Journal of Engineering Science and Technology
Special Issue on ICE & ICIE 2015, April (2016) 9 - 19
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FAILURE MODE AND EFFECT ANALYSIS (FMEA) OF BUTTERFLY VALVE IN OIL AND GAS INDUSTRY

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Abstract

Butterfly valves are mostly used in various industries such as oil and gas plant. This valve operates with rotating motion using pneumatic system. Rotating actuator turns the disc either parallel or perpendicular to the flow. When the valve is fully open, the disc is rotated a quarter turn so that it allows free passage of the fluid and when fully closed, the disc rotated a quarter turns to block the fluid. The primary failure modes for valves are the valve leaks to environment through flanges, seals on the valve body, valve stem packing not properly protected, over tightened packing nuts, the valve cracks and leaks over the seat. To identify the failure of valve Failure Mode and Effects Analysis has been chosen. FMEA is the one of technique to perform failure analysis. It involves reviewing as many components 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 form. Risk priority number, severity, detection, occurrence are the factor determined in this studies. Risk priority number helps to find out the highest hazardous activities which need more attention than the other activity. The highest score of risk priority number in this research is seat. Action plan was proposed to reduce the risk priority number and so that potential failures also will be reduced.

Keywords: FMEA, Risk priority number, severity, detection, occurrence

Abbreviations

FMEA	Failure Mode and Effect Analysis
RPN	Risk Priority Number

1. Introduction

1.1 Background of Study

A butterfly valve is used to control the flow of material through a circular pipe. Typically the material is air, gas, steam or liquid. Identically, the butterfly valve consists of a circular disc with its pivot axis at right angle to the direction material is flowing. The main component of this valve is disc. The disc is positioned in the centre of the pipe. A quarter turn rotational motion valve, the butterfly valves function is used to stop, start and regulate flow. The valve usually comes with an actuator where the hand wheel by gear is connected to stem. When the valve is fully open, the disc is rotated a quarter turn so that it allows free passage of the fluid and when fully closed, the disc rotated a quarter turns to block the fluid. To identify the failure of valve, Failure Mode and Effects Analysis (FMEA) has been introduced. FMEA is the one of technique to perform failure analysis. 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 form.

The reason of using FMEA is to analyze failures and a core task in reliability engineering, safety engineering and quality engineering. Thus, the aim of this study is to identify the potential failures maintained by Turcomp Eng Sdn Bhd. This company is responsible for servicing or maintaining the butterfly valves used in oil and gas industries. FMEA is widely used in development and manufacturing industries in various phases of the product life cycle and therefore it is proposed to be implemented in Turcomp Eng Sdn Bhd for manage and documentation of the failure. The objectives of this thesis is to identify the failure of butterfly valve in oil and gas industry application, to investigate the cause and potential failure, to analyze the cause and effect, propose the recovery method for a failed butterfly valve by applying FMEA tools as well to develop and recommend an action plan.

2.Literature Review

2.1 Butterfly Valve

Butterfly valves are mostly used in various industries such as water distribution, sewage, and oil and gas plant. It is commonly used as control equipment in applications where the pressure drops required of the valves are relatively low [1]. Therefore they cannot perform in every application [2]. They are used for a variety of reason like as phase liquid or gas, pressure, piping restrictions and solid content.

Butterfly valve has three different offset namely concentric, double eccentric and triple eccentric. The wafer type butterfly valve required even length because they have no protruding lugs [3]. Instead they are sandwiched between flanges on the adjoining piping. The design of lug type butterfly valve, basically the same as wafer but they have addition of lugs around the body. The lug are drilled and tapped to allow the valve to be attached directly to one of the flanges for easy pipeline modification or cleaning.

2.1.1 Type of Butterfly Valve

Butterfly valve has three different offset namely concentric, double eccentric and triple eccentric. The concentric butterfly valve is generally used. The shaft is located in the centre of the disc. During opening or closing position some component of the disc always in contact with seat. For the single offset, the shaft is located not in the centre but slightly behind the disc. This offset will make the valve has continuous sealing surface on the disc. The double offset valve is a valve that has two offset compared to others. The double offset type is when the shaft is located not in the pipe centre line but slightly side of the centre. The triple offset butterfly valve is where the valve has three offsets. Just like double offset butterfly valve, triple offset also has the same offset but has one additional offset where a conical shape seat [5]. The wafer type butterfly valve required even length because they have no protruding lugs [2]. Instead they are sandwiched between flanges on the adjoining piping. The lug are drilled and tapped to allow the valve to be attached directly to one of the flanges for easy pipeline modification or cleaning.

2.1.2 Advantages and Disadvantages of Butterfly Valve

Advantage of butterfly valve are they provide shutoff capabilities, some throttling capability and ease of operation, particularly in size 16 inch and larger [2]. Restriction of flow in a fully open butterfly valve is greater than in a fully open gate valve because the disc remains in the waterway. There are many advantages offered by butterfly valves compared to other types of valves including an inherently simple, economic design that consists of fewer components, which makes butterfly valves easy to repair and maintain [11]. The wafer type body and relatively light weight offer a savings in the initial cost of the valve and installation costs in person hours, equipment and piping support.

2.1.3 Valve Failure

The valve failure ranges from a valve perhaps physically failing in some way, for example external leakage from the valve body or the valve sizing, to a valve not operating or functioning correctly [4]. This may be because the hydraulic power supply failed or there was a fault in the control system, but overall, it is still classified as a valve failure. There is a need to identify the point and mode of failure [5]. First, perform the strength test of the failed component and then determine whether the valve had any locking device. Furthermore the damage component work also could be a cause of failure.

2.2 Failure Mode and Effect Analysis

Failure Mode and Effect Analysis (FMEA) is an engineering technique used to define, identify, and eliminate known and potential problems, errors, and so on from the system, design, process, and service before they reach the customer [14]. Traced the history of FMEA back to the early 1950s, when it was used for the design of flight control systems [7]. FMEA emerged as a formal technique in the aerospace and defences industry. By taking a functional approach, this guide will allow the designer to perform system design analysis without the traditional component level material. Managing risk is a must for any organization. Clause 0.1 of ISO 9004 mentions risk management along with cost and benefit considerations given its importance to the organization and its customers. Risk management is also important when dealing with equipment failures and their consequence on production, safety and the environment [4].

2.2.1 Purpose of FMEA

Performing a FMEA is to analyse the product design characteristic relative to the manufacturing process and experiment the design. When potential failure modes are identified, corrective action can be taken to eliminate them or to continually reduce a potential occurrence. The FMEA also documents the rational for the chosen manufacturing process. It provides for an organized critical analysis of potential failure modes and the associated causes for the system being defined. FMEA for short is used to find all possible faults that may happen in a system and to discover effects or causality based on the correlations among faults [20]. The classical procedure FMEA is to analyse potential failure modes within a system for classification by the severity and likelihood of the failures. The technique uses occurrence and detection probabilities in conjunction with severity criteria to develop a risk priority number (RPN) for ranking corrective action considerations. The FMEA can be performed as either a hardware or functional analysis.

One of the best tools for sorting out the above-mentioned problems is FMEA method. FMEA is especially efficient if applied in the analysis of elements which cause the whole system failure. However, it can be very complicated in the case of complex systems, which have multiple functions and are comprised of a number of components, since a variety of information on the system has to be considered [16].

FMEA is one of the most important and widely used tools for reliability analysis. It is intentional to be a proactive action process carried out in advance implementing new or changes in products or process ideally FMEA are conducted in the design or process development stages, although cond ting it an existing products and processes may possibly have benefits in effective FMEA identifies corrective actions required to reduce failures to assure the highest possible yield safety and reliability [19]. FMEA is intended to act in a preventive sense it is not a method which is carried out after a failure, with the purpose of satisfying the customer or the requirements of ISO/TS 16949 standard (QS 9000) or ISO 9001 series of standards [18].

2.2.2 Benefit of FMEA

The purpose of this study is to present FMEA methodology as one of the important tools used in maintenance. The benefits of FMEA are to increase customer satisfaction by improving safety and reliability and define problem before they reach to the customers [4]. Other than that, the benefit of FMEA is it can help to reduce the chance of failure that can result in injuries or adverse effect on the environment. However, FMEA can optimize maintenance efforts by suggesting applicable and effective maintenance task for potential of failure.

3. Research Methodology

3.1. Data Collection

The data collections were done by observation from actual failed valves. The problems including scratches of disc, broken seat and packing of valve were usually collected by image captured and interview from Turcomp Engineering Sdn Bhd. Turcomp is a company which supply, perform maintenance works, and commissioning the valve. The condition before and after service is also recorded. After data has been collected, the data will then be recorded on worksheet paper of FMEA. All failed components, potential effect and potential failure were stated and analyzed in the worksheet

3.2. Data Analysis

FMEA is one of most important tools for realibility analysis. FMEA is a system, for evaluating and identify where and how it might fail and to assess the relative impact of different failures in order to identify part need of change. FMEA include of the steps in the process, illustrated in Figure 3.1, and this help to product and evaluate what could go wrong, why failure happen and what the consequences.

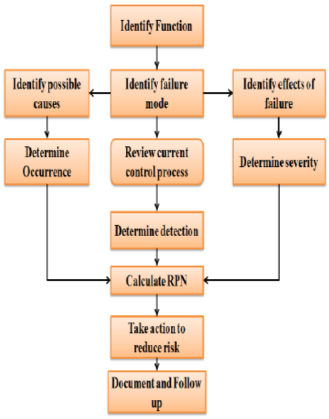

Fig 3.1 FMEA steps

3.3. Instrumentation

The combination of these three parameters called the risk priority number (RPN) to reflect the priority of th failure mode identified as described in Figure 3.4. The risk priority number (RPN) is simply calculated by multiplying the severity rating, times the occurrence probability rating, times the detection probability rating [19].

Risk Priority Number = Severity x Occurrence x Detection

3.3.1 Severity (S)

Severity is the seriousness of the effect of potential modes. Table 3.1 shows the details of rating and severity effect. Severity rating with the higher number represents the highest seriousness or risk which could cause death. The first step in assigning a severity rating is to identify the worst effect documented in the effects column. Severity is usually rated in scale 1 to 10.

Table 3.1: Severity table

Rating	Effect	Severity Effect
10	Hazardous without warning	Very high severity without warning
9	Hazardous with warning	Very high severity with warning
8	Very high	Destructive failure without safety
7	High	System inoperable equipment damage
6	Moderate	System inoperable with minor damage
5	low	System inoperable without damage
4	Very low	Degradation of performance
3	Minor	System operable with some degradation in performance
2	Very minor	System operable with minimal
1	None	No effect

3.3.2 Occurrence (O)

Occurrence ratings for FMEA are based upon the likelihood that a cause may occur based upon past failure and performance. Table 3.2 differentiates the occurrence classifications. This rating estimates the probability of failure occurring for that reason during lifetime. Usually used in scale from 1 to 10.

Table 3.2: Occurrence table

Rating	Classification	Example
10	Very high	Inevitable failures
9		
8	High	Repeated failures
7		
6	Moderate	Occasional failures
5		
4	Low remote	Few failures
3		
2	Remote	Failures unlikely
1		

3.3.3 Detection (D)

Detection rating is to estimate how well the control can detect the failure mode after they has happen, this is further described in Table 3.3.

Table 3.3: Detection table

Rating	Detection	Detection by Design Control
10	Absolute uncertainly	Design control cannot detect failure mode
9	Very remote	Very remote chance the design control detect failure mode
8	Remote	Remote chance the design control detect failure mode
7	Very low	Very low chance the design control detect failure mode
6	Low	Low chance the design control detect failure mode
5	Moderate	Moderate chance the design control detect failure mode
4	Moderately high	Moderate high chance the design control detect failure mode
3	High	High chance the design control detect failure mode
2	Very high	Very high the design control detect failure mode
1	Almost certain	Design will control detect failure mode

4. Result and Discussion

4.1. Butterfly Valve Components

As shown in Figure 4.1, the primary components in a wafer-style butterfly valve consist of a body, metal disc, stem, packing and seat. The body is located in between two pipe flanges. The metal disc is mounted on stem that passes through the center of axis at a right angle. The flow of fluid is controlled by the disc as it passes through the circular piping. A packing component is situated in between the valve body and the stem to prevent any leakage occurring as the flow moves through the conveying line. The seat acts as a buffer between the metal disc and body as avoid any leakage as the valve is in the fully closed position.

4.2. Valve Operation

The butterfly valve operates very similar to ball valve which is with rotating motion using a pneumatic system. The schematic diagram of butterfly valve operation was described in Figure 4.2 where rotating actuator turns the disc either parallel or perpendicular to the flow. When the valve is fully open, the disc is rotated a quarter turn so that it allows free passage of the fluid and when fully closed, the disc rotated a quarter turns to block the fluid. A quarter turn rotational motion valve, the butterfly valves function is used to stop, start and regulate flow.

4.3 Valve Failures

This section describes the butterfly valve failures, together with their causes and effect, and also the current action taken to troubleshoot the failures. Normally the main critical components which taken into account are body, disc, stem, seat and packing. All information were gathered based on the visual observation of the failed valve components, supported by further series of discussion with the designated senior engineer of the Turcomp Engineering Sdn Bhd, Mr Ivan Goh.

4.4 Failure Mode and Effect Analysis

To identify the failures of the butterfly valve, Failure Mode and Effect Analysis has been chosen. FMEA is the one of technique to perform failure analysis. It involves reviewing as many components 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 form. The reason of using FMEA is to analyze failure analysis and a core task in reliability engineering, safety engineering and quality engineering. The rating of severity, occurrence, and detection was rated after series of discussion with senior engineer in Turcomp Engineering Sdn Bhd. Figure 4.3 and 4.4 indicated the FMEA form of valve failure.

Figure 4.1 Butterfly Valve's Component

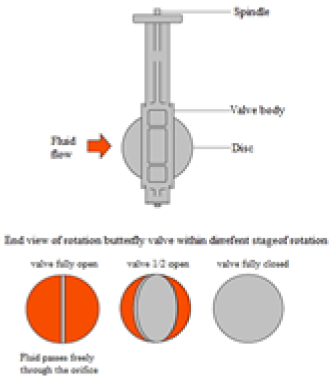

Figure 4.2 Valve Operation

Component	Potential Failure Mode	Potential Effect of Failure	S	Potential Cause of Failure	O	Current Process Control	D	RPN
Body	Fracture on outer and inner body	Pressure drop	6	Different temperature	3	Coating	3	54
		Over pressure	9	Leakage of liquid or gas	2	Use pressure regulator	2	36
		Fail to support pressure	7	Wrong selection	4	Double check requirement	2	56
		Vibration	3	Over tighten bolts	5	Use torque wrench	3	45
	Corrosion outside the valve	Erosion and lead to fracture	4	Environment temperature	9	Blasting and painting	1	36
	Corrosion inside the valve	Erosion and lead to fracture	8	Turbulence fluid erode the surface in the body	9	Clean inside the body	1	72
Disc	Scratches on the edge of disc	Leak when fully closed	3	Seat harder and resulting chip	4	Polish and replace	2	24
		Lost sealing point	7	Seat tear	4	Clean or change	3	84
		Cavitation resulted	4	None	5	None	4	80
	Corrosion on disc surface	Drop efficency and cavitation resulted	3	Chemical reaction	5	Polish and replace	3	45

Figure 4.3 FMEA Form of Valve Failure

Component	Potential Failure mode	Potential Effect of Failure	S	Potential Cause of Failure	O	Current Process Control	D	RPN
Stem	Torsion deformation failure	Failed to operate	8	Bearing jammed	2	Replace	5	80
	Stem fracture	Failed to operate	9	Torsion failure	1	Replace	3	27
	Stem misalignment	Leakage of gas or liquid	4	Differentpressure	2	Place to origin	7	56
	Hard to operate	Jerking	4	Over tighten packing	3	Adjust or replace	1	12
Seat	Scratches on surface which contact with disc	Scratches the disc surface	4	Stiffness and chipped disc	9	Replace	4	144
				Rapid usage	7		4	112
	Tear over the seat	Disc scratch and lost sealing point	7	Seat become thinner	5	Replace	3	105
				Impurities and foreign object	3		3	63
Packing	Wear on packing surface	Leakage on the stem	7	Rapid usage	7	Replace packing	2	98

Figure 4.4 FMEA Form of Valve Failure cont'd

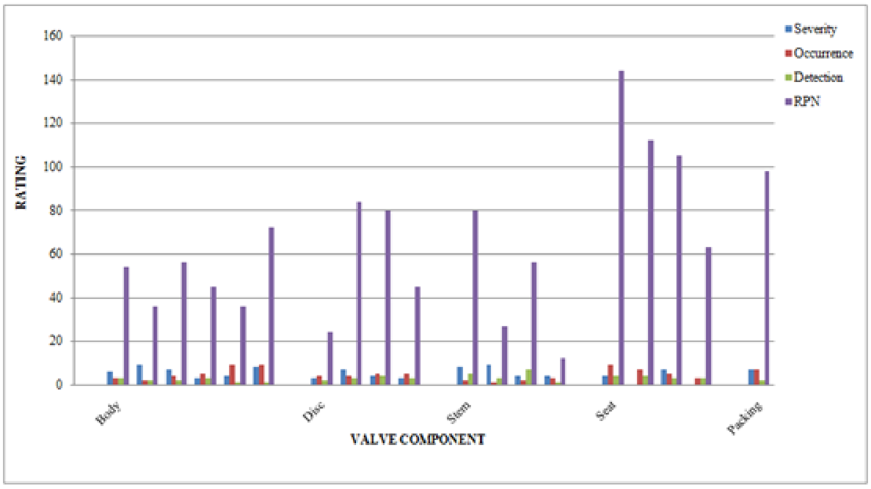

Figure 4.5 FMEA Form of Valve Failure

4.5 Risk Priority Number

Figure 4.5 indicates the risk priority number of all five critical failed components investigated in this research. As illustrated in Figure 4.5, seat component scores the highest value of risk priority number (RPN) resulted 144. The material of the soft seat is made of from Polytetrafluoroethylene (PTFE). Due to the material properties of PTFE, as friction is created during the operation it has high possibility to wear and tear. Next, packing component scores 98, which ranked after seat. The main factor of this high score was the material properties of the component, which is similar to seat. This leads to wear and tear of the component. At a RPN score of 84, the disc is ranked as the third highest in the RPN graph. The main function of the disc is to regulate the fluid flow through the piping. Scratch failure can occur to the metal disc edge due to friction between hardening of the seat material and the metal disc. The collision of foreign objects inside the pipeline against the metal disc as it is in fully open position can cause catastrophic scratch failure. Scratch failure on the edge of disc can cause sealing point losses during a fully closed position. The fourth highest rank component with an RPN scoring of 80 is the stem. Stem function is to support the rotation of the valve disc between the opening and closing position. Stem failure can be contributed to a jammed valve bearing as torque is applied. The lowest ranking RPN score of 56 is the body. Although corrosion can occur on the internal and external surfaces of the body, however owing to its static function as component housing is less acceptable to initial crack due to corrosion.

5.0 Conclusions

This research investigates the butterfly valve from Jamesbury Series, double eccentric, and wafer type by Metso. The FMEA method was applied in this research to analyze the five critical failure components which is body, packing, stem, disc and seat. From the analysis, the research concluded that the highest risk priority number score of 144 is the seat component. Made entirely from a soft material the seat acts as sealing element between disc and body. A repeated stroking of the valve between function positions and foreign object collision in pipeline causes significant wear and tear on the seat. Owing to its static function as a housing component, the body is ranked with the lowest RPN score of 56, this is primarily contributed to its non-contacting nature to other rotating components. An action plan was proposed to reduce the risk priority number in turn resulting in a corresponding parallel reduction in potential failures.

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