Utilizing the DMAIC Methodology to Drive a Built-In-Quality Changeover Process in a Thermoforming Line for an Automotive Component Manufacturer

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Abstract

Automotive component manufacturers are some of the organizations that are faced with a lot of complexities in their manufacturing streams. These complexities require a number of changeovers on the lines according to the sequences and derivatives that are required by customers. One of the challenges that component manufacturers face is the outflow of defective parts post their changeovers which hinders the ability to deliver and reduces capacities. An automotive component manufacturer which manufactures various bedliners was concerned about the outflow of defective parts after every changeover on their Thermoforming line. This pointed directly to a lack of built-in-quality in their changeover processes. This was primarily reflected in their approach of frequently adjusting the moulding machine and relentless reworking of the work being done in the moulds after changeover completion. This resulted in multiple destructive tests, high defect rates, and major delays in their ability to run the line and deliver to their customers. Given the magnitude of the problem in the organization, the aim of this study was to utilize the Lean Six Sigma Define, Measure, Analyse, Improve, and Control (DMAIC) methodology to bring about significant improvement in driving built-in-quality in the changeover process execution for the line. The results of the study were a streamlined approach to this problem, reduced defect occurrences after changeovers, and an overall changeover process that encompasses a built-in-quality approach in its execution.

Keywords:
DMAIC methodology, Changeover, Automotive component manufacture, Built-in-quality, defect rates

1. Introduction

Process changeovers in manufacturing organizations hold core to the mainstream of operations. These changeovers are a necessity to drive the much-needed flexibility of manufacturing to live up to the expectations of delivering various product ranges. According to Sugarinda et al. (2019) changeovers are fundamental to the production of the right products that are required by customers. The improvement around changeovers is mostly attributed to the Single Minute Exchange of Dies (SMED) methodology (Garcia-Garcia 2022), which focuses primarily on the reduction of the time it takes to complete the changeovers. What is often not considered in the process is the number of defective parts that are incurred after the changeovers are completed. The occurrence of such defects can be attributed to a lack of built-in-quality in the execution of the changeovers. Built-in-quality in the aspect of changeovers talks to the quality of application of material, correct positioning of tools and equipment, correct flow of materials, and proper tightening of tools and equipment. In the context of the Thermoforming manufacturing line, the changeovers occur on the main machine moulding process. These changeovers come in the form of changing of entire moulds or changing of inserts inside the moulds. The absences of quality sanity checks in the activities involved in the execution of the changeovers present many challenges that often result in poor quality products. Stapelbroek et al. (2022) advises that ensuring quality check completion during changeover processes is a significant approach towards attaining good quality first time through products. The checks are often ignored in the interest of completion time or omitted in the changeover procedures during the design phase of the process. There is little literature centred around the reduction of changeover defects and building-in-quality in the execution of the changeover processes. Most literature from various authors focuses on overcoming time

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constraints to drive greater efficiencies during changeover executions. The DMAIC methodology is one of the key approaches that can be used to streamline an in-depth improvement approach that focuses on the aspects of quality product yield during and after changeover execution, while ensuring that such is driven and controlled through a built-in-quality centred approach.

1.1 Objectives

- To identify the elements in the changeover process that contribute significantly to the occurrence of defects after changeover completion.
- To measure the impact of implementing quality assurance elements and improvement ideas on the good quality product yield of the line.
- To utilize the DMAIC methodology as a strategic baseline to improve quality yield on the manufacturing line.
- To define a new changeover procedure that is centred around driving built-in-quality during process execution.

2. Literature review

The DMAIC methodology has predominantly been used as a stratification methodology to improve processes and establish controls. The methodology can be defined as a quality control process that focusses on defining and analysing defects, errors, and variations to determine the root causes and improvement activities. The definition is cemented by Ponsiglione et al. (2021) by outlining that it is a process that deals with the improvement of process variations and the reduction of abnormalities in processes to bring about controls and stability. The methodology can be an enabler in the identification, measurement, analysis and improvement of changeovers process approaches. Improvement of a changeover process approach entails the reduction of errors during the execution of the changeover to ensure vertical start-ups with reduced defects in operations. According to Smętkowska and Mrugalska (2018), reduced errors in operations are key to the ability of organizations to deliver to the needs of their customers. The reduction of errors can be brought about by the implementation of built-in-quality in the process approach of changeovers.

Driving built-in-quality in the execution of changeovers is often a critical element that is not cemented in the design and development of execution procedures. There expectation during changeovers is that technical personnel and machine setters ensure quality work is carried out. What is often not clear is the existence of work instructions and standard operating procedures that have quality guidelines in them to effectively carry out the work with minimal defects upon start-up. Al Farisi (2021) embraces the effectiveness of standard operating procedures by outlining that clear standard operating procedures are fundamental to driving quality work in manufacturing operations. Many organizations rely on the technical skills and the know-how of their tool setters to carry out changeovers with procedures not reduced to paper. Secondary checks and verifications after the execution of changeovers are not developed or outlined as part of the changeover processes. The effectiveness of secondary inspections and verifications during work execution is emphasized by Bheda (2021) by outlining that inspections and verifications are key proactive approach mechanisms that continuously ensure quality process execution. The introduction of such inspections and verifications requires some degree of trade-off between expanded time due to additional verification work required and the impact of unverified work on time and reject yield (Sivakumar and Ganesan 2016). Building quality into changeover processes not only requires a focus in inspections, but also a major focus on the type of materials, equipment, and improved methodologies of executing changeovers in the best possible time with the least amount of scrap generated. According to Singh (2021), the use of appropriate material and equipment in the execution of work is fundamental to the attainment of effective quality assurance. This therefore necessitates the assurance of effective materials and equipment in the execution of changeovers for vertical quality start-ups.

Analysing methodologies and procedures of executing changeovers is crucial to the development of effective systems of changeover management that ensure reliable quality product yield. It is imperative to understand the types of materials used and the reaction of the materials under different application conditions (Moosavi et al. 2020). For processes such as the Thermoforming or vacuum forming, materials required during changeovers include but not limited to silicon, AB Putty, sanding discs, and grinding discs of different grits. Establishing an understanding of these materials in their application is key to ensuring effective built-in-quality in the execution of the changeover. Fan et al. (2020) advises that understanding such conditions is an enabler towards establishing whether certain activities can be executed offline or be prepared prior the execution changeovers. Bhade and Hegde (2020) refer to this type of understanding as the identification of internal and external elements in a changeover improvement approach. Further to the application of different materials during changeovers, it is crucial to establish standards around parameters that need to be adhered to in the execution of changeovers

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(Lonazo et al. 2019). For processes such as the Thermoforming, changeovers involve ensuring that the commencement of production activities is met with correct temperature parameters that can yield good quality products. Non-adherence to, or the absence of parameter standards is often the cause of excessive reject parts upon start-up (Militaru et al. 2018). This is primarily driven by a lack of understanding of the ripple effects of starting up machines prematurely with the hope of getting quality products. This prolongs changeovers and signals the absence of a quality driven mindset in the execution of changeovers.

Automotive component manufacturers are under immense pressure to continuously show the ability to deliver to their customers. With the ever-growing competition for business, great emphasis is placed on driving output while ignoring the drive for quality at the source. Changeovers have become some of the primary sources of inability to deliver to customers (Sankhye and Hu 2020), primarily due to a lack of emphasis on changeover quality at the execution phase. This is also driven by the fact that root-cause analysis approaches are also fixated on defects after changeovers have taken place and do not necessarily look at the changeover process as being the core and primary root-cause to the effects of excessive reject parts. There is little literature that outlines a streamlined approach towards executing changeovers with a built-in-quality mindset. Literature has indicated that a lack of understanding of the various materials that are applied to moulds and dies during changeovers pose a significant gap towards the implementation of a quality driven changeover approach. The impact of changeovers on product quality alone has not been thoroughly exposed by various authors, which strengthens the need for a streamlined approach of yielding possible improvements to the current status quo. An additional factor that contributes significantly to a loss of output after changeovers is the unilateral approach to the development of standard operating procedures for changeovers. Mazur (2020) advises that effective changeover procedures require a multi-disciplinary approach. This goes a long way in ensuring that pre and post changeover challenges are exposed to a wider audience to effectively drive changeover processes that have a built-in-quality mindset.

3. Methodology

The introduction of built-in-quality in any manufacturing stream or process requires a structured approach. The study focussed on utilizing the lean six sigma DMAIC approach as the core methodology to outroot results and bring about improvements that are quality focussed during changeovers. The approach was such that the DMAIC abbreviation was categorized as the steps to follow to improve the process. The detailed step by step approach to the DMAIC methodology was as follows:

Define phase

The define phase was concerned with establishing the foundational description of the problem that the study was resolving. Abdur (2017) defines this phase as one that confirms the existence of a problem in a process and works towards the development of the primary scope of the problem that is being resolve or subdued. Given this definition, the study in this phase commenced with the development of a project chatter for the project by filling in the elements of a project chatter. First it was an outline of the problem statement which gave a high-level overview of the problem at hand. This was followed by the purpose and the business case of the project which stated the fundamental reasons why this study had to be undertaken and the significance thereof of this study. This was proceeded by an outline of the ultimate goal that this study aimed to attain. Further to this, the scope of the study, which established the boundaries of the study as to what was within and outside the scope was outlined.

Measurement phase

The measurement phase of the study was concerned with statistical outlines of the changeover process on the Thermoforming line. Trimarjoko (2020) advises that this phase of the methodology focusses on the measurement of critical factors that are impacting on quality performance. For the purpose of this study, the measurement phase outlined the current number of defects graphically prior the implementation of improvements and after the implementation improvements on the changeover process. The measurement was key to outlining the ratio of changeovers over a period and the number of defective parts that were produced after changeovers took place. Further to this, the defects that occurred in the various changeovers were tabled to develop a direction of the possible causes to the problem outlined in the define phase of the study.

Analyse phase

The analysis phase of the study focussed primarily on the identification of the actual defects that occurred after changeovers relative to the measured defect occurrence data. According to Rana and Kaushik (2018), this phase of the lean six sigma approach is concerned with scrutinizing information and streamlining opportunities that can effect a reduction or total elimination of a problem. The execution of this phase in this study was that of tabling the possible defects on the line together with the statistical occurrence factors to narrow down a priority list of defects. The tabled data was then followed by a Pareto analysis graph which depicted the ranking of the defects that occurred. On the Pareto analysis, the defects were then segregated into those that fell within the 20% range

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which were the vital few, and those that fell within the 80% range which were the significant many. Depending on the magnitude of the defects that fell within the 20% range, the study took to weigh the impact of focussing on the 20% range or tackling all the highlighted defects. This determination was that of checking the 80/20 boundary, and if the defects that are in the significant many boundary are fewer than those in the vital few, the study would rather tackle all of the defects to bring about improvement.

Improvement phase

The improvement phase was concerned with the actual implementation of the recommended countermeasures to the root causes that were identified in the analysis phase. The study in this phase commenced with an outline of defect descriptions, possible causes, elements in the standard operating procedure and improvement recommendations to the analysed data. This was followed by the measurement of the results of all the countermeasures that were implemented to drive built-in-quality in the changeover process. A graphical representation of the improvement trend was then outlined to indicate a shift from the previous standard operating procedure to the newly improved procedure of working. The graphical trend was also measured over a period of 4 months relative to the number of defects that occurred post the implementation of the improved method of approach to changeovers. A comparison summary was then carried out to indicate the magnitude of the improvement that yielded as a result of following the DMAIC methodology.

Control phase

The control phased of the study was concerned with maintaining the improvements that were implemented for the changeover process. To establish control and sustainability of the newly improved process, the study documented a check sheet with parameter standards to standardize as procedural approach to the process and the inputs required from multi-disciplinary functions. The study developed the check sheet document that needed to be filled and verified by a multi-disciplinary team to ensure adherence to parameter specifications after every changeover and prior the commencement of manufacturing. The check sheet was outlined in the form of a template to be filled by a multi-disciplinary team. The quality focussed improvements of the changeover process were then subjected to continuous monitoring and a recommendation was made for the process to be continuously repeated to attain far greater benefits and drive a continuous improvement culture that is centred around built-in-quality in changeover processes.

4. Data collection

Data collection was conducted in line with the attainment of the objectives of the study. The primary data that was collected outlined the foundation statistical and theoretic data that was used to interpret results and draw results. The data enabled the DMAIC approach to be carried out effectively to drive built-in-quality in the changeover process of the thermoforming line in the automotive component manufacturer. The data collection also focussed on the measurement, analysis, and improvement phases of the DMAIC methodology. The data or information required for the define phase and the control phase formed part of the results of the study.

4.1 Measurement data collection

The measurement data was collected from secondary historical data records of the occurrence of defective units after the completion of changeovers. The data measured over a period of four months the number of changeovers that have taken place and the total number of defective units that came out of the Thermoforming line just after changeovers as depicted on Table 1. The occurrence of defective units was outlined on a weekly basis for the four months, and where weeks were overlapping, the defective units were summed up on the first or fourth week. For every changeover, the manufacturer set a target loss of three parts, which were then multiplied by the number of changeovers to depict the target loss per week. Based on the target loss, the actual number of defective parts losses beyond the target was outlined. Table 1 indicates the data summary for the defective units that took place prior the implementation of the built-in-quality approach in the changeover process.

Table 1. Defect occurrence data after changeover

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Measurement	Aug-22				Sep-22				October				Nov-22				Total
	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	
Number of Changeovers	5	4	4	3	5	6	5	4	2	7	6	5	3	5	4	5	73
Total number of defective units after changeover	43	32	28	41	55	73	48	39	17	79	67	63	29	48	49	61	772
Standard minimum unit defect loss per changeover	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	48
Weekly expected unit defect loss Target	15	12	12	9	15	18	15	12	6	21	18	15	9	15	12	15	219
Actual unit defect loss after changeover	28	20	16	32	40	55	33	27	11	58	49	48	20	33	37	46	553

4.2 Analysis data collection

The data collection for the analysis phase was also deduced from historical data of defect occurrence over a period of four months. From the number of defects that were collected after changeovers had taken place, a deeper analysis was carried out to determine the actual descriptions of the defects that occurred. The defects were grouped into eight category descriptions based on defect report analysis. The occurrences of the defects were then summed up for each defect on the respective historical months in which they occurred. The total number of defect occurrences was then summed up by description to indicate the number of defective units after changeovers for the defined period. The percentage ratio of each of the defect descriptions was then tabulated on Table 2 to indicate the percentage impact of each of the defects relative to the total number of defects that have occurred. The percentage ratios were crucial in determining the priority defects which the built-in-quality approach needed to impact according to an order of priority. Table 2 indicates the data analysis summary from the measured data.

Table 2. Defect analysis data summary

Defect descriptions after changeover	Quantity of defective units				Total Number of defective units	Defective unit % ratio
	Aug-22	Sep-22	Oct-22	Nov-22		
Cold spots	19	33	28	34	114	14,77
Deformed knuckles	2	13	5	16	36	4,66
Thick sides	3	2	9	4	18	2,33
Parts over length	1	33	23	17	74	9,59
Part not forming	38	23	31	31	123	15,93
Lines on the part	31	47	54	27	159	20,60
Dimples on the part	24	37	41	35	137	17,75
Pimples on the part	26	27	35	23	111	14,38
Total defective unit loss	**144**	**215**	**226**	**187**	**772**	**100**

4.3 Improvement data collection

The foundation for the improvement phase data collection is the determination and implementation of improvement countermeasures to the problem of the occurrence of defects after changeovers. The data collection in this phase commenced with an outline of all the defects and a determination of the possible causes to the defect after changeover was made. The possible causes were then linked to the changeover standard operating procedure by means of outlining the elements that were associated with the defect. On completion of this, improvement countermeasures which spoke to driving built-in-quality in the changeover process were then outlined. The improvements summarily comprised of countermeasures that spoke to the revision of standard operating

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procedures, development of standard parameters, Fabricating and revising mechanical components, and the development a standard check sheet that enforced a multi-disciplinary verification approach to the execution of start-up after changeovers have been completed. Table 3 outlines the improvement data that guided the implementation of improvements on the changeover process.

Table 3. Changeover improvement data or information

Defect description	Possible cause	Associated SOP elements	Improvement countermeasure
Cold spots	Low temperatures in the oven and temperature controllers.	Wait for the Oven and TCs to Warm-Up.	Develop standard temperature parameters for the oven and TC and only allow running of the machine at standard temperatures. Develop standard check sheet.
Deformed knuckles	Plugs on the mould over stretching the sheet due nuts being overweighed by plug cylinder stretch torque.	Adjust the strokes of the plugs and tighten them properly	Remove all current nuts on the cylinder plugs and replace them with lock nuts. Tool setters to ensure that lock nuts are used at all times.
	Mould slide stuck or opening slowly due to insufficient hydraulic pressure.	Close slide and clean off all debris inside the tool.	Part of the tool setter SOP must indicate that the setter must check the hydraulic pressure and hydraulic oil level during the changeover as a standard.
Thick sides	Low temperatures in the oven and temperature controllers.	Wait for the Oven and TCs to Warm-Up.	Develop standard temperature parameters for the oven and TC and only allow running of the machine at standard temperatures. Develop standard check sheet.
Parts over length	Fans are not blowing in the correct direction and machine is run with TCs below 70˚C.	Position the top plattern fans properly to blow in the mould	For every changeover, there must be a positioning guideline according to the derivative that is being run at the time.
Part not forming	Vacuum escaping the mould due to sealing misalignment of the top frame and the mould.	Ensure that the mould is positioned properly and sealing with the top frame.	Mark the top plattern frame positioning and fabricate mould locking guides for the bottom plattern.
Lines on the part	P120 grit sandpaper takes longer to flatten the AB Putty.	Fine sand applied with a flat discs surface grinder P120 grit to blend tool.	Source out P140 grit sandpaper for initial flattening of AB and finish off with P120 grid sandpaper.
Dimples on the part	Cracking of the AB Putty after application due to premature runs.	Apply AB putty and wait for it to dry. Ensure putty surfaces are smooth.	Develop a standard time for drying of the AB putty in the mould for all tool setters to be aligned.
Pimples on the part	Poor cleaning of debris after grinding of AB putty inside the mould.	Clean all debris on slide cavities and inside tool.	Install a dedicated air pressure pipe for blow cleaning debris. Add the cleaning element as part of a verification check sheet.

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5. Results and discussion

5.1 Define Phase

The define phase of the study focussed on outlining the project overview and the project scope of the study. The overview of the project comprised of the problem outline, purpose outline, the business case of the project and the goals of the project. The scope of the project defined the parameters of the study and defining what the study is concerned and not concerned with. Table 4 was the created as a result to depict the detailed results of the project chatter elements of the study.

Table 4. Project overview and scope

Project overview	
Problem/Issue	Defective units produced after changeovers
Purpose of the project	The Thermoforming line aims to have a maximum of 3 defective units after changeover. Defect parts after changeovers have spiralled out of control. This has had a significant impact on the quality control measures of the organization.
Business case	Defective units after changeovers have gone way beyond the set standard target of the organization. This is impacting on the ability for the organization to meet capacity and deliver on the complexities required by the customer. With the drive to combat the quality issues, Emphasis needs to be placed on driving built-in-quality in the execution of changeovers.
Project goal	By April the 30th 2023, the number of defective units after changeovers needs to be reduced from an average of 11 defects per changeover to the standard of 3 defects per changeover.
Project scope	
Scope covered	The changeover process and all the defect occurrences after changeovers
Outside of scope	Impact of time on building quality into the changeover process.

5.2 Measurement Phase

The results of the measurement phase indicated that there were significant spikes in the weekly defects after changeovers have taken place. With the weekly maximum target of defects per changeover, the results indicated that there were no weeks where defects were within the weekly maximum target after every changeover. This was a cause for concern as the results pointed to an uncontrolled process that had little or no mindset bearing to the quality of parts being produced after changeover. From the results, it could also be deduced that on average, the process yielded 11 defective parts after every changeover as opposed to the target of 3 defective parts per changeover. Further to this, the results entailed that there was little focus on driving quality from an execution perspective of the changeover processes. Figure 1 is the graphical depiction of the historical results of defects relative to changeovers. The Figure, at a glance, pointed to a strong need to intervene with a quality approach that could bring about some degree of control to the changeover process in as far as defect yield is concerned.

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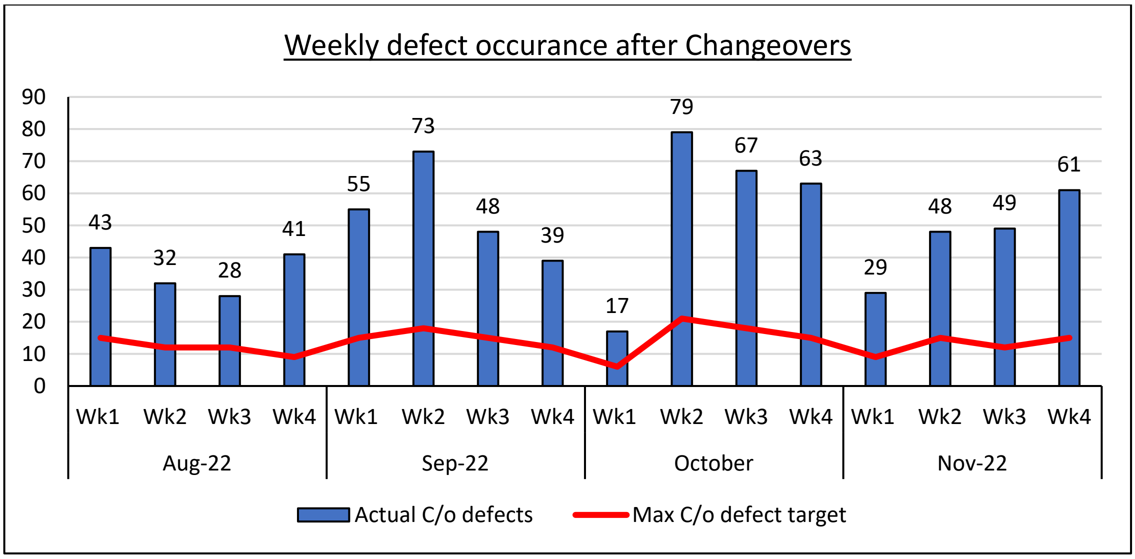

Figure 1. Weekly defect occurrences after changeovers results

5.3 Analysis Phase

Following the data collection for the analysis phase, a Pareto analysis graphical representation was then developed to depict the hierarchical ranking of the defect occurrences after changeovers as depicted by Figure 2.

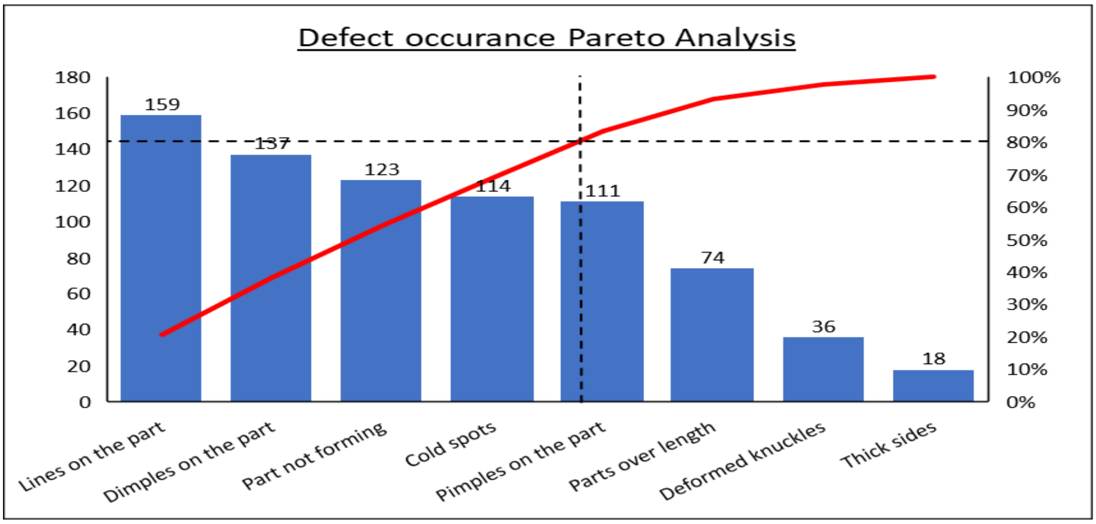

Figure 2. Defect Pareto analysis

The results of the Pareto analysis graph on Figure 2 indicated that there were 4 defects that were high priority and one defect that was partially a priority. These defects were at the 20% range of the Pareto graph and could be identified as Lines on the parts, Dimples on the parts, Part not forming, and Cold spots. These were the defects that needed urgent built-in-quality measures to be implemented to contain them in order to make a significant impact on the reduction of defects after changeovers on the line. With these defects posing as a priority, the study expanded to cover all the defect occurrences with possible countermeasures as only a handful of defects were in the 80% range of the Pareto analysis graph results. The coverage of this analysis with countermeasures was depicted by Table 3 on the improvement data.

5.4 Improvement Phase

The improvement results post the implementation of the countermeasures to the defects identified after changeovers indicated significant improvement to defect occurrence for the proceeding months. From a comparison approach, prior the implementation of the built-in-quality measures to the changeover process, there was an average of 11 defects per changeover. Post the implementation of the improvement measures, there was an average of 3 defects per changeover. Figure 3 indicated the results of the improvement measures. From the

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figure, it could be deduced that there was control on the outflow of defects after changeovers and majority of the weekly results were below the maximum loss target set out by the organization.

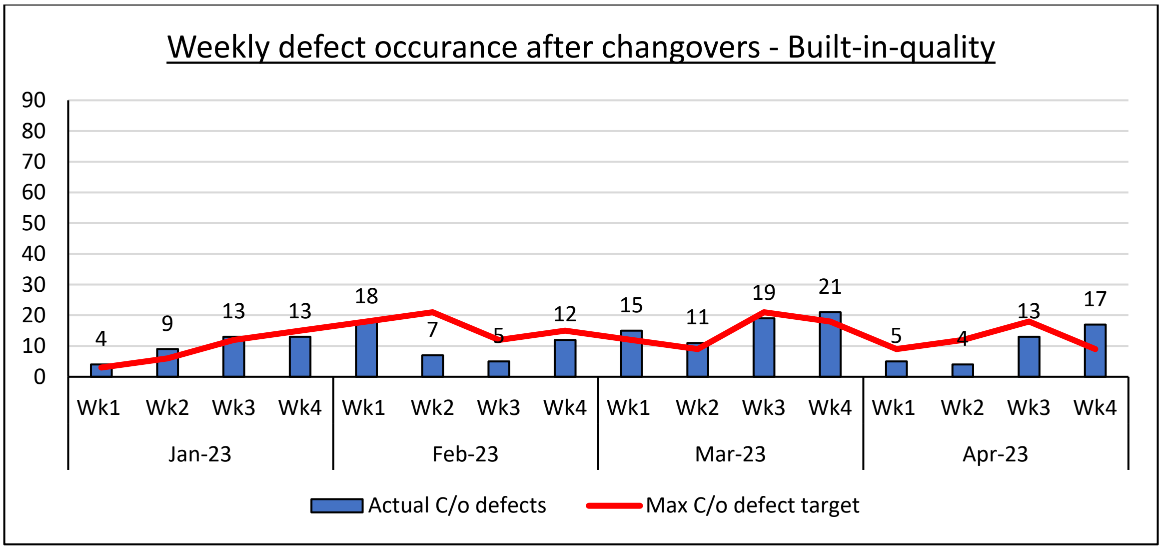

Figure 3. Weekly defect occurrence – Built-in-quality

Further to the weekly defect results on Figure 3, the study proceeded to carry out a comparison summary of the between defect outflow prior the improvement measures and post the built-in-quality measures. Figure 4 depicts the graphical summary of the results of the comparison for the proceeding 4 months after improvement implementation.

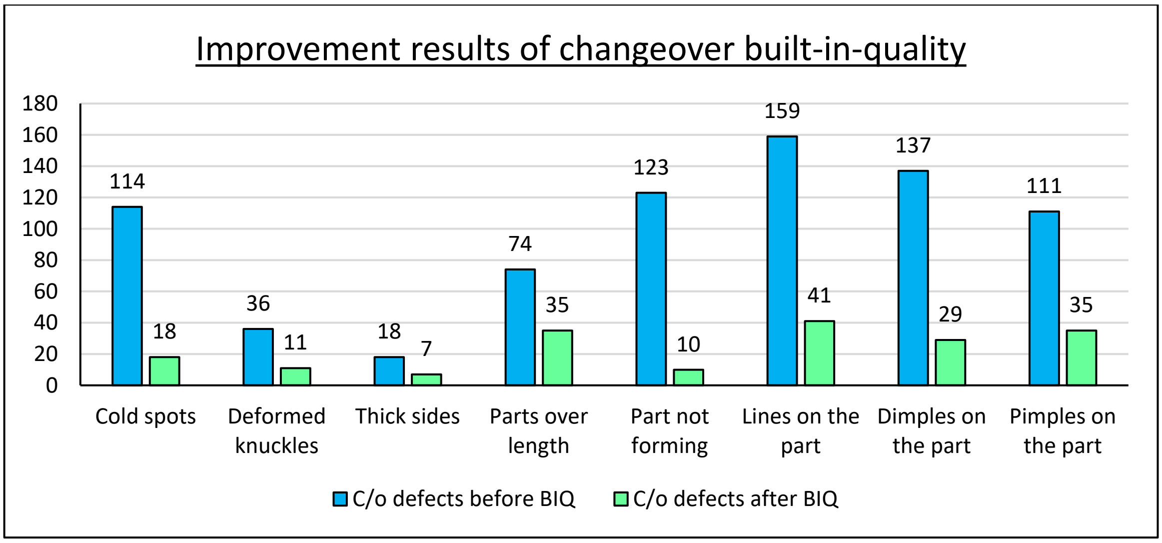

Figure 4. Comparison results – Before and after BIQ

5.5 Control Phase

To establish control of the improvement results, the study developed a changeover parameter and standards recording document to drive adherence to a built-in-quality approach. Figure 5 depicts check sheet document with specific parameter adherence measures and a multi-disciplinary sign-off on the check sheet. Adherence to the check sheet entailed secondary built-in-quality verification to the changeover process and the establishment of a process that is quality centred.

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PRODUCTION APPROVAL SHEET

TOOL / SUFFIX CHANGE

Functions required: Tool Setter, Production , Maintenance & Quality control

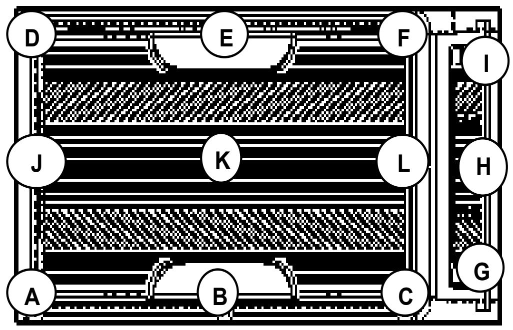
DATE: SHIFT: MACHINE:AR

SUFFIX DESCRIPTION: MOLD CHANGE: ☐ SUFFIX CHANGE: ☐

Check cooling fans for proper operation on top plattern frame: ☐

MOLD/SUFFIX CHANGE START TIME: SUPERVISOR SIGN:

Test part Approval YES ☐ NO ☐



MATERIAL	STD
HDPE	
TCs	70 - 98 °c
For TC controlling sides of rap cab please ensure TC is on 98°c	
Sheet out of oven	120 - 200 °c
Product out of Tool	≤ 85°c
Mold temperatures	70 - 98 °c
Hydraulic pressure	>6bar

Temperature recordings (Maintenance to fill out)

TC1	TC2	TC3	TC4	MOULD LAYOUT												SHEET	PRODUCT
				A	B	C	D	E	F	G	H	I	J	K	L	Bottom	Bottom

Dimensional check

Correct length Floor section				Maintenance Sign:............................
Correct RHS side length				
Correct LHS side length				Supervisor Sign:..............................
Hydraulic pressure within spec				
Check cooling fans are positioned properly and working				QC Sign:..

Figure 5. Changeover process check sheet

6. Conclusion

The study employed the lean six sigma DMAIC methodology to streamline an approach towards developing a built-in-quality centred approach to changeovers. The DMAIC methodology has proven to be effective in this study, as it established to a large extent a pathway for automotive component manufacturers to follow in order to drive quality in their changeover processes. The study has unearthed to an extent that there is largely ignorance around built-in-quality in changeover processes. The focus is primarily on the quickest way to wrap up changeovers and giving less consideration to the quality of products after the changeovers. The automotive component manufacturer needed to incorporate a multi-disciplinary approach to the execution of changeovers. The employment of built-in-quality strategies during changeovers brings into light significant benefits such as reduced defective unit outflow, increased capacities, ability to cope with complexities, and increased profitability. The first objective of the study was met through an outline of the possible defects, causes and the elements associated with the occurrence of the defects. This was outlined on the data collection phase of the study under

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the improvement stage of the DMAIC methodology. The second objective of the study was attained through a range of comparison results measured overtime for the periods where changeovers had no built-in-quality and post the implementation of improvements to drive built-in-quality in the changeover process. The third objective of the study was achieved through a strict following of the DMAIC methodology phases to bring improvements to the changeover process. The development of a new multi-disciplinary check sheet that drove parameter and standards checks addressed the last objective of the study. Majority of studies about changeovers from various authors are centred around the SMED approach. There is little or no dedicated focus on curbing defective parts after changeovers have taken place. The study presents a pathway for further research to be conducted around the development of a quality mindset or culture during the execution of changeovers.

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