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# DEFECT REDUCTION IN GAS TUNGSTEN ARC WELDING PROCESS USING FAILURE MODE EFFECTS ANALYSIS

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**Abstract:** To improve production quality and productivity by reducing potential reliability problems early in the development cycle, manufacturing industries are using the Failure Mode and Effects Analysis (FMEA) technique. It is a method that evaluates possible failures in the system, design, process or service. It aims to continuously improve and decrease these kinds of failure modes. In this present work, Process FMEA is done on Gas Tungsten Arc Welding (TIG) process of American Iron and Steel Institute (AISI) Type 304L Stainless Steel material. A series of welding process with different sample pieces are done and the potential failures and defects are categorized based on FMEA and Risk Priority Number (RPN) is assigned. The most risky failure according to the RPN number is found and the cause and effects along with the preventive measures are established. Since FMEA is a proactive approach to solve potential failure modes, this work serves as a failure prevention guide for those who perform the welding process towards an effective weld.
**Keywords:** Welding, Failure Mode and Effects Analysis, Risk Priority Number, Defect

## 1. INTRODUCTION

Demands are increasing on companies for high quality, reliable products. The increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the quality and reliability. The challenge is to design in quality and reliability early in the development cycle.

FMEA is used to identify potential failure modes, determine their effect on the operation of the product and identify actions to mitigate the failures. A crucial step is anticipating what might go wrong with a product. While anticipating every failure mode is not possible, the development team should formulate as extensive a list of potential failure modes as possible. The early and consistent use of FMEA in the design process allows the engineer to design out failures and produce reliable, safe, and customer pleasing products.

Similarly, Root Cause Analysis (RCA) is a method of problem solving that tries to identify the root causes of faults or problems that cause operating events. RCA practice tries to solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. RCA recognizes that complete prevention of recurrence by one corrective action is not always possible. There may be several effective measures that address the root causes of a problem. Thus, RCA is often considered to be an iterative process, and is frequently viewed as a tool of continuous improvement.

The role of joints whether welded, brazed, soldered or bolted is the most critical aspect to hold any assembly together especially in materials like Type 304L Stainless Steel. Joints are usually the weakest link in the total assembly and decide the overall integrity of equipment. Joint failures are as specific as the nature of joining process. Welded joints can fail due to lapses during the welding parameters, operational skills or merely because of properties inferior to base metal. These may be the failures caused as a result of welding but it is very important to analyze the failure modes, and effects of welding processes. Prior notification of these failures can prevent them by following control measures. This paper addresses the defect reduction in gas tungsten arc welding process using RCA and FMEA. Here, the prime objective is to evolve and test several strategies to eliminate defects *thereby improving quality. The methodology followed was that of continuous improvement which uses RCA and FMEA.*

*The rest of the paper is organized in the following manner. In Section 2, the relevant literature reviewed during this work is discussed. Section 3 gives a brief idea about the product and process. The various stages of operations practiced on the product are described in this section. An overview of FMEA is described in Section 4. In Section 5, the defect reduction methodology is discussed. Subsequently, implementation procedures along with results obtained are explained in Section 6. Section 7 concludes the paper with final remarks.*

## 2. BRIEF LITERATURE REVIEW

*Failure mode and effects analysis (FMEA), first developed as a formal design methodology in the 1960s by the aerospace industry [1] has proven to be a useful and powerful tool in assessing potential failures and preventing them from occurring [2]. FMEA is an analysis technique for defining, identifying and eliminating known and/or potential failures, problems, errors and so on from system, design, process and/or service before they reach the customer [3]. When it is used for a criticality analysis, it is also referred to as failure mode, effects and criticality analysis (FMECA). The main objective of FMEA is to identify potential failure modes, evaluate the causes and effects of different component failure modes, and determine what could eliminate or reduce the chance of failure. The results of the analysis can help analysts to identify and correct the failure modes that have a detrimental effect on the system and improve its performance during the stages of design and production. Since its introduction as a support tool for designers, FMEA has been extensively used in a wide range of industries, including aerospace, automotive, nuclear, electronics, chemical, mechanical and medical technologies industries [4-6]. This paper explains a Process FMEA done on Gas Tungsten Arc Welding (TIG) process of Type 304L Stainless Steel material.*

## 3. PROBLEM DEFINITION

*The procedure that has been followed for quality improvement is given in Figure 1. The selected product for this work is called "Vent port" and it is an acid storing container [Figure 2]. It is fabricated from four main sub parts welded by TIG Welding process. Due to poor weld quality and weld defects, the quality of product declines and rate of defect increases. The primary aims are: (1) Improve the quality of the product by reducing the defects and improving welding process quality (2) Implementation of process sheets in the fabrication that will pave way easy traceability of components. A detailed process study is performed to understand the current state process flow and the same is illustrated in Figure 3.*

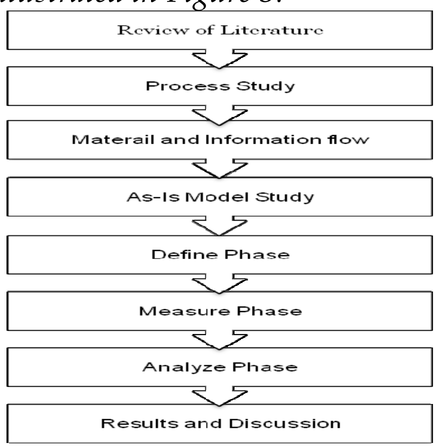


*Figure 1. Methodology*

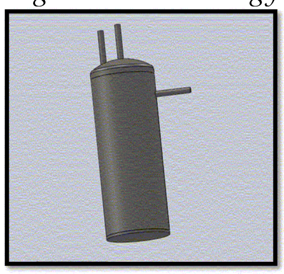

*Figure 2. Vent port*

## 4. OVERVIEW OF FMEA – Importance of FMEA in welding process

*A FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet.*

*The role of joints whether welded, brazed, soldered or bolted is the most critical aspect to hold any assembly together in S.S 304L materials. Joints are usually the weakest link in the total assembly and decide the overall integrity of equipment. Joint failures are as specific as the nature of joining process. Welded joints can fail due to lapses during* *the welding parameters, operational skills or merely because of properties inferior to base metal. These may be the failures caused as a result of welding but it is very important to analyze the failure modes, and effects of welding processes. Prior notification of these failures can prevent them by following control measures.*

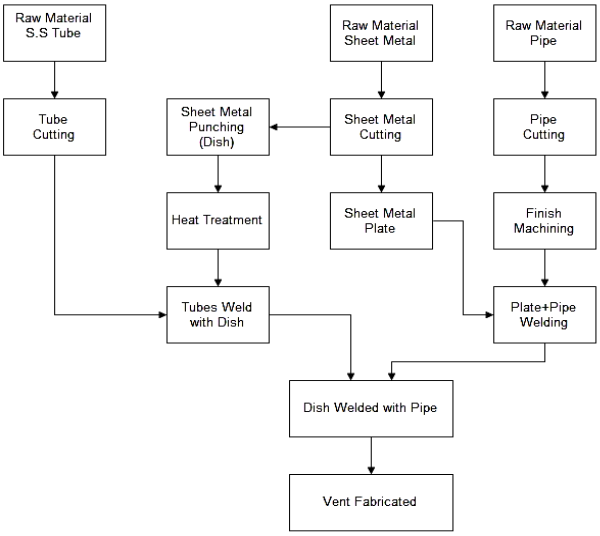


*Figure 3. Process flow – vent port*

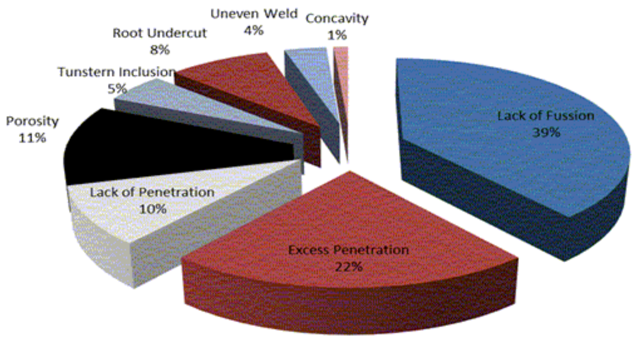


*Figure 4. Types of welding defects*

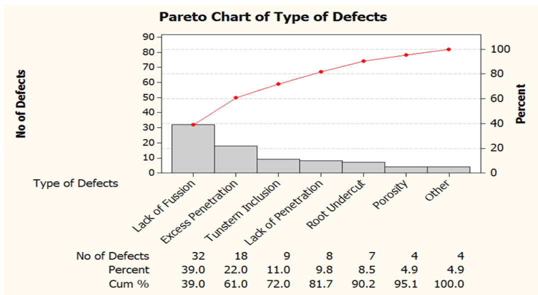


*Figure 5. Major constituents of welding defects*

## 5. DEFECT REDUCTION METHODOLOGY

*Defects are of various types in welding [Figure 4]. Finding the type of defect will narrow down the eradication of major problems. Pareto Chart [Figure 5] is drawn using Minitab 16.0 Software to find the major constituents of defects which affect the quality of the product. It depicts that 80% of defects are due to 20% of causes. So if we eliminate the 20% of causes, we can reduce the 80% of total defects.*

## 6. ROOT CAUSE ANALYSIS

*Root Cause Analysis (RCA) is a method of problem solving that tries to identify the root causes of faults or problems that cause operating events. RCA practice tries to solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. Considering this aspect, the cause and effect diagram for root cause identification is done and the same is illustrated for one of the major cause of welding defects "lack of fusion" in Figure 6.*

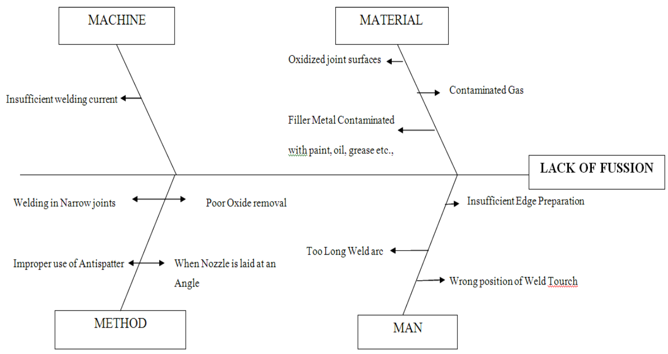


*Figure 6. Cause and effect diagram showing major causes for the welding defect "lack of fusion"*

*Table 1. FMEA chart - Lack of fusion*
*A=Severity; B=Occurrence; C=Detection*

| A | B | C | Cause | Solution | RPN |
|---|---|---|---|---|---|
| 9 | 7 | 6 | Insufficient Welding Current | Parameters Should be set | 378 |
| | 6 | 4 | Improper joint cleaning surfaces | Weld Material -cleaned | 216 |
| | 4 | 3 | Contaminated Gas | Gas Quality | 108 |
| | 4 | 5 | Filler Metal Contaminated | Good Quality Filler Metal | 180 |
| | 8 | 8 | Narrow Welding Groove | Proper Groove Cutting | 576 |
| | 5 | 4 | Poor Oxide removal | Weld Material -cleaned | 180 |
| | 4 | 5 | Improper use of Antispatter | Gas Quality | 180 |
| | 7 | 8 | Joint Configuration | Proper Groove Cutting | 504 |
| | 4 | 6 | Too long weld arc | Labour should be trained | 216 |
| | 6 | 7 | Insufficient Edge Preparation | Proper Groove Cutting | 378 |
| | 6 | 6 | Incorrect Torch Angle | Labour should be trained | 324 |

*Potential effect: Leads to breakage under High Temperature*

*Similarly, FMEA is used to identify potential failure modes, determine their effect on the operation of the product, and identify actions to* *mitigate the failures. A crucial step is anticipating what might go wrong with a product. Welded joints can fail due to lapses during the welding parameters, operational skills or merely because of properties inferior to base metal. Keeping these things in mind, the FMEA chart is prepared. A sample chart related to the problem "lack of fusion" is presented in Table 1.*

## 7. OPPORTUNITIES FOR IMPROVEMENT AND IMPLEMENTATION

*After identifying the root cause of major problems, the following improvement opportunities are identified and implemented.*

- *Updating work instructions is done to check the welding current whenever there is sheet thickness change*
- *Rust over material and moisture is cleaned before welding as a part of standard work procedure*
- *Root of weld joint and edge preparation is made standard for all parts*
- *Welding current is set before welding as per instruction*
- *For better traceability, process sheet is entered with the employee ID Part*
- *Drawing along with process sheet with complete process parameters for welding*

*Further, training to welder is provided to know how to study the drawing attached with the process. As a result of continued enhanced practices the defect level is reduced to a greater extent from 42 defects to 4 defects for the work order. The summary of improved sigma level is given in Table 2.*

*Table 2. Improved Sigma Level*

| Description | |
|---|---|
| No of parts/work order | 185 units |
| Total no. of Welds/work order | 1880 welds |
| Total no. of defective welds/order | 4 |
| Defects per 1880 opportunities | 4 |
| Defects per million opportunities | 1596 |

## 8. CONCLUSION

*The following conclusions are made:*

- *The major rate of defect is due to low skilled worker and no proper standards in production*
- *Pareto Chart states that lack of fusion, lack of penetration and porosity are the three major defects*
- *Process parameters play a vital role in eliminating the defects.*
- *From RCA, it is clearly visible that root gap and edge preparation impact the defect rate.*
- *From FMEA, it is found that the edge preparation, root gap fixation, welding current setting, gas flow have high RPN*

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