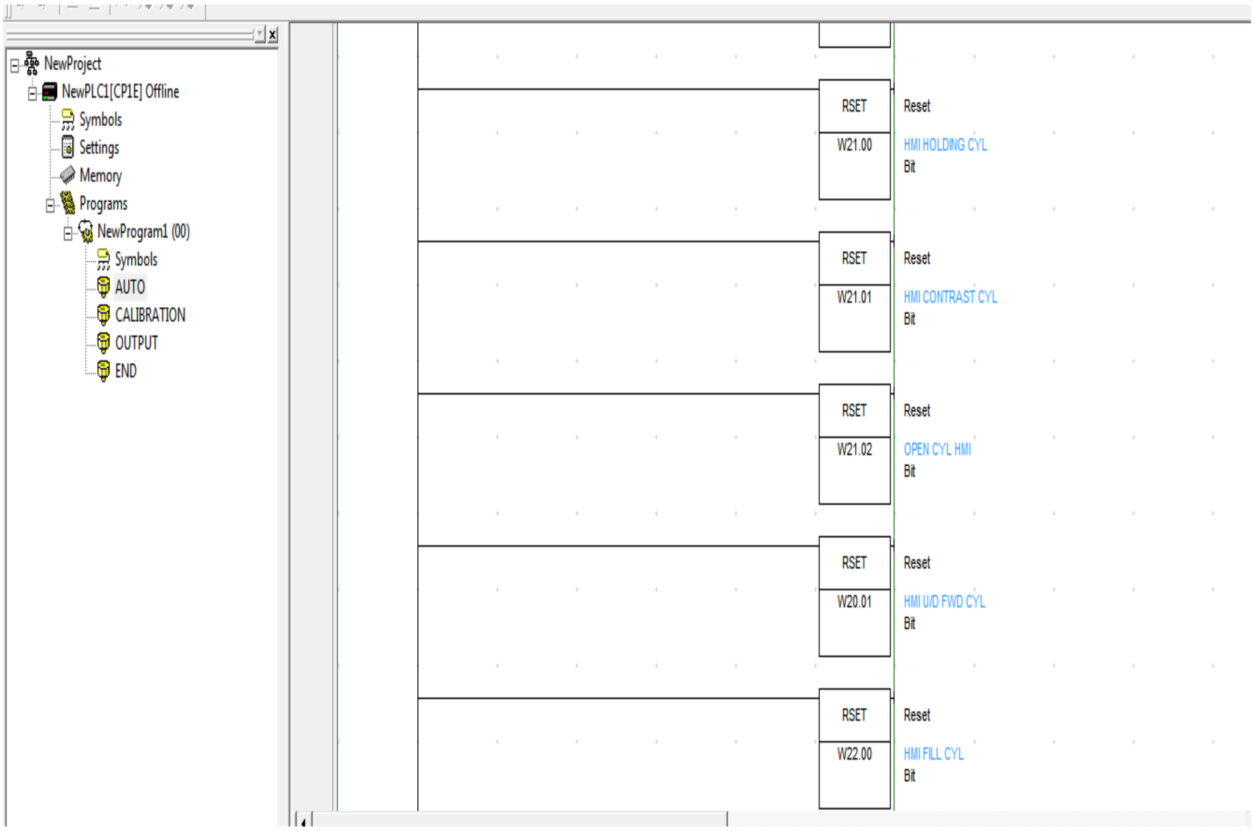


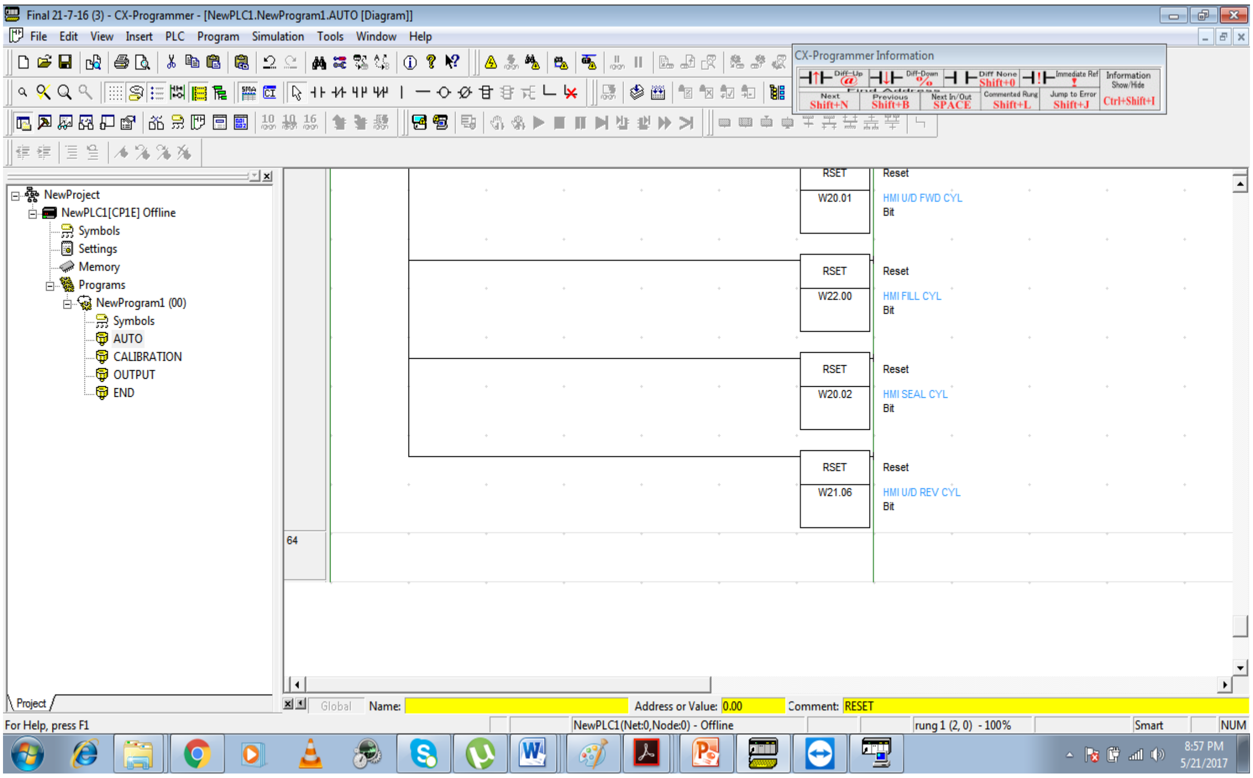
Annexure 10- Reset process





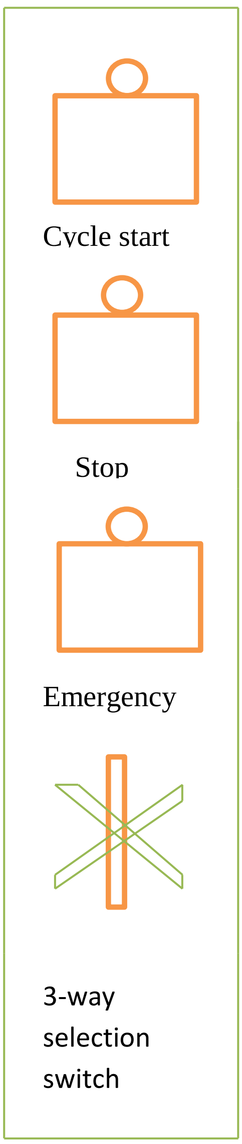
Annexure 11- Final reset process

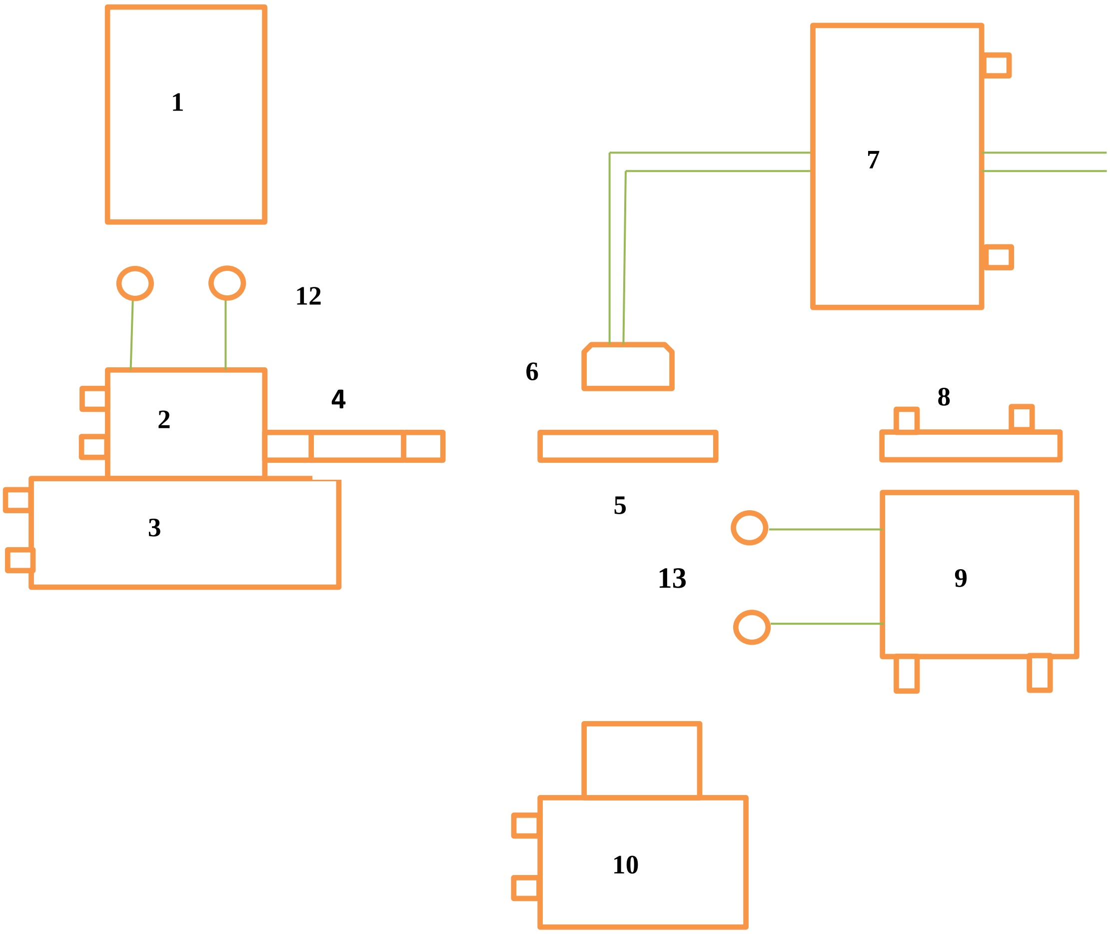




Annexure 12- Schematic diagram of the packaging machine

Operation panel box



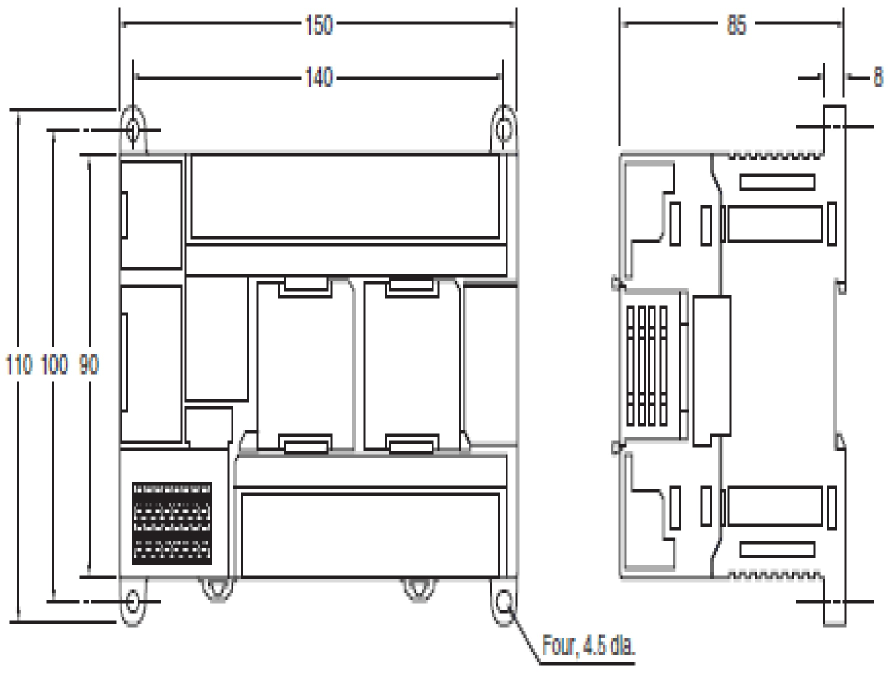


Note

1. Pouch tray
2. Horizontal cylinder (S.A)
3. Rotary cylinder (D.A)
4. Sealing cylinder (S.A)
5. Holding cylinder
6. Filler
7. Storage tank
8. Sealing cylinder
9. Opening cylinder (S.A)
10. Up/down cylinder
11. ▯ -Forward and backward movement sensor
12. , 13- Holder

Annexure 13- PLC used

CP1H XA 40 DR-A



Weight:
CP1H-□□□-A (AC power supply):
740 g max.
CP1H-□□□-D DC power supply):
590 g max.

Annexure 14- Data collection sheet

Company Name- Cavinkare
Department- Department of Packaging
Date- 02-02-2017

Name	Department	Position	Inputs
Ravi Varman	Packaging	Packaging Head	Packaging data
Swaminathan	Packaging	Supervisor	Packaging data and worker details
Michael Rajan	Packaging	Operator	Details about machine and process
Ravichandran	Packaging (Contract)	PLC Programmer Head	PLC program structure
Senthil Kumar	Packaging (Contract)	PLC Programmer Assistant	Existing PLC program details