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Design Failure Modes and Effect Analysis (DFMEA) Of Braking System of an ATV

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ABSTRACT
ATV is an all-terrain vehicle which can basically run on almost all types of topographies and moves on four low pressure tires with a seat bestrode by the Driver. BAJASAE is an ATV fabricating event organised by Society of automotive engineers (SAE), India for engineering undergraduates. BAJA SAE entails designing, Manufacturing and validation of an ATV which participates in series of events for 3 days which tests the agility of the buggy. Since the safety of the operator is imperative in such events so there is a need of a safe and infallible braking system. This involves the prediction of the failure modes in the designing stage. An efficacious procedure of failure analysis is the Design Failure Mode and effect Analysis. FMEA procedure is used in this paper to find out different failure modes, itseffects, causes, occurrence and different prevention ways for various components in a braking system of an All-terrain vehicle. Risk priority Number (RPN) is basically used to figure out which braking component is at the risk offailure and requires more surveillance.
Keywords: BAJASAE, ATV, Braking system, Failure Modes and effects Analysis (FMEA), Risk Priority Number (RPN)

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I. INTRODUCTION

An ATV is a motorized off road vehicle which runs on low pressure tires with seats designed to be bestrode by the Driver and handles for steering as defined by the American national Standards Institute (ANSI)[1].Society of Automotive Engineers, India organizes BAJA events for engineering undergraduates. This event involves designing, fabrication and on ground races to test its agility in terms of acceleration, manoeuvrability, speed, grad ability and braking characteristics.[2]

The design phase is paramount in development of the ATV buggy. Being an off-road vehicle, an effective and reliable braking system is essential. Various braking components can fail in different circumstances and can jeopardise the entire buggy. Hence an extensive and well-organized analysis of the braking system of the ATV is of supreme importance. This includes identification of potential failure modes in braking system, its causes and effects and preventive steps that can be taken to avoid that failure. The Failure Modes and Effect Analysis is one of the most widely used failure analysis technique used for systematic failure analysis. American society of Quality defines FMEA as a step by step approach to identify all possible failure in a design, a service or a product or a assembly process [3]. In the designing phase DFMEA is used in this paper to analyse the failure modes. Risk priority Number is employed in this paper to have a quantitative evaluation of failure modes and failure prioritization.

II. FMEA

FMEA has an ample number of applications in numerous sectors. In 1970's it was widely used by NASA in many of its space programs. Nowadays FMEA is used in many sectors like automobile, healthcare,software etc. [5][6][7]. It was also successful in prevention of failure of wind turbines at design stage.[8]

FMEA is sorted into 4 categories: DesignFMEA, ProcessFMEA, SystemFMEA, ServiceFMEA [9]. BeforeManufacturing, the design of the product is analyzed by the DFMEA. In this paper, FMEA has been used to figure out different perilous braking components. As prioritization of different braking component on the basis of risk of failure and its effects is necessary, so Risk priority number is used.

III. RISK PRIORITY NUMBER METHODOLOGY

First, various component of the braking systems wasoutlined. Following that failure modes, effects and causes of each braking component are identified. Next possibility of occurrence of failure, severity of failure and possibility of detection of failure were ascertained for failure modes of each braking components. All the parameters were given grading from 1 to 10. Analysis of the above parameters are done in the next section of this paper. Risk Priority Number is evaluated by multiplying aboverating. Risk priority Number is the product of severity of failure, possibility of detection and the possibility of occurrence.[10] RPN=(Severity grade score)*(Possibility of occurrence grade score)*(Possibility of detection grade score) [10] After calculation of RPN, Prioritization of failure modes different braking components were done on the basis of their RPN.

Failure modes of the braking components having high RPN are given more priority as compared to the component having comparatively lower RPN. [9]. A Priority graph is plotted to get an overview of critical component failures and its RPN. The Component with highest RPN is given utmost attention during manufacturing to prevent any failure. The primary objective of the comprehensive technique is to reduce the resultant RPN.[10]
Total RPN=Sum of all individual RPN

IV. SEVERITY OF FAILURE, OCCURRENCE OF FAILURE AND DETECTION OF FAILURE

Severity(S) is an indicator of the seriousness of the problem [9].It is rated on a scale of 10,Severity grading of 1 means almost negligible harm to the system or the problem has the least severity and a grading of 10 means the problem has the highest degree of severity and harms the system to the maximum.[10][11]

Likelihood of occurrence(o) is an indicator of the frequency of potential failure or how often a failure occurs[9].A grading of 1 means there is negligible chance of occurrence of failure and a grading of 10 means problem is persistent and inescapable[10][11]

Likelihood of detection(D) is an indicator of how likely the failure is detected with the current control system[9].A grading of 1 means detection of failure is almost certain by the current controls and a grading of 10 means it is almost impossible to detect the failure by the current controls.[10][11]The details are discussed in the Tables below.

TABLE-1: Severity assessment and Grading criteria

SL. No.	SEVERITY CATEGORIZATION	SEVERITY GRADING	ELUCIDATION
1.	**Immensely Dangerous without caution**	**10**	Failure takes place unforeseeably without any caution. Operator’s security is compromised. Failures are extremely dangerous and life risking and the damages are beyond repair.
2.	**Extremely dangerous with caution**	**9**	Failure is very dangerous and life risking ,but it occurs with a warning. It endangers operator’s life and results in severe damage to the braking system and makes it inoperable. Damages are beyond repair.
3.	**Very High**	**8**	Braking system is inoperable and generally takes place due to accident, use of parts that are not standardized. Immediate repair and rework is imperative.
4.	**High**	**7**	There is significant compromise in the performance of the braking system. Expansive repair and rework is imperative.
5.	**Modest**	**6**	Principal function of the braking system is unimpaired i.e. system is employable. Performance loss is there and in addition to that aesthetics is compromised. Repairing can be done to resolve the issue.
6.	**Low**	**5**	Performance of the system is affected but the system is operable. Repairing is enough, replacement is not needed.

7.	**Very Low**	**4**	There is no critical failure in the Braking system. Minor failures due to finishing and fitting problems which can be overcome by minor modification.
8.	**Minor**	**3**	System has no significant loss of function. Minor Repair is needed. It might cause little dissatisfaction among users.
9.	**Inconsequential**	**2**	Braking System in functional with least hindrance with performance slightly below optimal level. As failure is not observed easily, it is not of much concern and repairing is not needed.
10.	**Negligible**	**1**	Effects of failure is not observable and the operator and the braking system is not affected in any way. It is least severe among all categories. Performance of the braking system is unaffected.

Table-2: Possibility of occurrence

Sr. No.	**OCCURRENCE**	**GRADING**	**ELUCIDATION**
1.	Extremely high and failure is inescapable	**10**	1 in 2 components
2.	Very high chance of occurrence	**9**	1 in 5 components
3.	Chance of occurrence is high and failure is often repeated.	**8**	1 in 10 components
4.	Failure is quite frequent and occurrence is high	**7**	1 in 50 components
5.	Modestly High chance of occurrence	**6**	1 in 300 components
6.	Modest chance of occurrence: sporadic failure	**5**	1 in 1000 components
7.	Modestly low chance of failure: erratic failure	**4**	1 in 10,000 components
8.	Less chance of failure	**3**	1 in 60,000 components
9.	Very less chance of failure	**2**	1 in 3,00,000 components
10.	Almost negligible chance of occurrence of failure	**1**	1 in 2 million components

Table-3: Possibility of Detection

Sr. No.	**DETECTION**	**GRADING**	**ELUCIDATION**
1.	**Almost Impractical to Detect**	**10**	It is almost impractical to detect the failures.
2.	**Least Chance of Detection**	**9**	Least chance of detection of failure
3.	**Nominal Chance of Detection**	**8**	Minimal possibility of detection of failure
4.	**Very Low Chance of Detection**	**7**	Very low possibility of the failures getting detected.
5.	**Low Chance of Detection**	**6**	Possibility of detection of failure is quite low
6.	**Modest Chance of Detection**	**5**	Possibility of detection of failure is modest.
7.	**Slightly High Chance of Detection**	**4**	Good chance of failures getting detected.

8.	**High Chance of Detection**	**3**	Detection of failure is very High.
9.	**Extremely High chance f Detection**	**2**	Detection of failure is extremely high
10.	**Definite chance of Detection**	**1**	Detection of Failure is almost certain

V. DFMEA EXECUTION

Implementation of DFMEA is done in 7 critical components of the braking system. The Analysis was done on 7 different components of the braking system: Brake pedal, Master cylinder, Brake Hose, Brake calipers, Brake Rotor, Wheel Hub assembly, Tires. The analysis is demonstrated in the table-4.

Table-4: DFMEA Chart

Sr. No	BRAKING COMPONENT	FAILURE MODES	FAILURE CAUSES	FAILURE EFFECTS	S	O	D	RPN	PREVENTION STEPS
1.	**Brake Pedals**	Structural failure; bending and breaking of brake pedal	Wrong material, Low strength of pedal	Complete Braking Failure, Safety of operator is compromised	10	5	6	300	A material of High factor of safety must be chosen and more priority must be given to tasting and analysis.
2.	**Master Cylinder**	Piston failure, Piston seal failure	Excessive wear and tear	Leakage of brake fluids; Improper braking; Performance of the braking system is compromised	8	5	6	240	Periodic checking and replacement
3.	**Brake Hose**	Breakage of Brake hose	Wrong selection of material	Leakage of Brake-fluid which can cause improper braking and can even result in complete brake failure; Performance of the braking system is compromised	7	6	4	168	Periodic checking and replacement.
4.	**Brake calipers**	Uneven brake pads wear; Breakage of caliper brackets; Problems at joints	Excessive wear and tear; Accidents; Rough terrain travel, inadequate seal material.	Leakage of brake-fluids, Improper braking, clunking noise.	10	6	5	300	Periodic checking and replacement of brake pads, banjo fittings.
5.	**Disk Brake Rotor**	Wear and tear; Excessive heating; breakage of rotor	Improper material selection; rough terrain travel; accidents	Vehicle is out of control due to damage to rotor, risk to operator's life.	10	8	4	320	Periodic checking and replacement; Proper selection of material; Effective analysis and testing
6.	**Wheel Hub Assembly**	Breakage of wheel hub assembly	Accidents; faulty mounting	Vehicle becomes inoperable	9	3	4	108	Use of standard rims
7.	**Tires**	Tread separation; sidewall failure	Improper mounting, Puncture of tires by foreign debris; Excessive inflation	Safety of the driver is at stake. Performance of the Braking system is severely affected	8	7	3	118	Regular checking and replacement of tires. Proper mounting. Adequate material testing

S is the severity grading is the detection grading and **O** is the occurrence grading.

VI. PRIORITY NUMBER GRAPH

After DFMEA analysis, Prioritization of failure modes of different components of braking system is done according to their Risk priority number (RPN) in graph. Recommendedactions are then implemented on the basis of the prioritization. The priority graph is demonstrated in chart -1

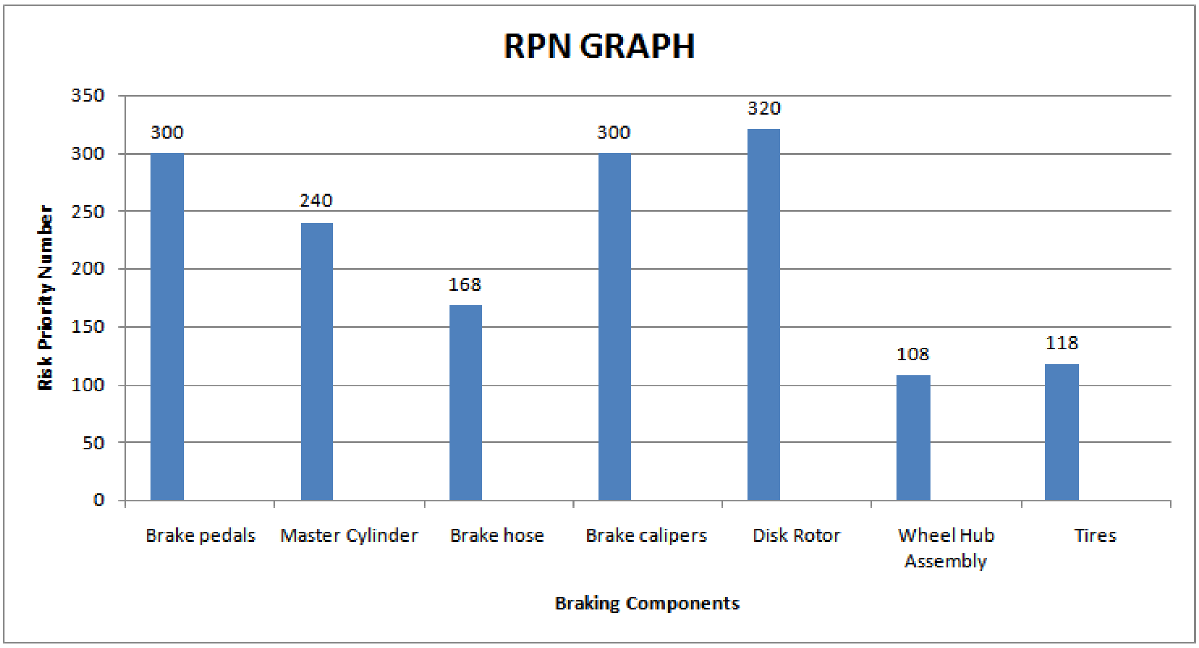

Chart-1: Priority Graph

VII. DFMEA EVALUATION

After prioritization of braking components on the basis of RPN, the analysis showed that Disk rotor, Brake Pedals and brake calipers are the critical components due to their higher RPN and requires the first-hand attention. Recommended actions are listed out to prevent failures and proper and proper actions are taken for all these braking components and requires first hand attention. Recommended actions are listed out to prevent failures and proper actions are taken for all these braking components

VIII. CONCLUSION

Implementation of DFMEA was done on the braking components. Different aspects of analysis like Severity, occurrence and detection were summarized and elucidated. On the basis of all these aspects grading was done and reckoning of RPN for each of the failure modes of the braking component was done then on the basis of RPN prioritization of critical components were done. Preventive Measures were suggested in this paper for each and every braking component for reduction in failure modes in the braking system.

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