Granulation Area Capacity Increase

Luis Daniel Torres Colón
Master in Manufacturing Competitiveness
Jose A. Morales, PhD
Industrial and Systems Engineering Department
Polytechnic University of Puerto Rico

Abstract *– Manufacturing pharmaceuticals are continuously looking for waste reduction to improve their processes and increase the manufacturing output. Granulation area capacity increase was evaluated for a solid dosage pharmaceutical industry in Las Piedras (LP), Puerto Rico. Volume increase for a pharmaceutical product is driving additional capacity requirement for granulation. Also, it was required to eliminate non-value added (NVA) tasks during the granulation activities. DMAIC process and its tools were used to increase the granulation capacity. Kaizen principles, process mapping and cycle efficiency, among others were used, providing a high-level view of the value stream being targeted in the improvement. Improvements such as new Ways of Working (WOW) to run two batches in parallel among others were actions implemented to granulation product capacity increase. As results of this project, the business benefits were a cost benefit of time saving 27% cycle time, representing 36 lots/month with a revenue of $1,947,886 per month.*

Key Terms *— Benefits, Capacity Increase, DMAIC, Improvement*

PROBLEM STATEMENT

A pharmaceutical industry in Las Piedras, Puerto Rico is focused in manufacturing solid product (tablets). As business competition is growing and get tougher, there is much pressure on manufacturing and service organizations to become more productive and efficient. Manufacturing area is constantly pressured to improve quality, decrease manufacturing cost and increasing production volumes with less resources. Therefore, the organization must reduce the cycle time and improve customer satisfaction.

The granulation area volume increase for pharmaceutical product is driving additional capacity requirement for granulation. Granulation capacity exceeded in year 2019 even with 24 hours operations. The current output for granulation area is 4-5 lots/day (130 lots/month) with a manufacturing cycle time of 4.4 hours/lot. The company requirements and forecasts must increase the granulation output to produce at least 160 lots per month, monthly, to meet the demand of 2019 and 2020. Each granulation lot is finally used to produce a solid dosage tablet.

Tablets are the most prescribed dosage form. The reason for this popularity is that tablets offer a convenient form of drug administration, provide dosage uniformity from tablet to tablet, are stable over extended and diverse storage conditions, and can be produced on high-speed compression, labeling, and packaging equipment. As a result, tablets production technology is constantly undergoing improvements that enhance their ability to deliver, with precision, a desired drug in a dosage form intended for immediate or extended therapeutic effect. In addition, the growth of the generic industry, as well as increased competition from both foreign and domestic markets, require that a tablet manufacturer have greater concern regarding the economics of tablet production by introducing less labor-intensive, higher-productivity manufacturing methods for making the increasing number of tablets products available today [1].

Also, as part of this project design it is important identify the potential NVA tasks during the granulation activities and define the strategy to minimize or eradicates it. There is a necessity of the companies to keep the balance between their operations and the dedication of resources for manufacturing. For this reason, on 2019, the

pharmaceutical industry in LP evaluated the necessity to increase the capacity for the granulation process pursuing the business benefits with a better work organization, standardization, granulation availability to meet the demand, and improve the cycle time.

Research Description

This design project considered to increase the granulation product output to produce at least 160 lots per month on a monthly basis, to meet the demand of 2020, 2021 and subsequent years. It is important this output incrementation for additional capacity requirement due to LP pharmaceutical products growth. Currently, the pharmaceutical industry in LP is the only supplier for Granulation product because of external manufacturing (India) compliance issues. Therefore, this design project could result in significant output and cost benefits for the company and other related organizations.

Research Objectives

The objectives were defined based on a requirement of the LP Operation Site to improve company performance to meet the demand and to be more competitive. The improvements enhance value or excellence, and these characteristics are part of the pillars of the company, and these objectives obey the need to show the capacity of making a more efficient production and better cost, because the plant is being compared against the network. The following are the objectives of this research work:

- Implement of parallel activities.
- Decrease the manufacturing cycle time by 27% (1 hour/lot, at least1700hours/year).
- Increase Granulation lots Output: 7 – 8 lots/day, Aprox.157 lots/month.
- Meet demand requirement.
- Eliminate NVA tasks activities (no waiting time, simultaneously activities).
- Standardize Work, visual factory and improve area organization through 5S methodology implementation.

Research Contributions

The execution and implementation of improvements in granulation area will contribute to achieve the demand responsiveness, reducing the granulation cycle time and resulting in an incrementation of production output (7 – 8 lots/day, Aprox.157 -160 lots/month). The actual output is 4-5 lot/days, 130 lots/month. These improvements resulting in a business benefit will provide a better and efficient new WOW, better work organization and standardization. In terms of compliance, this project will be contributing in the improvement of the area organization due to 5S methodology implementation and reducing material and equipment exposure time to the environment (quality).

Cost reduction from the elimination of the Non-Value Added related to different waste such as waiting for material, waiting for people and downtime. It includes to perform a granulation and milling/Pack-off activities simultaneously in the same Room (Parallel Activities) resulting in a time saving 27% cycle time and downtime tracking.

Also, it will help promote a culture of continuous improvement, since it leads us to periodically evaluate our manufacturing process (WOW) and avoid inappropriate or obsolete practices or policies.

LITERATURE REVIEW

Manufacturing pharmaceuticals are continuously looking for reduce waste to improve their processes and increase the manufacturing output. This project is focused in reduce costs avoiding waiting time (material and people) to eliminate NVA tasks in manufacturing activities using Lean methodology. Also, implementing new WOW to run two batches in parallel (additional granulation bowl), 5S implementation to manufacturing Room 402, creation of standard work and visuals to identify Room 402.

Lean manufacturing is a systematic methodology applied for continuously improvement that seeks to eliminate waste in a

process to improve its productivity. The productivity is a measure of the efficiency of an employee, machine, factory, or system in converting inputs into useful outputs. Lean Manufacturing principles were applied to this process to eliminate NVA tasks. The company will create more value for customers with fewer resources. The pharmaceutical industry in LP, understands the value of their customers and focuses its key processes to continuously increase it. For this case, Lean will be applied to the Glatt #9 capacity increase in a determined period using the Kaizen Methodology. DMAIC methodology will be developed to effort in the customer needs and to improve the process.

The researcher, as well as the company, are focused in the Lean thinking Philosophy, and observed the current state or process which has waste, variation, and rigidity. In this case, the granulation process is mainly performed by manufacturing operators. If a new granulation batch is required, a manufacturing order is created in a software application named System Applications and Products (SAP). All manufacturing orders are managed through SAP and simultaneously linked with the Manufacturing Execution System (MES). Once the manufacturing order is created in SAP, the orders can be printed and executed.

The current granulation manufacturing process is a wet granulation process. The main objective of fluid bed granulation is to produce granules that have good flow properties and compaction characteristics to enable the manufacture of tablets with the desired quality attributes. Granulation process is divided in the following main stages: Granulation solution preparation (Povidone), Active Pharmaceutical Ingredient (API) de-lumping and milling, Granulation/Drying, Granulation milling, and packaging process.

Delumping and weighing of the API is performed in Room 5132 prior to transfer it to the granulation step. A fixed quantity of 279 Kg of delumped API is used at the granulation stage.

Granulation activities are executed in the Fluid Bed Granulator, Room 402, with a top spray technology. Currently, only one lot can be processed at Room 402 during the Granulation/Drying, Granulation milling, and packaging process.

A binder solution is prepared in a stainless-steel tank by dissolving Polyvinylpyrrolidone (PVP; Povidone) in Purified Water (22.3% (wt)), using a low shear agitator to mix the solution until PVP is dissolved. The specified quantity of 279 Kg of API that was delumped on Room 5132 is charged to a Fluid Bed Granulator/dryer and granulated by spraying a fixed amount of binder solution onto the fluidized powder. After granulating, the material is dried until a satisfactory moisture content is achieved.

This fluid bed granulation step for a 300kg batch consists of two spraying phases and one drying phase. The only in-process test associated with the fluid bed granulation step is moisture by loss-on-drying (LOD) at the end of the Drying Phase, whose limit is not more than 1.0%.

Once the granulated API is dried, the granulated material is passed from the product bowl through the Bohle Turbo Sieve (BTS) Comil equipped with a 1.5 mm screen at a velocity of 490 to 510 RPM and discharged into the final packaging containers (plastic drums with two polyethylene bags). The expected gross yield after milling is in the range of 98 to 102%.

After the tasks are performed, the manufacturing orders are manually and electronically signed in MES program. Refer to Figure 1 for current process of the granulation activities.

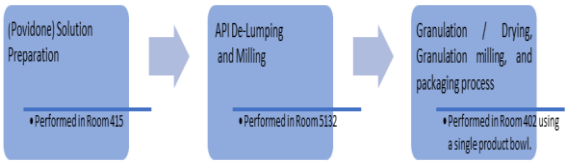

Figure 1: Current Process of the API Granulation Activities

In the current process, during the API granulation/drying process, granulation milling, and packaging processes phases were identified different activities as waste; also, it was identified

the variability or rigidity in the process. These identified activities are the following:

- Manufacturing activities in Room 402 are not performed following a standardize work or visual controls. Therefore, performed manufacturing activities are executed with highly variability.
- Only one lot can be proceeded at a time in the same Room (402) since start the API granulation until completed packaging process (rigidity). Only one granulation bowl is available to perform these activities resulting in wasting time for de-lumped material to be granulated and people (waiting to start the granulation step). The current cycle time is approximately 4.4 hours/lot.
- There are no Down Time Tracking to monitor and analyze the time loss.

After the waste activities were identified, the next step is to eliminate the activities using Lean tools as DMAIC methodology. This project is focused on optimize the flow throughout the process and add customer-value activities. These are the activities absolutely required to meet the need of the customer. However, the activities that uses process resources as time, money, and people for which the customer is unwilling to pay should be eliminated. These activities are the NVA Activities.

DMAIC approach methodology will be selected to reach the mainly goal of to increase the granulation area capacity. DMAIC is a data-driven quality strategy used to improve processes. It is an integral part of a Six Sigma initiative, but in general, can be implemented as a standalone quality improvement procedure or as part of other process improvement initiatives such as lean [2].

The DMAIC approach will be used as a problem-solving methodology designed to guide the improvement team from the pharmaceutical industry in LP through a systematic approach, from defining the problem through implementing solutions linked to underlying causes and establishing best practices to make sure the solutions stay in place.

DMAIC is an acronym for the five phases that structure the process. It should be executed in order and the phases are Define, Measure, Analyze, Improve and Control.

During the first phase, customer is defined, their Critical to Quality (CTQ) issues, the Core Business Process involved, the project boundaries that can stop and start of the process. In this phase, the process is defined to be improved by mapping the flow.

The second phase is to measure the performance of the process involved. A data collection plan for the process should be developed. Data is collected from many sources to determine types of defects and metrics. Customer studies results are compared to determine gaps.

The third stage analyze the data collected and the process map to determine root causes of defects and opportunities for improvement. Also, to identify gaps between current performance and goal performance. Prioritize opportunities to improve and identify sources of variation are also considered.

The fourth stage improve the target process by designing creative solutions to fix and prevent problems. Create innovate solutions using technology and discipline are studied. Then, develop and deploy an implementation plan.

The last stage, Control, considers the improvements to keep the process on the new path. Prevent reverting back to the “old way”. This stage promotes continuous improvement for a process; therefore, require the development, documentation, and implementation of an ongoing monitoring plan. Finally, institutionalize the improvements through the modification of systems and structures through the training and incentives.

METHODOLOGY

This project will apply the DMAIC methodology to improve the granulation area output and eliminate the NVA tasks. The five phases that structure the process in which was based this project were:

- **Define Phase:** The first step consisted in describe the problem, select a project team and stakeholders, and develop goals based on the voice of customer. This stage lays the foundation for the project. The team defined the problem, identified customers and their requirements, and selected the project team, including members who are directly affected by those issues related to the problem. Project measures, financials and a communication plan were also established [3] [5].
- **Measure Phase:** The goal on this phase was to measure the process to determine its current performance and quantify the problem. Measurement systems were identified or developed, validated, and improved as required. Baseline performance were established with trustworthy data [3] [5]. Data and information about the current process was collected to understand the problem.

  Descriptive univariate analysis was performed to examine the data distribution using frequencies, measures of central tendency and dispersion. In addition, bivariate analysis was carried out using the independent Student's t-test to assess whether the difference between time averages before and after the improvement's implementation are statistically significant. This Student's t-test was performed with a significance level of $p \leq .05$. The data can be showed in graphical and statistical forms.
- **Analyze Phase:** In this phase the cause (s) of the problem were identified. The critical inputs were also identified. Inputs that have a strong relationship with the outputs and root cause were determined [3] [5]. These critical inputs were the drivers of the performance.
- **Improvement Phase:** This phase consisted into improve the actual process by designing solutions to fix and prevent problems. Potentially solutions were identified and evaluated, and the process was optimized. The critical inputs that must be controlled were determined. Process capability and project financials were estimated [3] [5].
- **Control Phase:** The main purpose is to control the improvements to keep the process on the new path. This phase promotes continuous improvement for a process, therefore, require the development, documentation, and implementation of an ongoing monitoring plan. This is the stage that establishes mistake proof, long term measurement and reaction plans. The team developed standard operating procedures (SOP) and established process capability. Project financials were updated, verified, and reported. Ownership and control were transitioned to the process owner, and lessons were documented [3] [5].

RESULTS AND DISCUSSION

This section presents the problem analysis and improvement results using the Lean Methodology and DMAIC approach.

Define Phase

This project arises from the need to increase the capacity of the granulation area process of the pharmaceutical industry in LP and promote a culture of continuous improvement.

Currently, lack of capacity in the granulation area to meet demand requirement expected was identified as a potential problem to be increased using Lean Methodology and DMAIC approach.

A multidisciplinary team was selected to work with this project. The team developed a project charter that presented what the process problem is in measurable terms that tells how well the process is performing today (the baseline) and how performance should be after process improvement (the goal). Other activities for the team during the DMAIC measure phase were to collect data (Kaizen Event) of the current process focusing on overall time of each step and held recurring meetings to analyze the data and perform brainstorming to possible solutions.

The problem was defined as volume increase for granulated API and it is driving additional capacity requirement for granulation area. Also, eliminate NVA tasks during the granulation process. Currently, company needs to produce at least 160 lots per month, monthly. The current process is mainly performed by manufacturing operators. In the current process, it was identified some activities as waste and the variability or rigidity in the process that incremented the cycle time. These identified activities are not performed following a standardize work or visual controls. Therefore, performed manufacturing activities are executed with highly variability. The limitation of processing only a single batch in the manufacturing Room 402 since start the granulation until completed the packaging process added less flexibility (rigidity) to the process. Only one granulation bowl was available to perform these activities resulting in time loss (waste) awaiting to start the next batch. In addition, there are no Down Time Tracking; therefore, it suggests no consistency to monitor and analyze the time loss and process events.

In this stage, project measures, financials and a communication plan were established. The actual output represents a monthly revenue for the company accounted of $5,445,210. New manufacturing output are estimated of additional $1,947,886 monthly in revenue for years 2020, 2021 and meet the required demand. Revenues are calculated based on the quantity of batches and tablets produced for each granulation batch manufactured. After the implementation of this project, the new output will be approximately 35 additional lots per month of API granulations. Each granulation lot contains 300kg; therefore, it represents an additional 10,500Kg. Using a 10.500Kg of API granulation, can be manufactured 44 lots of Finished Good (solid dosage tablets). New additional revenues are calculated as follow, refer to formula "(1)".

$$1\ Lot\ (Finished\ Good)\ Benefit = \left(\frac{\$213.35}{TS}\right)\left(\frac{217.5\ TS}{1\ Lot}\right) = \$44,270.13 \quad (1)$$

TS= Thousand (Tablets)

Thus:

$$Potential\ Benefit\ per\ Month = \$44,270.13 \times 44\ Lots/Month$$
$$= \$1,947,886$$

The main goal of this project is to obtain an improvement in granulation area to achieve the demand responsiveness manufacturing two batches of API granulation in parallel and eliminate NVA tasks in the granulation area.

Measure Phase

In this phase, the data gathering was obtained from different sources. First, a query from SAP system was performed to obtain the manufactured lots from the years 2018 and 2019. The usage of equipment logbooks to determine the time elapsed from the beginning of the batch to its completion (Takt Time) were also studied. Measure phase also was focused on collect data from the SAP system of the current process concentrating on overall time of each step (Time Study). Go and see were performed to evaluate the WOW. To measure the performance of the granulation area and quantify the problem, the data was classified, segregated, and plotted in different graphs. A baseline performance was established with trustworthy data.

The first graph obtained was a monthly comparison on granulation lots manufactured from July 2018 to December 2019. Project improvements implementations were on April 2019. Data obtained was measured and compared for this period taking in consideration 9 months before and after project implementation. Refer to Figure 2.

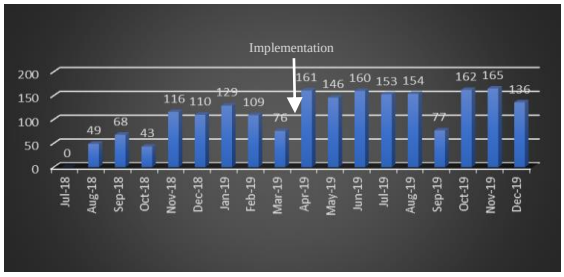

Figure 2
Monthly Comparison on Granulation Lots Manufactured before and after Improvements Implementation

Data was evaluated for the last two quarter of year 2018 and year 2019. It reflects the quantity of lots manufactured associated to this period. Data showed no activity for July 2018 because the shutdown activities performed during this month; therefore, as this does not represent the manufacturing activities, this month is not considered for the statistical evaluation.

Table 1

Descriptive Statistics for Granulation Lots Manufactured Before Improvement Implementation

n	Min.	Max.	Median	$\bar{X}$	SD
50	43	129	93	88	33

The data analysis from period April 2019 to December 2019 belongs to the lots manufactured after the improvement's implementation. Data showed for September 2019 that only 77 were manufactured lots. It was because of a cleaning validation and utility upgrade activities. Since this month was not representative of the manufacturing activities, data for this month will not be considered for statistical analysis. An increase in the manufacturing of granulation lots were observed after the improvements in compared with the output before the improvements.

Table 2

Descriptive Statistics for Granulation Lots Manufactured After Improvement Implementation

n	Min.	Max.	Median	$\bar{X}$	SD
50	136	165	157	155	10

This output means a significant difference of approximately 36 lots per month, considering the maximum lots manufactured for both periods (129 lots and 165 lots respectively).

The results suggest that there are statistically significance differences between the average time (Cycle Time) that elapsed during the execution of granulation process before and after improvements implementation. This represented an improvement in process cycle time of 1.2 hrs/lot, from 4.4 hrs/lot to 3.2 hrs/lot.

Table 3

Difference Between Time (Min.) Averages Before and After the Improvement Implementation

	n	Min.	Max.	$\bar{X}$	SD	t(98)	p
Before	50	239	287	264	10	47.391	≤.05
After	50	182	200	192	4		

Figure 3 shows a cycle time comparison on granulation lots manufactured before and after improvements implementations. Data obtained was measured and compared considering 50 manufactured lots before and after project implementation.

Figure 3
Process Cycle Time Before and After Improvements Implementation

A significant decrease in the manufacturing cycle time was observed after the improvements compared with the output before the improvements.

Analyze Phase

In this phase, the cause (s) of the problem were identified. Inputs that have a strong relationship with the outputs and roots cause were determined. Fishbone Diagram was used to analyze the root causes. Using an affinity diagram, the team could organize and summarize the natural grouping from many ideas and issues that could have been created during a brainstorming session. From this summary, the team could better understand the essence of problem and breakthrough solution alternatives. During this exercise were evaluated Material, Method (WOW), Machine (Equipment) and People. The top offenders of the current process are identified as Method and Equipment. Refer to Figure 4.

Machine (Equipment) was identified as one of the largest contributors for the final root cause. Different potential causes were identified such as lack of additional product bowl. The lack of additional granulation product bowl limited the

ability to manufacture more than one granulation lot in parallel. In addition, there was no effective electronic or manual system implemented to monitor the equipment downtime. Without an effective downtime monitoring system results in reduction of percentage of machine available capacity. Equipment downtime not only impacts the output of the granulation station itself, but if it is severe enough, it may cause a significant variation in the arrival at the downstream workstations, provoking congestion, and delay. Moreover, it was identified that the equipment remains without being use since waiting for material (next batch). This potential cause is because of the inability to manufacture of two lot in parallel.

For method evaluation, also it was identified one of the biggest contributors for the root cause. It was noticed that the SOP lack specifics instructions and the flexibility to run two lot in parallel in the same manufacturing Room. It was related to been followed inappropriate or obsolete company practices or policies (rigidity). As part of the method evaluation, it was identified a lack of standardize work (step by step), visuals and area organization. Even the 5S methodology is being introducing to the company, it had not been implemented in the granulation area. "The basic housekeeping discipline for both the shop floor and office is 5S (sort, straighten, shine, standardize, sustain). 5S should be considered in two ways: as an everyday continuous improvement activity for individual and small groups, or as a KPIV that should impact a 30,000-foot-level project/quality, or safety issues, 5S should be considered as an execution strategy" [4]. New layout for granulation Room was proposed to establish a new WOW. This new WOW is considering performing the manufacturing process of two granulation batches in parallel in the same granulation Room. Regarding to granulation Room layout it was identified that it must be modified to comply with the current GMP standard and Rooms segregation. Therefore, new Room layout and Room drawing must be modified and approved.

For material, there are not order/delivery system implemented for material supply. Lack of order/delivery system results in time loss, wasting for material to be delivered to start the de-lumping process. It was also found that due to not having an additional bowl and having a problem during the manufacture of a previous granulation batch, the next batch would have to be re-processed due to its expiration time during de-lumping stage.

For people, some types of commonly wastes such as wasting times and unused time of employees in the granulation area were identified. The operators spend time waiting the completion of the granulation process, meanwhile they did not perform any additional task. This is because of not being able to manufacture two batches in parallel or perform any related task for processing the next batch. Also, this is indicative a lack of an standardize work system.

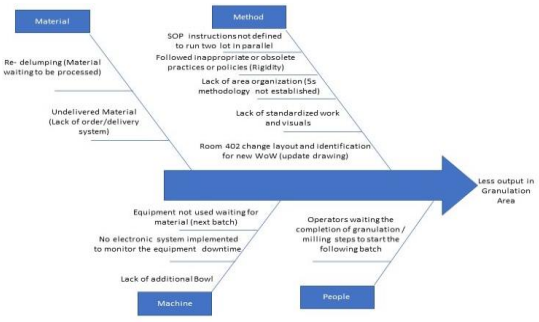

Figure 4
Fishbone Diagram

After evaluating the causes of the findings during the Fishbone Diagram exercise and before moving on to the Improve Phase, the team confirmed the proposed root causes are true by using data, process analysis, process observation and comparative analysis. From the Fishbone Diagram exercise, it was determined actions to be taken to correct or prevent these failures. Some of these actions will be explained.

For the limited ability to manufacture more than one granulation lot in parallel, it was identified the requirement to purchase a new product bowl. In addition, it was determined the need to create a new electronic downtime tracking system.

For the lack of specific instructions and flexibility to run two lot in parallel in the same manufacturing Room, it was identified that two procedures "Operación De Revestimiento o Granulación en el Fluidizador Glatt" and "Procedimiento para la Operación Del Glatt # 9", should be revised to include guidelines. In addition, as part of the method evaluation, it was identified the need to implement in the granulation area standardize work (step by step), visuals and area organization (5S).

The need of a new layout for granulation Room was identified to establish a new WOW. This new WOW considered performing the manufacturing process of two granulation batches in parallel in the same granulation Room. Granulation Room 402 drawing should be revised and updated to comply with the current GMP standard and Rooms segregation to manufacture two lots in parallel.

For material order/delivery, a new production material replenishment system should be generated to provide a standardized system to assure a continuous delivery of material.

Improvement Phase

This phase consisted in improve the actual process by designing solutions to fix and prevent problems. Creating innovate solutions using technology and discipline. For this stage, Project Management Fundamentals & Kaizen DMAIC tools were used to develop and deploy an implementation plan. The following actions and the benefits were part of the implementation plan:

- Cost benefit of time saving 27% cycle time decrease (1 hour /lot, at least 1700hours/year). This represents approximately a production increase in additional 36 lots/month (432 lots/year). Cost reduction from NVA waiting added to approximately $1,947,886 per month.
- New layout for granulation Room was established for a new WOW. This new WOW is considering performing the manufacturing process of two granulation batches in parallel in the same granulation Room. Granulation Room 402 was segregated into Side A and Side B. Side A is dedicated to performing the granulation Milling and Packoff processes while Side B to the granulation process.
- Procedures "Operación De Revestimiento o Granulación en el Fluidizador Glatt" and "Procedimiento para la Operación Del Glatt #9" were revised and implemented to include specific instructions to run two lot in parallel in the same manufacturing Room.
- Process standardization was generated and implemented for accurate and consistent job tasks. Having a standardized system for process improvement can increase efficiency, reduce variation, cost reduction from eliminated NVA (waiting) and create a lean culture. Standardize work includes the granulation activities (Step by Step) for both Room sides (A and B) to manufacture two lots in parallel.
- The visual board and production material replenishment system were implemented to monitor the daily/monthly production plan and provide a standardized system to assure a continuous delivery of material.
- Finally, a new electronic downtime tracking system was designed using the Spotfire App. It was implemented to monitor the equipment downtime and be able to easily graph the lost time and its causes to minimize or eliminate it.

Control Phase

The main purpose of this phase is control, the improvements to keep the process on the new path. This phase promotes continuous improvement for a process; therefore, require the development, documentation, and implementation of an ongoing monitoring plan. Finally, institutionalize the improvements through the modification of systems and structures through the training and incentives. Some tasks or documents that will be periodically monitored are:

- Standardize Work
- 5S

- Downtime Tracking System
- Visual Factory and Material Replenish System
- Procedure “Operación De Revestimiento o Granulación en el Fluidizador Glatt” (SOP 07-021) and “Procedimiento para la Operación Del Glatt # 9” (SOP 07-111)
- Personnel Training
- Governance

CONCLUSION

Using DMAIC approach was possible to increase the Granulation area capacity, driving additional capacity requirement at the pharmaceutical industry in LP. After collect and classify the data, Lean Manufacturing tools were used to determine what the possible root cause of the granulation lot output limitation and tasks with no value added. As result was obtained the improvements in the procedures, implementation of a new WOW to run two batches in parallel, new granulation Room layout, improvement in the granulation procedures, additional product bowl to provide additional capacity, 5S implementation and certification as well as the creation of the standard work and a new electronic downtime tracking system were actions implemented to increase the granulation capacity.

Also, a cost benefit of time saving of cycle time from 4.4 hrs./lot to 3.2 hrs./lot (1 hr./lot, at least 1700 hrs./year) was achieved. This represents a 27% in cycle time decrease. This represents approximately a production increase in additional 36 lots/month (432 lots/year). Cost reduction from NVA in waiting (Material and People), added to approximately $1,947,886 per month in revenue. In addition, as results of this project, the business benefits were a better work organization and standardization, improved area organization through 5S, granulation availability to meet the demand, flexibility to perform tasks in parallel and reduce respond time.

Even though the improvements were successful, and the expectations and goals complied, there are lessons and additional opportunities to improve in the manufacturing area. Some opportunities are to extend the granulation area improvements for Operations (Blending, Compression, Coating and Packaging Areas), evaluate in deep the cycle times, implementation of standardized work and manufacturing area 5S certifications.

REFERENCES

[1] H. A. Lieberman, L. Lachman and J. B. Schwartz, Eds., *Pharmaceutical Dosage Forms Tablets Vol. 3*, 2nd ed., New York, NY: Marcel Dekker, 1990.

[2] C. M. Borror, *The Certified Quality Engineer Handbook*, 3rd ed., Milwakee, WI: ASQ Quality Press, 2009, pp. 321–332.

[3] JR Excellence Solutions, “Focused & Accelerated Solution Tactics Improvement Program”, presented at the Project Management Fundamentals & Kaizen DMAIC Training, Caguas, Puerto Rico, 2018.

[4] F. Breyfogle III. *Implementing Six Sigma: Smarter Solutions® Using Statistical Methods*, 2nd ed., New York, NY: John Wiley & Sons, Inc, 2003.

[5] T. Pyzdek, *The Six Sigma project planner: A step by step guide to leading a six sigma project through DMAIC*. New York, NY: McGraw-Hill Education, 2003.