Failure Mode and Effect Analysis of Petrol Engine of Car

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Abstract: ***For successful preventive maintenance of a Maruti Suzuki Swift Car Failure Mode and Effect Analysis required to perform on it . FMEA is a effective method used for identifying the possible failures and mollifying their effects. In this paper Risk Priority Number (RPN) methodology is used to identify the critical parts which are more vulnerable to failure and needs more maintenance. Design Improvement can be planned according to the FMEA work table, especially for most severe failure mode with high prevention difficulty.***

Keywords: Petrol Engine, FMEA , RPN , Failure Mode

1. Introduction

The engine is the most important component of the car . It may also referred as heart of the car. The main purpose of engine is to produce power so that crankshaft can convert reciprocating motion of the piston into rotary motion of wheel . It is very important to keep information about all failure causes and effect on engine to prevent future failure when new engines are designed.

Engine has many sub component such as valve , fuel injection system , fuel ignition system , cooling system , air intake system , combustion chamber, connecting rod , piston ,piston ring , crankshaft and connecting rod each has different function due to which each has different failure mode and finally different risk priority number .

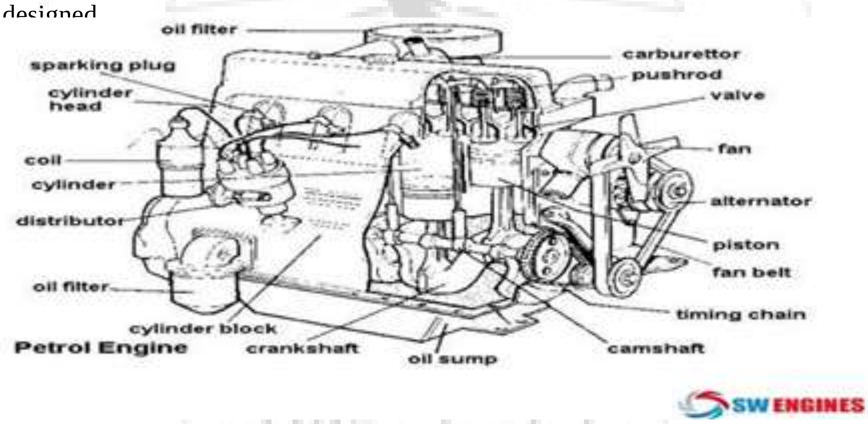

Figure 1: Components of engine

FMEA is a methodology designed to identify potential failure modes for the product, to assess the risk associated with those failure modes, to rank the issues in terms of importance, and to carry out corrective action to address the most serious failure modes. Failure modes may be introduced in design, manufacture, and/ or usage, and can be potential or actual . Effects analysis refers to studying the consequences of those.

Danny Faturachman of University Malaysia Pahang published a research paper on Failure Mode and Effect Analysis of Diesel Engine for Ship Navigation System. According to him the FMEA played a crucial role in preventing future failure in diesel engine of ships which reduce the number of accidents of ships in the sea.

In June 1996 Dr. Tae Woon Kim published a research paper on Failure Mode, Effect and Critical Analysis on Mechanical subsystem of Diesel Generator at Nuclear Power Plant. According to him this is first phase for implementation of RCM approach on diesel generator. It also included that it was the trail application of FMECA to diesel generator, there will be a more systematic failure analysis and logic tree analysis will be performed in future.

In April 2016, Manish Behera published paper on Design Failure Mode and Effect Analysis of a Human Powered Recumbent Vehicle in IJERT. According to him when he calculated Risk Priority Number of each component due to which it revealed the critical spot which are more likely to prone for failure which will help in modifying the design of Human Powered Recumbent Vehicle.

Thus in this study main objective is to carry out the comprehensive FMEA on Petrol Engine of a Maruti Suzuki

Swift car considering all the major assemblies and effect of their failure on the overall engine performance .

2. Failure Mode and Effect Analysis

Failure Mode and effect analysis (FMEA) is a step by step path for diagnosing all possible failure in a design, a manufacturing or assembly process or a product or service. It is very useful method when reliability centered maintenance is applied on design of any system.

FMEA was begun in 1940s by the U.S. military during World War II , FMEA was further developed by aerospace and automobile industries. Several Industries maintain formal FMEA standards . It became widely known within the quality community as a total quality management tool in the 1980s and as a Six Sigma tool in the 1990s. A team should apply FMEA to perform risk assessment to see what the customer will experience if a key process input (X) were to fail. The team should then take action to minimize risk and document processes and improvement activities. FMEA is living document that should be reviewed and updated whenever the process is changed (Jogger, 2002). It can be used in the define phase of the define, measure, analyse improve and control strategy as a voice of the customer input, but is more commonly created in the measure phase, updated in the analyse and improve phases and is a vital element of the control phase. FMEA is one of the most efficient low-risk tools for prevention of problems and for identification of more efficacious solutions, in cost terms, in order to prevent such problems.

To develop the FMEA, initially was done a survey on the functions of each component, as well as on its failure modes and effects. Were been used, as support for the analysis, the system textual description, contained in the technical operation instructions, the fault registers in the abnormality cards (service orders for maintenance) of the plant, the maintenance plans currently used and the instrumentation descriptions of the equipment and components. It was also performed a brainstorming in a join into the plant operators, so that it was possible to get with more details about the description of the possible failures of each component.

Failure Mode means the ways or modes in which something might fail.

Risk Priority Number is a numerical assessment of risk level associated with each potential failure mode of product or process in FMEA Analysis.

For the analysis, the data was taken from the field data, from the Maruti Suzuki Swift in Table 1 the specification data from the car and main engine specification.

Table 1: Data Spec and Engine of Maruti Suzuki Swift

ENGINE SPECS OF CAR	
Max Power	83 bhp @ 6000 RPM
Max Torque	115 Nm @ 4000 RPM
Cylinders	4 , Inline
Valve / Cylinder (Configuration)	4 , DOHC
Engine Type	K - Series VVT Engine
Engine Description	1.2 - litre 83.11 bhp 16 V K Series VVT Engine
Fuel Supply System	MPFI
Turbocharger / Supercharger	No

3. FMEA and RPN methodology

All the component of engine are identified. For each component failure mode, failure cause and effect is determined. Next, determine how serious each effect is which is known as severity rating or S. Severity is usually rated on a scale from 1 to 10, where 1 is insignificant and 10 is catastrophic. For each cause, determine the likelihood of occurrence which is known as occurrence rating or O . This rating estimates the probability of failure occurring in a component. . Occurrence is usually related on a scale from 1 to 10 where 1 is extreme unlikely and 10 is inevitable. For each control, determine the likelihood of detection which is known as detection rating or D . This rating determines how well the control can be detected either the cause or its failure mode after they have happened . Detection Rating is usually rated on a scale from 1 to 10 where 1 means the control is absolutely certain to detect the problem and 10 means the control is certain not to detect the problem. At last RPN is calculated .

$$RPN = (Severity)*(Occurrence)*(Detection) \quad (1)$$

$$Total\ RPN = Sum\ of\ all\ RPN \quad (2)$$

Above equation (1) and equation (2) represent the RPN and total RPN. After calculating RPN for all the component of engine of car are arranged in decreasing order of their RPN. Then at last Graph is plotted on the basis of RPN which will help to identify the critical parts which are prone to failure.

Table 2: Severity of Failure

Sr . No.	Severity	Severity Rating
1	Very insignificant effect corrected immediately by the operator itself	1
2	Insignificant effect corrected immediately by maintenance	2
3	Very minor effect, the component suffers to a gradual degradation. Repair is needed.	3
4	Minor effect component does not execute its function properly which can be overcome by maintenance	4
5	Low effect, vehicle is functional. Audible noise are heard. Minor vibration are there. Repair work is enough with no replacement necessary.	5
6	Moderate effect, Vehicle is operable, comfort and aesthetics are compromised. Performance loss take place. Replacement is required.	6
7	High effect, vehicle's performance is compromised greatly. Extensive repair work is required.	7
8	Very high effect, Vehicle is inoperable. Immediate overhauling is the requirement. Occur due to accidents, usage of non-standardized parts.	8
9	Very hazardous and occur with warning. Occurring due negligence in periodic maintenance work. Vehicle need to be abandoned.	9
10	Hazardous with maximum Severity and occur without warning. It can cause risk to the life of rider.	10

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Table 3: Occurrence Rating

Probability of Failure	Possible Failure Rates	Ranking
Very High : Persistent failures	≥ 100 per thousand vehicles/ items	10
	50per thousand vehicles/ items	9
High : Frequent failures	20 per thousand vehicles/ items	8
	10 per thousand vehicles/ items	7
Moderate : Occasional failures	5 per thousand vehicles/ items	6
	2 per thousand vehicles/ items	5
	1 per thousand vehicles/ items	4
Low : Relatively few failures	0.5 per thousand vehicles/ items	3
	0.1 per thousand vehicles/ items	2
Remote : Failure is unlikely	≤ 0.010 per thousand vehicles/ items	1

Table 4: Detection Rating

S. No.	Detection	Rating	Definition
1	Certain	1	Certain detection of failure mode by control
2	Very High	2	Higherpossibility of failure mode getting detected
3	High	3	Failure mode is high
4	Moderate High	4	Fair likelihood of detection of failure mode
5	Moderate	5	Moderate chance of detection of failure
6	Low	6	Failure Mode may be detected
7	Very Low	7	Failure identification become difficult
8	Remote	8	Hard to detect the failure mode
9	Very Remote	9	Very slight chance of detection of failure
10	Impossible to detect	10	Almost negligible chance to detect the failure

4. Implementation of FMEA on the engine of the car

FMEA was applied on the different component of engine of the car. Analysis was done on all the component or system of the engine. The detailed analysis using FMEA is illustrated in Table 5.

Table 5: FMEA Worktable

S.N	Component or System	Function	Failure Mode	Failure Cause	Failure Effect	S	O	D	RPN	Total RPN
1	Ignition System	To generate a very high voltage from the 12 volt battery and each spark plug to ignite air fuel mixture	Does not ignite the air fuel mixture	Battery is dead	Engine will not start	4	6	1	24	204
			Ignite the air mixture at the wrong time	Spark plug wire wear out	Engine performance is affected	6	5	6	180	
2	Fuel Injection System	To inject fuel to combustion chamber	Leakage	Fuel injecter is broken	Wastage of fuel	6	2	2	24	144
		To adjust the fuel quantity as engine output is proportional to injection quantity	Low performance	Engine control unit is damaged	It affect the engine output	6	2	4	48	
		Adjusting injection timing as fuel should be injected to coincide with the induction stroke of cylinder	Does not reach maximum combustion pressure	Engine control unit is damaged	It affect the engine output	6	2	4	48	
		Atomisation of the fuel. Breaking down molecule of fuel so that it can thoroughly mix with air	Incomplete combustion of fuel air mixture	Fuel coming through atomisation hole at pressure less then required pressure due to blockage of hole	Create pollution and decrease efficiency of engine	2	3	4	24	
3	Lubrication System	To lubricate all moving parts in the engine so that it can move easily	Noise	Leakage of lubrication oil	Risk of breaking of piston ,crankshaft and camshaft	5	6	2	60	60
4	Valves	The intake and exhaust valve open at proper time to let in air and fuel and to let out exhaust respectively	Leakage	Valve deterioration	Wastage of fuel	4	2	7	56	80
			• Overpressure • High pressure in at entrance and exit of combustion chamber	Flow obstruction due to internal breaking	Engine efficiency is decreased	6	2	2	24	
5	Combustion Chamber	The place where combustion of fuel take place	Leakage of fuel, Thermal relay performance	Internal crack form in chamber due to wear	Risk of accident	10	1	5	50	50
6	Piston Ring	To provide good sealing between piston and engine cylinder so that fuel does not mix with engine oil	Leakage of fuel	Piston ring is worn out	Lose some power during every power stroke	6	6	2	72	72
7	Air Intake System	To intake air which is enrich in oxygen for better combustion of fuel	Excessive wear of engine part	Air filter worn out	Decrease power output and engine efficiency	6	4	2	48	48

8	Car Cooling System	Continuous cooling the heated engine	Thermal relay performing	Leakage of cold water through pipe	Overheating of engine	4	3	7	84	132
			Cooling fan failure	Breakdown of fan due to wear	Overheating of engine	4	3	4	48	
9	Crankshaft	To help in converting the linear motion of the piston into rotary motion that can be delivered to the gearbox.	Noise	Misalignment of bearing	Decrease power output and engine efficiency	4	2	3	24	24

5. Priority Graph

From above work table of FMEA a graph can be represented of RPNs of all component of engine . Graph was plotted with RPN as Y-axis and component of engine as X-axis . Graph shows the comparison between the RPN of all components. Below Fig 2 shows the priority graph .

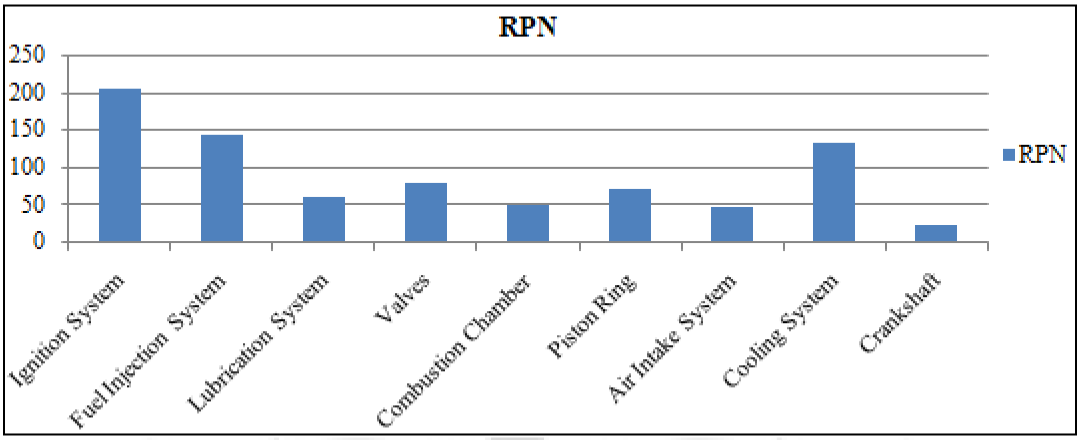

Figure 2: Priority Graph

6. Conclusion

A full fledged FMEA was carried out on the petrol engine of Maruti Suzuki Swift Car. Various aspect such as severity, likelihood of occurrence and detection were clearly described which help in calculating the RPN of each component of engine . From above analysis Ignition System , Fuel Injection System and Cooling System are the critical component with high RPN which require more attention and top notch maintenance so that preventive maintenance can be successful.

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