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APPLICATION OF LEAN SIX SIGMA AND THEORY OF INVENTIVE PROBLEM SOLVING TO REDUCE WASTE AND IMPROVE THE QUALITY MOTORCYCLE REAR ARM

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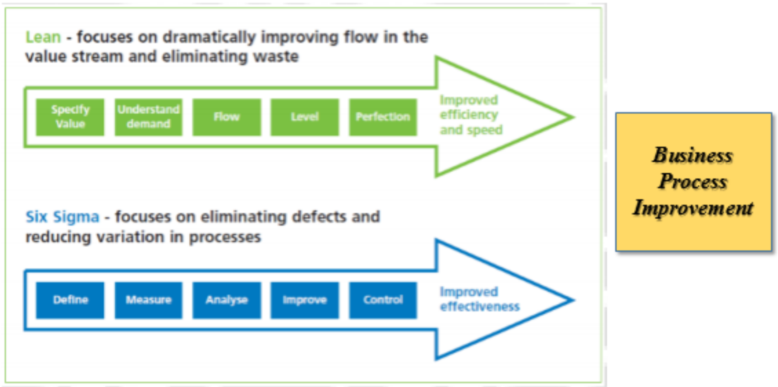
ABSTRACT

In a competitive global market, the need of high quality product and high efficiency production are increasing. An automotive spare part company is facing this problem because the production is not efficient and the defect ratio is still above the target. The company develops and makes an aluminum rear frame arm for motorcycle spare part. The purpose of this study is to improve production quality and efficiency by applying lean six sigma. The lean six sigma objectives are to reduce waste, non-value added work and cycle time. Based on the initial analysis, the sigma level of the company was at 3.8 sigma. The waste from the production process was 26.29%, unnecessary inventory was 20, 45%, and over production was 16.85%. The lean six sigma methodology of DMAIC (define, measure, analyze, improve, and control) is used for this study. The value stream mapping (VSM) is used to identify the waste while theory of inventive problem solving (known as TRIZ) is used at analysis and improvement stage to overcome the production defect problems in the production line. The result of this study shows that the sigma level is increased to 4,8 sigma with defect ratio of 0,51%.

Contribution/ Originality: This study contributes in the existing literature of lean six sigma implementation.. This study integrated lean six sigma with value strem mapping (VSM) and theory of inventive problem solving (known as TRIZ) to improve lean six sigma implementation.

1. INTRODUCTION

Lean is a process to increase efficiency. The concept was first proposed by Taiichi Ohno and Shigeo Shingo at Toyota production system, also became known as lean manufacturing. Lean manufacturing requires not only technical understanding of the complete manufacturing system, but also to understand the relationship that exists between manufacturing and other areas of the company such as supply chain management, customer demand and perceptions, distribution and logistics [1]. Six Sigma is a business improvement strategy that seeks to identify and remove the causes of defects or errors in business processes by concentrating on activities that are relevant to the client. A key component to the successful implementation of six sigma associated with the commitment of top management, supporting infrastructure, training and statistical tools [2].



Picture-1.1. The concept of Lean and Six Sigma

Source: Wedgwood [3]

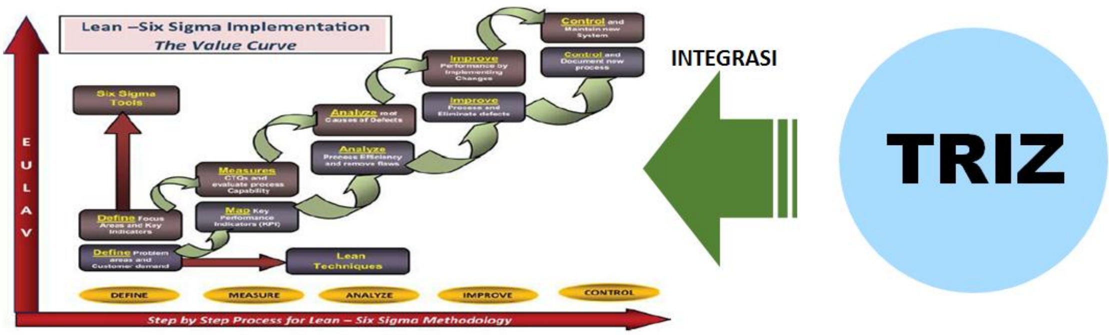
Lean described as a systematic methodology to eliminate waste and reduce the complexity of the process, while six sigma described as a systematic methodology to find the key elements to the performance of the process and set them to the best level [3]. The concepts of lean and six sigma strategy were combined into lean six sigma methodology.

An automotive spare part company which produces motorcycles and spare parts, experienced problems in the manufacturing part of rear frame arm that effect the efficiency and defect ratio. The defect ratio is still high, and above the top management target of 4% defect ratio. The real production approximately 250 unit per day while the target is 320 unit per day. Production and process flow efficiency improvements should be made to increase the quality and quantity of the overall production.

The purpose of this study is to carry out the reduction of waste and non-value added activity, in order to improve process efficiency and improve product quality. The lean six sigma and theory inventive problem solving is used to overcome the problems on rear frame arm production lines.

2. THEORITICAL BACKGROUND

Lean six sigma method is one engineering applications to improve the quality and quantity produced by a company. Lean six sigma is combination of lean concept with the six sigma, which is intended to improve process efficiency and focus on customer issues [1].

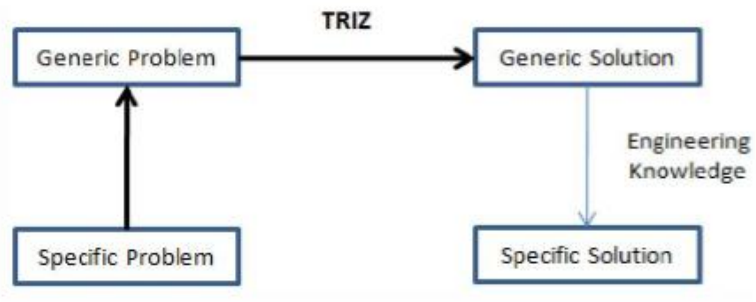


Picture-2.1. Integration of TRIZ in lean six sigma DMAIC phases

Source: Hu, et al. [4]

Lean six sigma (LSS) improvement refers to the five phases called DMAIC (define, measure, analyze, improve, and control). The goal of the DMAIC is to find problems, identify the cause of the problem, and find a solution or a way to fix it. LSS is a popular methodology to increase company business in term of customer satisfaction, cost and speed of the manufacturing process. The constrain of LSS implementation is a lack of creative approach to the problem. To improve traditional techniques of LSS, LSS can also be integrated with TRIZ methodology to enhance customer satisfaction, Wang and Chen [5]. The integration of this approach allows for the development of the instrument, capable of extending the capabilities of both six sigma and lean methodologies.

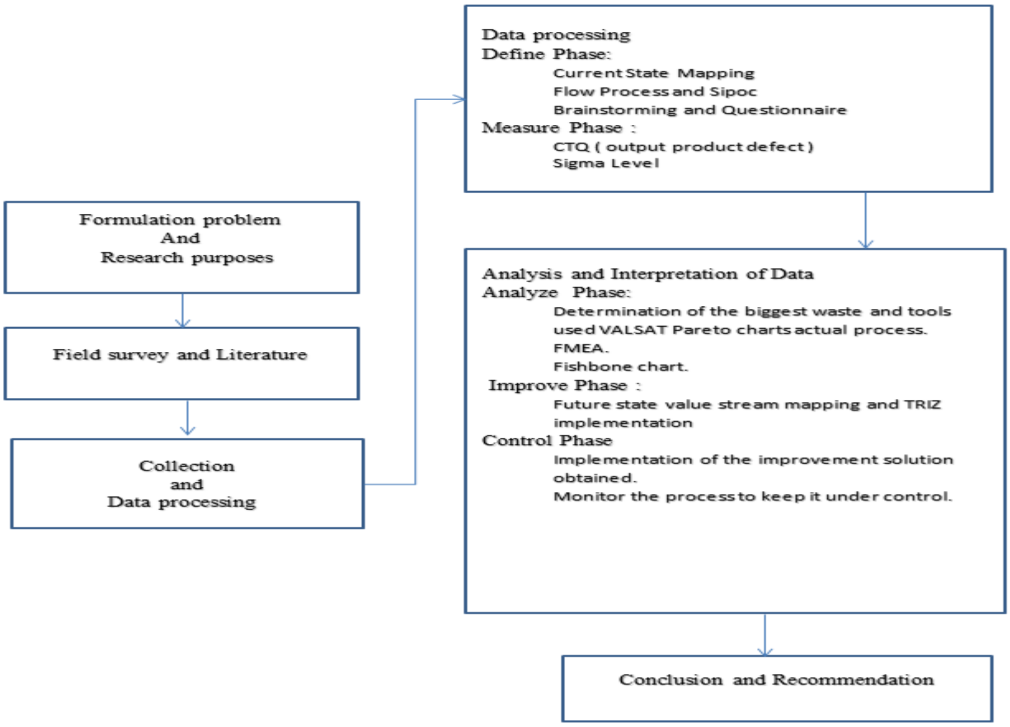
TRIZ is a problem solving method based on creativity, logic, and data to produce solutions to existing problems. The real purpose of development of TRIZ is to create a creative problem-solving method.



Picture-2.2. Triz *Solving Problem* [6]

Source: Savranksy [6]

3. RESEARCH METHOD



Picture-3.1. Research Method

Source: This picture is generated from this research

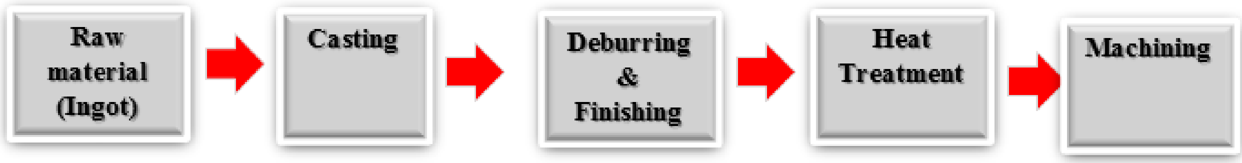
4. RESULT AND DISCUSSION

4.1. Define phase

There are 3 activities in the define phase:

1. Determine the production process flow of rear arm.

In general, production processes rear arm through four main process steps, namely the process of casting, deburring process finishing, heat treatment and machining processes



Picture-4.1. Production process flow of rear arm

Source: This picture is generated from this research

2. Make a SIPOC diagram.

By making Supplier, Input, Process, Output, and Customer or SIPOC diagram, all the relevant process elements of rear arm are identified.

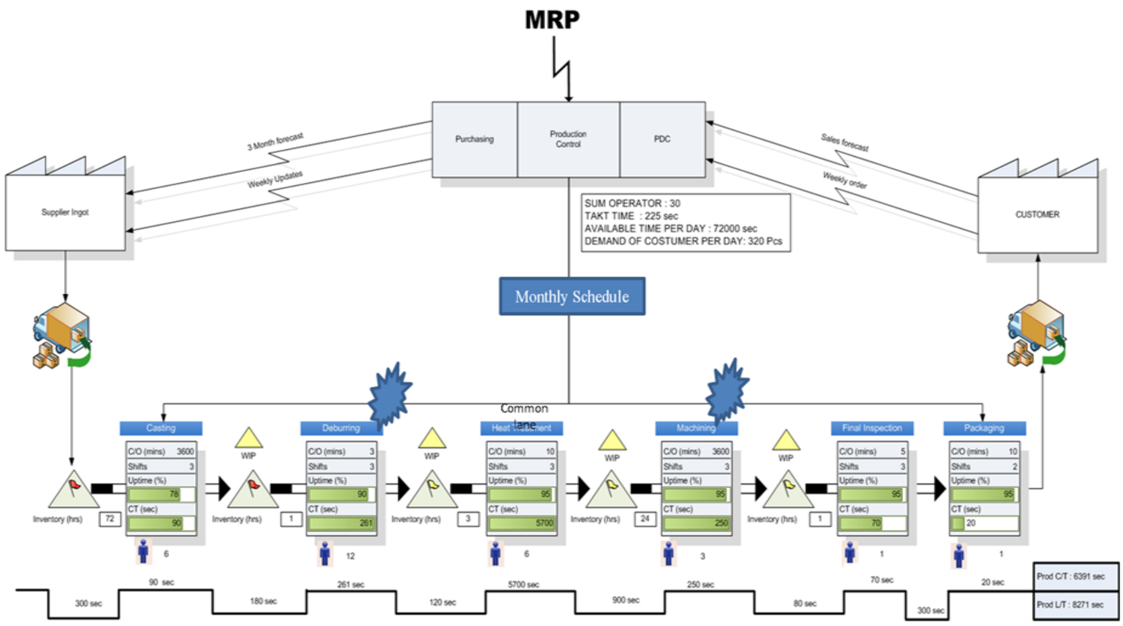
No	Supplier	Input	Process	Output	Customer
1	Material control department.	Ingot	Material	Molten	Production department-casting
2	Production department-casting	Molten	Casting	Casting product	Casting departement-deburring & finishing
3	Casting departement-deburring & finishing	Part finished-casting	Burrytory	Finishing part	Casting departement-heat treatment
4	Casting departement-heat treatment	Finishing part	T5	Part finish heat treatment	Production department-machining
5	Production department-machining	Part finish heat treatment	Machining	Finishing part	Final inspection department
6	Final inspection department	Finished goods	Inspection	Good quality finished goods	Warehouse

Picture-4.2. SIPOC diagram

Source: This picture is generated from this research

3. Make the current state value stream mapping (VSM).

Value Stream Mapping (VSM) is a tool to visualise the system and to identify the waste in the system. VSM has information flow and physical flow. The current VSM information flow start from material resources planning (MRP) generated by production and planning control. The physical flow starts from casting process up to final inspection activity.



Picture-4.3. Current state value stream mapping.

Source: This picture is generated from this research

The takt time of the process is 225 seconds, available time per day is 72000 seconds, and demand of customer per day is 320 units. From the takt time data, the process of deburring finishing and machining is a bottleneck. Value added ratio (VAR) of the current VSM is 77%. VAR is a comparison between value added and non-value added time.

4.2. Measure and analyze phase

There are 3 activities in the measure and analyze phase:

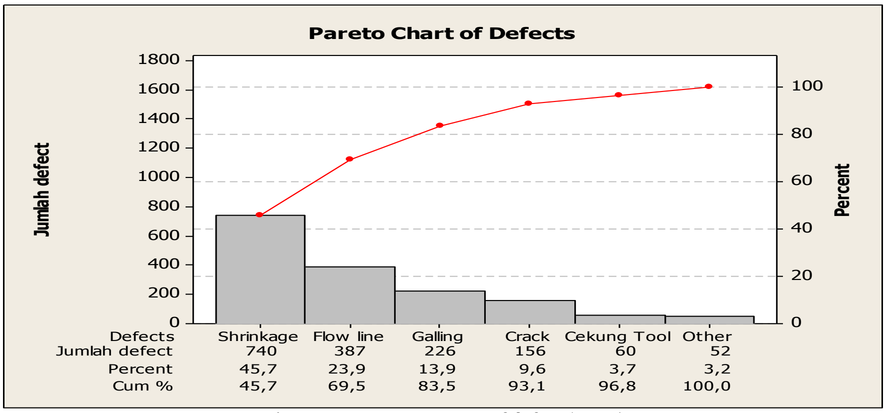
1. Baseline performance measurement.

Measurement of baseline performance is a calculation of the value of sigma. The measurement results will be determined in the form of attribute data using the performance measurement unit of DPMO (Defects per Million Opportunities). Level sigma represents the conversion of values into the table DPMO sigma.

Table-4.1. Defects ration

No	Flow process (Department)	Production (Unit)	Defects (Unit)	Defects (%)	Internal ratio target (%)
1	Casting	28034	1652	6%	3%
2	Deburring & finishing	26382	52	0,19%	2%
3	Machining	26330	0	0	1%

Source: This table is generated from this research



Picture-4.4. Pareto type of defect (CTQ)

Source: This table is generated from this research

Based on calculations it is known that the amount of scrap (defects) per one million opportunities (DPMO) in the manufacture of rear arm is 10 131 units. It is in the range of 3.8 sigma level.

Table-4.2. DPMO *existing*

Description	Value
Total Inspection	28034
Total Defects	1712
CTQ	6
DPMO	10300
Sigma	3.82

Source: This table is generated from this research

2. Waste identification and scoring.

Waste identification and scoring for every work station is conducted by discussion with each operator of the production line.

Table-4.3. Results and Average Waste.

Ranking	Waste	Average	Percentage
1	Defect	6,25	21,19
2	Over production	5,5	18,64
3	Unnecessary inventory	4,25	14,41
4	Inappropriate process	3,75	12,71
5	Wating	3,75	12,71
6	Transport	3,75	12,71
7	Unnecessary motion	2,25	7,63

Source: This table is generated from this research

Value stream analysis tools that will be used to identify the activities of non value added and value added of the production process.

Table-4.3. Ranked VALSAT tools

Ranking	Waste	Score	Percentage (%)
1	PAM	242,25	45,12
2	SCR	105,75	19,67
3	PVF	50,5	9,40
4	DAM	50,25	9,35
5	DPA	50,25	9,35
6	QFP	30.25	5,63
7	PSV	8	1,49

Source: This table is generated from this research

Appropriate priorities and to study the effectiveness of the selected Top rated value stream mapping tools in evaluating the waste that occurs that process activity mapping (PAM). PAM is a value stream mapping tools that able to evaluate nearly all types of waste.

Table-4.4. Number of activities per type of production

No	Activity	Qty	Time	%
1	*Operation*	13	502	73,4
2	*Transportation*	11	40	5,5
3	*Inspection*	4	105	15,6
4	*Storage*	5	20	2,4
5	*Delay*	5	24	3,1
JUMLAH		38	691 sec	100

Source: This table is generated from this research

Based on the calculation, Operation and Inspection activity is an activity with a longest time, and it will be used for consideration to make improvements.

3. FMEA

An analysis of the potential causes and the effectiveness of preventive detection of potential defects that already exist are presented in FMEA table. Based on discussions and observations of the actual condition, the prioritized improvements has the highest RPN.

Table-4.5. FMEA actual condition

No	Process	Failure Mode	Severity	Cause potential	Possibilty	Detection Prevention Potential	Effectiveness	RPN
1	Casting	Flow line	7	Freezing process uneven	7	Change Setting directions spray	4	196
		Shrinkage	8	Gas can not release during the casting process	8	add time Injection of the casting	8	512
		Galling	7	Draft angle	7	The addition of spray point on the chain area	4	196
		Crack	7	Cooling system	4	The addition of Jet cooling	4	112
2	Deburring and Finishing	Cekung tool	4	Unskilled operator	5	Quality Checked by QC Final Inspection	4	80
		Burry remaining (other)	4	Less accuracy in works	4	Quality Checked by QC Final Inspection	4	64

Source: This table is generated from this research

Based on the measurement results, it can be concluded that bottle neck are in the finishing deburring and machining processes. These 2 processes will be improved with future state value stream mapping while casting production lines to produce high levels of production defect, will be solved with TRIZ solution.

4.3. Improve phase

Finishing deburring process will be optimized by replace the tools of process and combining into a single work process, thus reducing the activity of non-need value added for transport activity. Total cycle time to 183 sec.

Table-4.6. Activity improvement finishing deburring process and time calculation

Activity	Description of Activities	Tools/machine	Time (sec)	Activity Improvements	Time (sec)
1	Waiting for WIP part deburring & Finishing		3		3
2	Pengambilan material Finish casting	Trolley	3		3
3	OP1 removal of residual overflow gate	Belton	68	Substitution tools belton by buffing	35
4	Transfer to OP 2		3		3
5	OP2 removal of residual gate runner	Belton	57	Substitution tools belton by buffing	36
6	Transfer to OP 3		3		3
7	OP3 removal of finishing side A & B	Sander	55	Reduction in the process of working with	46
8	Transfer to OP 4		3		
9	OP4 Finishing burry & pin ejector	Handycum	53	Reduction process of finishing work on the ejector pin	41
10	Material inspection (quality)	Visual	10		10
11	Keep a stock of part finish deburring & finishing		3		3
Total Cycle time			**261**		**183**

Source: This table is generated from this research

2. Improvement of Machining Production.

Machining process will be improved by combination of processes roughing and chamfering. The machining time becomes faster, and for the inspection process is a process of NVA. Total time in the machining process becomes 208 sec.

Table-4.7. Activity improvement machining process and time calculation

Activity	Description of Activities	Tools/machine	Time (sec)	Activity Improvements	Time (sec)
1	Waiting part WIP Machining		4		4
2	Taking parts Finish Heat treatment from basket	Trolley	4		4
3	Setting Machine		60		60
4	Waiting		10		10
5	Machining OP 1	Fanuc	30	tools combinations	23
6	Put and transfer the goods onto the conveyor	Conveyor	3		3
7	Machining OP 2	TC fanuc	32	tools combinations	24
8	Put and transfer the goods onto the conveyor	Conveyor	3		3
9	Machining OP 3	Fanuc	30		30
10	Put and transfer the goods onto the conveyor	Conveyor	3		3
11	Washing Process	Washing Machine	40		40
12	Inspections check the parts after the machining process	Visual & Air micro	27	"Balancing process, transfer of activity to the final inspection check "	
13	Keep a stock part finish machining		4		4
Total Cycle time			**250**		**208**

Source: This table is generated from this research

3. Improvement of casting production.

The casting process is improved to reduce the defect ratio. In this case it will use the TRIZ method to solve the problem. Step problem solving with TRIZ methods [7]:

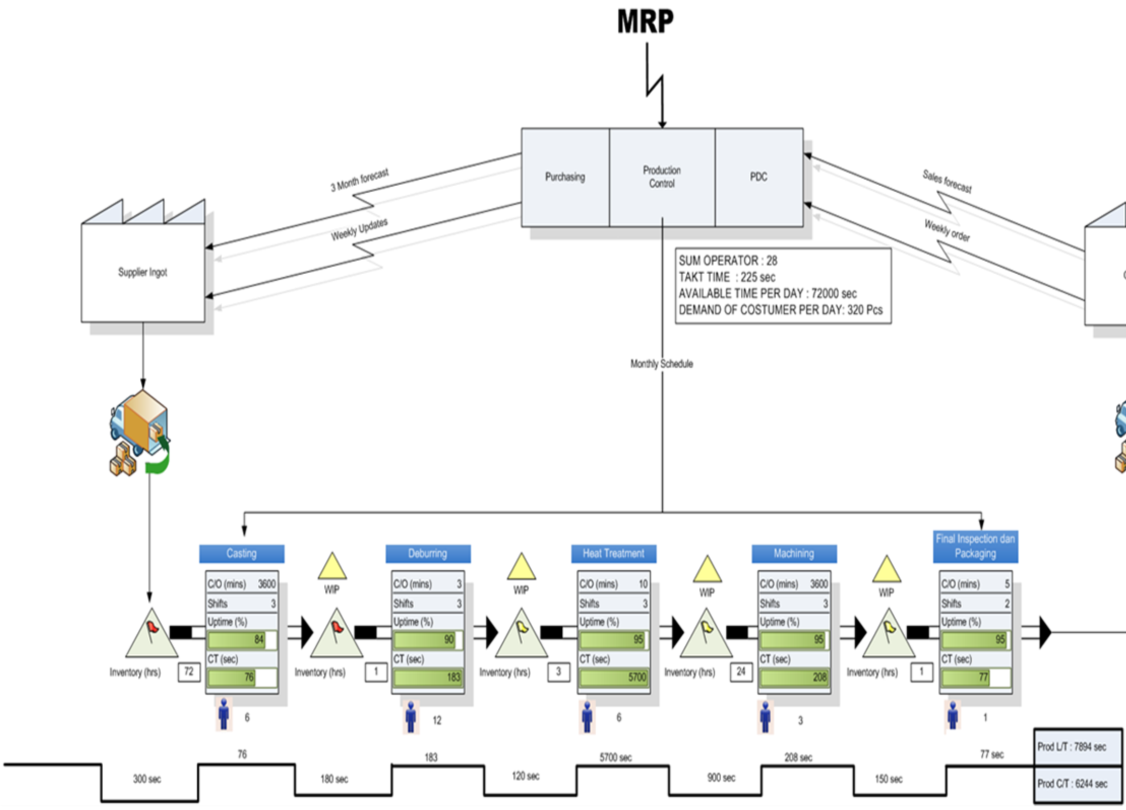
1. Identify the problem.
2. Formulate the problem.
3. Find a contradiction attributes and create a matrix that will be developed with the TRIZ through 39 engineering Principles.
4. Discover solving problems by seeing 40 Inventive Principles.
5. Apply problem solving TRIZ is still common into a solution that is more specific.

Table-4.8. Inventive principle and solution

Inventive principle	*Stired grain die cast (SGDC)*
22. Convert harm into benefit, "Blessing in disguise".	Try the new process flow, changes in die cast timer press for the formation of the product, as well as changing the temperature setting in the holding furnace.
35.Transformation of the physical and chemical states of an object, parameter change, changing properties	Changes in the holding furnace molten temperature of 700 ℃ to 620 ℃.
2.Extraction, Separation, Removal, Segregation	Separating molten from the holding furnace to perform the mixing process prior to rounding aluminum granules.
24. Mediator, intermediary	For mixing process using a material made of ceramic that can stand up to temperatures of 1000 ℃.

Source: This table is generated from this research

Repair defect ratio of the problem of shrinkage is the system HPDC semi-solid, in addition to reducing defect ratio. This process also changes and benefits to the production line a rear arm which decrease cycle time, the die cast to 34 sec, increasing the life time of mold / dies, and in terms of safety also reduces the temperature of the die casting machine area is reduced.



Picture-4.5. Future state value stream mapping.

Source: This table is generated from this research

From the results of the improvements, the future state of VSM is made. An increase from 78% to 85%, uptime on the casting due to lower defect ratio. While the finishing deburring production line cycle time is 183 seconds and the machining cycle time is 208 seconds. The VAR value is 80%.

Table-4.9. Sigma level after improvement

Description	Value
Total Inspection	9323
Total Defects	48
CTQ	8
DPMO	643.56
Sigma	4.8

Source: This table is generated from this research

5. CONCLUSIONS AND RECOMMENDATIONS

The lean six sigma and TRIZ implementation in an automotive spare part company can be summarised as follows:

5.1. Conclusions

1. Based on waste identification, the three biggest waste on the production line are defect or reject part (21:19%), over production (18.64%), and unnecessary inventory (14.41%).
    - Defect causes the biggest part in the production is casting production line with a defect ratio of 6%.
    - Unnecessary inventory, stock buildup occurred in the area of raw materials to the production line finishing deburring due to capacity constraints and the long cycle time in this process, so absorption of raw materials are not optimal.

- Overproduction causes excess production because much of its production defect products on production lines and capacity in the production process that is not balanced.

2. Sigma level of production rear arm is in the range of 3.8. Defect production is highest on the production line casting, types of product defects, among others shrinkage (45.7%), flowlines (23.9%), and galling (13.9%). With a total defect ratio by 6% overall production.
5. Improvements to increase the efficiency of the process:
   - Deburring finishing: replace the tools of process, combines the activities and eliminating NVA activity of transport to transfer material
   - Machining: upgrade the condition of machining tools become tools combination for roughing and chamfering process. And balancing process by moving the checking process part visually and airmicro check on the final quality inspection before packaging and delivery to the warehouse.
6. Improvements to reduce waste:
   - Defect: to overcome the highest defect production.
   - Unnecessary inventory: with perform balancing process cycle time, process improvement and capacity-ups.
   - Overproduction: setting rescheduling production and increase the quality of production, especially in the production line casting rear arm.
7. The results of the evaluation of the condition of improvement in the production process is the rear arm
   - The future state VSM shows improvement: finishing deburring process cycle time 183 seconds and 208 seconds machining which does not exceed the conditions of production takt time of 225 sec rear arm, so as to eliminate overtime and optimize the production line.
   - Level sigma after the repair is in the range of 4.8 sigma, with the condition defect ratio of 0,51% overall, and production is under control in terms of quality by looking at the production month of March 2016.

5.2. Recommendations

The advice can be given for further research includes the following:

- Calculate the financial benefits the company towards improvements that have been implemented.
- Do the simulation process for the various solutions to determine the impact or benefit of any recommendations for improvement.
- Conduct LSS integration with more innovative methods to identify the root causes.

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