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# Optimization of Process Parameter in Seat Hardfacing Process for an I C Engine Valves

Madhu G
Assistant Professor,
School of Mechanical Engineering,
Reva University, Bangalore 560064.

Vijee Kumar
[2] Assistant Professor,
School of Mechanical Engineering,
Reva University, Bangalore 560064.

Robinson P
[3] Assistant Professor,
School of Mechanical Engineering,
Reva University, Bangalore 560064.

***Abstract* - This research is carried out to optimize the process parameters in seat hardfacing process used to deposit cobalt based superalloy having higher wear, corrosion and heat resistance in an I C engine valves. The detailed study of operation, equipment & materials are done to find the root causes of the problem. Quality control tools such as pareto diagram, cause & effect diagram are used for the suggestions & modifications to overcome the defects like stellite deposition overflow, head melt, non uniform stellite merging, stellite unfill on seat and blowholes on the seat portion of the I C engine valves.**

***Key Words: Defects, I C engine valves, Root causes, Seat hardfacing process.***

## I. INTRODUCTION

The valve seat of an I C engine valves are repeatedly engaged with valve seat insert and it has to provide proper sealing in the engine cylinder [1]. Especially in an exhaust valve, portion of the valve seat is directly exposed to the high temperature and corrosive products of exhaust gas. Generally the valve seat must withstand exposure to corrosive gases passing there over at high pressure and at high temperatures ranging from about 538$^0$C or higher at different combustion cycle [2].

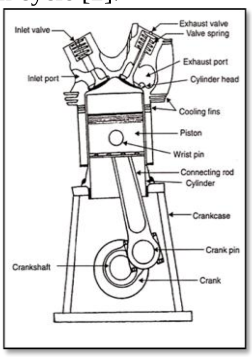


Fig 1: I C engine component details.

Seat hardfacing process to the I C engine valves is one of the well-known processes in the industry. In the manufacture of I C engine valves, it is common practices to weld the valve seat with a corrosion, wear, abrasion and heat resistant alloy to protect the valve seat and enhance the service life of the valve [3].

The hard facing material used in this process is cobalt based alloy such as stellite® alloy, this is usually applied to the valve seat portion by means of TIG welding process. This study is undertaken in the TIG welding machine, which is used for seat hardfacing process. During seat hardfacing process it is observed that defects like stellite deposition overflow, head melt, non-uniform stellite merging, deposition unfill on seat and blowholes. These defects increased the rejection level to the top position due to variation in the process parameters.

This study aim is to optimize the process parameter to reduce the rejection level by detailed study of operation, equipment, and materials by evolving suitable counter measure to get the defects free products in the seat hardfacing process.

## II. HARDFACING PROCESS

The hardfacing process is a technique, which involves depositing a layer of hard material like, cobalt based alloy to an I C engine valve for the purpose of increasing the required property. The use of this technique has increased significantly over the year as industry has come to recognize that base materials of softer, lower cost material can be hardfaced to have the same wear and corrosion resistance characteristics as more expensive base material of a harder material [4].

The selection of this process is mainly depended on a number of factors like, nature of work to be hardfaced, function of the component, base metal composition, size and shape of the component, accessibility of weld equipment, number of same or similar item to be hardfaced etc [5].

*A. I C engine valve material and hardfacing alloy*

I C engine valve material:-The detailed chemical composition and mechanical properties of the I C engine valve material of 21-4N used in this process is listed in the below Table 1&2 respectively.

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Table 1: Chemical composition of the I C engine valve material 21-4N.

| Chemical Composition of 21-4N Raw Material | | | |
|---|---|---|---|
| C% | Si% | Mn% | P% |
| 0.48/0.58 | 0.25 Max | 8.00/10.00 | 0.04 Max |
| S% | Cr% | Ni% | |
| 0.03 Max | 20.0/22.0 | 3.25/4.50 | |

Table 2: Mechanical properties of I C engine valve material.

| Mechanical Properties | | | | | |
|---|---|---|---|---|---|
| Raw material | Hardness | Yield strength $Kg/mm^2$ | Tensile strength $Kg/mm^2$ | Elongation % | Reduction area % |
| 21-4N | 25 HRC Min | 57 Min | 90 Min | 8 Min | 15 Min |

Hardfacing alloy:- The chemical composition and hardness of the hardfacing material used in this process are listed below.

Table 3: Chemical composition and hardness of the hardfacing alloy.

| Stellite grade | HRC | C% | Mn% | Si% | P% | S% |
|---|---|---|---|---|---|---|
| Stellite®1 | 54 | 2.43 | 0.3 | 1.2 | 0.009 | 0.007 |
| | Cr% | Ni% | Mo% | W% | Fe% | Co% |
| | 30.5 | 1.8 | 0.3 | 12.7 | 2 | Bal |
| Stellite®6 | HRC | C% | Mn% | Si% | P% | S% |
| | 43 | 1.25 | 0.08 | 1.26 | <0.001 | 0.013 |
| | Cr% | Ni% | Mo% | W% | Fe% | Co% |
| | 30.39 | 2.55 | 0.02 | 4.82 | 2.48 | Bal |
| Stellite®12 | HRC | C% | Mn% | Si% | P% | S% |
| | 50 | 1.51 | 0.24 | 1.37 | 0.005 | 0.015 |
| | Cr% | Ni% | Mo% | W% | Fe% | Co% |
| | 28.5 | 1.96 | 0.13 | 8 | 1.8 | Bal |

*B. Component processing details.*

Before seat hardfacing process of an engine valves following operations are carried out to obtain required size and shape of the engine valves.

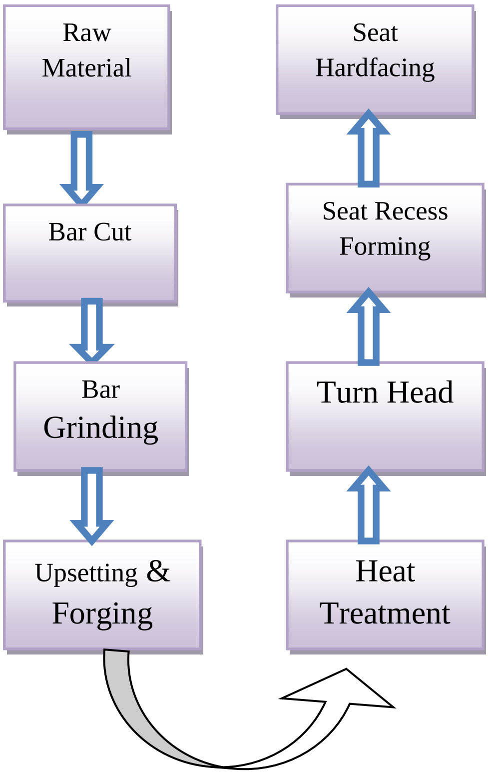


Fig 2: The detailed process flow diagram.

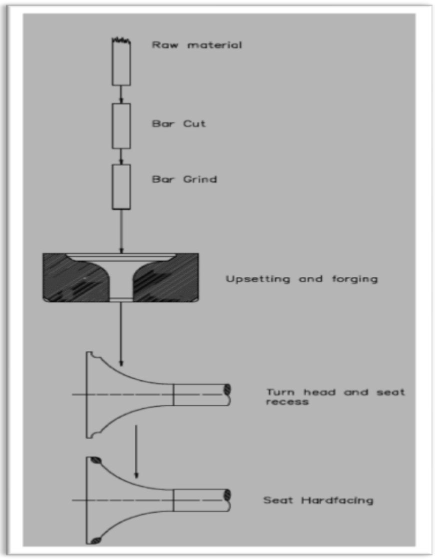


Fig 3: The schematic process flow diagram.

## III. TIG WELDING PROCESS FOR SEAT HARDFACING

In this process the electric arc fuse the hardfacing alloy on a seat portion of the I C engine valve in order to improve the required properties. During the process, the hardfacing alloy is fed into a welding zone generated by the TIG arc at high temperature. All welding parameters, including hardfacing alloy feed rate, power input, shielding gas flow rate as well as torch and workpiece movement are automatized by the TIG welding machine, which is shown in the below figure 4.

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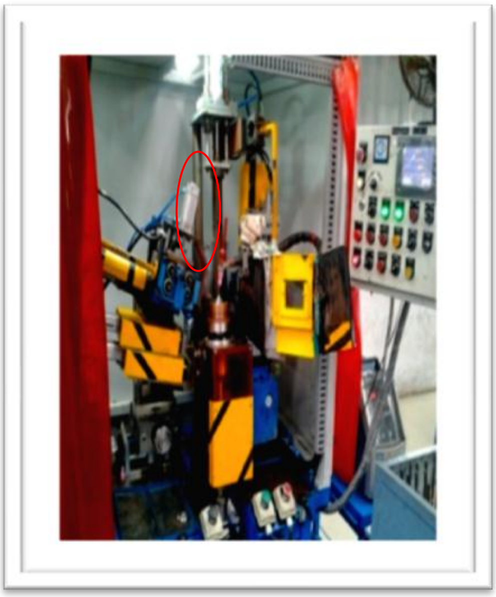

Fig 4(a) TIG Welding machine

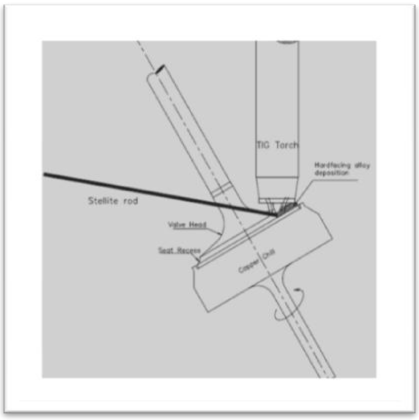


Fig 4(b) Partial schematic diagram for seat hardfacing process.

## IV. DEFECTS AND PROBLEMS IDENTIFICATION

### *A. Defects identification*

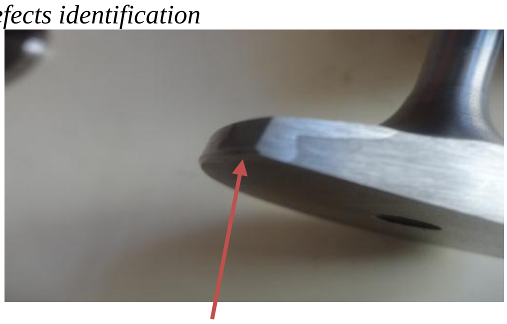

Fig (a) Stellite deposit overflow

Fig (b) Head melt

Fig (c) Deposit unfill on seat

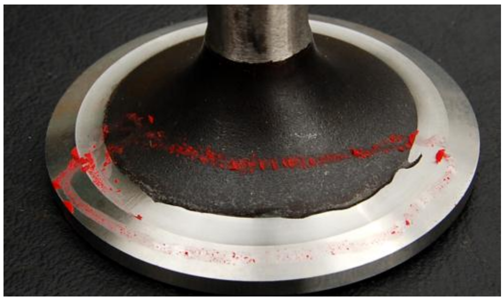

Fig (d) Non uniform seat merging

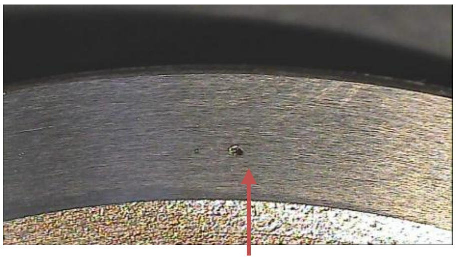

Fig (e) Blow holes

Fig 5: The Seat hardfacing process defects images.

### *B. Problems identification*

The seat hardfacing process is carried out with process parameters. Even though the seat hardfacing was satisfactory with these parameters, the results were not consistent. The rejection in this process was found to be around 2549 PPM. This was analyzed with the help of QC tools like pareto diagram shown in below figure 6.

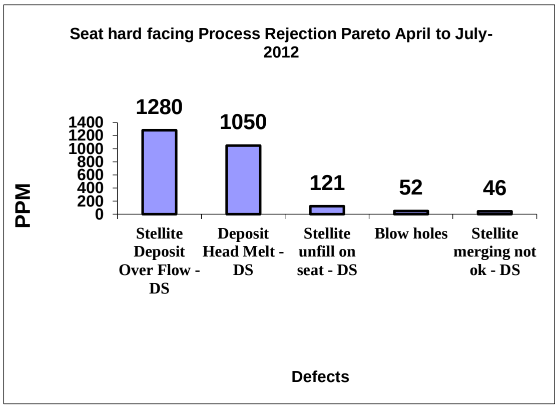


Fig 6: Total forge shop rejection Pareto diagram

## V. DETAILS OF INVESTIGATION

### *A. Identification of the defect*

The defects are identified at the time of final inspection and also after the seat hardfacing process of I C engine valve. Cause and effect diagram is used to identify the possible causes for the defects.

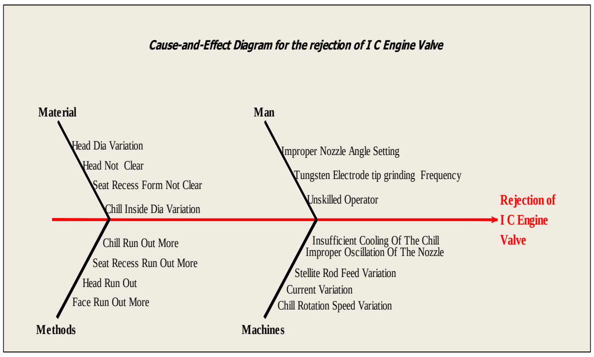


Fig 7: Cause and effect diagram for the rejection of I C engine valve

Based on the above identification the following possible causes are found significant and all these cause are validated by simulating the defects are shown in the below table 4.

Table 4: Significant causes for the rejection of seat hardfacing process.

| SL NO | DEFECTS | CAUSES |
|---|---|---|
| 1 | Deposition overflow, stellite unfill on seat and non - uniform merging. | Chill rotation speed variation. |
| 2 | Head melt, stellite unfill on seat, non-uniform merging and blowholes. | Current variation. |
| 3 | Deposition overflow, stellite unfill on seat. | Stellite rod feed variation. |
| 4 | Head melt, Blow holes. | Seat recess form not clear. |
| 5 | Deposition overflow, stellite unfill on seat and non - uniform merging. | Coining temperature variation. |
| 6 | Deposition overflow, stellite unfill on seat and non - uniform merging. | Forging pressure variation. |
| 7 | Head melt. | Head dia variation. |
| 8 | Blow holes. | Shielding gas flow rate variation. |
| 9 | Blowholes, stellite unfill on seat. | Tungsten tip grinding method and frequency. |
| 10 | Deposition overflow, stellite unfill on seat and head melt. | Improper nozzle & stellite rod feed angle setting. |

### *B. Experimentation*

The table 5 summarizes the changes effected in various process parameters and their effects.

| Process Variables | Actual | Recommended | Effects |
|---|---|---|---|
| Chill rotation speed high | 20 Sec | 28 Sec | By increasing Chill rotation time provides more time for depositing required amount the Stellite alloy and leads to avoid the Stellite unfill on seat. |
| Chill rotation speed low | 35 Sec | 28 Sec | By decreasing the Chill rotation time for avoiding more amounts Stellite alloy deposition leads control the Stellite deposition overflow. |
| Initial current high | 320 Amp | 280 Amp | By setting the Initial current to the actual specification can be possible avoiding the Head melt. |
| Initial current low | 220 Amp | 280 Amp | By setting the Initial current to the actual specification can be possible avoid the Non uniform Stellite merging. |
| Stellite rod feed high | 200mm | 180mm | By setting the Stellite rod feed to the actual specification leads to control the Stellite deposition overflow. |
| Stellite rod feed low | 150mm | 180mm | By setting the Stellite rod feed to the actual specification leads to control the Stellite unfill on seat. |

| | | | |
|---|---|---|---|
| Seat recess form not clear | 5 no's out of 250 | Nil | By providing clear Seat recess form can be possible to control the Head melt, Stellite deposition overflow. |
| Head dia high | 58.98mm | 58.85mm | By providing actual specification can be possible to control the Head melt. |
| Head dia low | 58.72mm | 58.85mm | By providing actual specification can be possible to control the Head melt and Stellite deposition overflow. |
| Shielding gas flow rate | No Flow meter | Suggestion to adopt Flow meter. | By adopting Flow meter can be easily set to the required Shielding gas flow rate and this leads to avoiding Blowholes. And by using nozzle with gas lens can be possible get the flow of shielding more stable at a longer distance thereby can be achieve more shielding at the welding zone. |
| Coining temperature high | No Pyrometer | Suggestion to adopt Pyrometer | By adopting Pyrometer for measuring Coining temperature can be easily set the required temperature, if it is set to more than required causes to defects like Deposition overflow and Non uniform Stellite merging. |
| Coining temperature low | No Pyrometer | Suggestion to adopt Pyrometer | By adopting Pyrometer for measuring Coining temperature can be easily set the required temperature, if it is set to less than required causes to defects like Deposit unfill on seat and Non uniform Stellite merging |
| Tungsten tip grinding frequency | 150 no's | Suggestion use tungsten grinding machine | By using specific tungsten grinding machine can be possible to achieve 500 no's and it is possible to avoid Blowholes due to contamination and Stellite unfill on seat due to burn out of the tungsten tip. |
| Improper nozzle and Stellite rod feed angle setting | No Angle plate | Suggestion to fix the angle plate | By setting the Nozzle and Stellite rod feed angle to a $60^0$-$75^0$ and $15^0$-$30^0$ respectively can be possible to control the Stellite deposition overflow, Head melt and Non uniform Stellite merging. |

## VI. RESULT AND DISCUSSION

A few trails were conducted to ensure the consistency in the results with a modified process parameters and adopting new suggestions for this process, they were found to be meeting the quality requirements.

Recommended for the shielding gas flow meter to control flow rate of the shielding gas. This gives fine control shielding gas flow rate and provides to avoid more shielding gas consumption from 10 liter/min to 6 liter/min.

Suggestion is made to use ceramic nozzle with gas lens instead of ceramic nozzle. This requires less amount of shielding gas and helps to make the flow of shielding gas more stable at a longer distance.

Recommended for tungsten grinding machine to prepare the tungsten electrode tip. This gives less problems with arc starting, arc stability, less contamination and leads to long life.

The procedure is given to set the stellite rod feed angle to $15$-$30^0$ and TIG torch angle to $60$-$75^0$. This avoids melting of valve head, stellite deposition overflow.

Suggested to preheat the stellite deposition temperature between the ranges of $400$-$450^0$C with the help of Pyrometer. This temperature is convenient for getting defects free product.

## VII. CONCLUSION

Recommendation was made for process parameters and it was successfully implemented. New suggestions have saved Rs 1, 12,835 appx to Rs 53,445 appx and also reduce the rejection 2549 PPM to 883 PPM.

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