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# Analysis of Rotary Gas Metal Arc Welding (GMAW) Process in Automotive Industry using 7 QC Tools

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**Abstract—***Present scenario of manufacturing industry indicates towards enhancement in socio-technical complexity of manufacturing systems to meet with ever increasing demands of the market. This has developed critical concern towards considerable increase in quality related issues, which needs prime attention to deliver quality products at customer's end. Present work focuses upon analysis of quality related issues identified in one of the automotive industry in rotary GMAW welding cell in Haryana using 7QC tools. The outcome of the analysis highlighted root cause for identified problem that needs immediate attention as, faulty fixture design, lack of training, operator negligence, non-compliance to SOP's. In future, implementation of such tools can aid to control considerable investment levels associated with rework or rejected products.*

**Keywords***: 7QC tools, quality, manufacturing industry, GMAW welding, automobile industry*

## 1. INTRODUCTION

The seven basic tools of quality is a designation which first arose in Japan, first introduced by Kaoru Ishikawa after being influenced be W. Edwards Deming lectures which he had delivered to Japanese engineers and scientists in the 1950s. The 7 QC tools are a set of analytical tools used to analyse a problem and find out areas of problem generation to rectify them.

The seven tools are: Cause-and-effect diagram ("fishbone" or Ishikawa diagram), Check sheets, Control charts, Histograms, Pareto chart, Scatter diagram, Stratification (flow chart).

7QC tools as the means for Collecting & analyzing data, identifying root causes and measuring the results and provides efficient process tracking and analysis which can be very helpful for quality improvement [1]. [2] Demonstrates how construction organizations can use the basic quality tools for the improvement of their processes and save materials and money. [3] Demonstrates application of 7QC tools in process industries. The research showed the possibility of systematic application of all of the 7QC tools in the frame of companies' overall quality management system and also that 7QC tools are not as widespread as expected, although they are quite simple for application and easy to interpret. 7QC tools can be used in all process phases, from the beginning of a product development up to management of a production process and delivery [4]. [5] 7 Quality control tools are very simple and easy to use for all majority industries and Quality improvement can be made by reducing rework and rejection with the help of 7QC tools.

Present work demonstrates application of 7QC tools in one of the critical area having quality related issue identified in automobile industry and is divided into 2 stages i.e. Problem definition and data collection stage to define the problem area, Analysis stage for analytical study of the collected data and to find root causes in the process

## 2. METHODOLOGY

Methodology followed for the present work is as shown in the Fig.1.

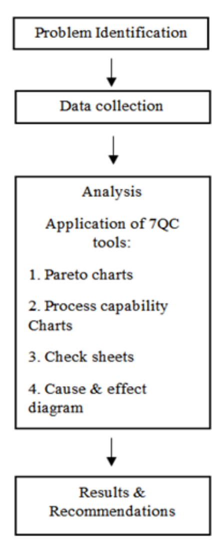


**Fig. 1: Methodology flow chart**

## 3. APPLICATION

This section is divided into 2 parts i.e. problem definition & data collection stage to identify the reasons for rejections on the production line and analysis stage to find out root causes for occurrence of those reasons

### 3.1 Problem definition & data collection

Fig.2 maps the process capability of the process considered for study. It can be seen that sample 9, 11, 14 and 15 indicates special cause of errors which resulted in unusually high rejections and affected the process capability.

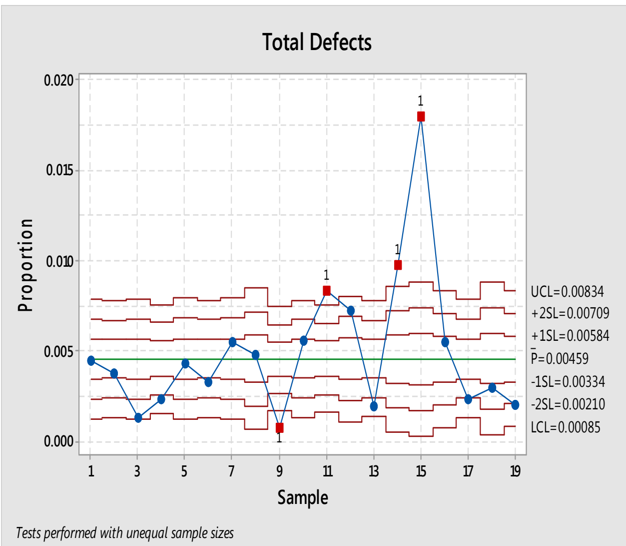


**Fig. 2: Total defects P-chart**

For further investigation pareto chart is plotted for all the defects occurring on the assembly line as shown in Fig.3.

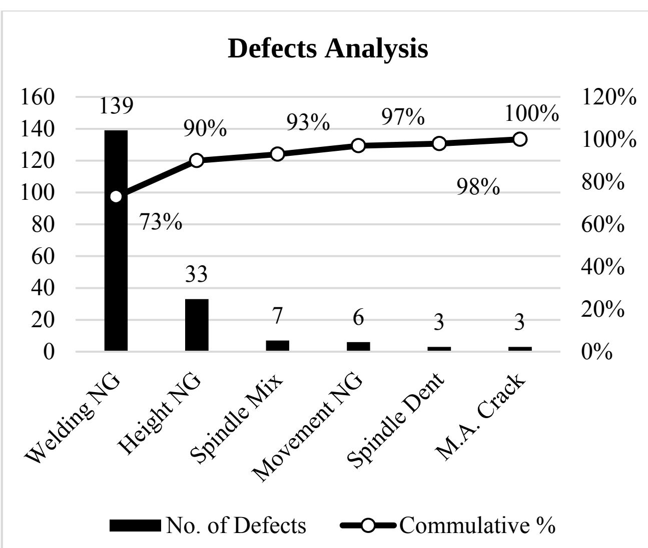


**Fig. 3. Defects analysis**

As depicted from Fig.3, Welding and Height defects alone amount to 90 % of total defects and therefore welding and height defects only are considered in present work for detailed analysis.

With reference to the Fig.2 it was investigated that on the day when sample 9 was collected, there were issues of low speed and jamming with rotary motor responsible for rotating welding fixture during welding operation. When sample 14 and 15 were collected, operator was changed for the welding cell and also trial runs were carried out by changing the shielding gas from Co2 to a blend of 80% argon and 20% carbon in between production. P chart was again plotted by neglecting sample 9, 14 and 15 as shown below in Fig.4.

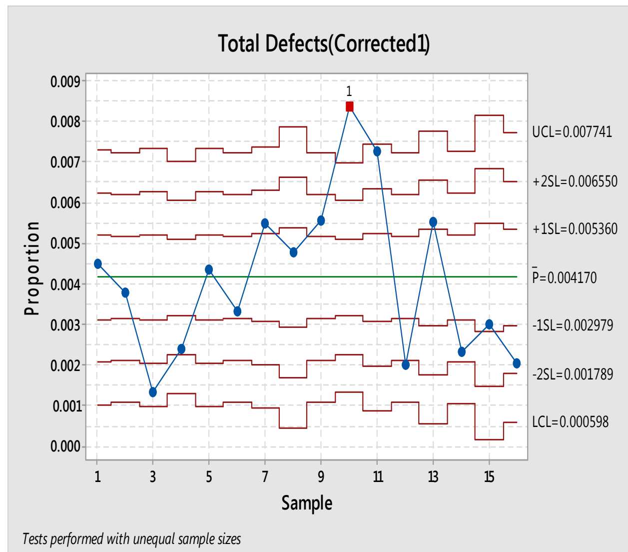


**Fig. 4: Corrected total defects P-chart**

As can be inferred from Fig.4 the process becomes unstable at point 10.Investigation reveals change in weld wire role on that day. Investigation of wire roll revealed traces of rust on weld wire leading to excess spatter and blocking of nozzle. The normal variation of the process is also significant as more than 60% of the points lie in $2^{nd}$ and $3^{rd}$ sigma limits and needs to be optimized.

From Fig.5, it can be inferred that 71% of the welding defects are caused by Undercut, Overflow and Blow holes.

### 3.2 Analysis phase

The problem definition and data collection phase significantly indicated that the performance level of the current process is unsatisfactory and needs to be improved.

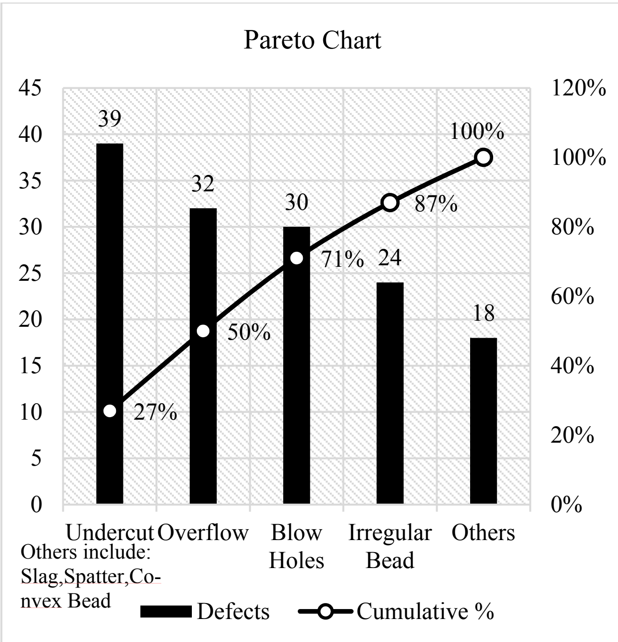


**Fig. 5. Weld defects Pareto chart**

There is no fixed welding station for a model and are assembled based on the production requirement by changing fixtures in the welding cell. 4 welding stations are utilized for production and therefore performance of each welding station was assessed so as to ascertain which station (or stations) is leading to increased variation in the process. The production statistics for the 4 stations is shown in Fig. 6.

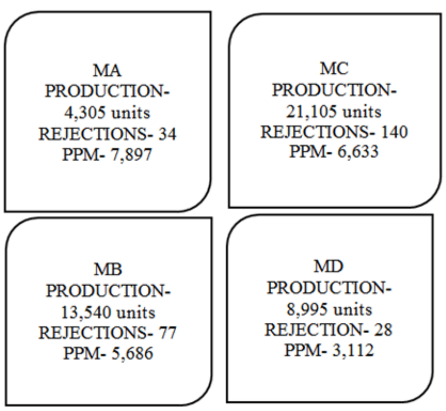


**Fig. 6. Welding cell comparison**

From Fig.6 it can be inferred that out of the 4 welding stations machine MA and MC are producing more rejections as compared to the other two and MD is showing minimum no. of rejections. Based on the above statistics, a maintenance review was conducted to compare machines MD and MB to MA and MC to find cause of their poor performance as compared to machines MD and MB.

Key findings of the maintenance review are summarized below-

1. In welding station MA and MC, proper nozzle and tip alignment was not maintained.

2. Improper and inadequate gas flow in MA and MC caused by deformation of nozzle leading to blowholes in welded parts.

3. Continuous operation without proper cleaning of fixture and not using anti-spatter spray regularly by operator leading to excessive spatter and uneven weld bead.

4. Misalignment of fixture with respect to welding torch by operator during production changes and absence of dowel pins in fixture design.

Cause and effect diagram was used to find out the root causes for welding defects. Causes of the welding defects related to methods, machine, people and material as shown in Fig.7 below.

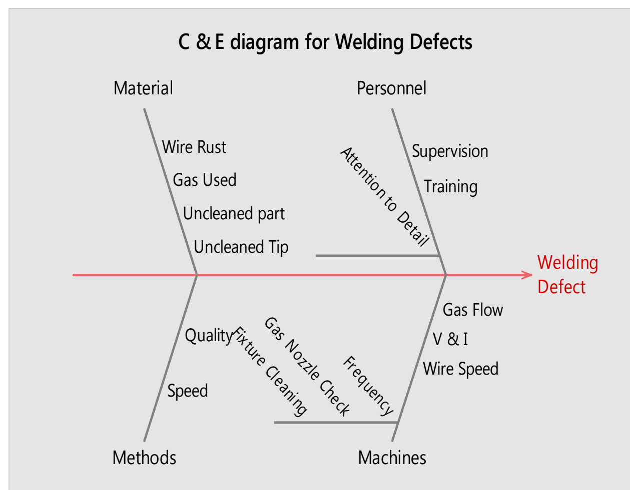


**Fig. 7: Cause and effect diagram (welding)**

Model 3 and 4 are not considered in this study due to low production. As can be seen from 1st entry in the table for Model-1/Model-2 and Model-3 the deviation is very large compared to others indicating special cause of variation. On investigation, the worker was found be at fault for this error.

Following were most critical causes identified-

1. Fixture cleaning and maintenance

2. Wire rust and moisture

3. Improper gas flow

4. Unskilled associates

5. Uncleaned child assembly

Attribute chart is not suitable for variable data like height hence $\bar{X}$and R chart is plotted taking 3 samples at intervals of every 2 hours from the assembly line to ascertain the process capability with respect to critical height of the welded component which needs to be maintained and to ascertain product to product variation.

Then ceafter, defects related to height were investigated in detail as shown in Fig.8 below

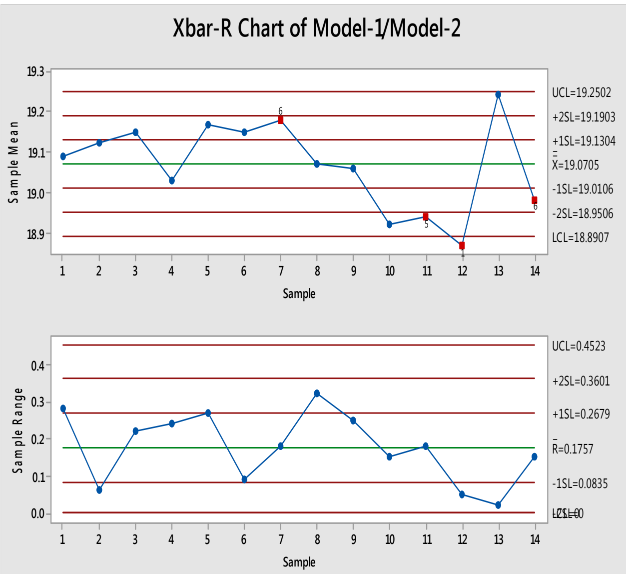


**Fig. 8. $\bar{X}$ and R chart for height defects**

As can be seen from the $\bar{X}$ and R chart, the process displays special causes of errors and needs to be controlled.

Table.1 shows height rejections. The average positive deviation from ideal (from 19.00mm) limit is +0.74mm and average negative deviation is - 0.5mm for Model 1 and 2.

**Table 1. Height defects check sheet**

| **Model** | **No.** | **Value(mm)** | **Desired (mm)** | **Variation From Ideal(mm)** | **Variation From Limit (mm)** |
|---|---|---|---|---|---|
| Model - 1/Model-2 | 10 | 20.45<br>19.34<br>18.54<br>18.36<br>19.67<br>19.75<br>19.65<br>19.67<br>19.72<br>19.67 | 18.7-19.3(Ideal-19) | +1.45<br>+0.34<br>-0.36<br>-0.64<br>+0.67<br>+0.75<br>+0.65<br>+0.67<br>+0.72<br>+0.67 | +1.15<br>+0.04<br>-0.16<br>-0.34<br>+0.37<br>+0.45<br>+0.35<br>+0.37<br>+0.43<br>+0.37 |
| Model -3 | 2 | 28.10<br>20.27 | 14.7-15.10(Ideal-14.9) | +13.20<br>+5.37 | +13.0<br>+5.17 |
| Model -4 | 3 | 15.46<br>14.52<br>15.53 | 14.7-15.10 | +0.56<br>-0.38<br>+0.63 | +0.36<br>-0.18<br>+0.43 |

The deviation analysis graph (Fig.9) depicts -

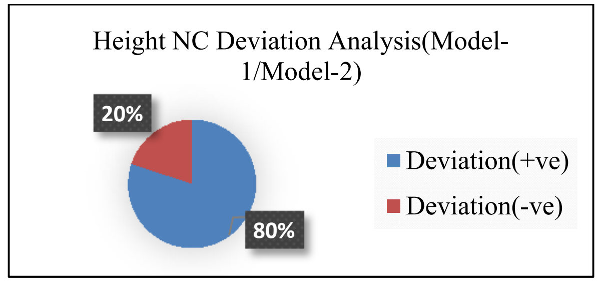


**Fig. 9. Percentage contribution of height defects**

that 80% of the Sub-Assemblies are showing positive deviations and 20% are showing negative deviations indicating that the process needs to be optimized for positive deviations.

Below (Fig.10) is the cause and effect analysis to find the root causes for low process capability with respect to height defects.

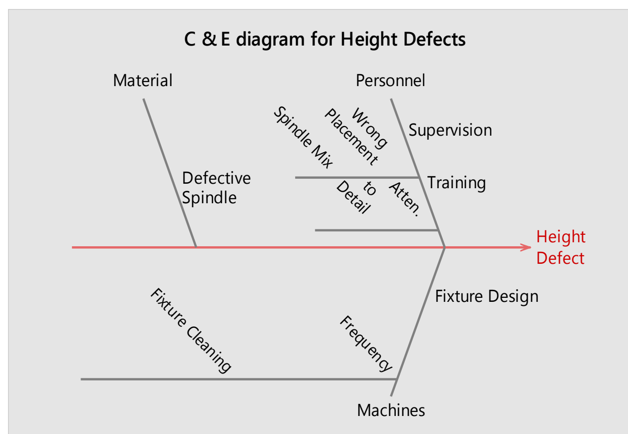


**Fig. 10. Cause & effect diagram (Height)**

As can be inferred from the Fig. above, most of the reasons fall under personal and machine class.

Major causes for height defects identified are-

1. Fixture cleaning- Accumulation of spatter and dust leading to positive deviation as the child part then sits higher than desired, causing the height between spindle and shifter assembly to decrease.

2. Use of worn out stopper in spindle bush resulting in negative deviations.

3. Fixture Design- deviation is found to be caused by improper/Inadequate clamping resulting in upward motion of part from spindle side which causes height defects.

## 4. RESULTS AND DISCUSSIONS

When process capability of the production process was analysed, process instability was identified. For detailed investigation pareto chart was plotted it was found that majority of rejections were occurring because of welding and height non-conformance. Thereafter plotting P-chart, erratic fluctuations indicated special causes of errors in the process which were affecting the capability of the process. It was observed that rejections during trial runs were mixed with production rejections giving a sense of understanding that there was a problem with the welding cells. It is recommended to use separate red bins for rejections during trial runs to prevent such occurrences in the future by providing apt training and instructions to operators.

Shortcomings in the *fixture design* were also highlighted in the present work. One being accumulation of dust and spatter on the *Bakelite stoppe*r in the spindle bush of the fixture leading to height non-conformance. It is suggested to use stopper with a small hole in between to avoid dust accumulation and the other design flaw being of not using dowel pins for setting up fixture on the rotating base resulting in welding defects like undercutting and overflow due to wrong placement of fixture during set up. It is suggested to use stepped dowel pins or threaded taper dowel pins so that dowel pins remain fixed on rotating circular base plate and the fixture can be guided using pins at the correct location every time during production changes. For this the similar design of the base of fixture has to be made so that during change in production model only the fixture needs to be changed without adjusting the welding torch/gun.

Deviations from standard operating procedures (SOP) by operator was also found to be a cause for rejections during production. Negligence in regular cleaning of fixture and welding torch from dust and spatter, not monitoring/maintaining specified voltage and current setting were observed. It is recommended to clean the resting block and fixture at intervals of every 25 parts produced, leadership violations to check such issues should be considerably controlled and workers should be provided over and again trainings to develop expertise in task performance.

## 5. CONCLUSIONS

Automotive industry is one of the fastest growing industry in present scenario. Technological advancements in this industry in recent past has been significantly witnessed. These advancements to some extent escalated many quality related issues. This triggers the need for continuous improvement in production process. In present work, 7QC tools were implemented to evaluate process capability in one of the automobile industry to identify the root causes of process lacunas like fixture design, leadership violations; defects like welding defects and finally recommendations like changes in design of fixture, training and enforcement of SOPs to operators to ensure continuous improvement are made to improve overall productivity.

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