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Mohammed Yunus [1]
Mohammad S. Alsoufi
Mohammed Irfan

APPLICATION OF QC TOOLS FOR CONTINUOUS IMPROVEMENT IN AN EXPENSIVE SEAT HARDFACING PROCESS USING TIG WELDING

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Abstract: *The present study is carried out to improve quality level by identifying the prime reasons of the quality related problems in the seat hardfacing process involving the deposition of cobalt based super alloy in I.C. Engine valves using TIG welding process. During the Process, defects like stellite deposition overflow, head melt, non-uniform stellite merging, etc., are observed and combining all these defects, the rejection level was in top position in Forge shop. We use widely referred QC tools of the manufacturing field to monitor the complete operation and continuous progressive process improvement to ensure ability and efficiency of quality management system of any firm. The work aims to identify the various causes for the rejection by the detailed study of the operation, equipment, materials and the various process parameters that are very important to get defects-free products. Also, to evolve suitable countermeasures for reducing the rejection percentage using seven QC tools. To further understand and validate the obtained results, we need to address other studies related to motivations, advantages, and disadvantages of applying quality control tools.*

Keywords: *Q Quality Control Tools, Continuous Improvement, Seat Hardfacing, TIG Welding, ICE valves, PDCA, Efficiency*

1. Introduction

The seat hardfacing (Deposition) process is used to deposit cobalt-based super alloy possessing higher wear, corrosion and heat resistance properties in I.C. engine valves, which is carried out at Kar Mobiles Limited, India. The company is manufacturing Inlet and exhaust valves for I.C. Engines such as marine, locomotive, battle tanks, farm tractors, automotive vehicles and high-performance cars using a TIG welding process. During the seat hardfacing process, defects such as stellite deposition overflow, head melt, non-uniform stellite merging, deposition unfilled on a seat, and blowholes are observed. Because of the combination of all these defects in this process, the rejection level was high in the forge shop. The research work aims to reduce the rejection level by the detailed study of the operation, equipment and materials and by studying the various process parameters using basic and advanced quality tools. Copper chill rotation,

[1] Corresponding author: Mohammed Yunus
email: yunus.mohammed@rediffmail.com

current, stellite rod feed and shielding gas flow rate during the TIG welding process are very important process parameters in terms of obtaining defect-free products. Therefore, identifying the various causes for the rejection and evolving suitable countermeasures to reduce the rejection level was a priority.

Information about the firms, processes involved like TIG welding, origin of defects as well as their level of priority and the use of basic and advanced Quality Tools were collected and after conducting various hypotheses tests, results were analyzed and discussed to standardize them.

In this article, we have presented a detailed aspect of application of quality tools with number of tables to bring awareness on the use of quality tools for various production companies irrespective of their size, type and strength. It also identifies the potential of each quality tool in continuous improvement and productivity. Finally, few suggestions are also included for future work to improve and extend this research.

2. Literature review

Every manufacturing organization is aiming to achieve the quality of their products as quality and productivity are considered for bringing prosperity into the organization as well as to the nation and improve the quality of work life. Quality is a relative term and refers to the end use of the product. The requirements of the end user will define a product's quality and quality is a continuous improvement process achievable in a planned and controlled way (Juran *et al.*, 1998). The seven QC tools are the simple statistical tools used for problem-solving developed by Japan. Kaoru Ishikawa suggested the role of these QC tools in solving almost 95 percent of all problems. An organization must be both effective and efficient to improve the quality of a product and such improvement is accomplished by recognizing the root of the problems and fixing them in an appropriate way (Rissik, 2013). In order to solve quality problems, the seven QC tools used are as follows:

1) Pareto Diagrams
2) Cause and Effect Diagrams
3) Histograms
4) Control Charts
5) Scatter Diagrams
6) Graphs and
7) Check Sheets.

Pareto Diagram is a QC tool to arrange items concerning the magnitude of their contribution so that particular items exerting maximum influence are identified. A Cause and Effect Diagram is a statistical tool to depict the exact correlation between an obtained result (a symptom/effect) and possible causes in a structured form. Histograms are also known as Frequency distribution diagrams represent bar charts having a large number of distribution of grouped observations arranged according to class intervals and order of magnitude. A control chart can be used to discover the amount of variability in a process due to random variations and unique events, to determine if a process is under statistical control. A control chart is simply a run chart with statistically determined upper control limit and lower control limit lines on either side of the process average. Then, sample averages are plotted into a control chart to determine whether these points fall within the limits or not. The fluctuations of the points indicate common causes within a system, which can then be corrected. A Scatter Diagram is a sample device for ascertaining whether or not two variables are related to each other to test the possible cause and effect relationships. Graphs of various types using a pictorial representation of data enable the user or viewer to grasp the meaning of the data quickly as shown in table 1. Check sheets are used to find the frequency and area location of a failure. The team members collect data based on sample observations to identify patterns becoming a logical start pointing to most problems solving cycles (Girish, 2011).

Table 1. Types of graphs and their purposes in quality control

Graph Types	Purpose
Bar Graph	To compare sizes of data
Line Graph	To represent changes of data
Gantt Chart	To plan and schedule
Radar Chart	To represent changes in data
Band Graph	To represent changes in data
Pie Chart	To indicate comparative weights
ISO Graph	To represent data using symbols

2.1. Development of hardfacing process

The first development of Hardfacing using welding is found in a patent by J. W. Spencer in 1896, but like many other processes, it was not developed industrially for a considerable time. In 1919, a British patent was granted to S. Z. de Ferranti for the protection of steam valves with cobalt-nickel alloys and by 1922 hardfacing alloys had been adopted extensively in oil well drilling for the facing of the cutting edges of rotary drills. This job was so successful that it brought about considerable demand for the hardfacing rod that is in fact the beginning of the art. As there were no oil wells in Great Britain, this major development in Hardfacing was carried out in the United States.

On the introduction of the cemented carbides in the 1920's inserts and small particles were welded into position by melting a steel welding rod around them, and again the oil-well drills were greatly increased and at one locality, for instance, in 1927 it required eighty-four forged and tempered steel fishtail bits to complete a well. The use of cobalt-based hardfacing alloys reduced this number to forty-four, and with carbides, only fourteen drills were used (Riddihough, 1975).

2.2. Hardfacing of internal combustion engine valves

The hardfacing technique in case of I.C. engine valves was developed in the early1920 (Singaiah and Charyulu, 2012). With the development of high compression ratios, valve head temperature increased, and as no suitable steel was available, hardfacing was used to protect the valve seating of an IC Engine valve (Singaiah and Charyulu, 2012). Present day, diesel and high duty petrol engine valves usually consist of an austenitic stainless steel body, nitride hardened on the stem to resist wear. The tip of the stem is hardfaced to resist tappet wear and the seating and often the entire head is hardfaced to resist corrosion and wear. Prior to the advent of the gas turbine virtually every poppet valve used in aero engines was hardfaced. Another extensive development in hardfacing, which was introduced in 1933, is its use for building-up worn railway crossings. A low alloy steel rod gives a tough deposit with high resistance to frictional wear and the process is now used extensively on the railways. Since 1930, hardfacing has been extended into most industries and the process is useful in reclaiming worn components. Its major use, however, is to enable new components to be manufactured with a minimum valuable alloy to give maximum service life and output (Ayano,).

In its early development, gas welding was carried out practically for all hardfacing and it was only later that electrodes were developed, thus widening its scope. A wide field was opened as the speed of deposition by the arc is greater than by the oxy-acetylene torch and practically all hardfacing alloys became available flux- coated for arc welding. This development was bound up with the widespread use of portable arc welding outfits, practically for maintenance and repair work on earth moving contracts and in the heavy industries generally (Olson *et al.*, 1993).

The Cobalt-based Stellite alloys are the most well-known and successful alloys, with best properties like excellent mechanical wear resistance, especially at high temperature, with very high corrosion resistance (Riddihough, 1975). Cobalt-chromium-molybdenum (Tribaloy) alloys were developed for resisting extreme wear combined with high temperature and corrosion. They are very suitable for using in adhesive wear conditions due to the high content of molybdenum possess excellent dry-running characteristics. Similarly, Nickel-chromium-molybdenum (Nistelle) alloys are developed to resist corrosion, especially in hostile chemical domain due to rich content chromium and molybdenum which provides superior pitting resistance rather than wear. Carbon particles in nickel or cobalt (Stelcar) alloys present in powder form can be applied by thermal spraying or weld hardfacing techniques. Iron based (Delcrome) alloys are developed to provide resistance to abrasive wear at very lower temperatures (up to 200°C) but their corrosion resistance is low compared to Tribaloy or Nistelle alloys (see. Hardfacing alloys and welding methods).

Figure 1 illustrates the Products of Kar Mobiles Limited Company. Table 2 and 3 provides the details of manufacturing capability and configuration of engine valves of the company.

2.3. Gas tungsten arc welding

In the case of the Gas Tungsten Arc Welding (GTAW) or HeliArc, two welding methods were developed namely, tungsten inert gas (TIG) and tungsten arc welding (TAW) during the beginning of 1940 when the need arose to weld magnesium which was impossible. Russell Meredith introduced and produced welding process using the inert gas helium and a tungsten electrode to fuse magnesium. This joining method replaced the riveting process of building aircraft with the aluminum and the magnesium components.

Figure 1. Photograph of products of car mobiles Ltd

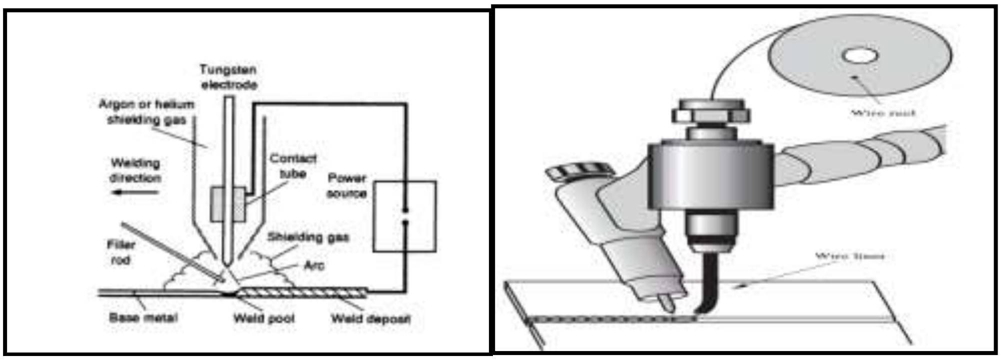

Figure 2. Schematic drawing of components and parameters and the automatic feeding of filler material for the TIG welding.

This welding process has continued with many refinements to this day and name changes, but without much changes in the fundamentals demonstrated by Meredith as shown in figure 2.

In the GTAW, the melting temperature required to weld materials is by an arc between a tungsten alloy electrode and the workpiece can approach 2500°C in the presence of an inert gas [argon, helium, or a mixture of helium and argon] which protects from atmospheric contamination (Bohnart and Staff, 2005).

Table 2. Manufacturing capability of engine valves

Specification	Min. (mm)	Max. (mm)	Raw Material Used
Head Diameter	18	105	Low Carbon Steel. Martensitic Valve Steel. Austenitic Valve Steel. Nickel Alloy. Stainless Steel.
Stem Diameter	5	22	
Overall Length	50	450	

Table 3. Configuration of valves in Kar mobiles Ltd

Mono Metal	Upsetting and Forging
Bimetal	Friction Welding and Projection Welding
Head Finish	Machine Finish and Forge Finish
Seat	Hardfaced Induction Hardened
Tip End	Flame Hardened, Induction Hardened and Stellite Faced

Advantages of Gas Tungsten Arc Welding are providing a concentrated heating of the work piece resulting in a narrow heat-affected zone, an effective protection of the weld pool by an inert shielding gas, independent of filler material, after treatment of the weld as no slag or spatter is produced and good for welding thin with similar or dissimilar material. Disadvantages of Gas Tungsten Arc Welding are slower deposition rate, necessity for a skilled hand-eye coordinated operator and the fact that the equipment costs more. Application of Gas Tungsten Arc Welding: welding of stainless steels, aluminium, nickel, nickel alloys, petrochemical, food, chemical, nuclear, offshore industry and power plants (see. Tungsten guidebook, 2002). Types of Tungsten electrode for TIG welding are pure tungsten electrode, Cerium tungsten electrode, Lanthanum tungsten electrode, Thorium tungsten electrode and Zirconium tungsten electrode (Bohmart and Staff, 2005; Technical specification for TIG welding; Tungsten Guidebook, 2002).

3. Research methodology

The following methodology or technique was used to identify the defects and evolve suitable counter measures to reduce the rejection in the Seat Hardfacing process in an I.C. Engine Valve.

- **Problem selection:** To clarify what the problem is that you are to solve.
- **Observation:** To clarify the reason for the selection of the problem by positioning the problem using Pareto Diagram and other tools.
- **Analysis:** This is the central activity in the problem solving procedure with the QC approach and it refers to an activity to quantitatively link the characteristics in question to the true causes and /or effective counter measures. Here, possible causes are identified by all the people concerned using a Cause-and-Effect Diagram, and then those causes which are considered to be root caused are verified using various statistical techniques including design of experiments.
- **Action:** To take action on the root causes which are identified through analysis.
- **Check:** This step is also a characteristic feature of the problem solving procedure with the QC approach and it means that the result of the actions taken must be confirmed and then the PDCA cycle must be rotated without fail.
- **Standardization:** Once the effect is confirmed, "standardization" should be

instituted in order to organizationally prevent occurrence of the problem.

- **Conclusion:** This step means what is yet to be resolved is made clear and the activity is to be reviewed to see if the process has been appropriate as a problem solving procedure and to find possible improvement for its future implementation i.e. the control cycle is to be rotated over the way the problem is solved (Ayano, -; Katsuya, 2001).

3.1. Problem selection

The rejection data was collected during the period of April to July for data analysis. During this period a total 2549 PPM were rejected and this constituted a rejection level to top level in Seat hardfacing process in an I. C. Engine Valves. From the data obtained, a Pareto diagram was drawn (refer figure 3) to identify the defects in this process. It was found that the defects in the Seat hardfacing process of an I C Engine Valve contribute to 2549 PPM of the rejection, which was the highest in the Forge shop.

Stellite deposition overflow, Head melt, Stellite unfilled on seat, Blowholes and Non uniform stellite merging respectively are the defects shown in figure 5.

3.2. Observation

By observing the component process flow diagram for the purposes of identifying the operation contributing to the rejection of I.C. Engine Valves in the Seat hardfacing process as shown in Figure 4.

3.2.1. GEMBA Study for clarity of data in seat hardfacing process

By observing the GEMBA (Work spot), Seat hardfacing is the process used to weld and fill the stellite rod to the seat recess portion by the TIG welding machine as shown in the figure 6. Before the Seat deposition process a seat recess operation is carried out on the Valve head for depositing the Stellite rod by TIG welding machine. During the seat recess operation, recess depth of 1.2 mm towards the radius is removed and matched with the profile drawing, which is used for checking the seat recess profile. During the seat deposition by TIG, many defects like Stellite deposition overflow, Head melt, Stellite unfill on seat, Non uniform stellite merging and Blowholes are identified.

3.3. Analysis

Based on the GEMBA study, brainstorming to identify all the possible causes for the I.C. Engine Valves defects is undertaken and its results are listed below.

Chill rotation speed variation, Current variation, Stellite rod feed variation, Head diameter variation, Head not clear, Tungsten electrode tip burn off more, Chill run out more (axis of the chill), Chill run out more (valve mounting area), Chill inside diameter variation, Seat recess form not clear, Seat recess run out more, Insufficient cooling of the chill, Seat height variation, Face run out more, Improper oscillation of the nozzle, Improper nozzle angle setting, Head run out, Face burr, Unskilled operator and Seat recess profile not ok, etc.

After identifying the possible causes through brainstorming, a Cause and Effect diagram (refer to figure 7) is used to show the systematic relationship between a result and its possible causes. The causes were categorized under the following headings:

- Material
- Man
- Machines
- Methods

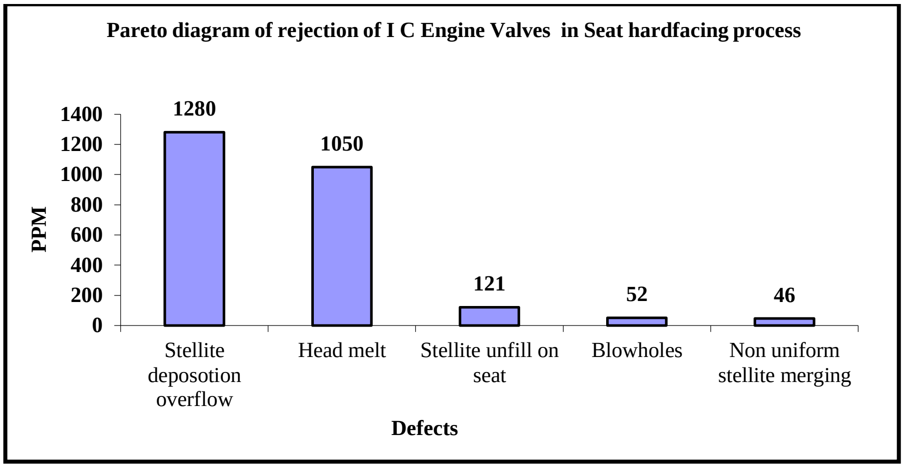

Figure 3 Pareto diagram for rejection of valves

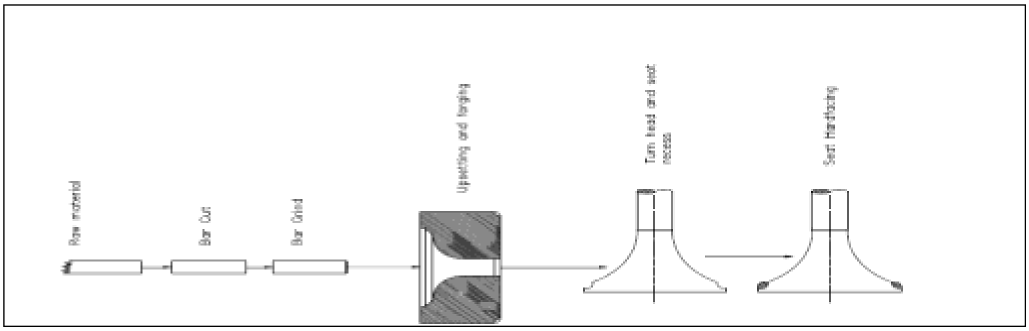

Figure 4. Schematic view of process flow diagram for valves

Figure 5. Photograph of I.C. Engine Valves defects

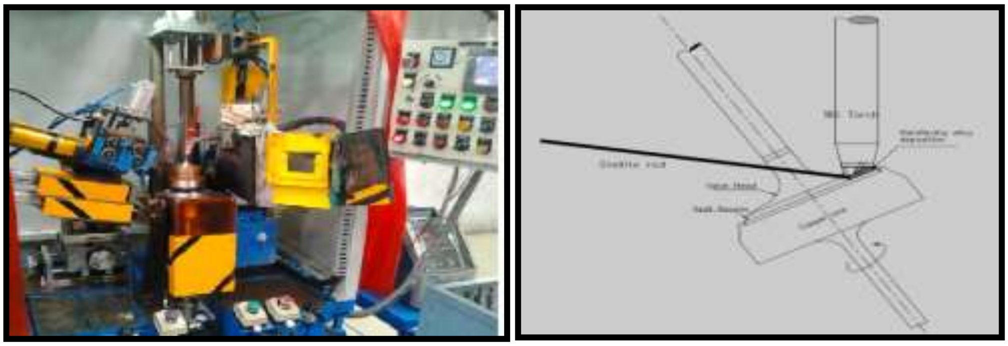

Figure 6. TIG welding machine and partial schematic drawing of seat hardfacing process

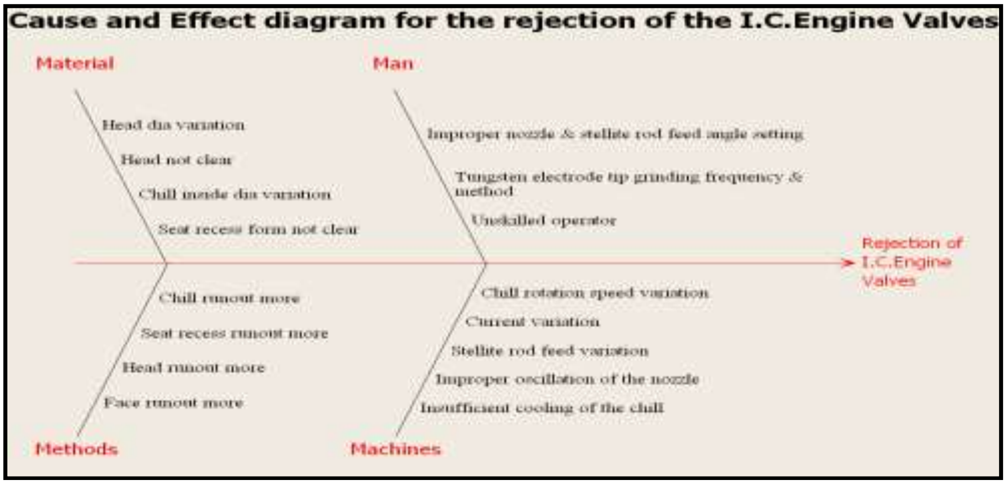

Figure 7. Cause and Effect diagram for the rejection of I C Engine Valves

3.3.1. Experimental data sheet for possible causes

Table 4 and 5 give the experimental data for the primary possible and secondary possible causes (Significant causes) for the rejection of I C Engine Valves. From these tables, it is found that some of the causes become significant and some of the causes are insignificant.

3.3.2. Root causes for significant causes by Why-Why analysis

By close study of the actual workplace and the generating of a counter measure plan which is readily accepted by the workplace.

Table 4 Data collection table for the possible causes

No.	Possible causes	Specification	Observation		Significant/ Insignificant
			Min	Max	
1	Chill Rotation Speed Variation	27-29 Sec	20	40	Significant
2	Current Variation	270-290 Amp	220	300	Significant
3	Stellite rod feed variation	180-185 mm	150	220	Significant
4	Head dia variation	58.80-58.90	58.60	58.90	Significant
5	Head not clear	Nil	No Head not clear found		Insignificant

6	Head run out more	0.10 mm	0.06	0.10	Insignificant
7	Chill run out more (axis of the chill)	0.10 mm	0.06	0.10	Insignificant
8	Chill run out more (valve mounting area)	0.10 mm	0.06	0.10	Insignificant
9	Chill inside dia variation	58.80-58.90	58.85	58.90	Insignificant
10	Insufficient cooling of the chill	20^0C	15^0C	15^0C	Insignificant
11	Seat height variation	Match with profile drawing	Match with profile drawing		Insignificant
12	Face run out more	0.10 mm	0.07	0.10	Insignificant
13	Improper oscillation of nozzle	Visual	Proper oscillation		Insignificant
14	Improper nozzle angle setting	60^0-70^0	Not specify		Insignificant
15	Tungsten tip burn off more	Per shift (500 No's)	150	200	Significant
16	Tungsten tip grinding method	Longitudinal direction with 15^0 Angle	Radial direction with uneven angles		Significant
17	Face burr	Nil	Nil		Insignificant
18	Seat recess profile not ok	Match with profile drawing	Ok		Insignificant
19	Unskilled operator	Skilled operator	Skilled operator		Insignificant
20	Seat recess form not clear	Nil	5 No's out of 250 valves		Significant
21	Seat recess run out more	0.10 mm	0.10	0.50	Significant

Table 5 Data collection table for the significant causes

No.	Possible causes	Specification	Observation		Significant/ Insignificant
			Min	Max	
1	Chill Rotation Speed Variation	27-29 Sec	20	40	Significant
2	Current Variation	270-290 Amp	220	300	Significant
3	Stellite rod feed variation	180-185 mm	150	220	Significant
4	Head dia variation	58.80-58.90	58.60	58.90	Significant
5	Tungsten electrode burn off more	Per shift (500 No's)	150	200	Significant
6	Wrong tungsten electrode grinding method	Longitudinal direction with 15^0 angle	Radial direction with uneven angle		Significant
7	Seat recess form not clear	Nil	5 No's out of 250 valves		Significant
8	Seat recess run out more	0.10 mm	0.10	0.50	Significant

Table 6. Root causes for the major causes by why-why analysis

Causes	Chill rotation speed variation [f15(1)]	Current variation [f15(4)]
Why	Voltage varying from 60-80 volts	Trigger signal not coming from main control card
Why	Supply coming from carbon brush is varying	Thyristor shorted & damaged the PCB card
Why	Due to worn-out of carbon bush	
Root causes	Carbon bush worn-out	Over load
Counter measure	Brush less DC motor is replaced	Control fuse provided
Causes	**Stellite rod feed variation[f15(3)]**	**Head dia variation**
Why	Voltage varying from 60-80 volts	Sliding movement of the tool is not proper
Why	Supply coming from carbon brush is	Hydraulic pressure variation

	varying	
Why	Due to worn-out of carbon bush	Conventional machine
Root causes	Change of carbon bush	Less consistency
Counter measure	AC motor with AC drive is provided	Operation is carried out by CNC machine
Causes	**Tungsten electrode burn off more**	**Wrong tungsten electrode grinding method**
Why	Tungsten electrode tip specification is not maintained	Tungsten electrode tip preparation is done manually
Why	Tungsten electrode tip preparation is done manually	
Why	Specific tungsten electrode tip preparation machine is not available	Specific tungsten electrode tip preparation machine is not available
Root causes	Tungsten electrode tip preparation should be done by specific machine only	Tungsten electrode tip preparation should be done by specific machine only
Counter measure	Procurement of Tungsten electrode grinding machine	Procurement of Tungsten electrode grinding machine
Causes	**Seat recess form not clear**	**Seat recess run out more**
Why	Sliding movement of the tool is not proper	Sliding movement of the tool is not proper
Why	Hydraulic pressure variation	Hydraulic pressure variation
Why	Conventional machine	Conventional machine
Root causes	Operation should be done by CNC m/c only	Operation should be done by CNC m/c only
Counter measure	Operation is carried out by CNC machine	Operation is carried out by CNC machine

3.4. Action

The following recommendations are for process parameters and setting methods to get the best results. A few trials were conducted to ensure consistency in the result, they were found to meet the quality requirements with advisable methods listed and discussed below.

3.4.1. Tungsten electrode grinding method

The tungsten electrode tip shape is an important process parameter in precision TIG welding process. Accurate tungsten electrode tip shape geometry demands to fulfil various attributes like longer life, difficult starting of arc, shallower weld penetration and narrower arc shape during the process.

Actual Method

Tungsten electrode tip grinding is done in the common grinding machine and also it is prepared by a manual method with radial grind marks (refer figure 8) and this leads to restriction of the welding current, causes arc wandering, difficult starting of an arc, less stability in the arc and contaminations lower weld quality and also decreasing the tungsten electrode life.

Advisable Method

Tungsten electrode tip grinding should be prepared with a specific tungsten grinding machine to avoid the contamination of the tungsten electrode tip. The tungsten electrode must be ground and cut properly to improve arc starting and arc stability during the welding. Always use diamond wheels for grinding and cutting to obtain smooth grinding with high surface finish.

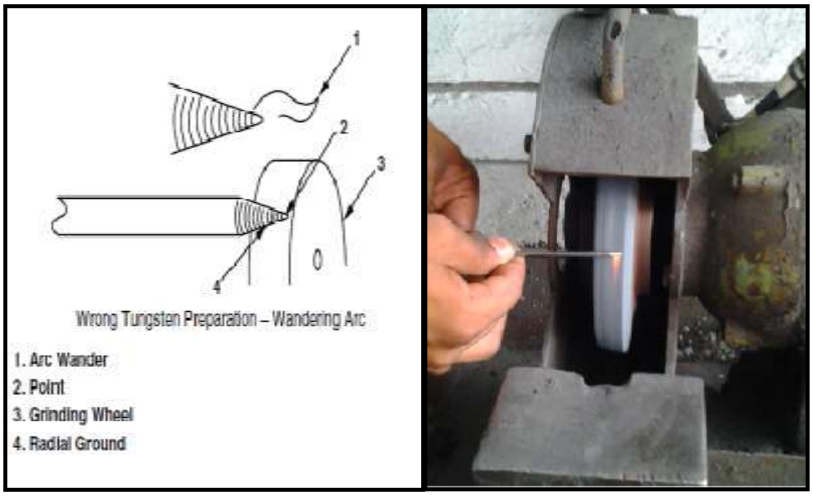

Figure 8. Wrong way tungsten preparation

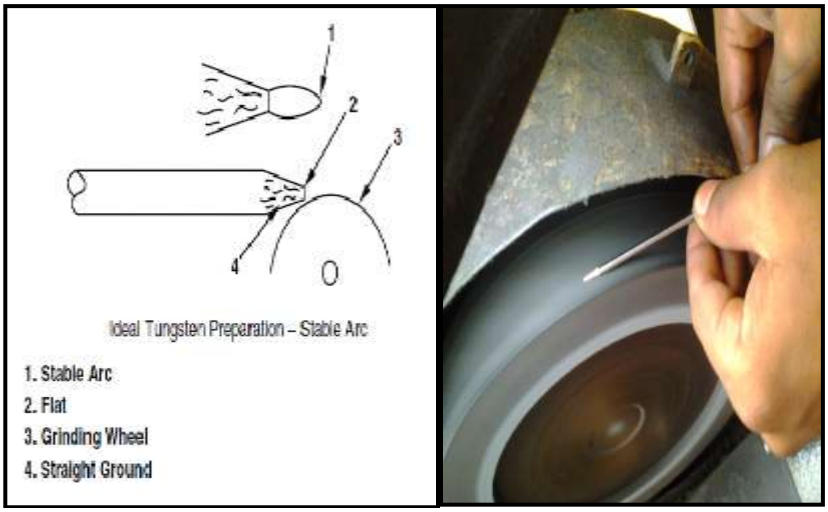

Figure 9. Ideal way of tungsten preparation

The most important element for proper taper grinding is that the electrode must be ground longitudinally (lengthwise) with a taper grind distance of 2-2.5 times the electrode diameter, tip flat of 0.25-0.5 times the electrode diameter and with an included angle of 15^0-30^0. For the best possible arc stability, the tungsten electrode should be done with the length of the electrode at a 90^0 angle to the axis of the grinding wheel with a tip flat and as a surface finish of a prepared taper surface should be within 20-40 RMS as shown in figure 9.

3.4.2. Tungsten electrode type

In general, most of the welders using TIG welding prefer tungsten that may contain an emission-intensifying oxide (such as Thorium, Cerium or Lanthanum). The emitted oxides have potential of migrating from inner core of the tungsten to the heat present at the tip of the electrode to give away their oxide in the arc and improve arc starting and arc stability. Thus, it forms a film of the metal alloy on the tip. Therefore, an electrode can produce different temperature at the tip based on the work capacity of the element.

Figure 10. 2% Thoriated tungsten and 1.5% Lanthanum tungsten electrodes and proposed tip preparation

Actual Method

Tungsten electrode with 2% Thoriated oxide contains thorium and has very low level radioactive material, thus vapors, grinding dust and disposal of thorium raises health and safety and environmental concerns. These electrodes are usually preferred for DC applications, the electrode is ground to a point and due to this the life of the tungsten electrode tip is shortened considerably and this leads to arc wandering and more difficulty in arc starting shown in figure 10.

Advisable Method

Tungsten electrode with 1.5% Lanthanum oxide is non-radioactive, these electrodes have excellent arc starting, low burn-off rate, arc stability and excellent re-ignition characteristics. 1-2% Lanthanum electrodes increase the current carrying capacity by approximately 50% for a given size electrode compared to pure tungsten and this leads to having longer life and providing greater resistance to tungsten contamination of the weld.

3.4.3. Gas nozzle with gas lens

The gas nozzle with gas lens is constructed in such a way that the shielding gas passes through a wire grid in order to make the flow of shielding gas more stable at a longer distance, because of this the electrode can have a longer stick-out thus allowing the welder to have a better view of the weld pool. Because of these characteristics the consumption of shielding gas can be reduced to 20-30% of common gas nozzle.

Actual Method

A common gas nozzle is used in the TIG torch, the shielding gas exit with a turbulent stream of flow and this begins to spread out at the tip of the gas nozzle, because of this the flow of shielding gas will not reach the welding zone and this leads to getting atmospheric air entry in the welding zone and causes welding defects. To overcome this problem it is necessary to use more shielding gas shown in figure11.

Advisable method

A gas nozzle with gas lens makes the flow of shielding gas (refer figure 11) with a column stream of gas and this allows the electrode to stick out for a longer time enabling the welder to have better visibility. The gas lens has a wire grid in order to make the flow of gas more stable at a longer distance so that the gas consumption can be reduced to a moderate level and this can -avoid the entry of atmospheric air into the welding zone and thereby we can achieve defect free welding.

3.4.4. Stellite rod feed and TIG torch angle

These angles play very important role in TIG welding. The stellite rod feed angle should lie within the range of 15^0-30^0 with the base metal and the TIG torch angle should lie within the range of 60^0-75^0. To prevent melting and achieve defect-free welding these are the best suited parameters for TIG welding.

Actual method
The stellite rod feed and TIG torch angles are set manually with approximate method. Due to this the TIG arc does not perfectly melt the stellite rod and the base material and for this reason welding will not satisfy the quality requirements.

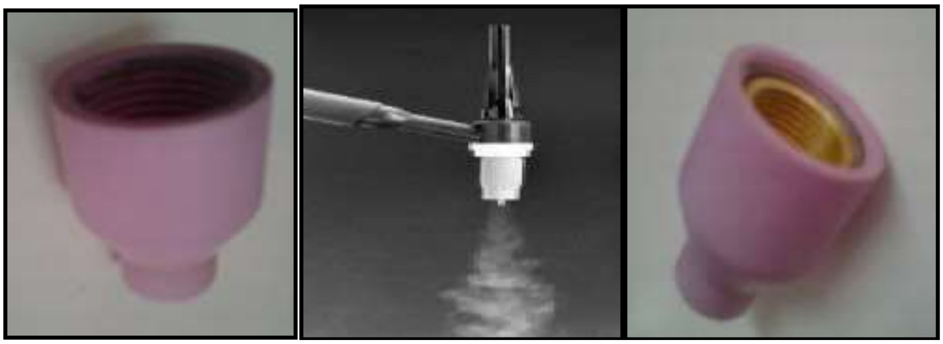

Figure 11. Common gas nozzle, TIG torch with common gas nozzle and gas nozzle with gas lens

Advisable method
The stellite rod feed and TIG torch angles should be set with the help angle plate for accurate measurement. The Stellite rod feed should be set within the range of 15^0-30^0 and the TIG torch angle set within the range of 60^0-75^0 as shown in figure 12.

3.4.5. Shielding gas flow meter

In order to adjust the required gas flow for the TIG welding it is necessary to provide a Gas flow meter.

Actual Method
The gas flow is set with approximate method, because of this sometimes the gas flow rate may be less or more and this leads to causing more likelihood of getting defects in the welding and also more shielding gas consumption during the welding process.

Advisable Method
In precision TIG welding the shielding gas constitutes a very important process parameter to get a defect-free welding. The gas flow rate should be 07-12 ltr/min for a common gas nozzle and 05-6.5 ltr/min for a gas lens nozzle. These can be accurately set by digital flow switch and from this it is possible to obtain the exact required flow rate during the TIG welding process.

The proposed counter measure and advisable methods need to be tried out in the actual production site and the person responsible for implementing the counter measure should have been decided by coordinating the matter with all the related departments. A decision is taken as to when the proposed counter measure will be tried out through 3W-1H format as shown in Table 7.

3.5. Check

Confirmation of effect is the most characteristic feature of the problem solving procedure in the QC story. Once the counter measure is fully implemented it is necessary to confirm its effects by the experimental data.

3.5.1. Experimental data

To confirm the effect of the counter measure for Chill rotation/ speed variation, Current variation, Stellite rod feed variation, Head diameter variation, Tungsten electrode tip burn off more, Wrong tungsten electrode tip grinding method, Seat recess form not clear and Seat recess run out more, the experimental data is collected and the result observed is as shown in tables 8-15.

3.5.2. Before and after defects pareto diagram

To see the result from the recommended counter measure and advisable methods to the rejection of seat hardfacing process for an ICE valve is done by using a Pareto diagram and is as shown in figure 13.

Table 7. 3W-1H format for implementing the counter measure

No.	What	When	Who	How
1	Chill rotation speed variation	15-11-14	Author[1]	Providing bush less DC motor instead of worn-out Carbon bush DC motor.
2	Current variation	12-01-15	Author[1]	Providing control fuse for avoiding overload to the machine.
3	Rod feed variation	05-02-15	Author[1]	Replacing Dc motor to the AC motor with AC drive for more accuracy.
4	Head dia variation, Seat recess form not clear, Seat recess run out more	06-12-14	Author[2]	Carry out the operation in CNC machine.
5	Tungsten electrode type	15-04-15	Author[3]	By purchasing 1.5% Lanthanum instead of 2% Thoriated.
6	Gas nozzle with gas lens	15-07-15	Author[2]	By replacing Import torch to Local torch with gas lens in the TIG torch.
7	Flow meter	04-08-15	Author[2]	By procuring flow meter and fixing in the machine
8	Stellite rod feed angle and TIG torch angle	04-08-15	Author[2]	By providing angle plate in the machine for stellite rod feed and TIG torch angle.
9	Tungsten electrode burn off more, Wrong tungsten electrode grinding method	04-08-15	Author[3]	By procuring tungsten electrode grinding machine and giving procedure for tip preparation.

Table 8. Experimental data for chill rotation speed variation

No.	*Specification in secs*	*Observation in secs*	*No.*	*Specification in secs*	*Observation in secs*
1	***Part No-1152367 16-18***	16	26	***Part No-1152367 16-18***	16
2		16	27		16
3		16	28		16
4		16	29		16
5		16	30		16
6		16	31		16
7		16	32		16
8		16	33		16
9		16	34		16
10		16	35		16
11		16	36		16
12		16	37		16
13		16	38		16
14		16	39		16
15		16	40		16
16		16	41		16
17		16	42		16
18		16	43		16

19		16	44		16
20		16	45		16
21		16	46		16
22		16	47		16
23		16	48		16
24		16	49		16
25		16	50		16

Table 9. Experimental data for current variation

No.	***Specification in amps***	***Observation in amps***	***No.***	***Specification in amps***	***Observation in amps***
1	***Part No-1152367 230-250***	240	26	***Part No-1152367 230-250***	240
2		240	27		240
3		240	28		240
4		240	29		240
5		240	30		240
6		240	31		240
7		240	32		240
8		240	33		240
9		240	34		240
10		240	35		240
11		240	36		240
12		240	37		240
13		240	38		240
14		240	39		240
15		240	40		240
16		240	41		240
17		240	42		240
18		240	43		240
19		240	44		240
20		240	45		240
21		240	46		240
22		240	47		240
23		240	48		240
24		240	49		240
25		240	50		240

Table 10. Experimental data for stellite rod feed variation

No.	***Specification in mm***	***Observation in mm***	***No.***	***Specification in mm***	***Observation in mm***
1	***Part No-1152367 75-80***	80	26	***Part No-1152367 75-80***	80
2		80	27		80
3		80	28		80
4		80	29		80
5		80	30		80
6		80	31		80
7		80	32		80
8		80	33		80
9		80	34		80
10		80	35		80
11		80	36		80
12		80	37		80
13		80	38		80

14		80	39		80
15		80	40		80
16		80	41		80
17		80	42		80
18		80	43		80
19		80	44		80
20		80	45		80
21		80	46		80
22		80	47		80
23		80	48		80
24		80	49		80
25		80	50		80

Table 11. Experimental data for head dia. variation

No.	***Specification in mm***	***Observation in mm***	***No.***	***Specification in mm***	***Observation in mm***
1	***Part No-1152367 42.81+/-0.05***	42.80	26	***Part No-1152367 42.81+/-0.05***	42.82
2		42.80	27		42.82
3		42.80	28		42.82
4		42.80	29		42.82
5		42.80	30		42.82
6		42.80	31		42.82
7		42.80	32		42.82
8		42.80	33		42.82
9		42.80	34		42.82
10		42.80	35		42.82
11		42.80	36		42.82
12		42.80	37		42.82
13		42.80	38		42.82
14		42.80	39		42.82
15		42.80	40		42.82
16		42.80	41		42.82
17		42.82	42		42.82
18		42.82	43		42.82
19		42.82	44		42.82
20		42.82	45		42.82
21		42.82	46		42.82
22		42.82	47		42.82
23		42.82	48		42.82
24		42.82	49		42.82
25		42.82	50		42.82

Table 12. Experimental data for Tungsten electrode tip burn off more

No.	***Specification***	***Observation***
01	The tungsten tip burn off should be Per shift (500 no’s)	Tungsten electrode tip burn off is 380-400 no’s (Manual grinding)

Table 13. Experimental data for wrong tungsten electrode grinding method

No.	***Specification***	***Observation***
01	Longitudinal with an angle of 15^0	Longitudinal direction with an angle of 14^0 to 16^0 (Manual grinding)

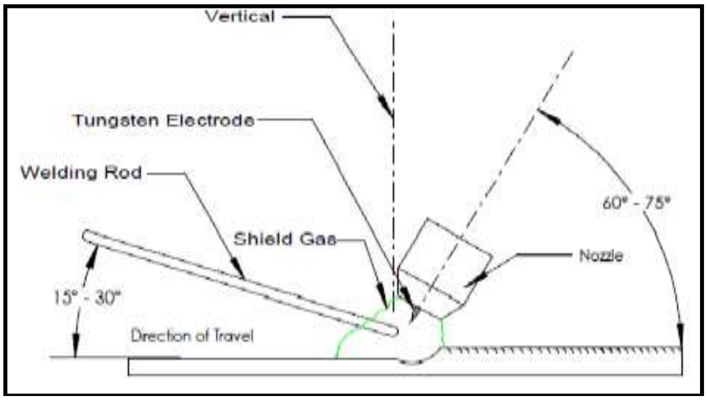

Figure 12. Stellite rod feed and TIG torch angles

Table 14. Experimental data for Seat recess form not clear

No.	***Specification***	***Observation***
1	Nil	Nil

Table 15. Experimental data for seat recess run out more

No.	***Specification in mm***	***Observation in mm***	***No.***	***Specification in mm***	***Observation in mm***
1	***Part No-1152367 Run out 0.10***	0.06	26	***Part No-1152367 Run out 0.10***	0.03
2		0.05	27		0.07
3		0.07	28		0.08
4		0.03	29		0.09
5		0.07	30		0.06
6		0.08	31		0.06
7		0.09	32		0.07
8		0.06	33		0.07
9		0.06	34		0.03
10		0.05	35		0.07
11		0.07	36		0.08
12		0.03	37		0.09
13		0.07	38		0.06
14		0.08	39		0.06
15		0.09	40		0.05
16		0.06	41		0.07
17		0.06	42		0.03
18		0.07	43		0.06
19		0.03	44		0.06
20		0.07	45		0.05
21		0.08	46		0.07
22		0.09	47		0.03
23		0.06	48		0.07
24		0.06	49		0.08
25		0.07	50		0.06

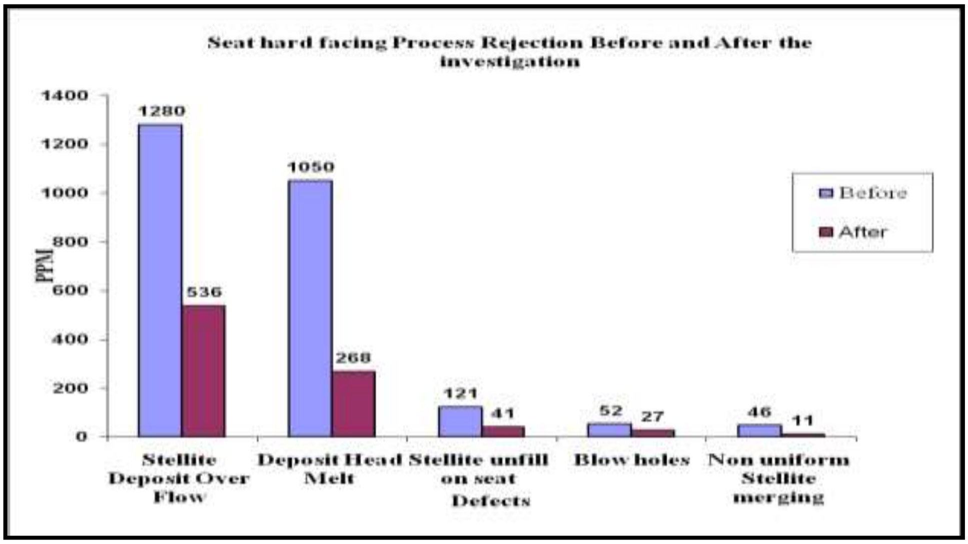

Figure13. Before and after rejection Pareto diagram

4. Results and discussion

A few trials were conducted after the counter measure and advisable method, they were found to meet the quality requirements as follows:

- The chill rotation speed in f15 (1) found to be constant during the process and also the TIG welding satisfies the quality requirements. Current in f15 (2) found to be constant during the process and also it is observed that TIG welding satisfies all the quality requirements. It is observed that, after the counter measure implementation in f15 (3), the stellite rod feed found uniform.
- The turn head, seat recess operations are carried out in a CNC machine and it is observed that no head dia variation, seat recess form Ok and also seat recess run out lies within the specification.
- By using 1.5% Lanthanum tungsten electrode in the TIG welding process, the tip life of the tungsten electrode becomes more i.e., 380-400 no's as compare 150-200 no's in 2% Thoriated tungsten electrode. And also it is observed that tungsten electrode found less contamination after the welding process.
- Suggestion is given to use gas lens in the TIG torch for the f15 (1), f15 (2), f15 (3) machines for better shielding gas flow to the welding zone during the TIG welding process. By using gas lens, shielding gas consumption is saved up to 50 Ltr / machine. Suggestion is also given to use flow meter in the f15 (1), f15 (2), f15 (3) machines for better control of shielding gas flow rate during the TIG welding process. Suggestion is made to provide an angle plate for stellite rod feed and TIG torch in all the TIG welding machines for better results in the TIG welding process.
- It is recommended for tungsten electrode grinding machine to prepare tungsten electrode tip for TIG welding process from preventing tip contamination, tip burn off and to get the required tungsten electrode tip geometry for

better results in the TIG welding process.

4.1. Standardization

Standardize the new counter measure and advisable methods to reduce the rejection of an ICE valves in seat hardfacing process by updating standard operating procedure, maintenance optimal check sheet and creating new part no for procurements of suggested item (Eker, 2010).

5. Conclusions

In this research work, role and systematic approach of 7 QC tools in producing defects free products from product development to managing processes have been presented in the production process. It is very important for any organization to produce high quality products and maintain that quality to promote customer satisfaction and maintain standards. This is achieved by the efficient use of men, material, machine and management. This means that the quality of a product is mainly dependent on the skill of the operator, efficiency of the machine and quality of the material used. This work on reduction of rejection in seat hardfacing process of an I.C. Engine valve was successfully completed by using seven quality control tools. As it is presented in selected defects, quality tools played an important role in the collection of data, analysis, visualization, standardization and making sound base for data founded decision making. Moreover, the suggestions as explained earlier will result in drastic reduction in rejection of I.C. Engine valves. The implementation of counter measure and some of advisable methods are shown to achieve significant results in the seat hardfacing process in an I.C. Engine valve. Finally, the new counter measure and advisable methods have saved USD 2000 approximately to USD 900, and also reduced the rejection level from 2549 PPM to 883 PPM.

Quality tools are quite simple for application, implementation and interpretation but they are not widely used as we expected in many processes. With the advancement of computer programming and automated data acquisition methods, technical obstacles can be easily removed and increases application of quality tools. In order to bring continuous improvement and awareness, certain discomfort towards quality tools are to eliminated through continuous staff education and training (Paveltic *et al.,* 2008).

To extend the work in future, the suggestions would be focusing on the comparison of procedures adapted for motivations, benefits and obstacles of using Quality Tools in small scale to large scale, process to production organizations. Also, comparison of non-certified organizations in different countries with standard certified organizations to develop software modules for reducing rejection levels to a greater extent (Fonseca *et al.*, 2015).

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Mohammed Yunus
Umm AlQura University,
Saudi Arabia
yunus.mohammed@rediffmail.com

Mohammad S. Alsoufi
Umm AlQura University,
Makkah
Saudi Arabia
m.s.alomsoufi@gmail.com

Mohammed Irfan
Reva Institute of Technology and Management,
India
irfan.mec@gmail.com