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Overall Equipment Effectiveness Improvement of Piston Machining Line using SMED and DOE

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ABSTRACT: Overall Equipment Effectiveness (OEE) is a powerful measurement of the complete Equipment Performance. In this study, the improvement of OEE in the Piston machining line was carried out through the implementation of Single Minute Exchange of Die (SMED) and Design of Experiments (DOE). SMED is one of the lean methodologies which was used for the reduction of setup time and the improvement in the Availability factor of OEE. It was implemented on the bottleneck machine of the machining line and calculated the setup time before and after the SMED implementation. The variables affecting the rejections of the piston skirt dia were analyzed and optimized in the Minitab17 software and increased the Quality factor of OEE. The optimized values From the DOE were suggested to the industry.

KEYWORDS: Overall Equipment Effectiveness, SMED, DOE.

1. INTRODUCTION

Overall Equipment Efficiency (OEE) is a measure of Equipment performance and is widely used in many industries. Rapidly changing in the highly competitive environment organization need to improve the performance of manufacturing organization by focusing on maximizing quality, cost cutting, increasing productivity levels, and guaranteeing deliveries in order to satisfy customers. OEE identifies and measures losses of important aspects of manufacturing namely Availability, Performance and Quality rate, which support the improvement of Equipment Effectiveness and there by its productivity. The product of Availability, Performance and Quality factors will results into machine Overall Equipment Effectiveness.

$$.Availabitlity = \frac{Actual\ \ Production\ \ Time}{Planned\ \ Production\ \ Time} \qquad Performance = \frac{Current\ \ Run\ Rate}{Ideal\ \ Run\ Rate}$$

$$Quality \frac{Good\ \ Product}{Total\ \ Product}$$

$$\text{Overall Equipment Efficiency (OEE)} = \text{Availability\%} \times \text{Performance\%} \times \text{Quality\%}$$

SMED was introduced by Shingo [4] and is one of the main lean production methods for reducing waste in manufacturing process. Nowadays, customer demand is with high quality and there is a need of continuous improvement in industries to meet the customer demand. They are forced to produce more products at smaller batch which results in more set up time. SMED provides a rapid and efficient way of converting the manufacturing process from running the current product to running the next product. Design of experiment (DOE) is a structured, organized method and powerful tool to regulate the relationship between the factors affecting a process and its output. DOE helps to explore the effects of input variables (factors) on an output variable (response) at the same time. The MINITAB17 software provides an easy and simple way of analyzing the design of experiments. In piston Machine shop plant the following flow chart shows the machining process of the piston.

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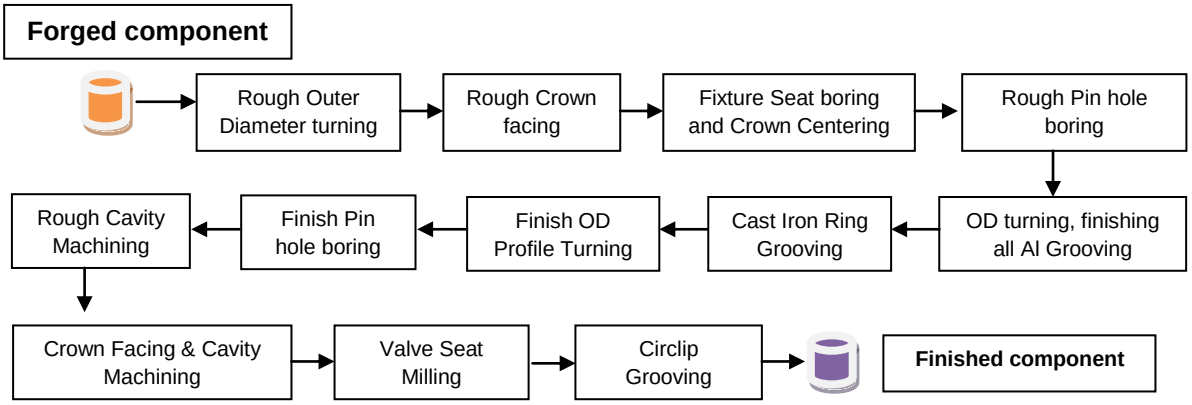

Figure 1: Machining process of Piston

II. LITERATURE REVIEW

The production planning and process improvement has been done through OEE techniques with the use of SMED tool [1]. Analysis of existing OEE through DOE and finding the relationship between the Availability, Performance, Quality factors was experimented [2]. From the referred journal papers the literature gap observed that they have conducted the study on the improvement of OEE through time studies [3] and SMED methods. Improving the availability and performance factors have taken into account but the improvement of quality factors is less and an approach is made to improve the OEE through DOE method and SMED technique.

III. PROBLEM DEFINATION

In piston machine shop there are seventeen different piston machining lines and as per data collected the 9th machining line has the lowest OEE of 47% than the other lines. Hence 9th machining line is taken as priority to improve the OEE.

IV. OJECTIVES

- **Improving the OEE for the bottleneck machine:** In the machining process fig 1 the OEE is improved for the bottlenecks which will result in major performance improvements in the line. The bottleneck machine for the 9th line is RTG machine which runs the Cast Iron Grooving process. This machine is selected since it has the maximum cycle time. Thus improving the OEE for this bottleneck machine will results in better production output of the machining line.
- **Identifying the factors affecting the OEE:** The OEE factors such as Availability (69%) and Quality (82%) are the quantifiable reasons for poor equipment performance. These losses of OEE factors can be captured and used for the root cause analysis and for the problem elimination progress.
- **Identifying the losses of the OEE:** The setup time and the rejections losses are identified as the major losses and these factors are to be concentrated for the improvement of OEE.

V. METHODOLOGY

In this study, improving the OEE is carried out by implementing the SMED and DOE methods. The SMED technique is used to implement the bottleneck machine in order to improve the availability factor by reducing the setting change time. DOE method was conducted in order to optimize the factors affecting the rejection rate of the piston skirt dia.

5.1 Analysis of setup time using SMED:

The Process involved in the SMED is as follows.

Step 1: Observe the current methodology: This is the preliminary stage which consists of studying the present setup process. To obtain the time corresponding to the various operation, the stop watch is used. Time studies were done on

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the operator who was performing the setup or changeover. Every activity of the process that took place was timed and recorded. After collecting the data with time was organized into table1 in which each one illustrates the set up process.

Step 2: Separate the internal and external activities: In this stage the identification and separation of the internal and external setups are done. Internal activities are those that can only be performed when the process is stopped, while external activities can be done while the last batch is being produced.

Step 3: Converting the internal setup to external setup: Converting internal setup to external, which converts the maximum internal setup operation to the external ones. This is done because all the setups which are classified as external will be carried out while the machining is running which results in decrease in setup time.

Step 4: Streamlining all aspects of the setup operation: In this stage all the internal and external activities are optimized by implementing the 5s methodology, parallel operations. 5s methodology involves the unnecessary and necessary tools and equipment in workplace are separated and arranged properly to easily carry out the process setup. The parallel operations involved two or more operation carried out simultaneously which decrease the setup time.

Table 1: Setup time before and after implementation of SMED

Operation No	OPERATION INVOLVED	Before SMED Time (mins)	Activity	After SMED (mins)
1	Production end of last Piston and awaiting for the setter	18	External	0
2	Collecting necessary tools like allen keys, wrenches, etc	10	External	0
3	Removing the fixture, flange & fastaning the new flange	12	Internal	12
4	Removing the tool pocket(finishing)	4	Internal	4
5	Waiting for the drawing and SOP sheet	9	External	0
6	Waiting for the new fixture & tool pocket(finishing) from the tooling department to be issued	16	External	0
7	Installing the new fixture and tool pocket finishing	17	Internal	18
8	Removing the rough tool from the pocket(carbide)	4	Internal	5
9	Waiting for the new rough tool to be inserted	11	External	0
10	Rough tool inserted	6	Internal	6
11	Center limit adjustment (clamping limit of the tail stock)	7	Internal	10
12	Setting the rough tool position and editing the program	6	Internal	5
13	Waiting for the instrumentation setup and Master piston	22	External	0
14	Adjusting the rough grooving process by checking the CI rough grooving Ht and Dia to Zero in the dial gauge if not editing the program	16	Internal	18
15	Setting the finish tool position and editing the program	5	Internal	5
16	Adjusting the finish grooving process by checking the CI finish grooving Ht and Dia to Zero in the dial gauge if not editing the program	36	Internal	31

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17	Piston is send to metrology department	33	Internal	18
18	If problem identified by the metrology and the correction involved	8	Internal	0
19	Waiting for the SQC department approval	9	Internal	0
20	Approved by the SQC	10	Internal	10
Total Time		**259**		**142**

Before SMED implementation the setup time was observed 259 minutes and after implementation it was found 142 minutes. Thus for each setup time about 117 minutes was saved which increases the Availability factor.

5.2 Analysis of rejections losses:

From the rejection data the skirt diameter and damages are the major rejections of the pistons. The various causes which lead to the rejections of skirt dia and damages are identified and are represented in the cause and effect diagram. Validation is done by discussing with the team and observation in the machining line and found out the main causes for the rejections which are underlined in the fish bone diagram.

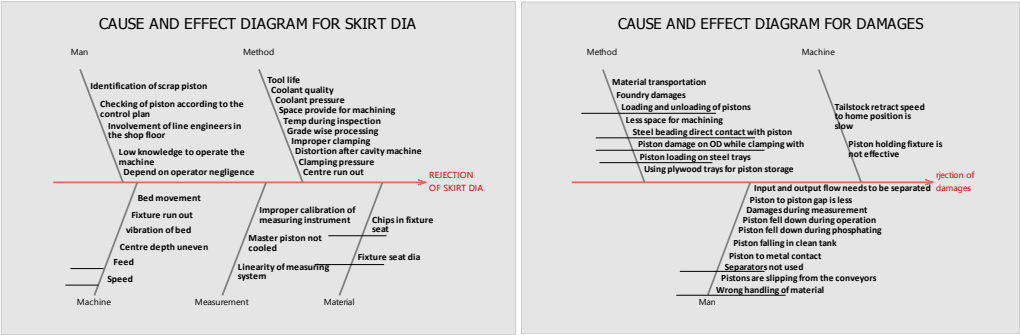

Figure 2: Cause and Effect diagram for the Skirt dia and Damages

Implementation is carried out by executing an action plan for the present causes. The corrective actions were implemented to balance the line, standardize output, reduce the scrap and for better utilization of the resources. From the figure 2 (cause and effect diagram for skirt dia and damages), validation of the causes underlined are identified as the root cause and necessary correction action plan is selected. The causes Speed, Feed and Fixture seat dia are considered as the input variables (factors) and are experimented in the design of experiments using the Minitab software. The DOE is used to identify the process condition that affects quality and to optimize a better result. Action plan was implemented for the causes of Skirt dia and Damages is as given in the table 2.

Table 2: Action plan for the causes

Problem	Present Cause	Suggestion	Status
Chips in fixture seat	Variation in skirt Dia	Awareness class conducted along with manager and engineers	Completed
Wrong handling of material	Operators awareness	Refresh training and improving awareness	Posters are made about handling of the pistons and displayed in shop
Material handling damages	Pistons are hitting each other while	Bins and separators are used	Implemented

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	moving one station to another station		
Loading and unloading of pistons	Metal surface is having sharp edges	Beading provided on the metal surfaces	Beading is provided
Steel beading direct contact with piston during phosphating	Piston hitting steel tray	Steel beading to be covered with plastic tubes	Plastic tubes covered on steel surface
Piston loading on steel trays	Piston hitting steel tray	Nylon stand to be provide on steel trays	Nylon stands procured
Piston damage on OD while clamping with V-block	Teflon Clamp damaged	New Clamping Teflon is fixed	Completed

DOE: A full factorial design was selected which measures the responses for all the combinations of the factor levels. The experiment is conducted for the 3 factors and the replicate is taken 2, so that the 16 experiment-runs have been conducted. Three factors such as Speed, Feed and Fixture seat dia are taken with the variation of 2 levels. Reference values considered are Speed 800 & 1000 rpm, Feed 0.25 & 0.35 mm/rev and Fixture seat dia -15 & +15 microns. The experimental-runs were carried out for all the 16 combination and the reading of the skirt dia was observed and is as given in the table3. Standard deviation is calculated for each run and is selected as the response.

Table 3: Experimental runs

Speed (rpm)	FEED (mm/rev)	Fixture seat dia (microns)	Experimental runs										Standard deviation
			1	2	3	4	5	6	7	8	9	10	
1000	0.25	-15	-3	5	-3	-4	-2	5	3	6	5	5	4.1379007
800	0.25	15	4	5	-3	6	7	5	4	-5	6	4	4.0013886
1000	0.25	15	3	0	-4	-2	3	2	5	-1	-4	-5	3.465705
1000	0.35	15	2	-3	1	0	4	2	1	4	5	1	2.3118055
800	0.35	-15	-4	5	6	-3	7	-2	-3	-4	6	-5	4.98999
800	0.35	-15	-4	-6	3	5	4	7	5	8	7	4	4.667857
800	0.25	15	2	0	3	0	1	3	2	-1	0	2	1.3984118
1000	0.25	15	2	3	0	1	-3	2	4	1	2	0	1.9321836
800	0.25	-15	6	4	5	6	7	6	-3	6	-2	3	3.5213634
1000	0.35	-15	4	-4	-5	-2	-1	6	2	4	2	4	3.7712362
800	0.35	15	3	-4	5	4	3	7	2	-3	-2	4	3.6651512
800	0.35	15	4	-3	3	6	5	4	-1	-3	3	4	3.2930904
1000	0.25	-15	3	-1	0	-4	-2	-4	-1	-3	-2	3	2.514403
800	0.25	-15	6	-3	6	-7	-3	4	6	5	7	6	5.0343266
1000	0.35	-15	-5	7	4	8	6	5	6	4	-2	-4	4.748099
1000	0.35	15	2	0	1	2	5	4	1	3	-3	4	2.3309512

Analysis of the factorial design is done by observing the Effect plots and the Residual plots. Normal plots are used to compare the relative magnitude and the statistical significance of both main and interaction effects.

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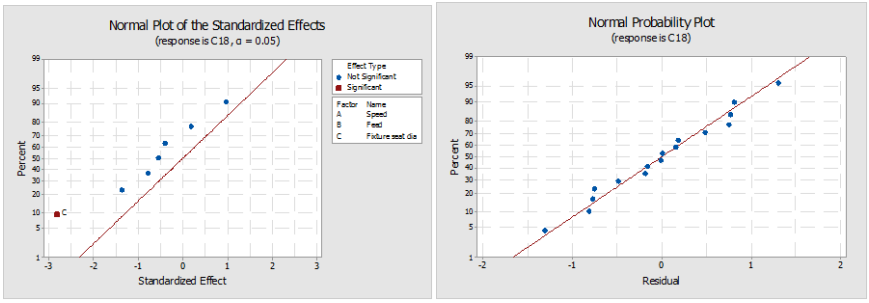


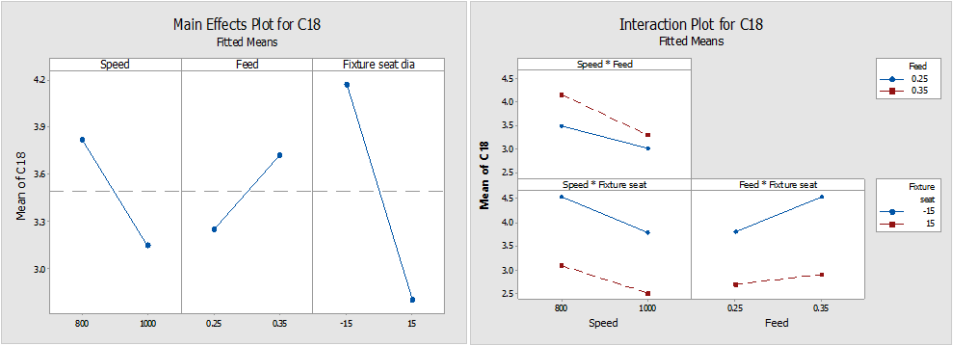
Figure 3: Normal plot and Normal probability plot

From the figure3 (Normal plot), the effect of 'C' is more significant i.e the fixture seat dia(C) has the standardized effect. The plot indicates that the direction of the effect and fixture seat dia has the negative effect. This means that when changes are made from low level to the high level of the factor, the response decreases. From the Normal Probability plot the residuals appear to follow a straight line and this result in meeting the normality assumptions.

Table 4: Anova table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	1	1.7951	1.79513	1.88	0.207
Feed	1	0.8895	0.88948	0.93	0.362
Fixture sear dia	1	7.5439	7.54393	7.92	0.023
Speed*Feed	1	0.1499	0.1499	0.16	0.702
Speed*Fixture seat dia	1	0.0328	0.03281	0.03	0.857
Feed*Fixture seat dia	1	0.2932	0.29319	0.31	0.594
Speed*Feed*Fixture seat dia	1	0.5923	0.5923	0.62	0.453

Figure 4: Main effect plot and Interaction plot



The p-value is used in the analysis of variance table to determine the significant effects in the model. The p-value is compared with α-level, in which the α-level used is 0.05. The p-value of 0.916 for 2-way and p-value of 0.453 for 3-way interactions is not less than 0.05; therefore the group of 2-way and 3-way interactions is not significant. The p-value of 0.023 for the main effect of fixture seat dia is less than 0.05; therefore there is significant evidence that the fixture seat dia factor has an effect on the skirt dia. The p-value of other 2 main effects is not less than 0.05 and hence does not have significant effect on skirt dia.

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From the interaction plot the 2 variables lines are parallel to each other hence the interaction effect on the response variable is not significant. From the variance table it is found that the statistically significant is the fixture seat dia. The main effect plot indicates that when the fixture seat dia is at the +15 µ level has less effect on the skirt dia and when the fixture seat dia is at the -15µ level, it has more effect on the skirt dia. Fixture seat dia has both the positive and negative tolerances. Hence DOE suggests only the positive tolerance.

VI. RESULTS AND CONCLUSION

As a performance improvement, the setting change time for the bottleneck machine before the SMED implementation was found to be 259 mins and after the SMED implementation was found to be 142 minutes. Such that about 117 minutes was saved in the setting change which leads to increase in the Availability from 69% to 76%. By optimizing the factor affecting the rejections of the skirt diameter through DOE and also through implementation of various actions causing the rejections for damages was reduced and leads to increase in the Quality factors from 81% to 87%. Thus OEE for the machining line was improved from 47% to 58%.

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