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MASTER OF SCIENCE IN AUTOMOTIVE ENGINEERING

MASTER THESIS

Analysis of manufacturing processes according to FMEA techniques and Implementation of IoT systems to prevent process failures

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ABSTRACT

Title: Analysis of manufacturing processes according to FMEA techniques and Implementation of IoT systems to prevent process failures

Processes operating within service or manufacturing companies are never perfect. On any given day, challenges may arise that will detract the company from its target objectives. Production and process engineers consider a process to be free of errors. Unfortunately, errors will propagate when people are present in any working module.

Knowing that there is uncertainty, the key to successful operational management is appropriate preparation, which includes creating contingencies that facilitate your organization's restructuring. In its usual way, Six Sigma Methodology provides a tool called Failure Mode Effects Analysis (FMEA), which aims to detect potential failures and eliminate or minimize the risk associated with them before they occur. Process Failure Mode Effects Analysis (PFMEA), based on the success of FMEA

The concept was developed to approach any process to identify risks and potential errors from various sources. Eventually, solutions were provided to prevent these potential failures in the production process. The goal is to set up failed production processes.

Here is the simple manufacturing process of producing pills using the Belloni Mono Eccentric Punch Machine. For these manufacturing processes, PFMEA is used to calculate potential risks and errors from a variety of factors. As a solution, IoT systems are used to control or minimize process failures. This study provides an overall idea of a simple manufacturing process in which the PFMEA application controls associated failures with the help of IoT systems. This allows the production facility to improve its performance, so it provides completeness. The project also explains how to apply these tools to the product or process of a smart manufacturing facility.

Keywords: Tablet Manufacturing Processes, Failure Mode and Effective Analysis, IoT

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Abbreviations

SOP – Standard Operating Procedure

CMAs – Critical Material Attributes

CQA - Critical Quality Attribute

FR - Functional requirements

CA – Customer Attributes

PP – Process Parameters

VOC – Voice of Customer

PD – Product Development

DFM/A – Design for Manufacturing and Assembly

RPN – Risk Priority Number

PCA – Permanent Corrective Action

PE – Process Engineer

NIR – Near Infrared

HPLC – High Performance Liquid Chromatography

SCADA – Supervisory Control and Data Acquisition

MES – Manufacturing Execution System

DCS – Distributed Control System

OOS – Out of Specifications

API – Active Pharmaceutical Ingredient

CHAPTER 1

1. INTRODUCTION

This report gives a summary of the development of the floriculture tablets. It emphasizes a scientific and process-based approach to product and process development and presents findings as a knowledge-based report. Where appropriate, ancillary data are summarized in tables or charts.

It inspires designers to anticipate production processes, focusing on how we can stop critical faults or possible ones that are about to happen. Process failure methods and effects analysis (PFMEA) is a tool for assessing how potential process failure points and failures can be perceived or observed by the customer. A 'customer' is not just an end user, but any user in the product line or anyone in between.

PFMEA is a step-by-step process for analysing a process and identifying and evaluating its critical failure patterns. The tool is best used during the design phase of a project and needs to be updated as the existing system is optimized. Once all the major system failure methods and their associated effects have been identified and weighed, the company itself can arrange for these opportunities to be properly eliminated or frequency reduction based on high priority. Appropriate documentation of potential system failures and associated risks enables continuous improvement efforts such as engineering controls. Once configured on the system, guarantees for enhanced strength can be simplified.

As the saying goes: “Teamwork makes dreams come true”. For an effective PFMEA assessment, a cross-functional panel with a mix of new and experienced eyes is required to ensure that different perspectives are calculated. For example, in the manufacturing process, we would like to make sure that we have all the basics in identifying key system weaknesses with our operational staff, process control team and reliability team of electrical and mechanical engineers at various levels.

With the appropriately identified computer objective, visual representations of the system are then generated, and appropriate indicators of points of weakness are mapped on the map. Continue to divide the process into units until the right amount of detail is found and ask important questions to ensure that the function of each stage is clearly identified with its risks.

1.1. Introduction to Failure Mode and Effective Analysis (FMEA)

There are many high-quality examples of products being remembered because of poorly designed products and / or processes. These failures are portrayed as the inability of manufacturers, service providers and suppliers to deliver a secure product and are discussed in the public forum. Failure Method and Impact Analysis, or FMEA, is a method of identifying all possible failures in a design or production process and allowing companies to anticipate failure at the design stage. Developed in the 1950s, FMEA was one of the first methods of improving structured reliability. Even today it is a very effective way to reduce the chances of failure.

1.1.1. What is Failure Mode and Effective Analysis (FMEA)?

Failure Method and Consequences Analysis (FMEA) is a structured approach to detect potential failures within the design of a product or process. Failure methods are ways in which a process fails. These failures are the consequences of ways that lead to waste, defects, or detrimental effects to the customer. Failure Method and Consequences Analysis These failure patterns are designed to identify, prioritize, and control.

FMEA is no substitute for good engineering. Conversely, it promotes good engineering by utilizing the knowledge and experience of a cross-operational team (CFT) to evaluate the design progress of a product or process, assessing its failure risk.

1.1.2. Why Failure Mode and Effective Analysis (FMEA)?

Historically, the sooner a failure is detected, the lower the cost. If a failure in product development or release is detected too late, its impact will be exponentially further catastrophic. FMEA is the tool to detect failure in its early stages in product or process design. Product Development (PD) using FMEA provides the benefits of:

- Many options for mitigating risk
- High ability to verify and validate the changes
- Collaboration between product and process design
- Improved design for production and assembly (DFMEA)
- Low-cost solutions and consistent job application

Ultimately, this method will help detect and correct process failures early on to avoid the negative consequences of poor performance.

1.1.3. When to perform Failure Mode and Effective Analysis (FMEA)?

There are several methods that can make sense of failure mode and consequences analysis:

- When you design a new product, process, or service
- When you plan to do the existing process in a different way
- When you have a goal to improve the quality of a particular process
- When the failures of a process need to be understood and improved

It is a good idea to do FMEA occasionally throughout the life of a process. Quality and reliability should be constantly reviewed and improved for best results.

1.1.4. How to do Failure Mode and Effects Analysis (FMEA)

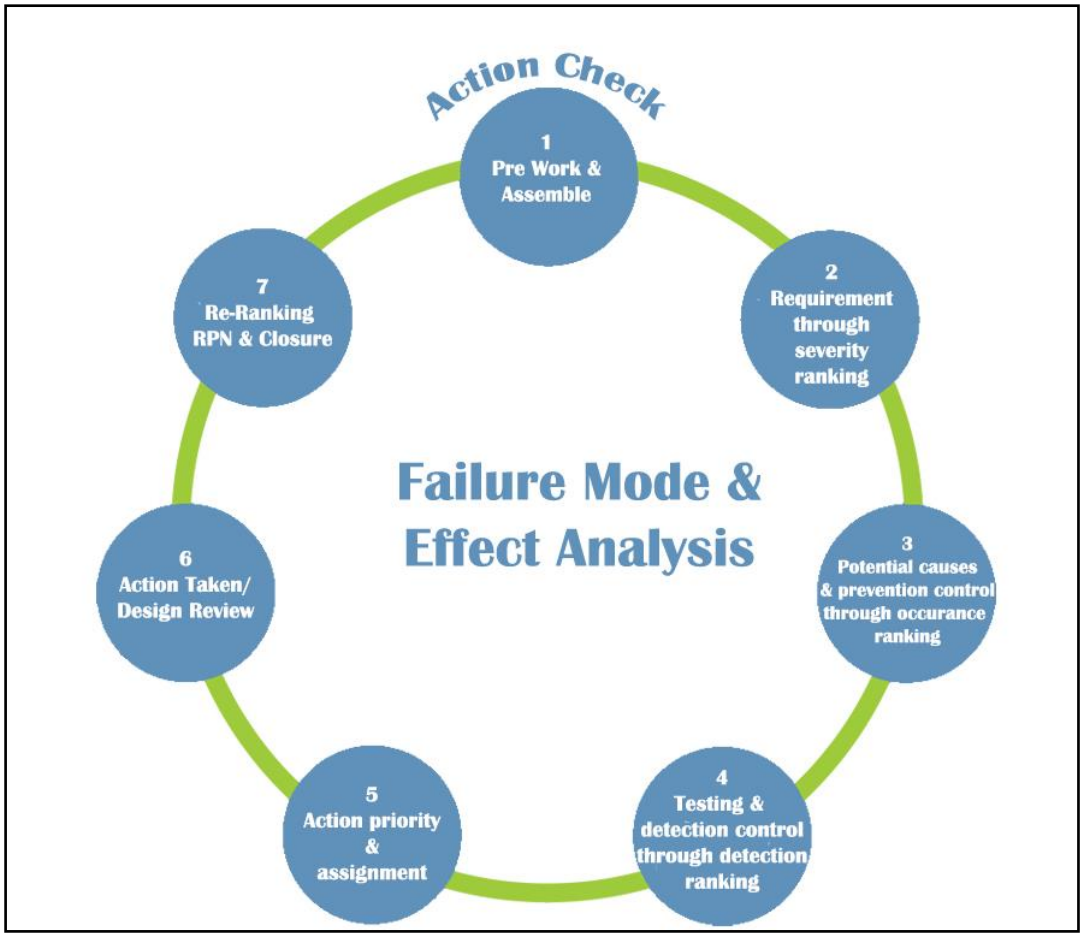
FMEA is done in seven steps, with key functions in each step. The steps are divided to ensure that there are only appropriate team members for each study.

The FMEA approach using Quality-One was developed to avoid the usual risks of making the analysis slow and ineffective. The Grade-One three-way model allows process priority and efficient use of team time.

Seven steps to create FMEA	
1.	Assemble the FMEA Pre-Work and FMEA Team
2.	Path 1 improvement (requirements with strict ranking)
3.	Path 2 Improvement (Possible Causes and Prevention Controls by Event Ranking)
4.	Path 3 development (testing and detection controls by detection ranking)
5.	Action Priority & Assignment
6.	Actions taken / design review
7.	Rank RPN & Closure

Table 1: Steps involved in creating FMEA

The following figure shows the clear description about the Failure Mode and Effective Analysis steps that supports developing any process or product in a better way.



1.1.5. FMEA Document Analysis

Deciding when to act on FMEA has historically been determined by RPN limits. Quality One does not recommend the use of RPN limits for setting action goals. Such goals are believed to reverse group behaviour because groups choose to get lower numbers below the threshold and are not at real risk but need mitigation.

An FMEA's analysis should include several level considerations, including:

- Intensity 9/10 or security and regulation only (failure mode actions)
- Critical combinations for severity and event (causal actions)
- Detection controls (testing and control project activities)
- RPN pareto

When completed, the actions will move the risk from its current level in the Quality-One FMEA Criticality Matrix to a lower risk level.

1.1.6. RPN action priority

When risk is determined to be unacceptable, Grade-One recommends the following action priorities:

- ✓ Error verification (eliminating the cause of the failure mode or address)
  - Failure mode (9 or 10 intensity only)
  - Causes with high incidence
- ✓ Improve potential process efficiency
  - Increase Tolerance (Tolerance Design)
  - Minimize process variability (statistical process control and process efficiency)
- ✓ Improve controls
  - Proof of error of tool or process
  - Improving research / evaluation techniques

1.1.7. FMEA relationship to problem solving

Failure methods in an FMEA are equivalent to problem reporting or problem announcement in solving the issue. The causes in FMEA are equal to the possible root causes in solving the problem. The consequences of failure in an FMEA are symptoms of problem solving. Additional examples of this relationship are:

- Issue reports and explanations are linked between the two documents. Problem-solving methods are completed quickly using pre-accessed information that is easily detectable from FMEA.
- Possible causes in an FMEA are used to immediately launch Fishbone or Ishikawa maps. Brainstorming already known information does not use time or resources properly.
- Data collected from problem solving is stored in an FMEA for future planning of new products or process quality. This allows an FMEA to consider real failures, categorized as failure methods and causes, and makes FMEA more effective and complete.
- The design or process controls in an FMEA are used in verifying the root cause and Permanent Corrective Action (PCA).
- The FMEA and Problem Solving reconcile each failure and cause by cross documenting failure modes, problem statements and possible causes.

There are two broad categories of FMEA,

- Design FMEA (DFMEA)
- Process FMEA (PFMEA)

1.2. Introduction to Design Failure Mode and Effective Analysis

DFMEA is a systematic approach to identifying potential risks introduced in a new or modified design of a product/service.

- Design FMEA initially identifies design processes, failure patterns, and impact on the customer with the severity rating/impact risk.
- Then, the causes of the failure system and their mechanisms are identified. The high probability causes indicated by the event rankings may be used to prevent or minimize the impact of the cause in the failure mode.
- Detection rankings demonstrate the ability to confirm the failure mode of specific tests/causes removed. Monitors DFMEA improvements through Risk Priority Number (RPN) reductions. By comparing back and forth to the RPN, the progress and risk mitigation history can be described.

Steps involved in developing DFMEA

✓ Step: 1 Define Failure Modes & Severity
✓ Step: 2 Define Causes & Mechanisms of Failure
✓ Step: 3 Define Current Design Controls
✓ Step: 4 Compute for RPN
✓ Step: 5 Repeat Until Desired RPN is Obtained

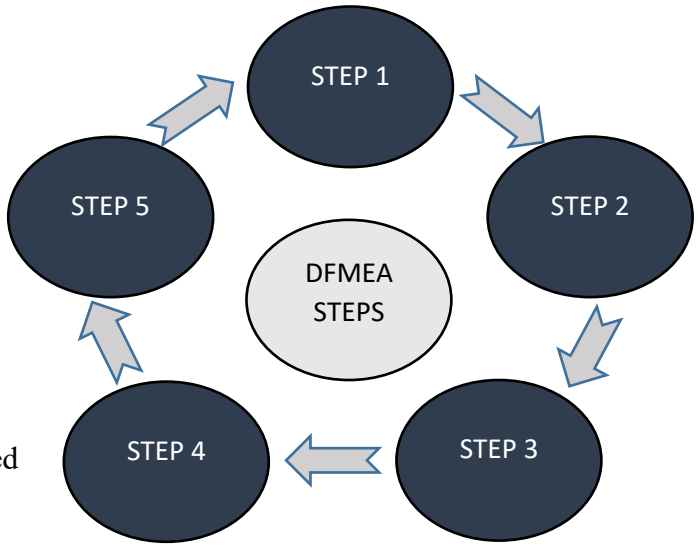


Figure 1: DFMEA Steps

1.2.1. DFMEA Steps

Design FMEA explores the possibility of product malfunctions, reduced product life, and safety and regulatory concerns derived from:

- Material Properties
- Geometry
- Tolerances
- Interfaces with other components and/or systems
- Engineering Noise: environments, user profile, degradation, systems interactions

1.2.2. Definition of Failure Modes & Severity

Potential Effects is Evaluated According to a Decimal Scale Value		
Effects	***Criteria : Severity of Effect***	***Rank***
Hazardous without Warning	When a Failure mode affects safe devoce Operation without Warning	*10*
Hazardous with Warning	When a Failure mode affects safe devoce Operation with Warning	*9*
Very High	Device Inoperable: Primary Function Loss	*8*
High	Device Operable: At a Highly reduced level of performance	*7*
Moderate	Device Operable: At at reduced level of performance	*6*
Low	Device Operable: At a slightly reduced level of performance	*5*
Very Low	Device Operable: Defect noticed by Most Customers	*4*
Minor	Device Operable: Defect noticed by Average Customers	*3*
Very Minor	Device Operable: Defect noticed by discriminating Customers	*2*
None	Almost No Effect	*1*

Table 2: Severity Selection Criteria for FMEA Process

1.2.3. Definition of Causes & Mechanisms of Failure

Potential Effects is Evaluated According to a Decimal Scale Value			
Probability of Failure	***Criteria : Occurence of Cause (DFMEA)***	***Criteria : Possible Failures Rates***	***Rank***
Very High	New technology/ new design	≥ 100 per thousand ≥ 1 in 10	*10*
High	Failure is unavoidable in new design, new application	50 per thousand 1 in 20	*9*
	Failure is acceptable with new design, new application	20 per thousand 1 in 50	*8*
	Failure is unrelaible with new design, new application	10 per thousand 10 in 100	*7*
Moderate	Frequent failures related with similar design, simulation and Testing	2 per thousand 1 in 100	*6*
	Occassional failures related with similar design, simulation and Testing	.5 per thousand 1 in 2,000	*5*
	Detached failures related with similar design, simulation and Testing	.1 per thousand 1 in 10,000	*4*
Low	Only Detached failures related with similar design, simulation and Testing	0.1 per thousand 1 in 1,00,000	*3*
	No observed failures related with exact design, simulation and Testing	≤001 per thousand 1 in 1,00,000	*2*
Very Low	Failure is neglected through preventive measures	Failure is eliminated through preventive measures	*1*

Table 3: Occurrence Selection Criteria for FMEA Process

1.2.4. Definition of Current Design Controls

Likelihood of Detection of Design Failures			
Opportunity for Decision	*Criteria: Detection of Design Control*	*Rank*	*Likelihood of*
No Detection Opportunity	No current Design control	10	Almost Impossible
Not likely to detect at any stage	Weak Detection by Design Analysis/Detection controls. Not correlated to actual operating conditions	9	Very Remote
Post Design freeze and prior to launch	With pass/fail testing prior to launch for product verification/validation after design freeze	8	Remote
	With test to failure testing prior to launch for product verification/validation after design freeze	7	Very Low
	With degradtion testing prior to launch for product verification/validation after design freeze	6	Low
Prior to Design Freeze	Product validation, relability, Development & Testing prior to design Freeze using pass/ Fail	5	Moderate
	Product validation, relability, Development & Testing prior to design Freeze using test to failure	4	Moderately High
	Product validation, relability, Development & Testing prior to design Freeze using degradation	3	High
Virtual Analysis - Correlated	Virtual Analysis (CAE, FEA) is higly correlated with actual or expected operating conditions prior to design	2	Very High
Detection not Applicable; Failure Preventation	Preventation of Faliure Mode or Failure Cause using through Design Solutions	1	Almost Certain

Table 4: Detection Selection Criteria for FMEA Process

1.3. Introduction to Process Failure Mode and Effective Analysis (PFMEA)

Process FMEA (PFMEA) derived from failure affecting product quality, decreased operational reliability, customer dissatisfaction and safety or environmental risks:

- Human factors
- Methods to be followed during processing
- Materials used
- Machines used
- Measurement methods affect acceptance
- Environmental factors on process performance

Production and process engineers consider a process to be free of errors. Unfortunately, errors and errors that are spread especially when there are people can be very disastrous. Process Failure Method and Impact Analysis (PFMEA) looks at each process step to identify risks and potential errors from different sources. Most Considered Sources:

- Man – Methods – Materials – Machines – Measurement – Mother Earth.

1.3.1. What is Process Failure Method and Impact Analysis (PFMEA)?

PFMEA is a systematic approach used to identify the risks involved in process changes. Process FMEA initially identifies process functions and formalizes their effects on the failure processes. If there are design inputs or special properties, the end user effect will also be added. The severity rating or risk of the outcome is determined for each outcome of the failure. Then, the causes of the failure system and their mechanisms are identified.

The assumption that design is adequate focuses on the process. The higher the probability of a cause, the more likely it is that the failure mode will enable actions to prevent or minimize the impact of the cause. Detection rankings determine the ability to confirm the failure mode of specific tests / causes are eliminated. PFMEA monitors improvements through Risk Priority Number (RPN) reductions. By comparing back and forth to the RPN, the progress and risk mitigation history can be described.

1.3.2. Why Process Failure Method and Consequences Analysis (PFMEA) should be done?

There is a risk of failure as an alternative to new processes. It is a good practice to identify the risks involved in each process as quickly as possible.

The main goal is to identify the risk before acquiring the tool. Reducing the risk identified prior to the first article or production area approval process (PPAP) will ensure the expectation for better process performance.

Risks are identified in new technology and processes that, if left unattended, can result in failure. When is PFMEA used:

- A new technology or new process that is introduced
- There is a current process with changes, that may include changes due to updated processes or operations, continuous improvement, Kaizen or Cost of Quality (COQ).
- There is a current process of exposure to change in a new environment or location (no physical change made to implement)

1.3.3. How to do Process Failure Method and Consequences Analysis (PFMEA)

There are five primary sections to the FMEA process. Each section has a separate purpose and a different focus. The PFMEA project is completed in sections at different times within the time frame, not all at once. Process The FMEA form is completed in the following order:

PFMEA Section 1 (Grade-One Path 1)

Process name / function

The process name / function column allows you to describe the process technology to be analysed by the process (PE) or production engineer (ME). Process A production function or an assembly. The function is the "verb-noun", which describes what the process function does. There can be many functions for any one process.

Requirement

The requirements or measurements of the process are described in the second column. Requirements are provided by a map or list of special properties. One of the characteristics is the matrix, which is a form of standard functional sorting (QFD) that combines properties with their process functions. Demand should be measurable and testing and inspection methods should be defined. These methods will then be placed in the control program. The first opportunity for the recommended action may be to explore and clarify the product needs and describe the product with the design team and design FMEA.

Failure methods are those in which the opposite functions or requirements are not met. There are 5 types of failure methods:

- Complete failure
- Partial failure
- Intermittent failure
- Depressed failure
- Unexpected failure

Consequences of failure

The effects of failure focus on processes, subsequent operations, and customer impact. Many consequences are possible for anyone failure method. All effects should appear in a single cell next to the associated failure mode. It should also be noted that there may be more than one customer; Internal and external customers may be affected.

Severity

The depth of each effect is selected based on process effects and design effects. The severity rating is usually 1 to 10.

- ✓ The typical intensity of process effects (when special properties / design inputs are not provided) is as follows:

- 2-4: Minor interruption with rework / adjustment at stations; Reduces productivity (does not describe a lean function)
- 5-6: Minor interruption in rework outside the station; Additional functions required (not describing a slim function)
- 7-8: major disruption, rework and / or scrap preparation; You can stop taxes within the customer or within the company
- 9-10: Regulation and safety of the station is of concern; Machine / tool damage or unsafe working conditions

✓ The typical severity of design effects (when special properties / design inputs are provided) is as follows:

- 2-4: irritation or noise and noise; Visual impairments that do not affect function
- 5-6: Decomposition or loss of secondary function of the material under study
- 7-8: Decomposition or loss of the primary function of the material under study
- 9-10: Regulatory and / or security impacts

High intensity is selected from several possible effects and placed in the intensity column. In the 9th or 10th place the actions that can change the design direction in any failure mode with the result of failure can be identified. If the recommended action is identified, it will be placed in the PFMEA's recommended actions column.

Classification

Classification refers to the type of attribute represented by risk. There are many different types of specialties in different professions. These special properties require additional work on design error verification, process error verification, process variance reduction, or error verification. The taxonomy column specifies the locations where the characteristics will be identified and then transferred to the control program.

PFMEA Section 2 (Grade-One Path 2)

✓ Possible causes / mechanisms for failure

The causes of the failure mode are defined and their impact on the failure mode to be analysed must be determined. The causes generally follow the Fishbone / Ishikawa map approach, because the brainwashing focuses on 6M: man, method, object, machine, measurement, and Mother Earth (environment). The use of terms such as bad, bad, defective and failure should

be avoided because they do not make risk calculations to mitigate the cause with sufficient detail.

- ✓ Prevention of current process controls

The prevention strategy used by the production or process team can benefit the process by reducing the incidence or probability. Strong prevention can eliminate potential cause through process design. The use of verified process standards, proven technology (with similar stresses), programmable logic controllers (PLC), simulation technology, and standard work assistance are routine preventive controls.

- ✓ Event / Occurrence

Event ranking is an estimate made based on known data or its scarcity. Events in process FMEAs may be related to known / similar technology or new process technology. Modification of the ranking table is recommended based on modules and specific usage.

The regular event rankings for new process technology (such as the DFMEA event rankings) are as follows:

1: Reasons for blocking the use of known design standards

2: Uniform or similar design with no history of failure

This ranking is often misused. To select this rating value, samples of sufficient products are required to obtain pressures and history in the new application.

3-4: Isolated failures

There may be confusion when trying to calculate the "isolated" level

5-6: Occasional failures in field or development / verification test

7-9: New design without history (based on current technology)

10: New design with no experience in technology

PROBABILITY of Failure	Failure Prob	Ranking
Very High: Failure is almost inevitable	>1 in 2	**10**
	1 in 3	**9**
High: Repeated failures	1 in 8	**8**
	1 in 20	**7**
Moderate: Occasional failures	1 in 80	**6**
	1 in 400	**5**
	1 in 2,000	**4**
Low: Relatively few failures	1 in 15,000	**3**
	1 in 150,000	**2**
Remote: Failure is unlikely	<1 in 1,500,000	**1**

Table 5: Occurrence ranking table

Measures can be taken against the causes of failure with high incidence. Special attention should be paid to materials with an intensity of 9 or 10. These severity ratings should be examined to ensure that due diligence is satisfied.

PFMEA Section 3 (Grade-One Path 3)

- ✓ Detection of current process controls:

Operations conducted to verify the product sees the specifications described by the product or process design are placed in the Current Process Controls detection column.
Examples are:

- Error verification devices (cannot create incompatible product)
- Error verification devices (cannot send incompatible product)
- Research devices that collect variable data
- Alarms for unstable process parameters
- Visual inspection

- ✓ Detection (D) Ranking

Detection rankings are assigned to the study based on each method or type of technique used. All detection rankings are provided using a predetermined quantity for each detection control. There is often more than one test / evaluation technique in a cause-failure mode.
The best practice is to list everything in a single cell and use the diagnostic rankings for each. The lowest in the detection rankings will be placed in the detection column. The typical process control diagnostic rankings are as follows:

- ✓ 1: The error (cause) is completely blocked and cannot occur
- ✓ 2: Error detection at the station will not allow incompatible product to be created
- ✓ 3: Failure detection at the station will not allow incompatible product to be sent
- ✓ 4: Failure detection outside the station will not be sent to the plant / customer
- ✓ 5-6: variable gauge, attribute gauges, control charts, etc. Operator required to complete the operation.
- ✓ 7-8: Visual, tactile or auditory study
- ✓ 9: Lots of samples by research staff

- ✓ 10: No restrictions

Measures may be required to improve research or assessment efficiency. This improvement will address weaknesses in the research and evaluation strategy. Actions The recommended actions are placed in the column.

PFMEA Section 4

- ✓ Risk Priority Number (RPN)

Risk priority number (RPN) is the product of three previously selected rankings, intensity * event * detection. RPN limits should not be used to determine the need for operation. RPN limits are not allowed for two main reasons:

- Bad behaviour of design engineers who try to fall below a certain limit
- This behaviour does not enhance or address the risk. No RPN value is required to be taken above or below that group.
- "Relative risk" is not always specified by the RPN

- ✓ Recommended activities

The Recommended Actions column is where all possible improvements to the process FMEA are placed. Completed actions are the purpose of PFMEA. Actions should be detailed enough to make sense if they are alone in a risk record or list of actions. Actions are executed against one of the previously assigned rankings. The objectives are as follows:

- Eliminate failure patterns with severity 9 or 10
- Less occurrence of causes by error correction, variance reduction or error correction
- Low detection in specific test improvements

- ✓ Responsibility and goal completion date

Enter the name and date to complete the process. If the timeline shows the relationship between the date and the selected milestone, a milestone name will be an alternative to the date.

PFMEA Section 5

- ✓ Actions taken and date of completion

List the actions taken or refer to the test report indicating the results. The FMEA process should result in actions that bring high risk materials to an acceptable risk level. It should be noted that acceptable risk is desirable and mitigation of high risk to low risk is the primary goal.

- ✓ Ranking RPN

The new (re-ranked) RPN should be compared with the original RPN. It is desirable to reduce this value. Once the measures are taken, the remaining risk may be even higher. If so, a new action sequence will be created. This is repeated until an acceptable residual risk is obtained.

1.4. Study Outline

The dissertation is organized as follows.

Chapter 2: Introduction to Tablet Compression Machine, Description of Production Process

Chapter 3: Implementing PFMEA in the Production Process

Chapter 4: Implementing IoT Systems to Prevent Process Failures

Chapter 5: Conclusion

CHAPTER 2

2. INTRODUCTION TO THE TABLET COMPRESSION MACHINE

DESCRIPTION OF PRODUCTION PROCESS

In this section, we will see the introduction of the tablet compression machine and its functions. And detailed description of Production processes.

2.1. Introduction to the Tablet Compression Machine

The preparation of oral solid-sized granule forms such as tablets is a complex multi-stage process under which the starting materials change their physical properties several times before the final dosage form is prepared.

Traditionally, tablets are made by granulation, which provides the two primary properties of compression and fluidity. After the particles have been prepared (in case of wet granulation) or by slacking (in the case of dry granulation) or after mixing the materials (in direct compression) they are compressed to obtain the final product. Abbreviation is done by either single punching machine (stomping press) or multi station machine (rotary press).

The tablet press is a high-speed mechanical device. Its 'presses' the material very precisely into the desired tablet form. It can be made into a tablet in many shapes, although they are usually round or oval.

Each tablet is made by pressing the particles inside a dye made of hardened effluent. The tie is a disk shape with a hole cut in its centre. The powder is compressed into two hardened steel punches in the centre of the tie, which are applied to the top and bottom of the tie. The punches and descents are mounted on a circular rotating tower.

As it rotates, the punches are driven together by two fixed cams with an upper cam and a lower cam. The top of the top punch (punch head) sits on the edge of the upper cam. The bottom of the bottom punch sits on the bottom cam edge.

There are two types of the Compression Machine

- Single Punch / Single Station / Eccentric Press
- Multi-Station / Rotary Press

2.1.1. Single Punch/Single Station/Eccentric Press

- Single Punch is a simple machine for making tablet presses, also known as Eccentric Press or Single Station Press.
- This machine uses a set of station tooling (a tie and a pair of lower and upper punches).
- The compression force on the filler is applied only by the upper punch, while the lower punch is a constant action equivalent to the hammer motion, and as a result the single punch pressure is referred to as the stamping process.
- The single punch tablet press typically produces 60-85 tablets / min.

Figure 2: Mono Eccentric Punch Machine

Advantages of Single Punch Tablet Press

- Single punch system is rational and small.
- Easy to operate and operates at a high application rate.
- It can produce odd, shaped products up to 20 mm in diameter.
- It is suitable for tablets and small volume production development.
- Single punch tablet press, at the same time using high pressure to reduce weight variations between tablets while maintaining low noise level.

2.1.2. Multi-Station \ Rotary Press

The multi-station press is a mechanical device that, unlike a single punch tablet press, has several tool stations that compress the particle / powder mixture into tablets of uniform size, shape (depending on the punch design) and uniform weight. It was created to increase the release of tablets.

In the rotary press, the compression force on the filler material is applied by the upper and lower punches, compressing the powder particles in the middle. This is called the accordion

type of pressing. The ability of a rotary tablet press is determined by the rotational speed of the tower and the number of stations in the press.

Advantages of Rotary Press

- One can get more productivity with less labour while saving money.
- Rotary Press has an output between 9000 - 234000 tap / h, thus saving time and meeting the high demand of the tablet dose form.
- Powder filled pit can be managed automatically by moving feeder.
- Rotary Press reduces waste of valuable formula on unspecified tablets.
- Allows the machine to control both weight and stiffness independently.

2.1.3. Differences between Single Punch Tablet Press and Rotary Tablet Press

Two main differences between a Single Punch Tablet Press and a Rotary Tablet Press are

- Single punch tablet presses use single page compression to make tablets, while Rotary presses use double page compression.
- Single punch tablet press compression cycles do not have a stay time (dwell), whereas rotary presses typically use a punch head flat which activates a dwell time.

2.2. Details about the punch machine considered in this study

Single Punch Tablet Press, is also known as Eccentric Press or Single Station Press, is the simplest machine considered in this project for tablet production.

This is a simple manufacturing process carried out for the preparation of tablets used in vegetable garden floriculture. The current Belloni Eccentric Automatic Compression Machine was designed and built to the modern level prior to the implementation of the Machinery Directive 89/392 EEC.

The machine identification data is given below:

- Belloni Mono eccentric automatic compression engine
- 3000 tablets per hour
- Department: Floriculture of vegetable gardens

Features	Template 2	Template 3/B
Maximum diameter of punches	25 mm	35 mm
Work pressure	3500 kg	6500 kg
Engine power	1.2 kw	1.6 kw
encumbrance	550 * 630 mm	800 * 850 mm
height	1650 mm	1750 mm
Net weight	330 kg	550 kg
beats per minute	45	35

Table 6: Machine Data

The compression force on the filler material is applied only by the upper punch, while the lower punch is fixed; The action equivalent to the hammer motion and, consequently, the single punch pressure is referred to as the stamping process.

The number of pieces that can be produced is given by

Number of Pieces / hours = Shots per minute x 60

2.3. Composition of the machine

The eccentric and limited tablet press essentially from:

- Structure or body in cast iron
- Flywheel shifter of cast iron double pipe
- Group movement
- Group press
- Control panel
- Electric motor

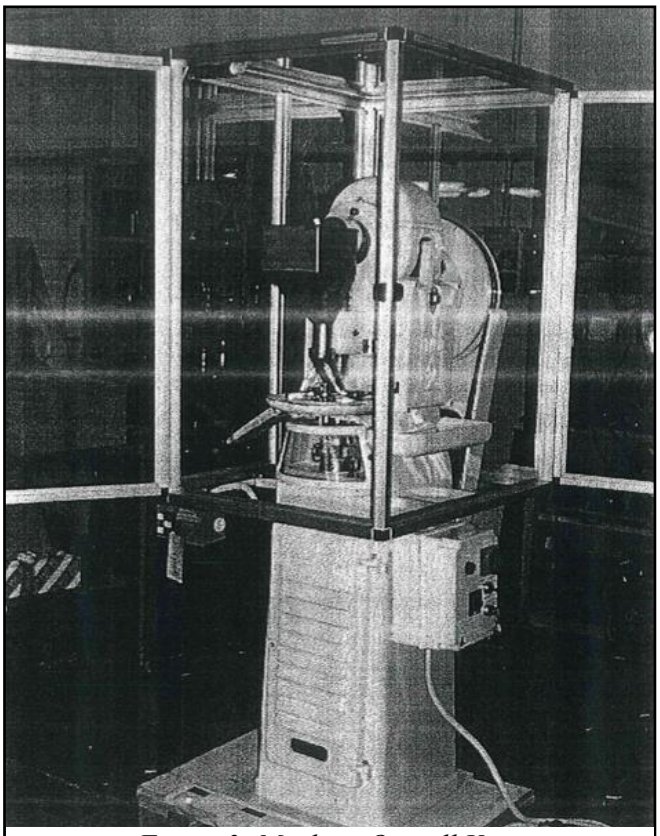


Figure 3: Machine Overall View

Machine body: It is composed of a cast iron and the casting is painted blue. The fusion is hollow internally and is made up of two parts: the inferior has the specific support task, while the upper one has the task of supporting all the mechanisms.

The two parts are bolted together and form a single whole.

In the inferior part is housed the electric motor which gives the movement to the whole complex (Figure 3). There are also two compartments for the storage of service tools, the manual and small objects of use. Everything is covered by a cast iron carter that must be opened using Allen keys.

The upper part carries three bearings: two for the through shaft of the movement and one for the flywheel pulley.

The movement group is protected by a cast iron cap (Figure 4), also held by Allen screws.

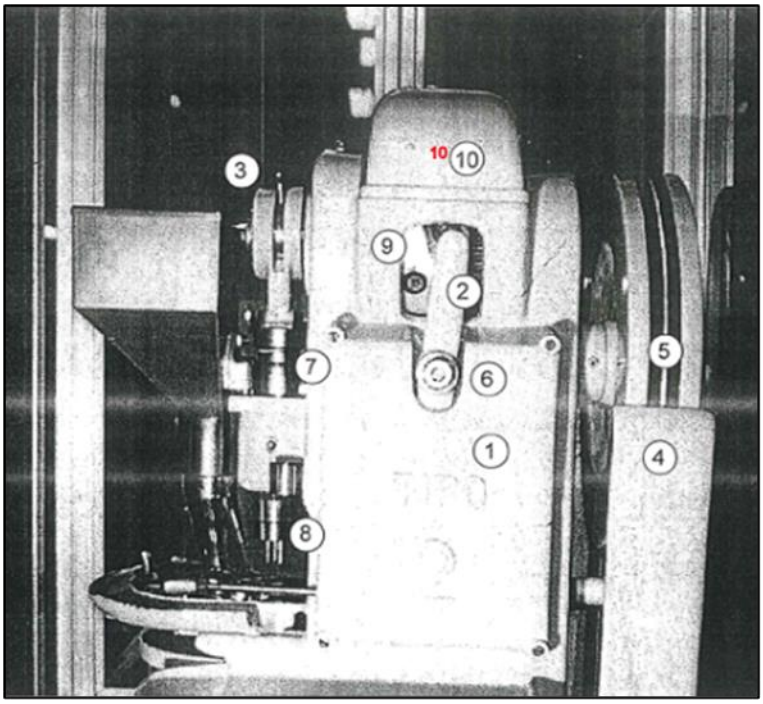


Figure 4: Press Movement Group

Press Movement Group

1. Protection Guard
2. Lever movement lever
3. Top punch eccentric cam
4. Carter protection belt
5. Pulley fly with double groove
6. Lever stop bolt
7. Punch holder rod
8. Upper punch
9. Hopper
10. Protective cover

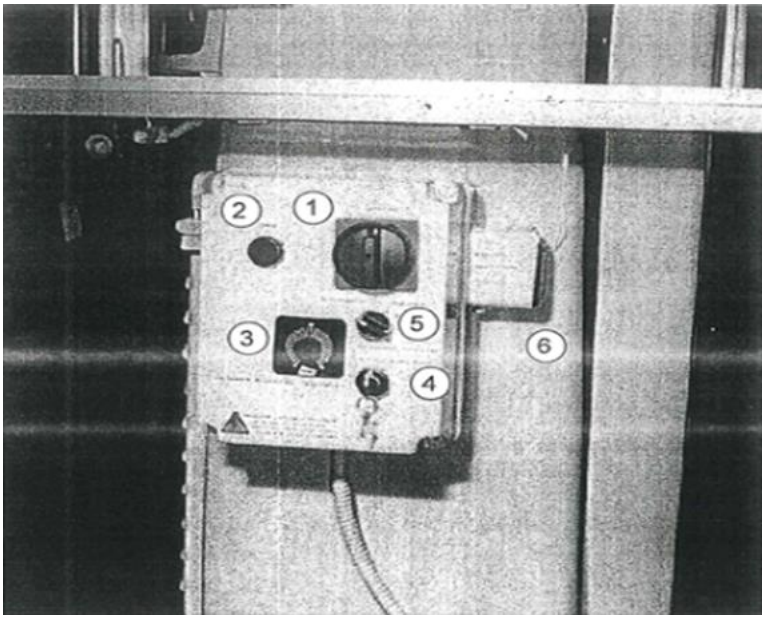


Figure 5: Press Electric Square

Press Electric Square

1. General Switch
2. Network Indicator Light
3. Aspirator Speed Regulator
4. The Aspirator Insertion Switch
5. Pulse Start Command
6. Suction Socket

The flywheel and the pulley are made of cast iron for the rotation of the movement group. It has a double groove to house the two belts that connect it to the small pulley. On the other side of the through shaft it is connected the pinion which transfers the rotation to the gear of the shoe forming cam.

The small pulley is forced on the axis of the electric motor and serves to transfer the movement to the compression device by means of the flywheel pulley. (Figure 4 & 5)

All movement, pulleys, and belt, are enclosed by the guard (Figure 5)

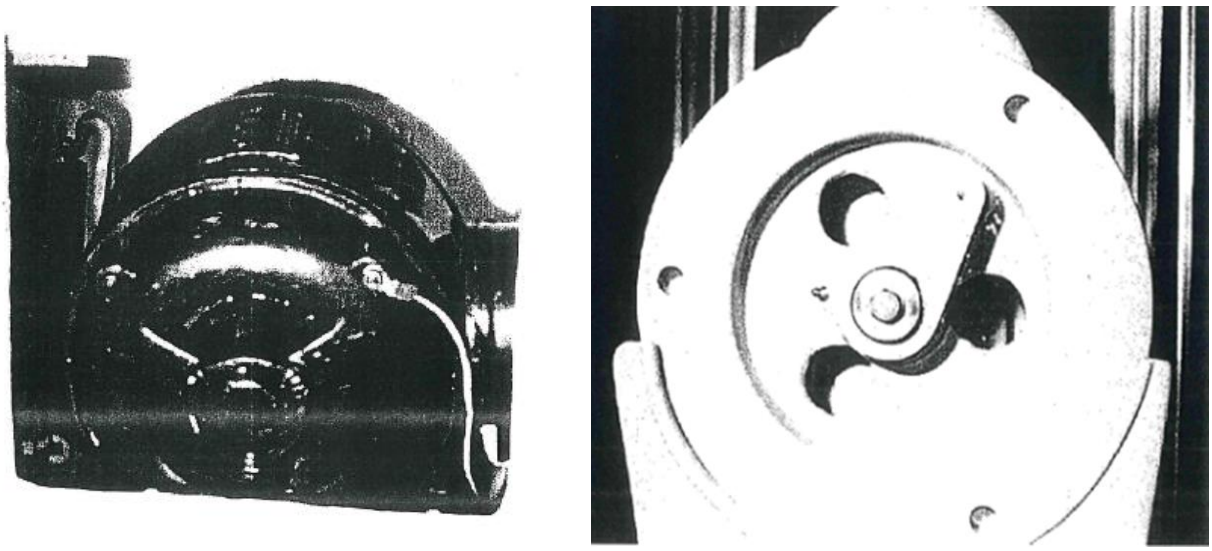


Figure 6: Flywheel Pulley

Movement group

Is formed from

1. Steel through shaft
2. Range with gear (Figure 8)
3. Eccentric lower punch movement
4. Eccentric upper punch movement (Figure 7)
5. Punch holder shaft

The alternate movement of the upper punch is obtained through the front eccentric. The coaxial eccentric controls the movement of the lower punches by means of rockers and a contrasted shaft**.**

Eccentric upper punch

1. Eccentric
2. Bolt
3. Pressure adjustment lever
4. Punch holder shaft
5. Alarm cam connection

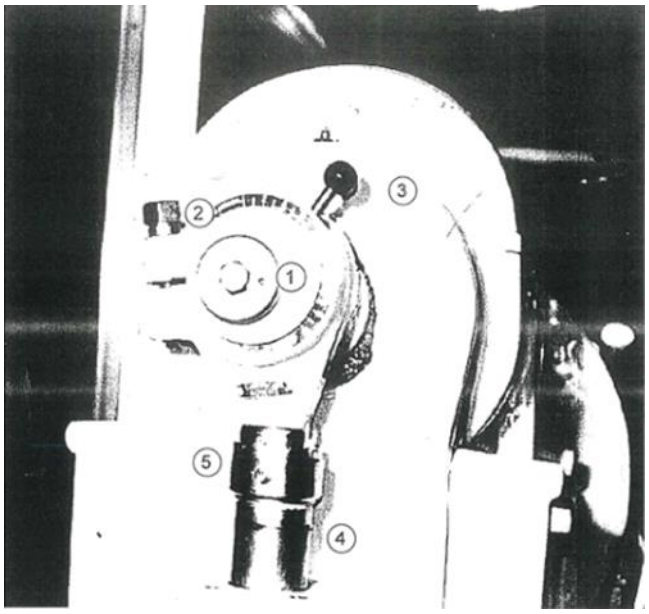


Figure 7: Details of Eccentric Upper punch

Press group

The press unit consists of

1. Upper punch
2. dosing shoe
3. door mold
4. lower punch
5. pressure regulator
6. volume regulator
7. stop regulator

The lower punch slides in the mold holder and the agenda must be adjusted on the adjustment devices. It receives movement from the eccentric coaxial to the shaft of the movement group.

The dosing shoe receives movement from the grooved cam (Figure 8) by means of a lever (Figure 4) and a transmission arm. His movement and alternating rotation, covering, and uncovering the lighthouse of the mold. It also carries the detaching knife for the pad.

The mold holder is a simple steel element that carries the mold.

The upper punch is simply inserted into the shaft by means of a bolt.

The pressure regulator and the stop regulator are two serrated disks kept locked by a spring device.

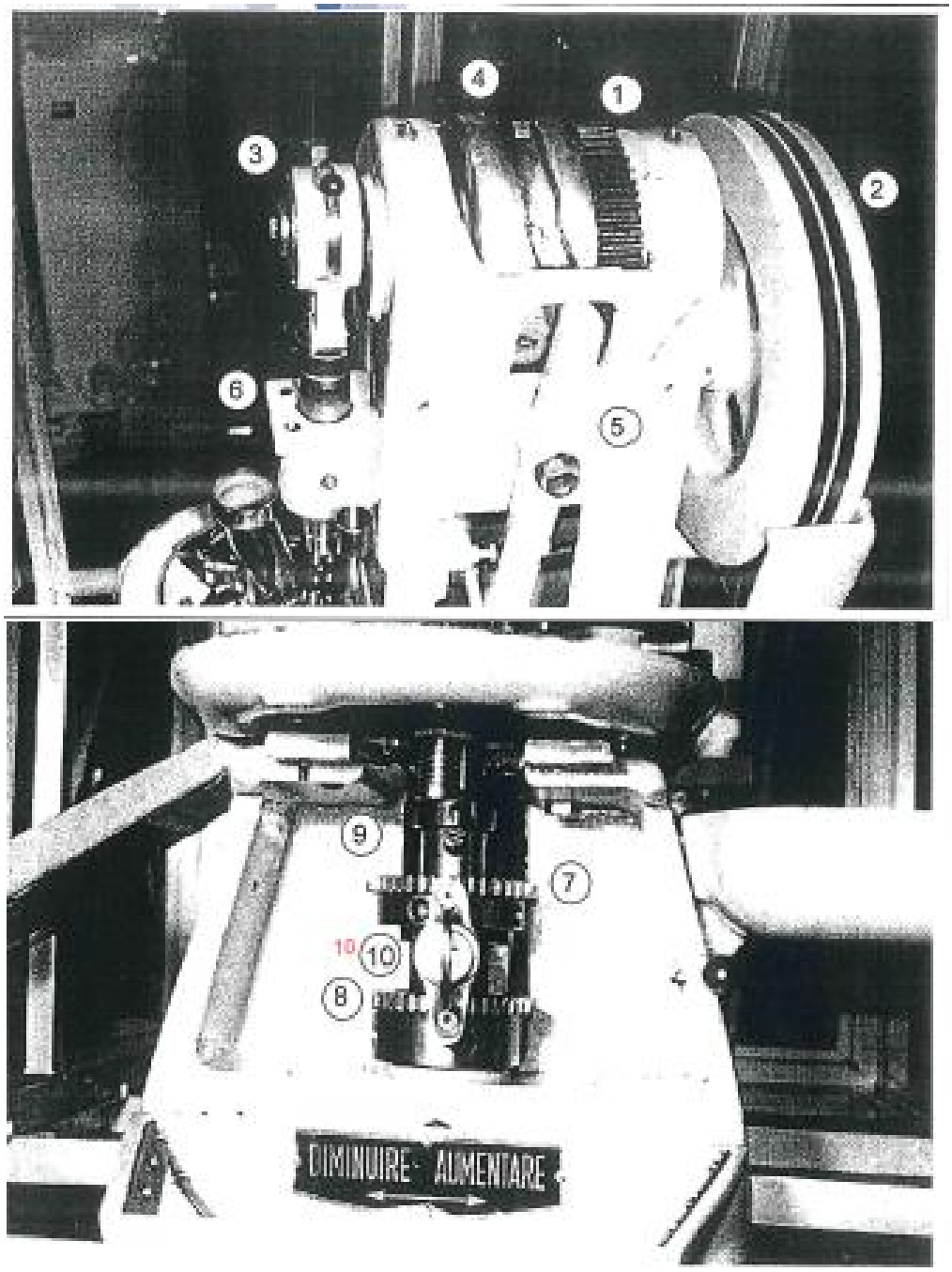


Figure 8: Compression Press Movement Group

1. Start stop button

2. Emergency stop

3. Box for protection and soundproofing

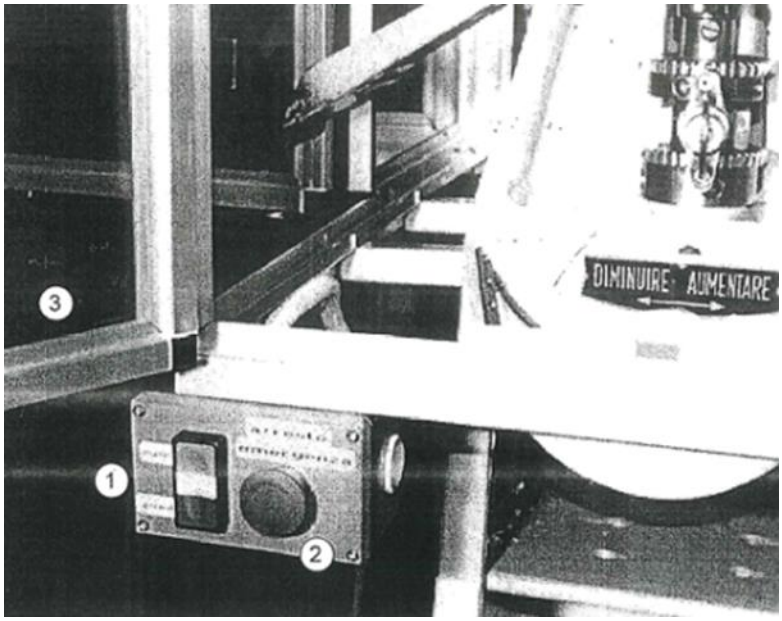


Figure 9: Buttons

Parts of a Single Punch Tablet Press

Hopper: It is used to compress substances (medicine or by-products / particulate matter).

Dice: Dice define the shape and size of the tablet, allowing the bottom and top to come close to pressing the punch material.

Lower and upper bouts featured two cutaways, for easier access to the higher frets.

Game track: This is the component used to guide the movement of the punches.

Capacity regulator: Adjust the position of the bottom punch and lower the required amount of material.

Ejection Regulator: To adjust the position of the bottom punch, its highest position is parallel to the surface of the tie.

Driving Wheel: This assists in the movement of the lower punch, upper punch and hopper shoe and checks their movement.

Intended use of the machine

- The machine is designed to process products under powder form and includes different ingredients to produce homogeneous tablets.
- The shape of the product is defined using the appropriate equipment. The shape of the product is defined using appropriate axes. Given the number of pieces that can be produced

- Strange tablet press has the following movements: Flywheel rotation and alternating movement of the punches for molding.
- The machine can perform both hollow and mounted movements. It is best to avoid using the machine when it is empty and avoid punching or breaking the machine lock.

The machine should be used exclusively for the preparation of tablets, tablets for medicinal and herbal use.

Workplace

- The work of the machine is unique and is located on the front side where the start and stop buttons are located.
- The machine can work automatically without the presence of the operator, which should only be for manual loading and unloading operations.
- No specific lighting required; the workplace will glow comfortably according to applicable safety regulations.
- Access to the workplace should be allowed only by authorized persons or persons responsible for carrying out certain interventions.

Command, shutdown, emergency shutdown and exit service modes

Machine modes

- Command modes: Only automatic control module is provided.
- Normal shutdown methods: The engine must be stopped when the object in the hopper is deemed finished.
- Emergency stops: An emergency stop that removes tension from the entire engine and interrupts the operation of the engine.
- Out of order: The machine can be offed from service by disconnecting the power by activating the main switch on the control panel located on the hopper side at the rear of the engine. A sign with the words "Not in service" should be placed on the machine and the operator should make sure that the switch is open. If the upper and lower punches contact before the end of the run, without material, the engine will stop if an electric motor block is formed.

To protect

By removing the plug from the socket, the machine will be safe when completely disconnected from the power sources. The only function of the general switch on the control panel is not the machine in complete protection from electrical insulation view.

Adjustment devices

Tablet Press fitted:

1. Pressure regulator (Figure 7-3)

2. Volume control (Figure 7-8)

3. Stop Adjuster (Figure 7-7)

Auxiliaries and accessories

Electric panel: Made of plastic square with a switch that does not allow the door to open if not in the open position. It is designed to comply with CEI 60204 standards and includes all electrical and electronic components that control the operation of the electric motor.

Electric motor: Strong structured motor with self-ventilation.

Access structures and methods

The machine is completely sealed and secured. There is also a box of aluminum profiles with Plexiglas doors secured by a microswitch. The box is for protection and soundproofing.

Handling

The machine, once assembled and grounded, is considered a stationary, immovable structure. For transport, it should be placed on a sturdy wooden board, attached, and secured with a plastic sheet.

Lower punch

The lower punch and its list are set as follows:

1. When the machine is stopped, after removing the Plexiglas base, open the bottom punch card and bend it slightly to remove it.

2. Remove the diaphragm metering shoe from the appropriate bolt and release it from the drive arm

3. The lower punch axis will appear at home until the flywheel is rotated manually.

4. Operate the serrated disc (Figure 8 - 8) to adjust the punch stroke.

5. Move the flywheel manually (requiring a certain effort) Check that the bottom punch is aligned with the axis plane with the dead center and does not cross it to allow movement of the blade.

6. To adjust the position of the punch according to the size of the mold surface, it is necessary to operate the serrated disk (Figure 8 - 7).

Upper punch

At the time of assembling the top sponge it should be checked to see if anything is playing inside the mold. For this you need to loosen the bolt, check the clearance manually and re-tighten the bolt at the end of the process.

Changing die and mold punches.

To change punches and the die, we need to:

1. Remove the hopper from the joint

2. Remove the program shoe from the attachment with visible bolts and drive hand

3. Remove the top sponge by loosening the bolt with the hexagon call.

4. Do not remove the plateau unnecessarily

5. Draw the agenda matrix on the appropriate point.

6. Draw the bottom diaphragm punch into its own hexagonal slot

7. Holding openings are described in reverse order

8. Maintain the new high sponge and check the game as mentioned above

Functional description.

Equipped with automatic tablet press. There are two types of functions:

- Normal gear
- Jog Gear

In the first case, the operations are completely automatic, in which, once the engine is started, the production of tablets continues until the material in the hopper is finished.

This is necessary for normal driving: Rotate the public switch to the on position. The signal light is on. Press the Start button.

To stop the engine, press the stop button at the bottom.

Beginning of the pulse start

Impulse gear aims to adjust and tear the engine one movement at a time. To jog, turn the selector to the right and press the Start button. The engine will stop after completing a full cycle. The aspirator is excluded during jack operation

Insertion of the aspirator.

The aspirator is inserted by the command of a two-step key switch. The vacuum cleaner is connected to the socket. The aspirator can be adjusted using the bubble.

Maintenance

Maintenance and repair operations are generally limited because the machine makes very slow movements.

It should be carried out by machine maintenance specialists who are knowledgeable about the machine and its components and hazards and potential hazards.

All interventions must stop the engine and disconnect from the power supply or disconnect the electrical panel. Maintenance interventions are related to lubrication and water lifting.

Lubrication program

Numerous greasing points are provided with grease nipples.

Lubricate with FIAT MR3 grease every 1000 hours.

Checks belts

Belt tension must be checked, at least once a year or with frequent use.

2.3. Production of tablets by direct compression method

The direct compression method of tablet production is widely used because it is a time saving process. This method of tablet production does not involve a lengthy granulation and drying process.

In recent years, the processing of drugs has often been achieved through wet granulation or related unit operations. Gradually, other methods of revolutionizing and gradually replacing the old tablet manufacturing methods appeared. Among the new techniques, the direct compression method uses the most advanced technology.

From the word "direct abstraction", this method is defined as the compression of compounding and processing ingredients into tablets. The tablets are directly obtained from the powder API or other supplements. Successful adaptation of this method has led to reduction in operating units, reduced mechanical involvement and reduced processing time.

The preparation of tablets using the direct compression method involves three repressible processes. The sequence that follows these processes involves the use of induced die feeders, dry binders, and finally direct compression by-products.

In the manufacturing process of using induced die feeders, a special feeding device is used. Prevents the device from disassembling and completes the powders to flow down the hopper from the hopper into the die pit of the compression machine. The use of Indus Die Feeder generally reduces the problem of air, thereby increasing the density of the filling powder and making it compact. Usually used for a small formation that does not fill the tie hole.

In medicine, the use of binders ensures that the active and inactive ingredients stay together. The materials used as dry binders must have the required cohesive properties to ensure that the tablets have the approved hardness and crispness. It is also recommended that the clearance binder and drug ratio be maintained to ensure satisfactory doses of tablets containing high doses. Microcrystalline cellulose and polyethylene glycol are some examples of dry binders that are commonly used to make tablets using this technique.

The by-products control the success of the direct compression method. Direct compression exhibitors can be defined as non-pharmaceutical inactive substances that are combined into a compound with pharmaceutical products. The overall property of the tablet related to the component powder fluidity is determined by the direct compression sub. Other properties that can be affected by hardness, fragmentation and melting. Examples of direct compression

exhibitors used in tablet manufacturing include fillers, compression aids, distortions and lubricants and glitters.

The tablets preparation by direct compression is advantageous because the whole process generally requires fewer steps to operate without the use of moisture and heat. Tablets prepared as a product of this method have faster dissolving properties compared to wet granulation.

There may be two reasons why direct abstraction does not apply to all products. The main reason is that high doses can cause problems and low doses can manifest a homogeneous mixture.

Direct abstraction is gradually becoming one of the most widely used and expensive pills making methods in the pharmaceutical industry. Although the basic principles who govern the direct abstraction system, it is only recently that this method has been fully adopted. The main reason for this is the introduction of various accessories designed for use only with direct compression techniques.

2.3.1. Description of Production processes

The pill compression process used in different pharmaceutical companies is divided into four different stages. These are called filling, calibration, abstraction, and discharge. These four steps are explained below:

Filling

- This process of the tablet compression machine involves converting the particles to the position for tablet compression.
- The final product is then mixed into a homogeneous mixture. The mixture is then pressed into a punch-tie hole.
- Punch-tie pit is made up of punch-tie and bottom punch. Then the low punch level in the tie is responsible for the size of the pit.
- This size must be adjusted accordingly to the weight of the particles to be compressed to make the tablets.

Metering

- The measurement process for the tablet compression process involves the removal of excess particles from the machine.
- At this stage, the required quantity of the particles to be compressed into tablets is controlled by the height of the lower punch and the height of the lower punch by the measuring camera.
- To obtain the required weight of the particles in the punch-tie pit, the lower punch tie is raised to the required size.
- Excess particles are wiped off the surface of the die table. The measurement method is like the process of determining the weight of the dough when making the cake.

Compression

- During the compression phase, the pressure between the top and bottom punch (tablet tooling) comes together to form the tablet.
- When the punches enter the compression position, the upper and lower punches move between two large wheels called compression rolls. These abstract scrolls push the punches into the words.
- Therefore, the distance between the upper and lower punches determines the thickness and hardness of the tablets.
- When the punches are very close, a thin and hard tablet is formed. Today the AWC (Automatic Weight Control) engine is used for a better result.

Ejection

- The discharge process for the tablet compression process involves removing the tablet from the lower punch-tie station.
- At this point, the top punch retreats from the die pit and rises above the tower table.
- Then the bottom punch rises into the tie, which pushes the tablet upwards over the surface of the tie table and out of the die hole.
- Then with a scraper, the tablets are collected in the container.

A step-by-step diagram of the production process also illustrates the way in which the pills are produced is shown in the flowchart below.

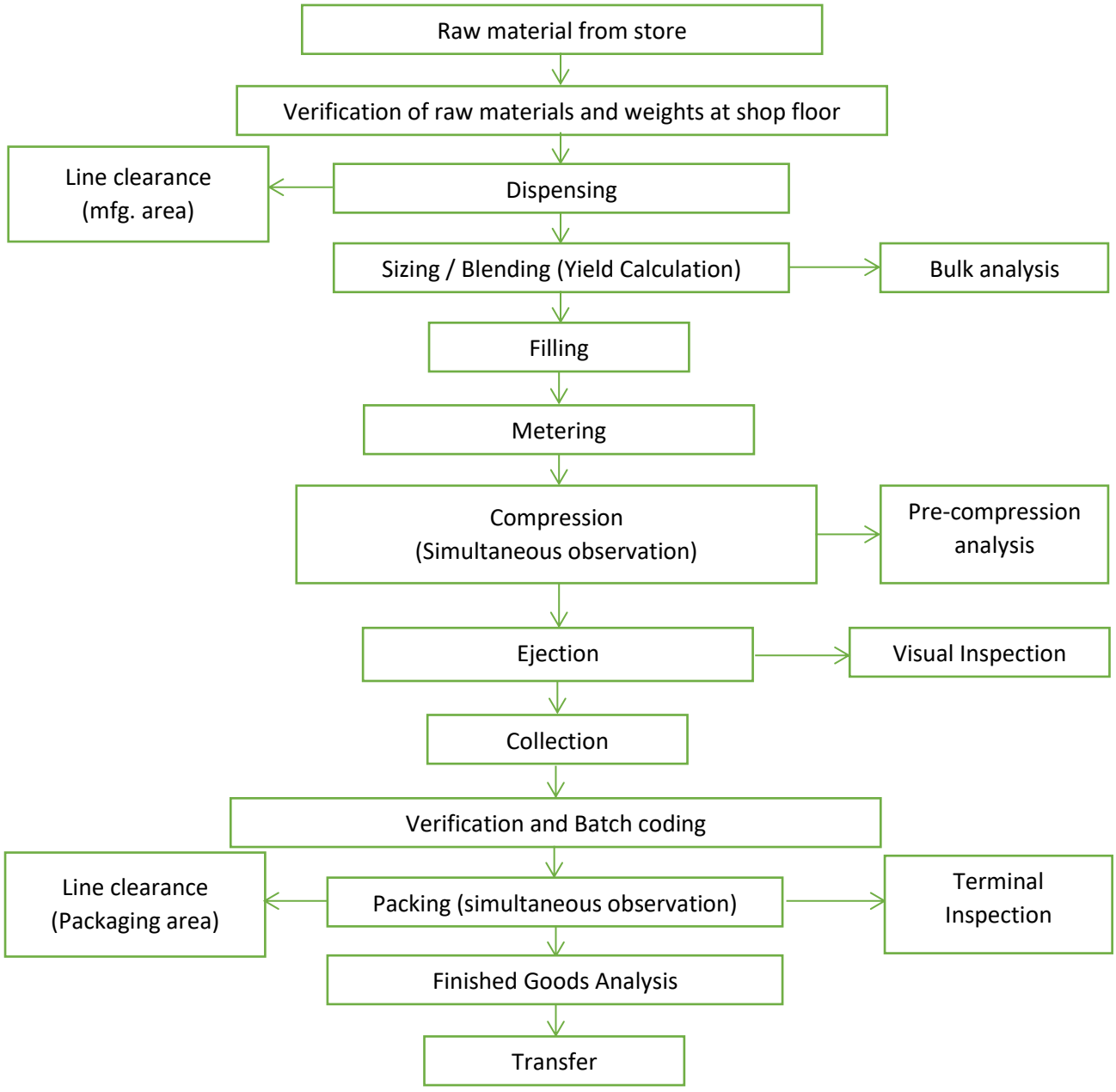


Figure 10: Manufacturing process flowchart

2.3.2. Area required for manufacturing of tablets

- Raw material warehouse
    - Receiving quarantine
    - Approved raw material section
- Dispensary
- Production room
    - Mixing Section
    - Tablet Punching Section
    - Coating Section
- Quality control section
- Packaging Section.

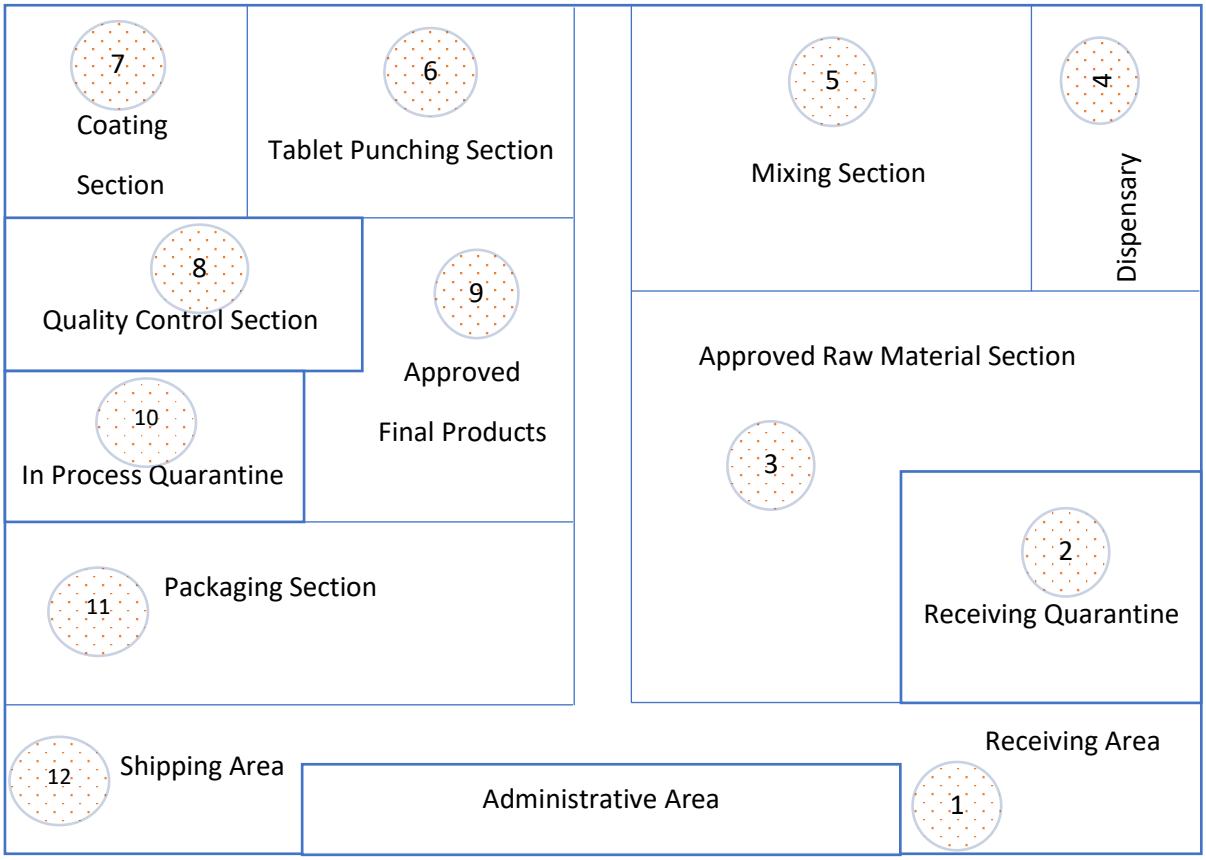


Figure 11: Tablet Manufacturing Layout

2.3.3. Tablet manufacturing equipment / machines

Includes common equipment used in the manufacture of pills

Distribution: Each ingredient in the tablet formula is accurately distributed according to weight. This is the most important steps in any development process and should be done under technical supervision.

Weight balance / reserves: e.g., total weight balance (weight in kilograms), electronic weight balance (weight in grams and milligrams).

Powder mix: To obtain a uniform and homogeneous powder mixture, the powders are mixed using a suitable blender. The substance and by-products of the drug are mixed in a geometric diluent. E.g., pneumatic mixers (air-mix mixer or air drive mixer), diffusion / dumbbell mixers (e.g., V-blender, double cone blender, cubic mixer, drum blender), convective mixers (e.g. Ribbon blenders, orbiting screw mixers, horizontal high-intensity mixers, planetary mixers, diffusion mixer with intensifier bar / agitator, Forberg mixers, horizontal double-arm mixers, vertical high-intensity mixer).

Tablet abstraction: This step involves compressing the particles into a flat or convex, rounded, elliptical or distinctly shaped, marked, or unmarked tablet; The tablet is engraved with a logo identifier and / or code number. Single punch tablet pressing machine.

Quality control equipment: e.g., decomposition equipment (Manesty single unit disintegrating apparatus or Erweka multiple units disintegrating apparatus), USP Dissolution Tester, Tablet Hardness Tester, Tablet Thickness Tester, Tablet friability Testers.

Packaging machines: e.g., blister packaging machines, strip packing machine, aluminum foil packaging machine etc.

CHAPTER 3

3. IMPLEMENTING PFMEA IN PRODUCTION PROCESSES

This chapter will look at the implementation of the PFMEA in tablet compression machine processes in the manufacturing sector.

FMEA: This is an excellent tool and is a step-by-step approach to detecting all possible failures in a design, production, or assembly process or product or service; Examining the consequences or consequences of those failures; And eliminating or minimizing failures; And eliminating or minimizing failures, starting with the highest priority.

- Methods (Modes) of failure: It means the method or modes by which something can fail. Failures are any errors or omissions, especially affecting the customer, and may be potential or actual.
- Outcome (Effect) Analysis: Refers to studying the consequences of those failures.

The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest- priority ones

Failures are prioritized depending on how severe their consequences are, how often failures occur, and how easily failure can be diagnosed.

3.1. PFMEA for "Tablet Compression Machine Process."

PFMEA is also called Potential failure mode and effects analysis or failure modes, effects and critically analysis.

- Process Failure Method and Outcome Analysis (PFMEA) is an active tool used to identify, evaluate, and prioritize potential weakness or failure patterns in any organization.
- The prior step in risk assessment is to collect all possible factors that may affect product quality systematically.

To identify these factors, I reviewed the literature and collected some data during early developmental studies. These factors were hierarchically organized using the Ishikawa or "fishbone" map.

The parameters outlined in the Ishikawa chart help identify failure patterns (i.e., ways or methods by which a system, process, or piece of equipment may fail).

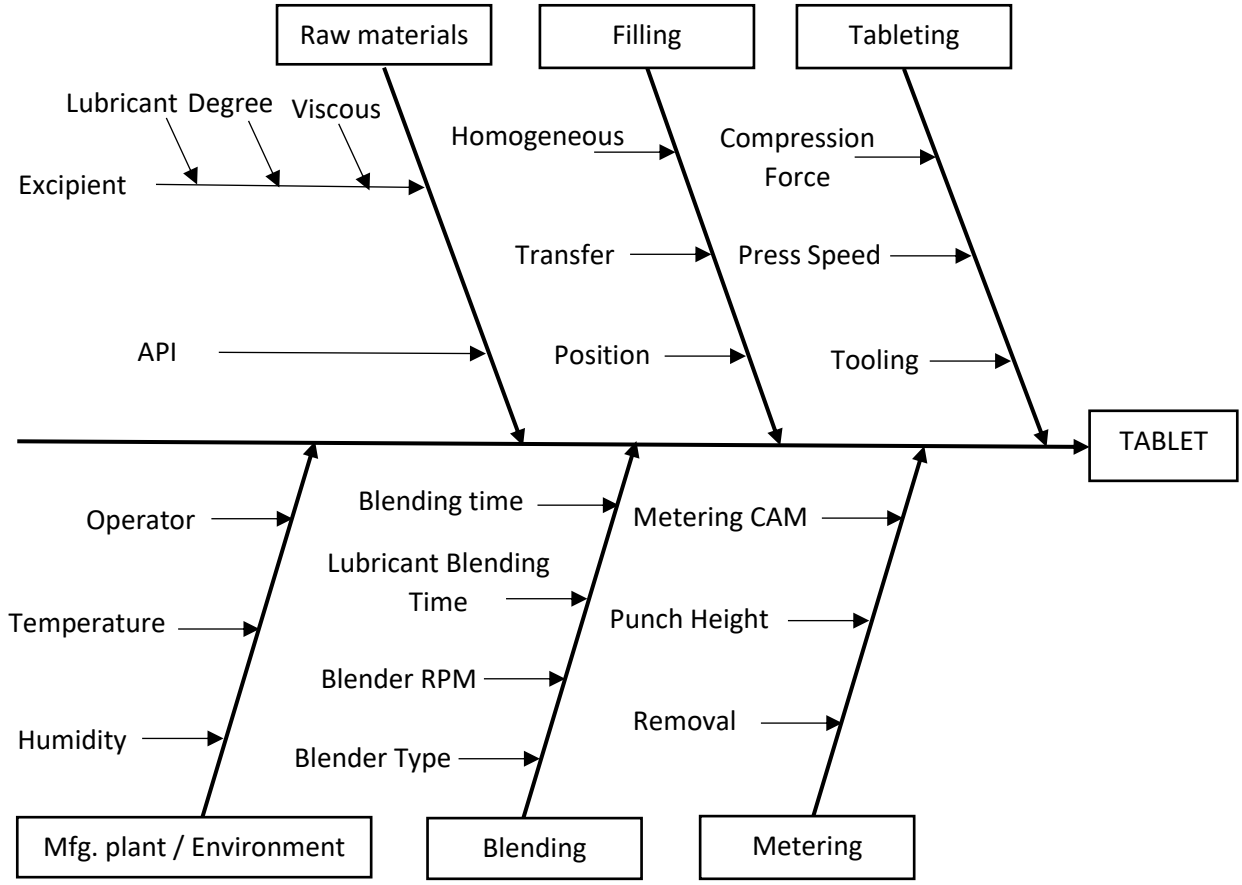


Figure 12: Fishbone diagram for Tablet Manufacturing

Using PFMEA, methods of failure in operation can be prioritized for risk management purposes according to the severity of their consequences (consequences).

To verify possible failure during operation, I did PFMEA for the entire production process and tried to detect possible failure during operation.

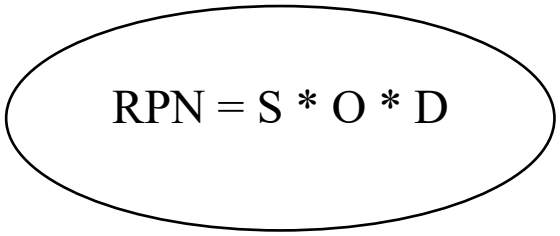
Typically, FMEA starts at an early conceptual stage of design and continues throughout the life of the product or service.

The first step of FMEA is used during design stages to prevent failures, and then it is used for control before and after the operation of the process. We use it to control the processes of production processes.

Risk priority numbers (RPNs) for each combination of the effect of an FMEA, the severity of the failure mode, the probability of occurrence and the probability of detection are used to rank the risk.

FMEA defines RPN as:

The combination of the three ratings defines the overall risk level, the Risk Priority Number (RPN), which indicates the suitability of each failure mode affecting the system. The RPN is calculated for each failure mode according to the following equation:



Parameter S, severity, measures how severe an impact a given failure mode can have. We sorted these,

- 5, severe effect
- 3, moderate effect and
- 1, no effect

The next parameter O is the probability of occurrence or probability of occurrence; We sorted these out

- 5, is likely to occur
- 3, 50:50 occurrence chance and
- 1, unlikely to occur

The final parameter D is the easy detection of the detection or failure mode because the higher the detection of the failure mode, the lower the risk to the product quality. For D, we sorted

- 1 is easily detectable
- 3 moderately detectable, and
- 5 Hard to find

Using this procedure, we generated the ranking shown in Table 3.1

PROCESS FMEA									
S. No.	**Item / Process step**	**Potential Failure Mode**	**Potential Effect(s) of Failure**	**Failure Cause(s) of Failure**	**Detection or Control Method**	**S**	**O**	**D**	**RPN**
1.	Raw material	level	Dissolution, hardness	Operator error, poor development	Disintegration, dissolution, hardness tester	5	5	5	125
		Vendor grade differences	Dissolution, hardness	Poor development, operator error	Disintegration, dissolution, hardness tester	4	5	4	80
		Different sources	Physical properties	Physical variation	Visual inspection	4	3	3	36
		Particle size	CU, Dissolution, hardness	Material variation	Hardness tester	5	3	4	60
2.	Temperature & Relative Humidity	Manufacturing plant / Environment	Material fails to meet the specification	Material is not stored as per specified temp. and RH	Area maintained by HVAC System	5	2	1	10
3.	Blending	Blending time	Content uniformity (CU)	Poor monitoring	NIR	5	1	1	5
		Fill level		Operator's error	NIR	5	2	1	10
		Blender speed		Operator's error, equipment failure	Near Infrared (NIR)	5	3	1	15
		Humidity		Poor air handling	NIR/hygrometer	3	1	1	3
4.	Filling	Loading method	Time leading	Poor handling	Visual inspection	5	1	1	5
5.	Metering	Fill Level	Material loses	Operator's error	Metering CAM	5	1	1	5

6.	Tableting	Humidity	CU and hardness	Poor air handling	Hygrometer	3	3	3	27
		Compression force	Hardness, dissolution	Poor granulations	Disintegration, dissolution, hardness tester	5	5	4	100
		Compression speed	CU	Operator's error, equipment failure	NIR/HPLC	3	3	3	27
		Tooling shape	CU, tablet weight	Operator's error, equipment failure	NIR/HPLC	1	1	3	3
7.	Finished product mix up	Collection	Market complaint	Transfer of goods do not follow SOP	As per SOP transfer the goods	5	1	1	5
8.	Improper carton packing		Market complaint	Untrained packer	In process check of carton	5	1	1	5
S, severity of excursion = 1 (low), 5 (high); O, probability of occurrence of the excursion = 1 (low), 5 (high); D, detection of excursion = 1(easy), 5 (hard).									

Table 7: PFMEA for the simple manufacturing process

3.2. PFMEA Post Work

3.2.1. Determining action priorities

After completing the initial identification, we need to determine if further efforts are needed to reduce the risk, including ratings for failure methods and effects, causes and controls, severity, occurrence, and detection.

In the present study, very large RPNs were used to identify the most hazardous parameters for product quality and therefore need to be examined in more detail.

Because of the inherent limitations in resources, time, technology, and other factors, they must choose how to prioritize these efforts. The initial focus should be on failure methods with higher intensity rankings.

When the severity is 4 or 5, it is necessary to ensure that the risk is mitigated by existing design restrictions or recommended actions.

For failure methods with a severity of 3 or less, reasons with higher incidence or detection rankings should be considered.

It is one's responsibility to look at identified information and determine an approach and how to prioritize risk reduction efforts that best serve their company and customers.

One approach to assisting with action priority is to use a risk priority number.

1–29 low risk, 30–59 medium risk (thick), 60–125 high risk.

3.2.2. Operational priorities for the tablet press machine

Table 3.1 is a partial list of factors to consider when doing FMEA. To start FMEA, we divided failure methods into creation or raw inputs and process-derived methods. Process failure methods were further broken down by unit operations, which were the mixing of internal particulate matter, the mixing of additional granular material and the compression.

Changes in humidity leading to variation in product humidity were less risky because all development work was carried out under good manufacturing practice (GMP) conditions and previous compatibility studies to evaluate the dynamics and equilibrium moisture content of the drug, by-products, and compounds. Demonstrated no significant impact on product quality properties under relative humidity of 40 to 75% RH.

In addition, performance-influencing variables generally received higher scores, while naturally controlled variables such as humidity and instrument shape scored lower.

This score difference is linked to both the detection and severity associated with each failure outcome. For failure effects that could have an impact on processing and product physical quality, the detection capability was high during unit operation or during the finished product test.

Risks associated with changes in input raw materials (changes in API particle size, transition to magnesium stearate source and transition to decomposition stage: binder level) and process parameters for homogeneous mixing, filling, and calibration have been identified as high risks., Compression key, compression speed and tool design.

3.2.3. Recommended prevention, corrective action

In general, preventive measures (i.e., minimization of occurrence) are more desirable than diagnostic measures. An example of this is the use of process design error checking instead of random quality tests or related inspection. The purpose of any recommended action is to reduce the rankings in the following order: severity, occurrence, and detection.

- To reduce the severity (S) rating
- To reduce the Occurrence (O) ranking
- To reduce the detection (D) rankings

To reduce the severity (S) rating

Only a design or process correction can bring about a reduction in radical rankings. A product / process design change and does not mean that its intensity will be reduced. Any product / process design change should be reviewed by the panel to determine the impact on the product function and process. For maximum efficiency and effectiveness of this approach, changes in product and process design should be implemented at the start of the development stage.

To reduce the Occurrence (O) ranking

Process and design corrections may be required to minimize the event. Reduction in event rankings may be affected by eliminating or restricting one or more causes of failure mode by product or process design correction. Studies can be implemented to understand the sources of process variability using statistical methods. These studies will lead to actions that reduce the incidence. Furthermore, the knowledge gained may help to identify appropriate constraints, including continuous feedback and current feedback of information for appropriate actions to prevent the problem.

To reduce the detection (D) rankings

The preferred method is error / error checking. Redesign of the detection system will lead to a reduction in the detection rankings. In some cases, a process step may require a design change to increase the likelihood of detection (i.e., reduce the detection ranking.) In general, improving detection controls requires knowledge and understanding of the dominant causes of process variability and any specific causes. Increasing the frequency of the study is generally not an effective process and must be used as a temporary measure to gather additional information about the process to implement a permanent preventive / corrective action.

The following are implemented to reduce the intensity (S), incidence (O), and detection rating (D), respectively. Also, some settings were implemented to automate it.

The seller can control the quality differences and particle size with the help of the following tests.

Processing of the decomposition test: Decomposition is a process in which the tablets are broken down into particles or small particles. To prevent and ensure that fractures do not occur during production and use, and to maintain the proper dosage of the pills, a decomposition tester is added to the process.

Implementing the Dissolution Tester: When the dosage form is used, the release rate of the active substance is important to ensure that the drug is delivered correctly at its guaranteed rate. Used to ensure the quality of the drug dissolving tester.

Implementing Hardness Test: Also known as Crush Strength Test. Tablets require some amount of strength or hardness to withstand mechanical shocks handled during production, packaging, and shipping.

Visual inspection: The inspection system checks the top, bottom, and body of each tablet, using sophisticated image processing and easy-to-set algorithms. To ensure optimal appearance quality, the capsules are inspected for a wide spectrum of defects including decay, cracking, burrs, presence of foreign particles and discoloration.

- **HVAC systems**

Used to control the environment in the production area and in the storage area of the pharmacy. Heating (H), Ventilation(V) and Air Conditioning (AC) is a system used to filter air and control the humidity in the air.
Having control over changes in the area humidity maintained by HVAC systems can lead to variation in product humidity.

- **Nearby infrared spectrum (NIR)**

Proximity infrared spectrum (NIR) is widely used in pharmaceutical production because it can quickly measure the critical material properties (CMAs) of a product in real-time, non-destructive, and non-contact during production processes as a process analysis technology. NIR has shown practical applicability to various processes in drug production.

- **High Performance Fluid Chromatography (HPLC)**

HPLC is a form of liquid chromosome that is commonly used in the pharmaceutical industry because it can provide the exact results needed. The output can be used to analyse the finished pharmaceutical products and their quantity and quality during the manufacturing process.

One of the advantages of HPLC is its ability to clarify its structure and determine the level of contaminants in pharmaceutical formulations.

A strip packing machine is a device for making products into strip bags. The strip bag machine is widely used for tablets and tablets. Strip bags are good for moisture-proof and light-proof baking using Alu / Alu; Or plastic / plastic film material.

3.3. Resulting RPN

The following RPN is the product of Severity (S), Occurrence (O) and Detection (D) evaluations resulting from the implementation of the recommended action.

Based on the FMEA ratings (see Table 3.1) the following potential CQAs were identified for further study: API and filler-binder particle size, starch gelatinization level, viscosity and hydroxypropyl cellulose particle size, and lubricating oil source.

Similarly, the main processing variables to be studied were pressure, feed rate, lubricant mixing time and tablet compression speed selected for further investigation.

Therefore, we chose the Blacket-Burman test design, which is a widely used screening design to identify the "key factors" that cause variation in product quality.

Tablet Weight Variation, Tablet Breaking Force, Tablet Decomposition and Liquidation,

Process results and status

This section identifies the results of any completed actions and their effect on the S, O, D rankings and RPN.

After the implementation of various control methods for the process. The RPN range was reduced to the acceptable level

Implementation includes bringing in HVAC systems, NIR, HPLC and IoT systems. The production process is in safer control after the role played by the support systems.

3.4. PFMEA Report

After the prevention / adjustment operation is completed, it is to determine and record the resulting severity, occurrence, and diagnostic rankings. And, to calculate and record the resulting action (risk) priority indicator (RPN). All revised rankings should be reviewed.

Actions alone do not guarantee that the problem has been solved (i.e., the cause stated), so should be completed as a proper analysis or test verification.

Upon successful completion of PFMEA, a report is written to document the achievements.

In PFMEA, the process or function to be analysed is identified. It also includes process characteristics that include methods and processes that allow process operations to proceed smoothly to meet only partial quality requirements.

Here, I have defined the following high RPN processes with high risk,

- Defects of raw materials with RPN 125
- Compression Pressure & Speed RPN 125
- Compression key with 100 RPN during tablet operations

After the successful implement of the IoT and its support system, These RPN were brought down to acceptable level. Thus, it helps the production process to achieve its goal progressively.

The role of SCADA, MES, and DCS systems plays a important role in making the production process automated and that can remotely controlled and accessed regularly and especially during the emergency.

Table 3.1., shows the reporting section of PFMEA for the simple manufacturing processes. That more cleanly explains the system before and after the implementation of support systems. And especially how the RPN is listed and controlled lately.

CHAPTER 4

4. IMPLEMENTING IOT SYSTEMS TO PREVENT PROCESS FAILURES

In this chapter, we will see at the implementation of IoT systems in tablet compression machine design and the functions to prevent process failures.

The Internet of Things is a buzz word in the field of information technology (IT). The Internet of Things (IoT) is an interconnected computer system with unique identifiers (UIDs) capable of transmitting information over a network. The applications of IoT in pharmaceutical production are to improve product quality, increase productivity and reduce errors at different stages of pharmaceutical preparation. During pharmaceutical production, IoT can be useful for real-time monitoring and monitoring and improving various unit functions to enhance productivity.

After the commence of information technology enabled services, there is a sea change in the daily routine of human beings and in the activities of industries and companies. Because it is of great importance, it is becoming an important model through most vertical and horizontal trading, including the daily routine of a normal human being. The evolution of the Internet of Things (IoT) is largely due to the needs of large-scale businesses, which derive greater benefits from the ability to predict and monitor and monitor all objects.

The Internet of Things is a revolutionary example in the world of information technology. The Internet of Things, also known as IoT, is made up of two words, "Internet" and "Things". The term Internet is a global network of interconnected computer systems that use a standard Internet protocol (Transmission Control Protocol / Internet Protocol) that connects millions of people worldwide. Identification) such as tags, sensors, actuators, mobile phones, and a unique address system that can communicate and interact with others to achieve common goals through a variety of wireless, computer, and optical networking technologies.

4.1. Advantages of using the IoT in tablet manufacturing

- The benefits of traditional large-scale pharmaceutical or biotechnology production are same to those who experienced in other industries; These normally revolve around connected data, provide a better understanding of performance and equipment usage, and provide the ability to predict maintenance and prevent breakdowns. In my opinion, the main distinguishing

feature of the pharmaceutical industry is the need to file and report everything that happens during production for compliance reasons. IoT can become a catalyst for paperless production because the equipment and recipe parameters are more closely linked and available, i.e., less manual interventions may be needed. Similarly, as the industry moves toward smaller-scale production, IoT will provide the ability to capture data and integrate complex equipment and processes, ranging from individual production or outcome-based and diagnostic-focused therapies. Not just process, efficiency, and effectiveness.

- Pharmaceutical manufacturers implementing IoT technologies can easily meet the requirements for deployment and can apply the intelligent data already required in the pharmaceutical manufacturing environment. They can connect their devices, networks, and systems so that they can share information up to the plant site and management package and standardize their processes. Previously, pharmaceutical manufacturers stored product information on paper for reference - making it very difficult for operators or executives to make process or business decisions. With an excellent plant and IoT-enabled solution, manufacturers can access data in real time to better monitor production and gain visibility from production to distribution. Manufacturers can easily pull data to track and detect products during an issue and quickly and efficiently recall specific affected products instantly. Overall, it enables manufacturers to improve quality through design and gain a clearer understanding of their processes - helping to improve consumer safety and protect the company's brand.
- IoT provides the infrastructure that allows it to expand data collection across various layers of automation and information technology (IT). More specifically, data collection for analysis or electronic volume recordings enables cheaper and faster data integration without disturbing the control system.
- Another feature of IoT in pharmacy is the limitation of pharmaceutical manufacturing plants. IoT Infrastructure allows modular automation for modular drug production to increase or decrease production according to market requirements. It enables rapid time-market for pharmaceutical products in accordance with regulations and required approvals for specific markets and regions.
- The most amazing benefits we see with a focus on real-time monitoring and control, optimal decision making, reduced costs and improved patient outcomes. Advances in sensors and IoT gateway devices, while maintaining the same strict security and regulatory compliance forced by the industry, are one reason all of these are possible because they are so affordable to deliver.

4.2. Characterization of the status of IoT in pharmaceutical production

- The pharmaceutical industry is beginning to realize the benefits of IoT, especially with modularization, which is already in a state of comprehensive implementation and application. Pfizer's PCMM collaboration with GEA and G-Con is an example for companies that benefit from this technology. In addition, companies have begun to implement OPC UA [integrated framework] at the device level to enable more comprehensive data analytics. For the full potential of IoT, especially for the pharmaceutical industry, it is essential to adopt advanced industrial cyber-security practices and complete verification features.
- Now, IoT is one of the technological drivers that will shape the future of our industry, which is closely related to other high-focus topics like cloud and big data. Understanding the potential role of robotics and how to collaborate with them, the future pharmaceutical manufacturing plant should embrace and integrate these different technologies. The need for direct and on-demand access to goods and all their assets will increase through contract manufacturing companies (CMOs) and external suppliers. Today's MES, data historian systems and control systems demonstrate the basis for collecting and storing collected data. The close integration of these systems is essential for the future. Direct contact between objects or via IoT is not yet widespread.
- At the production level, the industry's current focus is on integrating production data using MES, process analysis technology and control and automation systems. Combining automated and manual operations gives companies the ability to realize paperless and continuous production. Digitalization and paperless manufacturing is true in some factories, but there are still some ways for most companies to understand how to incorporate IoT equipment and technology into their current processes. For new processes such as individual modules, more work has already been done and some success is being achieved.
- Standardizing the way machines interact is important in connecting them effectively. OPC Unified Architecture (UA) is an operating system-independent, machine-engine, industrial communication protocol that is "the key technology for integrating devices into the industrial system and eventually transforming it into the IoT [Industrial Internet of Things] device" by Torsten Wingler of Honeywell Process Solutions. Says Andrew Duga, President of Special Life Sciences EMEA and Director of Engineering at Digital Transformation. "Not all devices need to be connected to the Internet to add value to a large IoT ecosystem. In fact, these

existing devices can be interconnected by specialized IoT gateways, SCADA and DCS systems.

- Another key technology is the management and communication framework specified by Winkler & Duga, the 2015 Architectural Model Industry (RAMI) 4.0, issued by the German Association of Electrical and Electronics Manufacturers (ZVEI) and its partners. RAMI 4.0 provides a basis for further integration of national (German) and international standards to further "Industrial 4.0", which, according to ZVEI, "refers to the complete digitization and integration of the industrial value chain.

4.3. IoT needs to be highly optimized in pharmaceutical production

- Requires a better understanding of IoT from manufacturers and suppliers. IoT is often limited to small-point solutions that focus on a specific need (e.g., cell culture), i.e., real energy is often not realized. Process scientists and R&D need to have a good understanding of the advances in production technology when deciding on new formulas or treatment delivery methods.
- The challenge for the future of production is to be more flexible with adaptive automation production. Today, there are many more manual processes in pharmaceutical product and pharmaceutical product preparation. Managing data and automatically adjusting or making decisions based on data refers to advances in data management and the desire to rely on [data] collecting systems. In addition, the various stakeholders in the plant should work better together in traditional pits such as production and quality.
- How people interact with data is another aspect that is often overlooked. What data do individuals need? In today's production environment, a lot of data is produced, but they are not always integrated or contextualized. It is must for operators and managers to provide innovative and effective ways to interact with data.
- The benefits of using the IoT technique in pharmaceutical applications, such as increased visibility and information integration, do not occur automatically. IIoT-friendly sensors provide a large amount of large data, but IoT software applications are in the hands of the manufacturer for visualization, analysis, and operation of active decision-making and real-time visibility during operation. Such applications are available today, allowing pharmaceutical manufacturers to realize the big data in the cloud and make timely decisions based on actionable information.

4.4. The primary concerns that pharmaceutical companies are setting up to integrate into their systems

- Pharmaceutical manufacturers want to maintain the quality and safety of their product above all else. Low quality product release can affect consumer health and damage the manufacturer's image and base. As a result, when implementing IoT technologies, manufacturers are concerned about the security of their data, production process and intellectual property. To help improve plant and product safety, manufacturers can implement a safety-deep approach that includes safety measures at the physical, utility and device level. This approach minimizes the unnecessary impact of critical processes and the need to re-evaluate large production areas, allowing the use of new and improved safety measures in stages, rather than significant tearing and alteration.
- The mix of information technology and operational technology (OT) contexts is an issue and should be carefully considered. Large pharmaceutical companies have established institutional level safety practices that apply to the manufacturing and operational space. However, these may not be designed with this context in mind.
- Manufacturers are primarily concerned with data. Once I attach an ‘item’ from my manufacturing plant, I increase the risk. How is it managed? Is it safe? To show the FDA, can it be accessed quickly? The pharma sector will undoubtedly play its part in reducing risk-resistance, digitalisation and IoT. The key question is whether pharmaceutical companies need to ensure that the benefits outweigh the risks. Companies that can use systems confidently and easily will reap greater benefits. Therefore, it will have strong cyber security and the right people and technology partners as key collaborators on this journey.
- Safety and verification features are under global standards and are of initial concern to many industries, including pharmaceuticals. The pharmaceutical industry must adhere to advanced cybersecurity practices and verification standards, such as the International Electrotechnical Commission (IEC) or the International Society of Automation (ISA).

4.5. IoT in other industries

- The automotive industry is now adopting IoT technologies, and this is just one example of the untested manufacturing environment that currently transcends pharmacy. That is, the pharmacy is not in a backward position; Some examples of leading companies in this field are Pfizer, JHL Biotech and Sanofi-Aventis.
- Industries that focus on assembly and individual manufacturing, such as medical devices or vehicles, are usually considered to be at the forefront of pharmacy. A feature introduced with product life cycle management systems, demonstrating data integration through product, plant, and production life cycle.

4.6. IoT in pharmaceutical production

In the future pharmaceutical industry, data collected by Internet-connected manufacturing equipment will improve performance.

The Internet of Things is portrayed as a "smart" refrigerator that can send a message to a smart phone or grocery store when the milk supply is low. Industrial Internet of Things is known as a network of devices with sensors that collect data in real time and communicate to other machines or individuals using the cloud or internal organization systems.

Volume production has been ongoing in the pharmaceutical industry for the past few years, but automated processing systems can be used not only to regulate tools and materials, but also to improve pharmaceutical production capability and other related functions.

IoT-enabled devices can conveniently send performance data to other devices or production supervisors. And this information really helps to manage the industry in a way that helps to increase the production rate.

The manufacturing process in a pharmaceutical industry involves the processing, manufacturing, extraction, refining and packaging of pharmaceutical products. The production process is divided into two main stages:

The first step is the production of the active drug ingredient

Contains the conversion of a secondary active drug ingredient into a finished pharmaceutical product.

The production of tablets involves various unit processes such as grinding, mixing, granulation, drying, shrinkage, coating, and packaging.

By utilizing IoT-based applications, the pharmaceutical industry produces clinically smart tablets, which are a significant sector of investment in the pharmaceutical industry. In pharmaceutical manufacturing, the IoT control system analyses the entire chain of production lines up to the packaging of the finished product. Helps to modify the nearby monitoring system, eliminate setbacks, and eliminate unnecessary work.

Sensors are central to every device management, providing real-time process information and sending smart results to the central network to ensure product quality. Every condition such as granulation, milling, coating, and packaging is constantly monitored.

To maintain a product quality that is only possible by monitoring production, all environmental variables in the pharmaceutical process must be monitored. IoT plays a key role in remotely monitoring actual product quality using smart devices and sensors.

The environment is a major factor influencing the production of pharmaceutical drugs. Therefore, IoT can be activated to monitor environmental conditions. IoT aims to make drug processing transparent using real-time sensors. These sensors detect information on environmental parameters such as humidity, light, temperature, and radiation exposure that can be controlled using intelligent devices. To avoid damage caused by these environmental factors, a warning may be triggered. IoT sensors can be used to ensure product quality. The information collected by the sensors helps to understand the status of the various stages of the product development cycle.

Details include raw materials used, temperature changes, removal and transportation. Product quality depends only on product-certified real-time monitoring. Product quality is protected by IoT-based pharmaceutical applications that monitor production processes. Quality control is an important and significant step in the pharmaceutical industry.

Essentially, IoT plays two important roles in pharmaceutical production. First, it helps to integrate the "things" that make the production-machinery and equipment manufacturing processes work most efficiently. This role is usually performed by sensors and analog-to-digital converter (ADC), SCADA, albeit in a limited way.

Alternatively, we can tap the data collected or triggered by products, make products "smart" and use that data to build businesses for the benefit of customers. IoT-based technologies can

be enabled to integrate and control pharmaceutical equipment, networks, and systems, as well as monitoring control, data acquisition and standardization of processes.

By using sensor-based information, it enables us to create self-learning forecast models and provide diagnostic facilities throughout the company's equipment portfolio - improving performance, durability, or reduced intervention. Furthermore, by collecting real-time information on the use, calibration and quality of equipment, the production team is able to make informed decisions that increase tool performance, reduce idle time, increase resource allocation, reduce production costs and reduce rotation times.

Production devices can already be connected and controlled by supervisory control and data acquisition (SCADA) systems that feed data to production processing systems (MES), which collect and manage output data, and distributed control systems that control equipment (e.g., turning off and turning on valves). IIoT is an additional system characterized by "big data" that can be used to improve productivity.

4.7. Architecture of IoT

The framework consists of several layers, including new hardware, embedded software, connectivity, software running on remote servers, a set of security tools, and integration with enterprise business systems and external environments.

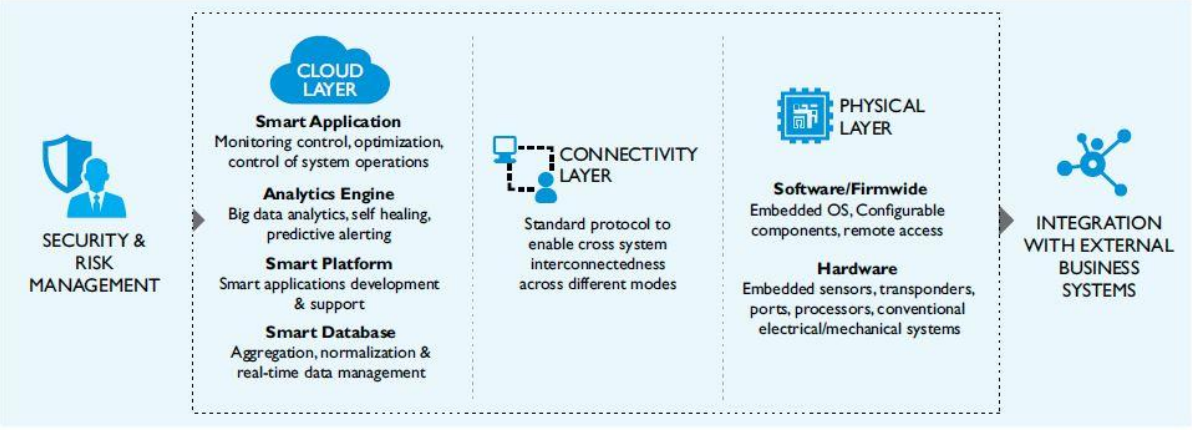


Figure 13: IoT Architecture

Process monitoring

Process tracking software can be used for real-time statistical process control and captures measurement and processing data from all machines on the ground by integrating data

collection modules (DCMs) with machines. Data can be collected on all modifications, and individual machines can be isolated to improve peak performance. Quality process monitoring solutions collect data for any process variable parameters — rotation time, fill time, hold time, charging time, injection start pressure, maximum injection pressure, take-off time, switch-over position, cushion level, screw speed, barrel temperature, feed Common examples are throat temperature, nozzle temperature, refrigerant return temperature, and thermostat supply temperature.

Although production monitoring is about parts and time, process control intelligence is not possible without integrated hardware. This data enables manufacturers to streamline their processes and deliver quality products efficiently.

4.7.1. Supervisory control and data acquisition

Supervision Control and Data Acquisition (SCADA) is a combination of hardware and software used for industrial automation. SCADA allows users:

Supervise and control the industrial processes both locally and remotely

Obtaining, processing, and recording data

Communicate with local machines through HMIs (human-machine interfaces) and PLCs (programmable logic controllers) to communicate with the SCADA system

SCADA systems allow companies to make better decisions, improve performance and reduce idle time. SCADA is used in various industries and is widely used in manufacturing, automation, oil and gas, and wastewater.

SCADA systems work by connecting local sensors, devices, and PLCs that collect data called tags to an onsite server or remote/virtual machine. The data will be stored in the historical database so that it can be analysed later. Users communicate locally with the SCADA system to control operator workstations, HMIs, or processes directly on the SCADA server.

SCADA brings visibility to make informed decisions

A SCADA system brings more visibility to users to make informed decisions. For example, a plant supervisor at a refrigerated bottle plant would like to see all production lines, improve working hours, and reduce idle time based on the current performance of the plant. To accomplish this, tags are required from each station in the production process. With the SCADA system, the line supervisor will receive an alert when the nozzle pressure of a filling

station decreases by 20% and the rotation time increases by 5 seconds. The line supervisor can quickly send a technician to replace the damaged node and bring the line back to normal capacity. Using a SCADA system, the plant supervisor could diagnose and fix the problem, which could lead to process interruptions at later stations or bring down the entire line due to a significant partial failure.

Improving ignition for SCADA

OnLogic has collaborated with Inductive Automation to bring hardware and software together. Ignition, the SCADA solution for inductive Automation, is a platform that connects all the devices in your plant base. It is hardware-ignorant, so you can use the various PLCs, databases, and PCs you need. Ignition has powerful built-in visualization and reporting tools, so decision-makers can make the right decision at the right time. Inductive Automation also has a coordinator program that allows you to work with certified integration specialists in your area to create the perfect solution for you.

One of the inherent risks of IIOT (Industrial Internet of Things) applications is that computers must have an Internet connection to function correctly. Inductive Automation solves this with their Ignition Edge software, a lightweight version of their Ignition Gateway designed to be used on the edge of your network. Ignition Edge allows computers to operate independently until a network connection is re-established. There are several versions of the Ignition Edge, the most common being:

- Edge Panel, which allows local HMIs to run autonomously from other networks.
- Margin IIOT facilitates data transfer through the lightweight MQTT protocol.
- Enable Edge Compute REST APIs, Python scripting, or serial function charts

4.7.2. Manufacturing Execution System

A Manufacturing execution system (MES) is an innovative, interactive software that is used to gain insight into their processes (personnel, equipment, automation, orders, logistics, equipment, and processing algorithms) at the plant site. The software provides real-time visibility in Shop Floor Data, allowing you to take immediate action, maximize performance, maximize profits, and make changes to their facilities.

The goal of MES

- Upgrading the entire supply chain with the MES system is highly appropriate for controlling workflow and procedures
- Improving process safety and reliability
- Recognize deviations at an early stage
- Immediate documentation of process steps
- Improved data quality for evaluating products and processes
- Visibility and transparency throughout the production process: only deviations should be analysed, detailed study of operations in the normal flow is no longer required
- Reduce storage costs due to reduced lead times (WIP)
- Reduce administrative work to maintain production records
- Creating and approving primary volume records
- Reduce the number of lost blocks
- Reduce operating costs and prevent isolated solutions due to greater integration
- Quick access to current data: Management based on minute information for all important business events

Architectural Design of Tablet Production

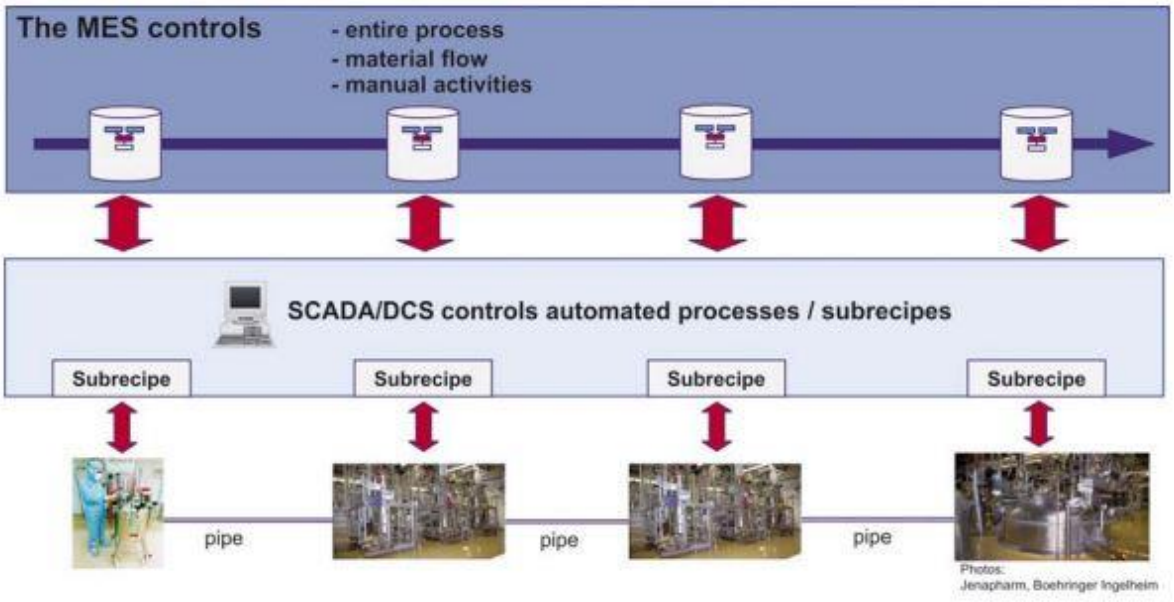


Figure 14: Tablet Production Architecture

One of the characteristics of the production of dosage forms is the flow of material using containers. Master patch logs specify fixed volume size limits relative to container size. Input object sizes and subsequent functions are based on these limitations.

Following the weighing / distribution of the material in a container, it is transported from the work centre to the work centre, where it is processed according to the specification. Sometimes the production workflow in a building involves multiple sites. Some containers are carried in elevators and sometimes gravity facilitates material transfer.

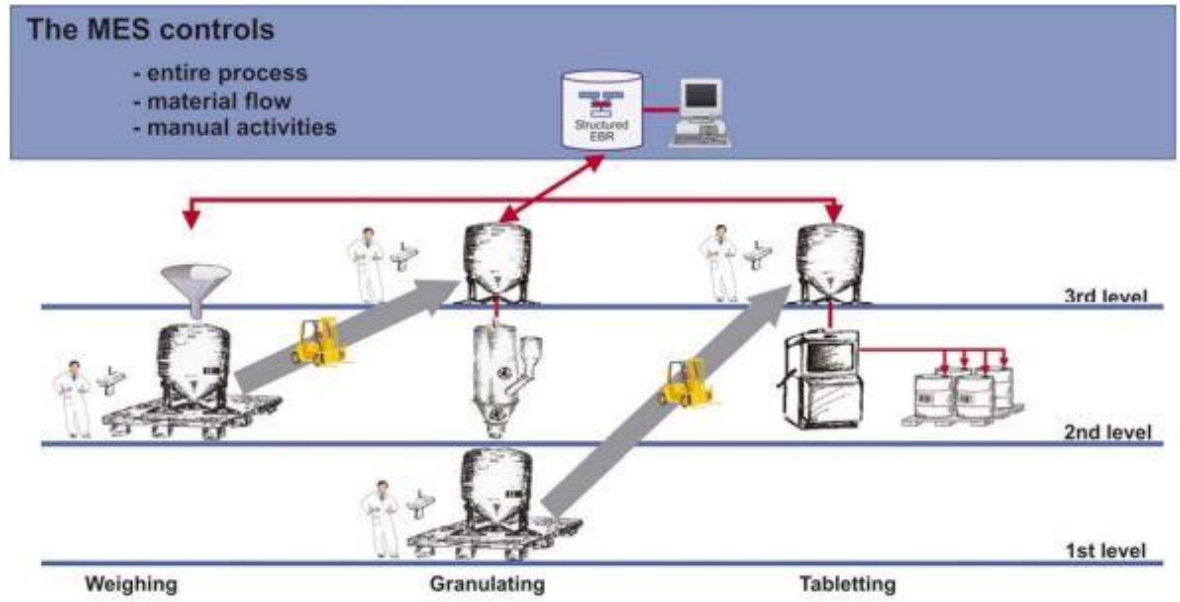


Figure 15: MES Controls

Placement of MES

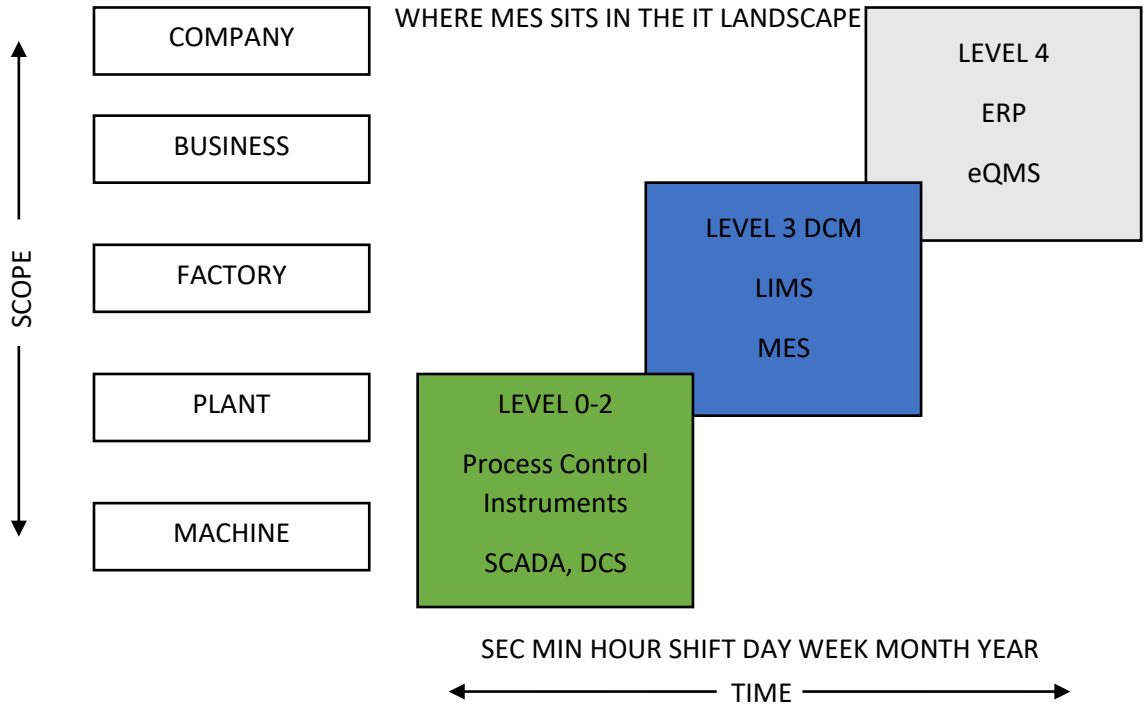


Figure 16: Placement of MES

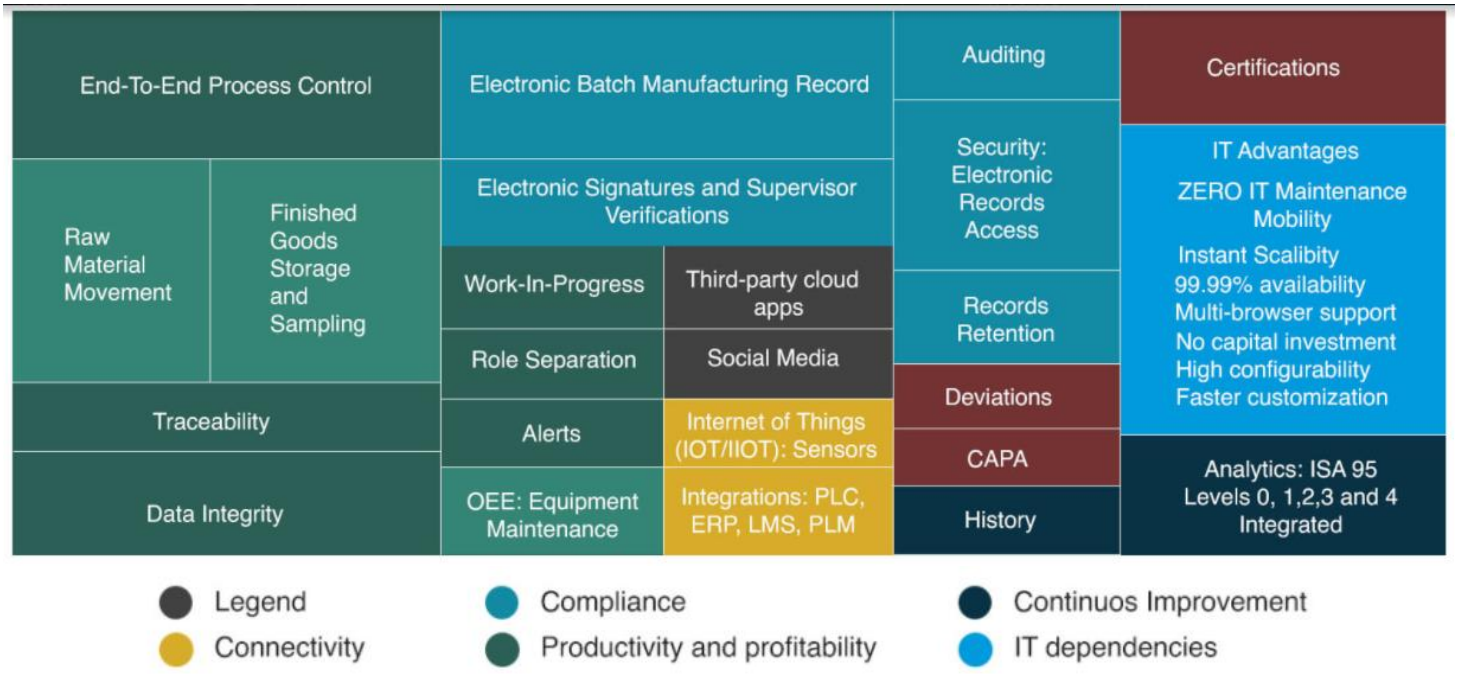


Figure 17: Detailed MES Functionalities

Below is a list of the issues and solutions that MES can deliver to any pharmaceutical or medical device company. Please note that this list is updated on a regular basis as it was continuously configured to better serve the needs and requirements.

Problems	**Solutions**
Drugs adulteration within the Section of the Federal Food, Drug, and Cosmetic Act, in that the methods used in, or the facilities or controls used for, their manufacture, processing, packing, or holding do not conform to, or are not operated or administered in conformity with, CGMP	Manufacturing Execution Systems (MES) enforcing the strict conformity to the cGMP requirements to ensure that right procedures are used and enforced at every step of the manufacturing process along with the equipment cleared for the production lines.
Investigation of out-of-specification (OOS) laboratory test results failed to identify a root cause or provide adequate corrective actions.	The whole Batch Manufacturing Record (BMR) or electronic Batch Manufacturing Record (eBMR) data needs to be captured without compromising for the data integrity to analyse and understand the root causes of the out-of-specification products manufacturing

Continuous improvement of the manufacturing process	Corrective and Preventive actions need to be identified, documented, and implemented
Reliability of the manufacturing equipment used in the process	Line clearance checks need to be strictly enforced with all the relevant information and signatures holding the accountability of the individuals.
Failure to establish and follow adequate written procedures describing the handling of all written and oral complaints regarding a drug product. Failure to maintain an adequate written record for each investigation conducted, that included the findings of the investigation and follow-up.	Corrective and Preventive actions need to be identified, documented, and implemented.
Mixed up drugs caused by inadequate cleaning procedures, personnel flow, equipment suitability, material flow, line segregation, inappropriate line-clearance documentation, etc.	Manufacturing Execution Systems enforcing the personnel certifications for the processes, capturing the Line clearance checks and ensure that the materials are dispensed with proper sampling activities are completed
Failure to establish appropriate controls over computers and related systems to assure that changes in master production and control records or other records are instituted only by authorized personnel.	MES, CAPA and any other shop floor systems security needs to be properly ensured so that only authorized individuals have access to the data
Adequate documentation to prove that the processes are designed to manufacture the product safely, documented and operators have been trained and systems are ensuring that these processes are followed	Ensure that Standard Operating Procedures are backed by adequate design documentation, training, and process control documentation
Lack of appropriate documentation for rejecting the semi-finished/finished/packaging products, etc.	Documentation of scrap/product rejection reasons.

Reliability of the processes, equipment used, personnel worked on the batches	Documentation of the processes performed, equipment used along with Line clearance checks and personnel certified and ensure that e-signatures are captured. Any deviations need to be captured and shall generate the triggers
Failure to establish and document the accuracy, sensitivity, specificity, and reproducibility of test methods employed by the firm.	Ensure that the processes are closely monitored by Manufacturing Execution Systems
Failure to routinely calibrate, inspect, or check according to a written program designed to assure proper performance and to maintain adequate written records of calibration checks and inspections of automatic, mechanical, or electronic equipment, including computers, used in the manufacture, processing, packing, and holding of a drug product.	Ensure that the Equipment are closely monitored by Manufacturing Execution Systems

Table 8: Issues and Solutions (MES)

4.7.3. Distributed Control System (DCS)

Rockwell Automation's updated PlantPAx improves DCS automation and control.

The latest release of PlantPAx Advanced Distributed Control System (DCS) by Rockwell Automation includes a higher production design environment to maximize automation productivity, easier adoption of new technologies to enhance the user experience and advanced control capabilities to achieve operational goals.

To provide reliable and accurate system configuration for operators, the PlantPAx system now includes expanded evaluation, design, and development guidelines. Updating the documentation and design capabilities help increase automation productivity, reduce the time required to deploy a maintainable and modern system, and reduce life cycle costs. The pre-configured control strategies developed in the Rockwell Automation Library of Process Objects provide a consistent user and maintenance experience.

By enhancing network upgrades and built-in mobility, the PlantPAx system provides an enhanced, reliable user experience. Extended industrial Ethernet switches support Layer 3 topologies, enhancing scaling for a variety of applications. Small control systems can now be integrated into larger enterprise networks with a common, fully supported network infrastructure. Includes Cisco technology embedded for integrating and translating network switches, operational technology, and information technology. This makes it so easier for process operators to configure and manage computer networks.

The PlantPAx system now includes mobile components that allow users to create scenarios and interact with process data across any HTML5-compatible mobile operating system. The software is responsive to the user-specific system, allowing workers and plant managers to access and view the performance of metrics and data analytics in their preferred format.

New built-in control features such as integrated PlantPAx model forecast control (MPC), alarm management and volume management now operate in a common environment, which helps to improve plant performance and operational efficiency. Control-based PlantPAx MPC provides the ability to predict external and complex process interruptions. This allows for continuous improvements in performance while minimizing waste and variability.

The updated system uses the recently introduced module utility tool to reduce the risk, time and cost of implementing module control systems. The toolkit, which includes documentation, application examples, and sample code, provides engineers with a starting point for creating and maintaining a standard volume control system. This provides flexibility to customize system components for increased functionality.

4.7.4. Internet of Things (IoT) in Pharmaceutical Manufacturing

Business requirement	Methods	IoT solutions	Advantages
To enhance the manufacturing efficiency	By reducing the downtime* of the equipment (*Machine is out of action)	Whole operational data and status (run time, temperature load, and ready to use/in operation/under cleaning/under maintenance) are	Real-time dynamic scheduling for the shop floor processes

		gathered using smart equipment	
	To permit the visibility around the equipment for planning and scheduling of operations	Gathering real-time information on the data to predict the equipment downtime status	More efficient utilization of the equipment
	Promoting automatization for incident-related queries	Sensors are added for collecting data and information using industrial IoT platforms	Reduced downtime of the equipment
	Lowering the variability and improving the yield		Tracking of the overall equipment effectiveness
			Both productivity and efficiencies are enhanced

Table 9: IoT in Pharma

The promising benefit of IoT in pharmaceutical production is reduced production costs, real-time monitoring, control, improvement of pharmaceutical unit functions, and patient outcomes. IoT-based production control systems are defined as supervisory control and data acquisition system, production implementation system, production data, and distributed control systems. These systems will help to monitor and control production activities to improve the quality of production.

4.8. Decision on IoT

Conventional IoT models are complex because they have enormous impacts on human life (e.g., safety, mobility, environmental sustainability safety, energy efficiency, health, etc.). Therefore, issues and challenges related to IoT should be considered in the light of various perspectives such as community and environmental impacts, technologies, business models, services, and applications.

CHAPTER 5

5. CONCLUSION

This work aims to test the validity of a particular quality tool, namely FMEA, which is used successfully in many contexts such as automotive and pharmaceuticals. In the specific field of floriculture, here is an assessment of the failure of the process of producing pills.

The FMEA method is used as a life tool throughout the product/process realization process. This study aimed to try the use of FMEA quality tools and methods to develop a safe and more efficient manufacturing process for tablets production.

In this paper, it is focused on the PFMEA of a particular process, identifying sources of uncertainty through the probabilities of failures and specific interventions, and improving the accuracy and precision of the work.

This method helped to focus on the various important steps that are important to product quality and process. PFMEA analysis involves more excellent reliability, better quality, increased security, and its contribution to cost savings with shorter growth time and reduced waste and value-added performance. The results can be used to identify the most vulnerable components and guide resource development for optimal benefits.

It was selected here using the cause-and-effect Ishikawa map to help identify potential primary and secondary causes of the problem, subdividing them into different reference categories and looking at almost all aspects of the problem together. It classifies actions that emerge from failure/risk analysis according to Ishikawa's 4Ms as manpower, materials, methods, and machinery.

The human factor is of particular importance to the process being analysed here. The production process is done manually by highly qualified personnel. Despite this, human errors can occur and significantly affect the process because some of their steps and procedures require more experience and consistent control of equipment and materials. Therefore, the protocols should be designed clearly to minimize the undesirable effects on the results, preventing mistakes or minimizing the associated risk.

Since all development work is carried out under Good Production Procedure (GMP), changes in humidity that can lead to variation in product humidity is at low risk.

Risks associated with changes in input raw materials (changes in API particle size, conversion to magnesium stearate source, and transition to decomposition stage: binder level) and process parameters for homogeneous mixing, filling, and measurement have been identified as high risks., Compression key, compression speed, and tool design.

Therefore, the Blacket-Burman design was chosen, which is a widely used screening design to identify the "key factors" that cause variation in product quality.

Once the screening has been classified and evaluated, the next step is to carry out the safe process of manufacturing. So, there comes the usage of support systems to maintain, control the production process parameters. It is concluded that the implementation of an IoT-based (support systems) manufacturing process leads to the prevention of process failures and that the IoT systems associated with the production process minimize the various critical shortcomings that may occur at each stage of the production process. Systems such as SCADA, MES, and DCS were implemented to control and monitor the production process it was sufficient to reduce the risk associated with systems itself.

IoT can add new features to a variety of functions by enabling smart technologies for anywhere, anytime, anything, and any media interaction. IoT is constantly improving communications and manufacturing processes, and applications and solutions are constantly being developed. They were increasing productivity and efficiency while gaining an in-depth view of customer behaviour patterns and needs. However, some obstacles, such as ignorance, still need to be overcome. Having IoT-trained workers and experts in this area locally will equip them with the right tools to benefit businesses and create a better future.

For the future purpose of this project, it has been decided that a fully designed IoT-based manufacturing facility will be grounded to manufacture the tablets in a efficient and effective way. Meanwhile, solar power will be considered a secondary power source for the successful operation of the production plant in the future.

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