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Critical Analysis of Fuel Pump Bleed Valve for Typical Jet Engine by Using FMEA Method

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Abstract: ***Since the invention of gas turbine and its rapid growth in aviation propulsion, the engine technology has grown more complex. The necessity for a modular design for assembly and replacement of components while maintaining the assembly's ability to perform is needed from the operational and maintenance perspective. The requirement of accurate alignment precision centring and positive drive cannot be compromised. This demands a valve arrangement which satisfy the above requirements present out of all known valve mechanisms, Bleed valve is the best choice and has been substantially proved by its usage in many of the gas turbine engines fuel pumps manufactured by renowned engine houses through the world. The largest and most important fluid system in a jet engine is the fuel system. This fuel system consists of fuel pump, there are many components assembled in the fuel pump. Among that Bleed valve is one which plays an important role in the fuel pump. The main function of this valve is to bleed the air bubble from the fuel lines. The bleed valve is operated manually by using plunger or pin before every start of an engine. This bleed valve after working for some times or some cycles there is a slit leakage in the valve which in turns results in effecting the performance of the engine. The project aims to bring out Critical Analysis of the Bleed valve used in a typical gas turbine engine fuel pump and identifying critical part which is creating leakage by using FMEA method.***

Keywords: Bleed valve, fuel pump, critical analysis, turbine engine, FMEA.

1. Introduction

The gas turbine is an internal combustion engine that uses air as the working fluid. Turbojets are the oldest kind of general-purpose jet engines. Turbojets are rotary engines that extract energy from a flow of combustion gas. They produce thrust by increasing the velocity of the air flowing through the engine and operate on Newton's third law of motion "For every action there is an equal and opposite reaction". All powered aircraft require fuel on board to operate the engine(s). A fuel system consisting of storage tanks, pumps, filters, valves, fuel lines, metering devices, and monitoring devices. Each system must provide an uninterrupted flow of contaminant free fuel regardless of the aircraft's attitude. Since fuel load can be a significant portion of the aircraft's weight, a sufficiently strong airframe must be designed. Varying fuel loads and shifts in weight during maneuvers must not negatively affect control of the aircraft in flight. The bleed valve is located in jet engine fuel pump. The main function of bleed valve is to prevent fuel flow to the fuel nozzles and bleeds the fuel manifold at engine shutdown to prevent post-shutdown fires. It also bleeds the air bubbles in the fuel line of fuel pump.

2. Failure Mode and Effect Analysis

The FMEA is a powerful design tool that provides a mean to compare, from a risk point of view, alternative machine system configurations. The FMEA is a formalized but subjective analysis for the systematic identification of possible Root Causes and Failure Modes and the estimation of their relative risks. The main goal is to identify and then limit or avoid risk within a design. Hence the FMEA drives towards higher reliability, higher quality, and enhanced safety. It can also be used to assess and optimize maintenance plans. The causes of failure are said to be Root Causes, and may be defined as mechanisms that lead to the occurrence of a failure. While the term failure has been defined, it does not describe the mechanism by which the component has failed. Failure Modes are the different ways in which a component may fail. It is vitally important to realize that a Failure Mode is not the cause of a failure, but the way in which a failure has occurred. The effects of one failure can frequently be linked to the Root Causes of another failure. The FMEA procedure assigns a numerical value to each risk associated with causing a failure, using Severity, Occurrence and Detection as metrics. As the risk increases, the values of the ranking rise. These are then combined into a risk priority number (RPN), which can be used to analyze the system. By targeting high value RPNs the most risky elements of the design can be addressed. RPN is calculated by multiplying the Severity by the Occurrence by the Detection of the risk.

3. Background of the Project

The largest and most important fluid system in a jet engine is the fuel system. This fuel system consists of fuel pump, there are many components assembled in the fuel pump. Among that Bleed valve is one which plays an important role in the fuel pump. The main function of this valve is to bleed the air bubble from the fuel lines. Bleed valve is an assembly of four components, it consists of valve body, steel ball, spring and valve stop. The bleed valve is operated manually by using plunger or pin before every start of an engine. This bleed valve after working for some times or some cycles there is a slit leakage in the valve which in turns results in effecting the performance of the engine.

4. Objective of the Project

1. The main objective of this project is to analyze all the parts of fuel pump bleed valve.
2. Identifying the critical part by using FMEA method.

5. Critical Analysis of Bleed Valve by Using FMEA Method

Main parts involved in bleed valve assembly
1. Valve body
2. Steel ball
3. Spring
4. Valve stop

Steps in FMEA
The following is a procedure for performing an FMEA.
Step1. Define the scope of the analysis.
Step2. Prepare a block diagram of the system.
Step3. Identify possible failure modes for each component.
Step4. Identify possible causes for each failure mode.
Step5. Analyze the effects of the failure modes.

A. Severity

Severity is the assessment of the seriousness of the effect of the potential failure mode. In this we have to determine all failure modes based on the functional requirements and their effects. Severity rating is given below.

Table 1: Severity rating chart

Rating	*Meaning*
1	No effect
2	Very minor (only noticed by discriminating customers)
3	Minor (affects very little of the system)
4/5/6	Moderate
7/8	High (causes a loss of primary function)
9/10	Very high and hazardous

B. Occurrence

Occurrence is the chance that one of the specific cause/mechanism will occur. In this step, it is necessary to look at the cause of a failure and how many times it occurs. Occurrence rating is given in following table.

Table 2: Occurrence rating chart

Rating	Meaning
1	No effect
2/3	Low (relatively few failures)
4/5/6	Moderate (occasional failures)
7/8	High (repeated failures)
9/10	Very high (failure is almost inevitable)

C. Detection

Detection is an assessment of the probability that the current process control will detect a potential weakness or subsequent failure mode before failure mode the part or component laves the manufacturing operation or assembly location. Detection rating table is shown below.

Table 3: Detection rating chart

Rating	Meaning
1/2/3	Almost certain
4/5/6	Moderate
7/8	Low
9/10	Very remote to absolute uncertainty

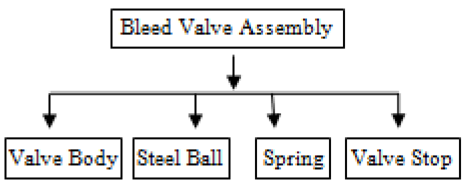
D. Risk Priority Numbers (RPN)

RPN is the indicator for the determining proper corrective action on the failure modes. It is calculated by multiplying the severity, occurrence and detection ranking levels resulting in a scale from 1 to 1000.

$$RPN = Severity \times Occurrence \times Detection$$

The small RPN is always better than the high RPN. The RPN can be computed for the entire process and/or for the design process only. Once it is calculated, it is easy to determine the areas of greatest concern. The engineering team generates the RPN and focused to the solution of failure modes.

E. Block Diagram of Bleed Valve Assemble



F. FMEA Chart of Bleed Valve Assembly Parts

Item	Failure mode	Failure causes	Failure Effects	Severity	Occurrence	Detection	RPN	Control Measures
Valve body	Material wear	Poor surface finish	Fitment problem	5	4	4	80	Improving surface finish
Steel ball	Material wear	friction	Ball seating problem	4	3	4	48	High surface finish
spring	Loosing stiffness	Poor material quality	Valve leakage problem	8	6	4	192	High quality materials
Valve stop	Material wear	friction	Spring seating problem	4	3	5	60	High surface finish

6. Conclusion

Higher value of risk priority number is obtained for spring. Detailed part wise reliability analysis should be conducted on the assembly to reduce its failure rates. Proper care and maintenance should be given to assembly parts while scheduling preventive maintenance. The present work deals with the FMEA study of Bleed Valve Assembly parts. The basic concepts are studied and failure modes are identified. Potential effects of failures are evaluated with their severity value and then the causes and their prevention are calculated along with their occurrence value .The Detection value was assigned to the failure mode, and finally the R.P.N value is calculated. FMEA analysis helps in identifying the most critical part in the assembly, so that it should be evaluated and corrective action must be taken.

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