Failure Modes and Effective Analysis of All-Terrain Vehicle and Go-Kart: A Review

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Abstract: ***The failure modes and effects analysis (FMEA) is used to identify the risks in a process, to quantify the effects that failure would have on customers, and to establish mitigation plans for high-risk items. The remainder of this paper outlines the use of the spreadsheet and explains how to complete each field. This paper indicates the current situation, use, and effectiveness of Failure Modes & Effects Analysis (FMEA) and its role in improving the standard and reliability of automotive products. The need for a formal methodology for identifying the product failure modes and effects is developed. Lastly, a set of case study of recommendations and opportunities for student research pertaining to SAE competitions where FMEA are presented with an ultimate goal of improving the FMEA process and ultimately the reliability of automotive products.***

Keywords: Failure Mode Effective Analysis (FMEA), Risk Priority Number (RPN), Failure, Product, Effect

1. Introduction

An important challenge facing automotive industry is to bring a product to the consumer that meets the Voice of the Customer or customer requirements with high reliability. Although not an explicitly stated requirement, the desire for highly reliable products is an implicit want of most, if not all customers. The specific challenge to an OEM is to develop products with high reliability under shortened design cycles, cost reduction initiatives, and pressures to produce products with focus market appeal. The Failure Mode and Effect Analysis (FMEA) is one of the more familiar of the system safety analysis techniques in use. It has remarkable utility in its capacity to determine the reliability of a given system. The FMEA will specifically evaluate a system or subsystem to identify possible failures of each individual component in that system and, of greater importance to the overall system safety effort, it attempts to forecast the effects of any such failure(s). Because of the FMEAs ability to examine systems at the component level, potential single-point failures can be more readily identified and evaluated.

2. Literature Review

FMEA is an inductive engineering technique used to define, identify, prioritize, and reduce or eliminate potential modes of failure in product and process design. FMEA can be defined as "a systematic group of activities intended to: (a) recognize and evaluate the potential failure, (b) identify actions that could eliminate or reduce the chance of the potential failure occurring, and (c) document the entire process" [1]. Primarily applied to the design and manufacturing of products, FMEA is widely used in industries such as automotive, aerospace, electronics, medical, telecommunications, and building and road construction [2, 3]. Failure mode and effects analysis (FMEA), The tool was first proposed by NASA in 1963 for their obvious reliability requirements. Since then, it has been extensively used as a powerful technique for system safety and reliability analysis of products and processes in a wide range of industries – particularly aerospace, nuclear, automotive and medical [4]. FMEA is an easy to use and yet powerful pro-active engineering quality method that helps to identify and counter weak points in the early conception phase of products and processes [5]. Failure Modes and Effects Analysis (FMEA) is a systematic method for analyzing and ranking the risks associated with various products (or processes), failure modes (both existing and potential), prioritizing them for remedial action, acting on the highest ranked items, reevaluating those items and returning to the prioritization step in a continuous loop until marginal returns set in [6]. Since FMEA method is based on finding, prioritizing, and minimizing the failures, it has been broadly utilized in numerous types of industrial areas [7,8]. FMEA has been widely adopted by reliability practitioners and has become standard practice in Japan, America, and European manufacturing companies [9,10].

3. Procedure of FMEA

In order to perform this method, the FMEA team should be concurrently formed including experienced engineers familiar with project process and also experts who have the most understanding of the designated product/ process. One of the benefits of this team working is that each activity is defined always will be agree by all the organization units. These teams are responsible for all related activities from the first stages until implementation of proposed actions and survey their results and finally competition of FMEA. FMEA procedure commences with reviewing design details, illustrating equipment block diagram and recognizing all potential failures, respectively. Following recognition, all possible causes and effects should be classified to the related failure modes. After this practice, priority of failures due to their disaster effects should be ranked by a Risk Priority Number (RPN), which is the multiplication of severity of failures (S), their portability of occurrence (O), and the possibility of detection (D) [7].

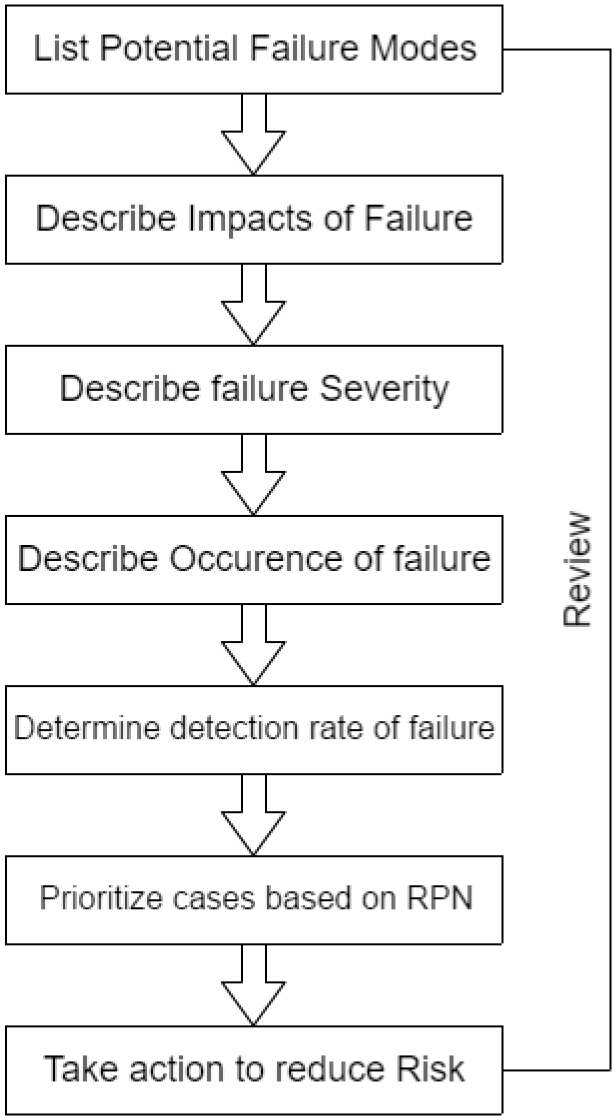

Figure 1: Flow Chart for procedure of FMEA

4. Collection of Information and Determining Potential Risks, Causes and Effects

For effective FMEA analysis the information should be accurate, useful and comprehensive about the considered project, we can get help through interview with informed and skilled people, practitioners, administrator's workshops and warehouses. Also, brainstorming sessions involving employees from various departments can be used for understanding about performance and risks associated with equipment, warehouse and workshop environment. The use of scientific resources such as articles, books and Internet are also other useful and helpful ways. Then, a list of failures, their causes and conceivable mechanism should be provided and the causes must be possible completely and briefly. Similarly, adequate knowledge of the evaluation area can help to identify the reasons for the creation of risk. In order to better assess risks, we should pay enough attention to documents, operation standards, requirements and regulations governing the workplace and the working conditions.

4.1 Deterioration rate (Severity)

Severity or deterioration of risk is only considered in its "effect"; reducing the deterioration of risk is only possible through changes in process and how to do activities. There are a few quantitative factors for this deterioration of risk that is expressed on a scale of 1 to 10 [8].

4.2 The possibility of risk (Detect)

Probability of detection is a kind of assessment that exists for identify a cause/ mechanism of risk. The team must use an evaluation criterion and rating systems even if some changes be necessary in special cases. The best determine controls those that are done during the process of the development projects in the earliest possible time. Also, the team should review potential risks scores after scoring and ensure that the rating is still remains. Although FMEA prioritises more critical failures, it also requires an analysis of each component of a system and this might be time consuming for the available resources [9].

4.3 The probability of event (Occurrence)

Occurrence is the probability emergence of a specific cause or mechanism. In other words, the probability of occurrence specifies that a potential error occurred with what frequency. The probability of occurrence is assessed based on a 1 to 10 scale [8]. In order to achieve this number, survey previous Records and documents, check the control processes and labour laws can be helpful [9].

5. FMEA of Student Project: Go-Kart and All-Terrain Vehicle

5.1 Go-Kart

A Go-Kart also written as Go-Cart is a type of pen-wheel car. Go-Karts come in different shapes and forms which are powered by electric motors to high-powered IC engines. In some countries, Go-Karts can be authorized for use on public roads. Though there are some restrictions, e.g. in the European Union a go-kart on the road needs head light (high/low beam), tail lights, a horn, indicators and a maximum of 20 hp.

5.2 All-Terrain Vehicle (Quad-Bike)

As the name indicates, it is designed to handle a wider variety of terrain than most other vehicles. By the current ANSI (American National Standards Institute) definition, ATVs are intended for use by a single operator, although some companies have developed ATVs intended for use by the operator and one passenger. These ATVs are referred to as tandem ATVs [10]. The use of these vehicles are limited but are being developed in the field of automotive industry. Various student competitions are held for designing and manufacturing of an All-Terrain Vehicle. The FMEA helps in assisting of various aspect of the competition.

6. DFMEA Table of a Go-Kart

Process step	Potential failure modes	Potential failure effects	SEV	Potential causes	OCC	Current process controls	DET	RPN
CHASSIS	when linkages are not welded properly, when appropriate material type is not chosen,	can lead to collapse of the vehicle , leads to over vibration in the vehicle	**2**	when proper welding type is not studied , when material type is not analyzed in an analysis software	**1**	analysis software's like SOLIDWORKS SIMULATION, ANSYS can prevent this type of failure	**5**	**10**
TYRES	Improper seating with steering links, tires subjected to high wear and tear	may lose control of the vehicle leading to an accident, skidding especially on wet roads, affects the vehicle speed performance	**2**	less importance to fasteners (bolts and Nuts),low quality tires	**3**	good quality tires that are having good results with go-kart currently, fasteners with Ok stickers are to be purchased	**3**	**18**
ENGINE	improper lubrication, low qualitied spark plugs, improper fuel valve tuning, less swept volume	deformation due to overheating, burning of spark plugs, incomplete combustion leading to very less mileage	**4**	Insufficient volume of the lubricant and very less idea about the type of the lubricant that is to be used and heat transfer of engine.	**2**	proper exposure to air for sufficient engine cooling , appropriate lubricant is to be used fulfilling the purpose	**4**	**32**
IGNITION SYSTEM AND BATTERY	Improper ignition switch condition, improper battery selection.	Will not start the engine.	**4**	improper wiring and design .	**5**	batteries from reputed manufactures are to be purchased	**5**	**100**
TRANSMISSION	improper material type , improper gear meshing , low qualitied bearings	leads to unsatisfied performance , leads to high amplitude vibrations	**6**	inadequate results from 3D designing , less knowledge on the type of bearing to be used , low qualitied chains used in chain drives ,	**4**	ensure that the drive and driven shafts holding the chain are parallel to each other , proper greasing of the chain , proper bearing type .	**3**	**72**
REAR AXLE	improper machining, improper mounting	break down, transmission loss	**2**	inadequate results from 3D designing, less knowledge on the type of bearing to be used.	**7**	roundness checking, proper mounting, diagnosis	**3**	**42**
STEERING SYSTEM	steering ratio varies, tie rod alignment, steering geometry	improper stability, more tire wear, chance for collision	**5**	improper designing and mounting	**5**	steering calculations	**4**	**100**

7. DFMEA Table of an All-Terrain Vehicle (Quad-Bike)

Process Step	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Process Controls	DET	RPN
CHASSIS	when the appropriate welding is not done. when the material type is not chosen properly.	may lead to total collapse and vibration in the vehicle.	10	when the welding is improper and the material usage is not studied or analyzed properly in an analyzing software.	8	analysis software such as SOLIDWORKS, ANSYS etc. can be implemented to prevent this type of failure.	1	80
STEERING SYSTEM	steering ratio varies, tie rod alignment, steering geometry.	chances of accident is more due to improper stability of vehicle, tire wear.	8	improper designing and mounting.	9	steering calculation	4	90
TYRES	improper joining with steering links, high wear and tear of tires.	control of the vehicle may be lost which may lead to accident. Skidding on wet roads may affect the performance.	5	quality les fasteners and tires.	4	good quality fasteners and tires that are having good results with quad torc vehicles are used	5	75
ENGINE	improper lubrication, low qualitied spark plugs, less swept volume	deformation due to overheating, incomplete combustion leading to less mileage.	8	very less idea about the type of lubricant used for heat transfer.	3	appropriate lubricant is to be used to fulfil the purpose.	3	65
IGNITION SYSTEM AND BATTERY	improper switch condition, improper battery selections.	engine will not start.	6	improper wiring and design.	8	switches and batteries from reputed companies are to be purchased.	8	25
TRANSMISSION SYSTEM	low qualitied bearing, improper gear meshing.	leads to high vibration, poor performance.	7	low qualitied chain used for chain drive, poor bearing material.	10	ensure proper bearing is used, ensure that drive is parallel to drive shaft, proper greasing is made.	10	15
BRAKES	improper design	low brakes may lead to panic situation.	10	less importance to brake wires and brake oil.	7	brake calculations.	7	35
SUSPENSION SYSTEM	improper selection of suspension	may lead to total collapse and vibration in the vehicle.	10	improper mountings	6	load distribution analysis	9	28
A-ARMS	improper selection of material	chances of accident is more due to improper stability of vehicle, tire wear.	9	improper mountings	6	material and load analysis	8	20
KNUCKLE	when the appropriate welding is not done. When the material type is not chosen properly.	may lead to total collapse and vibration in the vehicle.	9	improper designing and mounting.	5	load distribution analysis	9	10
REAR SHAFT	over load and improper selection of material	may lead to failure of the transmission system	8	lack of knowledge about the loads	8	analysis software such as SOLIDWORKS, ANSYS etc. can be	9	55

						implemented to prevent this type of failure.		
COUPLING	shear force and torsional effect	may lead to total collapse and vibration in the vehicle.	**7**	improper designing and mounting.	**8**	analysis software such as SOLIDWORKS, ANSYS etc. can be implemented to prevent this type of failure.	**3**	**60**
STEERING TIE-ROD	steering ratio varies, tie rod alignment, steering geometry.	chances of accident is more due to improper stability of vehicle, tire wear.	**8**	lack of knowledge about the steering	**8**	analysis of steering using lotus software	**8**	
BUMPER	when the appropriate welding is not done. When the material type is not chosen properly.	may lead to lethal damage of the vehicle and rider	**10**	improper material selection and welding	**10**	analysis of material and weld using analysis software	**9**	**28**
SWING ARM	When appropriate mountings are not given it will fail	leads to high vibration, poor performance.	**9**	improper designing and mounting.	**2**	analysis of material and weld using analysis software	**4**	**72**
NUTS	low quality lead to rusting and erosion	may lead to irremovable permanent joints	**2**	improper material selection	**6**	checking for quality and material	**9**	**70**

8. Conclusion

This paper reviews the FMEA process of two different student competitions where FMEA play a great role in assessing the failure modes, effects and its causes and help the users in developing the system or rectify it. The failure mode and effect analysis is an excellent tool for foreseeing the potential effects of failures within a required system or at a component level. It also offers some flexibility in safety system analysis because of its nature to examine the failure modes and effects within the system or subsystem. It helps an engineer in identifying the problem before they reach the customer and helps him race towards the peak of perfection.

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