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Failure Mode and Effect Analysis of Automotive Charging System

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ABSTRACT:

***Failure Mode and Effects Analysis* (FMEA)** *technique is used to identify the potential failure modes, estimates the causes and its effects, and determine what could eliminate or reduce the chance of failure. The results of the analysis can help the analysts to identify and rectify the failure modes that have a detrimental effect on the system and improve its performance during the various stages of design and production. The intention of this research paper is to find out the different failure modes of automotive charging system using FMEA technique and rectify the field complaints regarding its failure by necessary corrective actions.*

Key words: *FMEA, Failure Mode, RPN, Severity, etc.*

1. INTRODUCTION:

Failure Mode and Effects Analysis (FMEA) was developed by reliability engineers in the 1950s. FMEA is an analysis technique used for defining, identifying and eliminating known and/or potential failures, problems from system, design, process and/or service before they reach to the customers. The results of the analysis work can help the analysts to identify and rectify the failure modes that have a detrimental effect on the system and improve its performance during the stages of design and production.

2. CHARGING SYSTEM:

An automobile battery supplies a sufficient amount of energy to the automobile's electrical components such as starting motor, head light and wipers. However, the capacity of the battery is limited and is not capable to provide continuous power to the automobile. Therefore, it is required for the battery to always be fully charged so that it supplies the required amount of electricity at the required time to each of the electrical components. Consequently, the automobile requires a charging system to produce electricity and keep the battery in fully charged condition. When the engine is in operation; the charging system produce electricity to both recharge the battery and to supply required amount of electricity to the electrical components.

3. ALTERNATOR:

An alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current.

Most alternators use a rotating magnetic field with a stationary armature but occasionally, a rotating armature is used with a stationary magnetic field; or a linear alternator is used.

In principle, any AC electrical generator can be called an alternator, but usually the term refers to small rotating machines driven by automotive and other internal combustion engines. An alternator that uses a permanent magnet for its magnetic field is called a magneto. Alternators in power stations driven by steam turbines are called turbo-alternators.

The Alternator output is used to charge the battery; it also supplies power to all the electrical loads in the vehicle. The inbuilt full wave Rectifier converts the A.C into D.C output.

4. ADVANTAGES OF ALTERNATOR:

- Better efficiency due to heat dissipation by two fans provided in the Rotor.
- Less weight and compact in Size.
- Low operational noise.

5. HOW TO USE FMEA?

- Identify all the possible failure mode of a system.
- Identify all the possible causes of failure of a system.
- Create a column with assigned value for frequency of occurrence (O), degree of severity (S) and chances of detection (D). The value assigned will be from 1 to 10, with 1 very unlikely a failure occur and 10 very likely occurrence, 1 is for very less effect of failure on customer and 10 shows extremely severe, 1 for very likely to detect and 10 means extremely difficult to detect.

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- After this, Risk Priority Number (RPN) is calculated by multiplication of O, S and D.
- The larger value of RPN shows that the failure is very much effective to the customer and is required to remove or rectify first than the lower RPN failure problem. This RPN value helps in deciding the priority to focus on each failure.
- After this, the required corrective action is taken to overcome or rectify the problem.

Table 1.1: FMEA RESULT TABLE OF CHARGING SYSTEM								
Customer Complaint / Mode 1: Frequent Battery run down.								
Probable Cause	**Root Cause**	**Frequency of occurrence (1-10)**	**Degree of Severity (1-10)**	**Chance of Detection (1-10)**	**Risk Priority Number (1-1000)**	**Failure Detection Method**	**Specification limits**	**Corrective Action**

The above sample table 1.1 FMEA shows all the necessary details which are required for the implementation of Failure Mode and Effect Analysis technique to any system and helps in reducing the chances of failures.

6. ALTERNATOR FIELD COMPLAINTS:

1) **Battery getting discharged:** If battery is not getting charged, then it requires checking the failure of alternator. It may get discharged due to open connection of alternator with battery. The particular failure reason is find out and then rectifying it.
2) **Warning lamp glows constantly**,
3) **Warning lamp does not glow,**
4) **Regulator intermittent / No regulation**
5) **Stator overheated / burnt:** Stator may get overheated due to overload and continuous running of alternator which fail the insulation and hence stator burn.
6) **Rectifier Positive / Negative failure:** During rectifier positive failure of alternator, it give zero output of positive cycle of input and during negative failure, it give zero output to input of negative cycle. To overcome these types of failure, respective diode can be replaced.

To find the failure diode, use an ohmmeter for testing the diodes, both regulator diodes and rectifier diodes. A diode is a "one way valve" for electricity, so each diode should show some resistance reading on the meter one way, and no reading, or infinite resistance the other way. If a diode will have infinite resistance both ways, then it shows that it is faulty and replaces it.

7. ALTERNATOR TESTING:

The factors which affect the life of an Alternator include:

- Loose and excess fan belt tension.
- Fused warning lamp bulb.
- Loose Battery cables & warning lamp socket connections.
- Carrying out arc welding without disconnecting battery connections.

Testing of an alternator (on Vehicle) using Clamp Meter:

Fig.1.1: Testing of Alternator Charging Current using clamp meter

The Value of alternator charging current depends on Electric Loads, Engine RPM and Battery charge status. Fig.1.1 gives the testing of alternator charging current using clamp meter.

8. FMEA RESULT ANALYSIS:

The FMEA result tables for charging starting are as follows from table 1.2 to table 1.5. These all tables gives detail about different failure mode, their probable and root causes, how frequently these failures occur in number between 1 to 10 with 1is for very unlikely occurrence and 10 for very likely a failure occur. The degree of severity or the effect of failure on customers

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or severe (S) number in between 1 to 10, with 1 shows little effect of failure on customer and 10 means very extremely severe. After this the chance of detection (D) of each failure is identified and a value is assigned in between 1 to 10, with 1 having the chances of easily detection and 10 means very difficult in detection. Thereafter, Risk Priority Number is calculated and then different failure detection methods are obtained with the necessary corrective actions for the charging system.

Table 1.2: FMEA RESULT TABLE OF CHARGING SYSTEM (MODE 1)

Customer Complaint / Mode 1: Frequent Battery run down. Symptom : warning lamp does not glow when Ign key is "ON"

Probable Cause	Root Cause	Frequency of occurrence (1-10)	Degree of Severity (1-10)	Chance of Detection (1-10)	Risk Priority Number (1-1000)	Failure Detection Method	Specification limits	Corrective Action
a) Battery is in very poor state of charge / drained / run down	a) Leakage current due to various direct electrical loads bypassing the Ignition key switch.	2	6	2	24	a) Switch off the Ignition key, b) Remove the negative terminal from the battery c) Connect the clamp meter prods in ammeter mode in series with negative post & terminal	Must be " 0 " amps	Ensure that the loads are connected thru ' switches. Not to connect directly to the battery
	b) Usage of starter for prolong / cont. cranking could reduce the battery capacity drastically.	7	7	5	245	a) Check for cable resistance, cable length should not be more than 5 mtrs.	a) Battery capacity should not be less than 70%	Check cable ends for loose connections,
	c) Battery voltage may be less than 8 Volts.	3	9	2	54	With the help of clamp meter the voltage between the battery posts can be measured	OCV : 12.5 V Minimum	Battery must be replaced if it does not meet the specifications
b) Battery cables open circuit / posts & terminals dirty	a) Dirty, sulphated battery posts & terminals which avoid conductivity / loose term on posts	8	7	3	168	Decolouration & worn out battery posts, Visible & shaky terminals		cable ends must be cleaned & soldered for good coductivity, to minimise voltage drop
	b) Usage of graphite / MT Grease instead of petroleum jelly / vaseline, increases insulation	8	6	2	96	Look for dirty / sulphated battery posts & terminals.		Petroleum jelly melts & spreads the posts to conduct whereas the grease becomes insulated
	c) Cable between warning lamp & Ignition key switch open	4	5	3	60	Check the conductivity of the cable		Use the right cable

Table 1.3: FMEA RESULT TABLE OF CHARGING SYSTEM (MODE 2)

Customer Complaint / Mode 2: Battery run down. Symptom : Warning lamp is "ON" while engine is running & No output

Probable Cause	Root Cause	Frequency of occurrence (1-10)	Degree of Severity (1-10)	Chance of Detection (1-10)	Risk Priority Number (1-1000)	Failure Detection Method	Specifications limit	Corrective Action
a) Faulty rectifier bridge	a) Solder melted in the junctions	2	7	3	42	Visual & continuity check	Values as per specs.	Solder with proper iron.
b) Stator open circuit	a) Poor soldering of phase connections	2	6	3	36	Visual & continuity check	Res value should read around 0.12 Ohms	Replace the stator if necessary.
	b) Winding coil open circuit	3	7	4	84	Visual & continuity check		Replace the stator.
c) Stator winding short	a) Poor insulation	2	7	3		a) Series lamp check	Series lamp must glow	Replace the stator.
						b) Check with 500 V Meggar	should read Infinity	
	b) Physical damage	2	7	2	28	Visual check		Replace the stator.

d) Aux diode open	A) Semi conductor (DIODE) has become insulator which can not rectify / detect the ac current waves in self excitation circuit	6	6	3	108	Check with multimeter	One side the diode should show continuity, otherside no continuity	Replace the rectifier assy if necessary.
	b) Warning lamp holder pin earthing	4	5	2	40	Check the cluster for earthing		Replace the plastic holder.
e) Faulty regulator	a) F & A leads open in the regulator	5	6	2	60	Visual check for open leads		Change if necessary.
f) Fuse blown	a) Reversal of polarity	3	8	7	168	Check for the correct polarity		Check the battery.

Table 1.4: FMEA RESULT TABLE OF CHARGING SYSTEM (MODE 3)

Customer Complaint / MODE 3: Battery does not charge properly / warning lamp flickers

Probable Cause	Root Cause	Frequency of occurrence (1-10)	Degree of Severity (1-10)	Chance of Detection (1-10)	Risk Priority Number (1-1000)	Failure Detection Method	Specifications limit	Corrective Action
a) Loose fan belt	Loose adjuster bracket	2	5	2	20	Check for the tension	10 to 15 mm when pressed midway in longest point	Check for adjuster bracket &replace if necessary
b) Very high resistance in the warning lamp / Loose Lucar connection	Warning lamp not as per specs	2	6	2	24	Check the power of the warning bulb & loose connections	12 Volts : 2.2 Watts, filament with Resistance recommended by OE	Check for loose connections, Use proper warning lamp
c) Dirty / faulty slip rings	a) Highly carbonised / dirty / scoring slip rings	5	6	3	90	Visual check		Clean slip rings with lead free petrol
d) Faulty regulator	a) F (Field) & A (Armature) leads open in the regulator	5	6	2	60	Visual check for open leads		Change if necessary
	b) Electronic components inside the regulaor defective due to fair, wear & tear	8	7	3	168	Check the regulator with ARTD	Values as per operating manual	TR Mode: 0.49 to 0.53 Regulator cut in must be 14.2 to 14.7 v & 27 to 28 v for 24v system
e) Faulty rectifier bridge (poor solder)	a) Solder melted in the junctions	2	7	3	42	Visual & continuity check	Values as per specs.	Solder with proper iron.
	b) Diodes open circuit	4	7	3	84	Check with multimeter	One side all the diodes should show continuity, otherside no continuity.	Replace the rectifier assy if necessary.

Table 1.5: FMEA RESULT TABLE OF CHARGING SYSTEM (MODE 4)

Customer Complaint \ Mode 4: Battery is charging / warning lamp glows "DIM" when engine is running

Probable Cause	Root Cause	Frequency of occurrence (1-10)	Degree of Severity (1-10)	Chance of Detection (1-10)	Risk Priority Number (1-1000)	Failure Detection Method	Specifications limit	Corrective Action
a) Defective Aux diode	A) Semi conductor (DIODE) has become insulator which cannot rectify / detect the ac current waves in the self excitation circuit	6	6	3	108	Check with multimeter	Values as per specs.	Check the diode connections & repair

b) Stator open circuit	a) Poor soldering of phase connections	2	6	3	36	Visual & continuity check		Replace
	b) Winding coil open circuit	3	7	4	84	Visual & continuity check		Stator assembly
c) Improper Warning lamp	a) Poor quality / wrong bulb	4	5	3	60	Check the warning lamp / LED	12 Volts : 2.2 Watts, LED with Resistance recommended by OE	Replace with corrct warning lamp
d) Battery is in poor state of charge	Usage of starter for prolong / cont. cranking could reduce the battery capacity drastically	7	7	5	245	a) Check for cable resistance, cable length should not be more than 5 mtrs.	a) Battery capacity should not be less than 70%	Check cable ends for loose connections, Defective relays / EDC must be replaced by the customer
e) Faulty rectifier bridge	a) Solder melted in the junctions	2	7	3	42	Visual & continuity check	Values as per specs	Solder with proper iron
	b) Diodes open circuit	4	7	3	84	Check with multimeter	One side all the diodes should show continuity, otherside no continuity	Replace the rectifier assy if necessary

9. CONCLUSION:

In this paper, the FMEA is carried out to investigate how failure of automotive charging system takes place. From the FMEA result table of charging, it is observed that most of the charging system failure would result in replacement of that particular failure part like poor insulation of stator winding or physical damage of stators would cause the stator to be replaced with the new one. Similarly, if the battery voltage is not as per the desired specification then it also causes the battery to be replaced. This type of failure which cause the complete of part or product of the charging and starting system in an automobile creates very much severity to the customer or in other words cause the total cost loss to the customer.

FMEA technique help to the customers to find the failure cause of the parts and take all the necessary precautions in maintaining the life of the automotive charging system.

10. FUTURE SCOPE OF THE WORK:

In this paper, the work is done on battery, starting motor and alternator. There may be failure mode and effect analysis technique applied to the various other parts of automobile i.e.

- The FMEA technique can be applied to fuel injection system.
- It can be applied to ignition system i.e. on battery and magneto ignition system.
- The present FMEA thesis work is on Lead Acid battery, it can be applied to Li-ion battery also.

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