Service Failure Analysis for Commutator of Brushed DC Motor

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Abstract
Failure mode and effect analysis (FMEA) is a tool used for assessing probable failure modes and their reasons. It aids in ranking the failure modes and mentions remedial actions for the avoidance of sudden failures in system and enhancement in availability of system. In this work, an attempt has been made to use FMEA for the commutator of series DC motor. This approach is helpful in ensuring effective motor performance.

Keywords: commutator, FMEA, RPN

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INTRODUCTION

Failure Mode and Effect Analysis (FMEA)

FMEA is one such quality tool which is used for reliability analysis and is fruitful to improve reliability of a product or system. FMEA scrutinizes the potential failure modes of system and analyse reason and effect of each failure mode. It helps to identify loop holes in system, puts forward development measures and design plans, so as to improve the reliability of product or system.[1–3]

FMEA also find its application to describe quality review points, preventive maintenance actions, operational constraints, measures required to lessen the failure risk.[4–8] Ideally, FMEAs are applied in the product design or process development stages, although use of FMEA on existing products and processes can also yield substantial benefits.[9–11]

In this paper D C series motor is taken for study. In series motors, the field coil and armature have series connection. This project is about the commutator failure in DC motor by using FMEA technique which identifies how the process will flop and how to abolish or reduce risk of failure.

DC Motor

To obtain mechanical energy from electrical energy electromechanical energy conversion process is required. Electromechanical conversion device is a linkage in the middle of electrical and mechanical systems. Dynamo is such type of a device. Dynamo convert electrical energy to mechanical energy or mechanical energy to electrical energy.

When a dynamo is run by a prime mover and it supply electrical energy then it is called as generator while when dynamo takes electrical energy as input and gives mechanical energy as output then it is called as motor (Figure 1).[5]

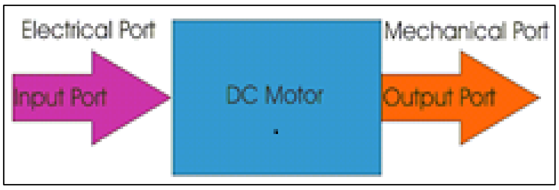


***Fig. 1.** Basic Diagram of Energy Conversion in Motor.*

Constructional Features of DC Motor

Construction of DC motor includes following parts:[6]

1. Stator Frame: The stator frame is the static portion of the motor. That frame comprises the motor casing, along with two or more permanent magnet pole pieces.[9]
2. Armature: It is rotating part of DC motor. It has slots, teeth and winding in slots. These windings are electrically connected with commutator.
3. Commutator: It is cylindrical structure mounted on the shaft through commutator hub. It is made up from wedge shaped hard drawn copper segments which are highly conductive. These copper segments are separated from each other through thin mica insulation. These slots are arranged on steel cylinder. This assembly is forced and press fitted on the shaft. The EMF produced in armature conductor is alternating. The direction of EMF is reversed when conductor passes from North Pole to South Pole. This reversal process of current is known as commutation. Failure in such process results in sparking between interface of commutator and brush causing wear and pitting on commutator surface and of brushes. [12–14] Major concern is required to prevent such failure. In present paper FMEA is being done for commutation failure. This FMEA is helpful in understanding various failure modes and their severity. This analysis also includes control action as a part of preventive maintenance so that sudden failure in system can be prevented to occur. Causes of failure modes helps designer to modify design so that chance of such failure can be lowered.
4. Brushes and brush holder: Brushes are required to gather the current through rotating commutator or to lead the current to it. Carbon or graphite is generally used as brush material. So that, the commutator surface is not decayed. This brush is housed in brush holder. Spring attached with brush holder presses brush against the commutator (Figure 2).

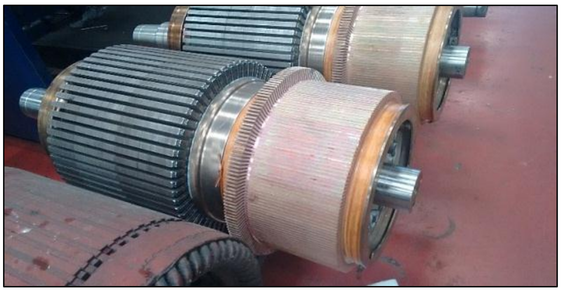


Fig. 2. *Commutator of DC Motor.*

Application of DC Motor

DC motor is variable speed motor. These motors have high torque at low speed and low torque at high speed as shown in Figure 1[5] Due to its characteristics it is used in places where high torque is required at low speed. So such motors found their application in electric locomotives, elevators, cranes, trolley cars, etc. (Figure 3).

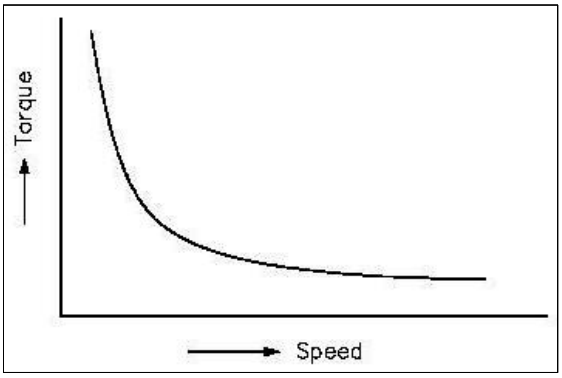
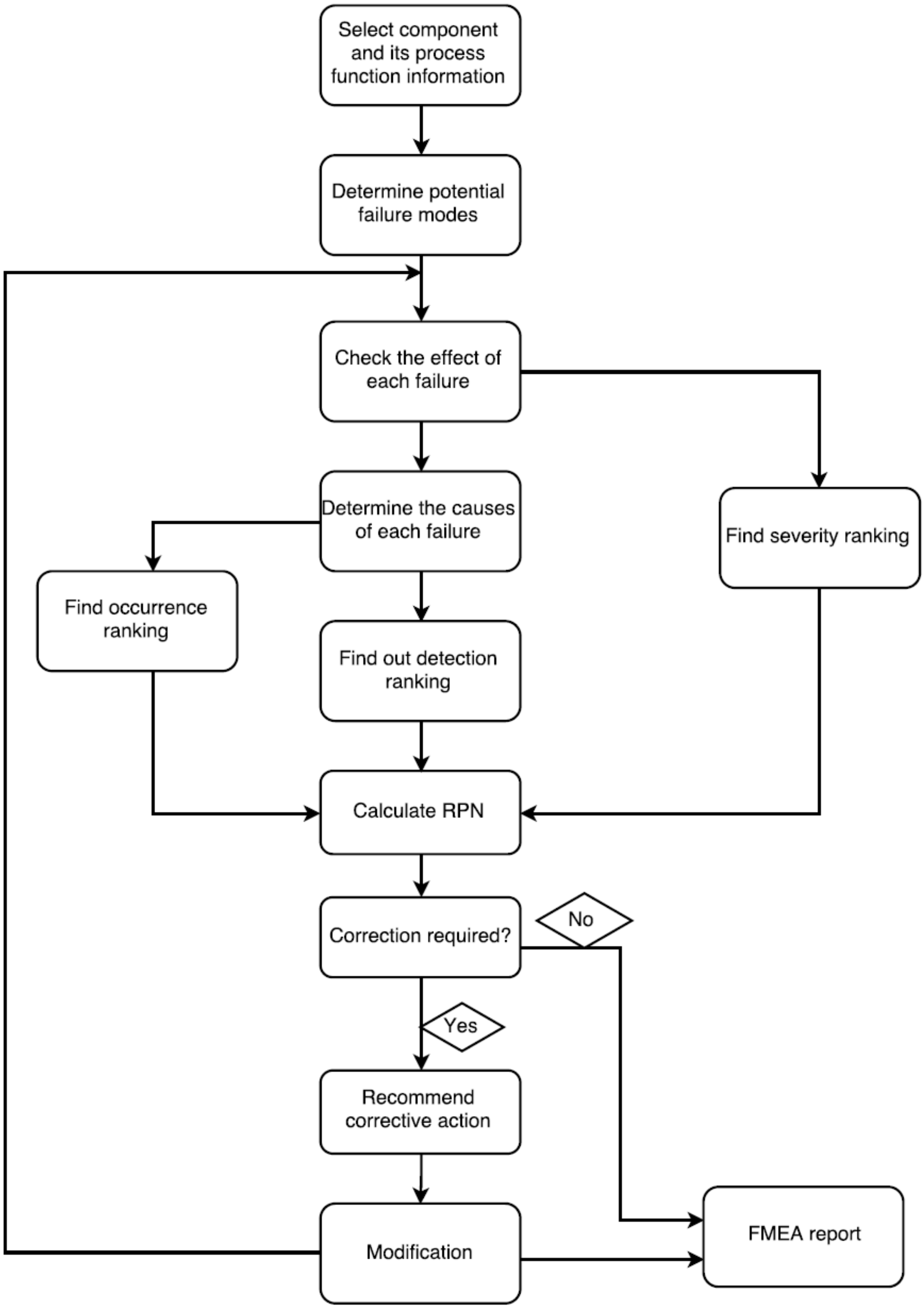


Fig. 3. *Torque-Speed Characteristics of DC Series Motor,[5] where Torque in N-m, Speed in rpm.*

BRIEF HISTORY OF FMECA

FMEA is invented by the United States in the 1950s. For enhancement in primary flight control system Aircraft Corporation implemented 'failure mode and effect analysis. This study was conducted by lacking of criticality analysis, although it gave fruitful results. [3] In the mid-1960s, FMECA was formally used by the USA's aerospace industry and were specifically focused on safety issues. The goal with safety FMEAs was, and remains today, to prevent safety accidents and incidents from occurring.[11] In midway of 1970 automotive began to use FMEA. They found FMEA as a quality step up tool for industry. In 1980 microelectronic industry also started to use FMEA. American automotive industry began to use FMEA methods in the mid-1980s.[3]



Flow Diagram for FMEA Procedure.[13]

METHODOLOGY

The Basic steps or procedure required to perform for FMEA is pronounced in us military standard document MIL-STD-1629A. [11] Process required to perform FMEA includes some steps. These steps are given below.

- The first step required to perform FMEA is to select and define the system.
- Construct system block diagram.
- Identify all possible potential failure modes and their immediate effect on system operation or on its functionality.
- Value each failure mode in terms of the most awful consequences i.e. classify the failure effects by severity.
- Calculate risk priority number.
- Find techniques for failure recognition and compensating provisions for each failure mode.
- Find out actions required to prevent the failure or identify correctness in design to control the risk.
- After taking corrective action modifications will be done to check the effects of each failure.

Prepare a FMEA report and also mark out the problems which are not able to be corrected by design changes. For such problems identify the measures which are able to diminish the threat of failure.

TERMINOLOGY IN FMEA

(1) Failure mode: It concerns the ways through which system or component get fail to perform its intended function.

(2) Failure effect: It is an influence of failure on process, system or on equipment. It is hostile consequence that the handler might experience.

(3) Failure cause: It considers reasons of failure.

CALCULATION OF RPN

RPN i.e. risk priority number is the indicator for the determining proper corrective action on the failure modes. Risk Priority Number is evaluated by multiplying three variables. These variables are severity, occurrence and detection. For each failure mode different values are assigned for its severity, occurrence and detection. These ranking values vary from 0 to 10.

RPN = Severity × Occurrence × Detection

The value of RPN vary from 1 to 1000.The area of great anxiety is become easy to determine after calculating RPN. Smaller value of RPN is better than higher value of RPN. [10]

Severity Ranking

If a failure occurs it may be very serious for the system or may have very less effect on system. Failure seriousness on the system is ranked by this severity ranking.[2] Severity scale ranking vary from 1 to 10. Table 1 helps to select rank for various failure effects.

Occurrence Ratings

It denotes frequency of failure. Each failure mode has to be given some occurrence ranking from 1 to 10. Table 2 describes the scale of occurrence rating.

Table 1. *Severity Scale Ranking and Description.[2]*

Severity rating	Description
1–2	Minor effect on system and difficult to detect change in system performance
3–5	Failure slightly harm system performance
6–7	Change in system performance and degradation in component can be detected
8–9	Severe changes in system performance and lead to non-functionality of system
10	System suddenly comes to breakdown or even may cause physical injury

Detection Ratings

Based on the probability that particular failure mode will be detected before it causes serious effect on system detection ranking is given in Table 3 (Table 4).

Table 2. *Scale of Occurrence Rating.*[2]

Occurrence rating	Meaning
1	Failure eliminated or no know occurrence
2,3	Low or very few
4,5,6	Moderate or few occasional
7,8	High or repeated failure occurrence
9,10	Very high rate of failure or inevitable failures

Table 3. *Effect on System Detection Ranking.[2]*

Detection rating	Description
1	Very certain that the failure will be detected
2–4	High probability that the defect will be detected
5–6	Moderate probability that the failure will be detected
7–8	Low probability that the failure will be detected
9–10	Very low probability that the defect will be detected.

Table 4. *FMEA Chart of Commutator.*

S. no.	Component	Function	Potential failure mode	Potential cause/mechanism of failure	Effect of failure	Preventive action	S	O	D	RPN
1	Commutator	Commutation	Streaking	a) Too porous brush grade b) Insufficient brush spring tension c) c)Contaminated atmosphere	a) Copper particles starts pickup from commutator b) System not affected very much unless severe streaking	a) Adjust spring pressure b) Prevent it from atmospheric contamination	2	8	3	48
			Threading	a) Too porous brush grade b) Insufficient brush spring tension c) Contaminated atmosphere d) d) Uneven current distribution	a) Rapid brush wear b) Transfer of excessive amount of metal to brush from commutator during commutation	a) Adjust spring pressure b) Prevent it from atmospheric contamination	6	7	4	168
			Grooving	a) Abrasive dust in atmosphere b) Use of too abrasive brush grade	a) increase in electrical resistance b) Heat generation on brush and commutator c) Flash over arc may be produced between	a) Adding filters or ducting for clean air b) Clean air borne abrasive dust	8	6	5	240

					brush and commutator					
			Baredge burning	a) Excessive vibration b) Incorrect brush alignment c) Commutator becomes over heated and softened	a) Sparking at brush commutator surface d) Overheating	a) Check and adjust neutral setting of brush b) Check interpole strength Install split brushes to improve current distribution	8	6	7	336
			Copper drag	a) Vibration of high frequency and low amplitude b) Use of abrasive brush	a) Make machine prone to flash over b) At low load condition increase in friction c) Hammering effect on commutator	a) Try to avoid low load condition b) use suitable grade of brush	9	5	8	360

CONCLUSION

Commutation is very important process in D C motor functioning. In this paper failure mode effect analysis is being done for commutator failure. Failure in commutator will result in functioning loss of D C motor or even arcing may cause. Some preventive action is also given to prevent the commutator failure. [15] As catastrophic failures are reduced through implementing suggested action functioning life of commutator get enhanced. Downtime of D C motor is also reduced by preventing commutator failure.

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BIOGRAPHIES

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