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| University of Central Lancashire Logo | **SCHOOL OF ENGINEERING** | **Coursework Cover Sheet**  **MP3701 – COURSEWORK** |

*Students should add this coversheet, to the start of their assessment before submission through Turnitin.*

| Seminar Tutor (If appropriate): | |
| --- | --- |
| Module Title: **MECHANICAL SYSTEMS RELIABILITY** | Programme Title:  **BEng (Hons) IN MECHANICAL MAINTENANCE ENGINEERING** |
| Module Code: **MP3701** | Year of Study: **2023 - 2024** |

***Academic Misconduct / Plagiarism Declaration***

By attaching this front cover sheet to my assessment I confirm and declare that I am the sole author of this work, except where otherwise acknowledged by appropriate referencing and citation, and that I have taken all reasonable skill and care to ensure that no other person has been able, or allowed, to copy this work in either paper or electronic form, and that prior to submission I have read, understood and followed the University regulations as outlined in the Academic Integrity Policy and Procedure for Academic Misconduct available at the following link:

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| **Have you checked the following in order to maximise the grade you can achieve for this assignment?** | **Please mark X to confirm** |
| --- | --- |
| Learning Outcomes have been addressed | X |
| Similarity checks via Turn-it-in | X |
| Referencing accuracy according to provided guide | X |
| Grammar | X |
| Spelling | X |
| Word count (or other length limitation as described in the brief) | x |

**WELLBEING**

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| We wish to support any student who is experiencing mitigating circumstances which prevents students from performing to the best of their ability when completing or submitting assignments. If you are experiencing such circumstances then you may apply for mitigating circumstances**.** Wherever possible this must be done prior to handing your assignment. | I believe **I do not need** to apply for mitigating circumstances for this assignment at this moment in time  Please **delete** as appropriate  (You may still apply for mitigating circumstances if you subsequently feel that your performance has been adversely affected by issues that you may currently be unaware of). |

**SELF – REFLECTION**

***This section suggested for inclusion if appropriate to the assessment otherwise can be deleted***

| **Assessment Criteria:**  Details of this can be found in the assignment brief. In order to ensure the assessment process is fair, we want to make sure that the assessment criteria are clear to you in advance. | **Self-Evaluation:**  Simply rate how you think this assessment will perform against the assessment criteria; i.e. 1st (very good/excellent), 2:1 (good), 2:2 (competent), 3rd (basic), fail (weak).  This helps us provide detailed comments on your work and clarify things you do not understand. |
| --- | --- |
| E.g. Understanding, including knowledge | 1 |
| E.g. Applying, including analysis and evaluation | 1 |
| E.g. Researching, including range of sources, referencing and citation | 1 |
| E.g. Communicating, including structure, clarity of argument and use of English | 1 |

 

**2023/2024 MODULE CODE: MP 3701**

# DESIGN AND OPERATION OF SUSTAINABLE SYSTEMS

## ASSIGNMENT

REG / ID NUMBER: G21012515

DATE:14/04/2024

By submitting electronically, I confirm that this piece of submitted work is all my own work (unless indicated otherwise within the assignment) and that all references and quotations from both primary and secondary sources have been fully identified and properly acknowledged in the body of the writing, with full references at the end.

Abstract

This assessment focuses on 3 methods of reliability analysis in an electric car system, Reliability Block Diagram (RBD), Failure Mode Effects Analysis (FMEA), and Fault Tree Analysis (FTA). These methodologies help assess reliability along with failure modes of electric car systems. This assessment also includes analysis of these three methodologies and suggests countermeasures to mitigate system and sub-system failures.

The assessment starts with an introduction that includes the history and the methodologies to analyze automobile systems.

Following this, a Reliability Block Diagram (RBD) analysis is constructed using a study that collects failure data of various components of an electric car. Next, using questionnaires or reasonable assumptions, FEMA data collects and presents the data using the FMEA worksheet. Also, a fault tree is constructed and a fault tree analysis is performed. AND/OR logic gates provided assumptions for event failures. Finally, the report compares the differences between RBD, FMEA and FTA methodologies and discusses mitigation techniques for system and sub-system failures.

Introduction

The evolution of vehicles has led to significant advancements such as the development of safe, efficient and environmentally friendly vehicles. It is very important to ensure the reliability of vehicle systems with innovations. In this context, this report examines the history and methodology of automobiles used to analyze the automobile system and gain knowledge about challenges and opportunities in automotive engineering. This assessment uses 3 methods to identify potential failure modes, evaluate their impact, and suggest countermeasures: Reliability Block Diagram (RBD), Failure Mode Effect Analysis (FMEA), and Fault Tree Analysis (FTA). Each of these methods provides unique perspectives on reliability.

Task 1

* History

Although steam-powered vehicles were invented earlier, the history of the automobile in Europe begins with the development of the gasoline engine in the late 19th century. Pioneers such as Karl Benz and Gottlieb Daimler introducing the first gasoline-powered vehicles. Earlier all the automobile industries were small shops. When the United States invented mass production techniques, it influenced almost every industry in the world in the early 20th century. Mass production was originally attributed to Henry Ford's assembly-line methods, and the Ford Model T (1908-27) became the first automobile affordable to the common man. (Ford, 30 Jan. 2024,). America’s dominance of the automobile industry shifted to Western European countries and Japan in the second half of the 20th century. The widespread adoption of automobiles has led to societal transformations, including changes in urban planning, transportation infrastructure, and lifestyles. From more efficient internal combustion engines to a combination of hybrid and electric powertrains, technologies have evolved over time. Lightweight materials started to be used to develop various parts of the vehicle. To improve engine efficiency, technologies such as emission control fuel injection systems, turbocharging and variable valve timing were introduced. Advancements like Automated vehicles, Electric vehicles improved overall efficiency.

As engineers in the automotive industry strive to push the boundaries of innovation, ensuring the reliability of vehicle systems is paramount. Therefore, methods for analyzing automobile systems have evolved in parallel to meet the challenges of the increasingly complex automotive landscape. There are many methods to analyze the performance of automobile systems. Evaluating performance of systems such as engine, acceleration, braking and handling using the techniques like dynamometer testing, computer simulations, and real-world performance measurements. Tests such as crash tests, safety ratings, and computer simulations analyze

safety features such as crashworthiness, occupant protection, and accident-avoidance systems. Utilizing life cycle assessments (LCAs) to identify environmental impacts including energy consumption, resource depletion and emotions’ cause of failures are analyzed by the techniques such as reliability block diagram (RBD), failure mode effects analysis (FMEA), fault tree analysis (FTA)that increased reliability and durability of the system. (Binder, 27 Mar. 2024,)

* Reliability Block Diagram (RBD):

Reliability block diagrams (RBDs) are graphical representations of complex system failures and their sub-failures. RBD is widely used to analyze the reliability of engineering systems. Petri nets and higher-order-logic theory are recent techniques for analyzing RBD, but traditionally paper-and-pencil proofs or computer simulations have been used. (osman Hasan, 2015)

* Failure Mode Effects Analysis (FMEA):

A systematic approach to identifying potential failure modes that originated in early 1950s and 1960s, FMEA gained prominence in the automotive industry in the 1990s introduced by Ford Motor Company. It makes complex systems easier to analyze because of its simple structured, systematic and reliable analysis method. (Umut Asan, october 2015)

* Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a deductive analysis method developed by Bell Labs in the 1960s was used to detect component-level failures that cause system-level failures using "events" and "logic gates". (Hessing, 2020)

Task 2

**ON BOARD**

**CHARGER**

**(R1)**

**DC/DC**

**CONVERTER**

**(R3)**

**EMS**

**(R5)**

**BMS**

**(R6)**

**AUXILIARY**

**(R7)**

**ELECTRIC COMPRESSOR**

**(R8)**

**STEERING**

**(R9)**

**HV**

**BATTERY**

**(R2)**

**INVERTER**

**(R4)**

**MOTOR**

**(R10)**

**TRANSMISSION**

**(R11)**

* The given below table shows the reliability of an electric car components for 5years. (All datas are assumed)

|  |  |  |  |
| --- | --- | --- | --- |
| Components | MTBF/hours | Failure rate/hours | Reliability  R (43800) |
| **On board charger** | 52560 | .000019 | 0.435 |
| **HV battery** | 87600 | .000011 | 0.606 |
| **DC/DC converter** | 42000 | .000023 | 0.365 |
| **Inverter** | 68000 | .000014 | 0.541 |
| **EMS** | 14000 | .000071 | 0.044 |
| **BMS** | 15000 | .000066 | 0.055 |
| **Auxiliary** | 16000 | .000062 | 0.066 |
| **Electric compressor** | 87600 | .000011 | 0.606 |
| **Steering** | 61320 | .000016 | 0.496 |
| **Motor** | 52560 | .000019 | 0.435 |
| **Transmission** | 31000 | .000032 | 0.246 |

Reliability =

=1/MTBF

t=5years

Reliability equations,

Series:

Parallel: 1- (1 – …. (1 –

Reliability of first section

Reliability of R8 and R9(Parallel)

=1-(1 -

=1-(1-0.606) (1-0.496)

=0.801

Reliability of R3, R5, R6, R7, R8 and R9 (Series)

=R3R5R6\*R7\*R8\*R9

=0.365\*0.044\*0.055\*0.066\*0.801

=.0000466

Reliability of second section

Reliability of R4\*R10\*R11(Series)

=0.541\*0.435\*0.246

=0.057

Reliability of third section

Reliability of first section, second section and R2(Parallel)

=1-(1-.0000466) (1-0.606) (1-0.057)

=0.628

Reliability of whole system

=R1\*Reliability of third section

=0.435\*0.628

=0.273

Task 3

* Failure Mode Effects Analysis (FMEA)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Failure mode | Cause | S | O | D | RPN | Measures |
| **On board charger** | Semi-conductors  fault | High operating temperatures and frequent charging | 3 | 6 | 3 | 54 | Use high quality components |
| **DC/DC converter** | Semiconductors and capacitor failures | Overheating and voltage fluctuations | 6 | 6 | 3 | 108 | Avoid extreme loads |
| **EMS** | Software bugs | EMS is complex and chance to create bugs | 7 | 6 | 2 | 84 | Use updated hardware and software |
| **BMS** | Sensor malfunction | Over charging and under charging | 7 | 4 | 5 | 140 | Proper driver education |
| **Auxiliary** | Failure in HVAC system | Refrigerant leaking | 3 | 2 | 3 | 18 | Regular maintenance |
| **Electric compressor** | Compressor clutch issues | Wear and tear | 3 | 3 | 3 | 27 | Use quality parts |
| **Steering** | Electric motor issues | Over heating | 6 | 5 | 2 | 60 | Use efficient cooling system |
| **HV battery** | Degradation | Over time and repeated charging | 9 | 8 | 2 | 144 | Use advanced cell chemistries |
| **Inverter** | Control circuit malfunction | Component failure and software glitches | 7 | 6 | 4 | 168 | Advancement in circuit design |
| **Motor** | Abnormal noise | Bearing damage | 6 | 4 | 5 | 120 | Proper lubrication |
| **Transmission** | Power loss | Belt damage | 4 | 4 | 6 | 96 | Proper alignment of belts |

(All datas are assumed)

S = Severity

O = Frequency of occurrence

D = Chance of detection

RPN = Risk Priority Number = S\*O\*D

TASK 4

* Fault Tree Analysis (FTA)

**Electric car failure**

**DC/DC converter failure**

**Motor failure**

**Inverter failure**

**Bearing failure**

**Control circuit failure**

**Capacitor failure**

**Semi-conductor failure**

**Battery failure**

**Rotor failure**

**Control circuit failure**

**Over load**

**Voltage fluctuations**

**Frequent fast charging**

**Manufacturing defects**

**Short circuit**

**Physical damage**

**Over heating**

**Voltage fluctuation**

|  |  |  |
| --- | --- | --- |
| Sl. No | Root causes | Probability of failure |
| 1 | Voltage fluctuations (C1) | 0.2 |
| 2 | Over Load (C2) | 0.2 |
| 3 | Physical Damage (C3) | 0.2 |
| 4 | Frequent Fast Charging (C4) | 0.2 |
| 5 | Over Heating (C5) =(C2+C1) | 0.4 |
| 6 | Manufacturing Defects (C6) | 0.2 |
| 7 | Voltage Fluctuation (C7) | 0.2 |
| 8 | Short Circuit (C8) | 0.2 |
| 9 | Semi-conductor Failure (C9) =(C8+C7) | 0.4 |
| 10 | Control Circuit Failure (C10) | 0.2 |
| 11 | Capacitor Failure (C11) | 0.2 |
| 12 | Control Circuit Failure (C12) =(C6+C5) | 0.6 |
| 13 | Rotor Failure (C13) | 0.2 |
| 14 | Bearing Failure (C14) | 0.2 |
| 15 | Battery Failure (C15) =(C4+C3) | 0.4 |
| 16 | Motor Failure (C16) =(C15+C14+C13) | 0.8 |
| 17 | Inverter Failure (C17) =(C11+C12) | 0.8 |
| 18 | DC/DC Converter Failure (C18) =(C9+C10) | 0.6 |

(All values are assumed)

C = Cause

Probability Failure of Top Event (Electric car failure) =C18+C17+C16

=0.6+0.8+0.8

=2.2

TASK 5

* Preventive measures and Comparisons
* Measures to prevent system/sub-system failure
* Use high quality materials in EV components
* Proper supervision throughout the development process
* Use proper thermal management system
* Regular maintenance
* Focus on driver training and education
* Regular software updates
* Use advanced manufacturing techniques
* comparison

|  |  |  |  |
| --- | --- | --- | --- |
| ASPECTS | RBD | FMEA | FTA |
| **History** | Barlow and Proshan established the theoretical foundations of RBD in 1975, first introduced in the 1940s and adopted in automotive engineering by the Ford Motor Company in the late 1970s. | First introduced in the 1940s and adopted in automotive engineering with the publications of AIAG FMEA manuals in the 1990s | Developed in the 1960s by Bell Labs. (Hessing, n.d.) |
| **Methodology** | Using graphical representation that breaks down complex systems into series, parallel, or combination configurations of components. (corporation, 2021) | FMEA is a systematic approach to identify failure probabilities of components, their impact on system performance and counter measures. (Kent, 2016) | FTA builds a tree of all possible contributing events from a top-level event or failure using a deductive analysis method |
| **Focus** | Focus on analyzing system reliability and identifying critical factors by representing it in graphical form | The main focus is on identifying potential failure modes of processes evaluating their impact on system performance and prioritizing preventive measures to improve reliability and safety | FTA mainly focus on identifying combinations of event that cause high-level failure assessing their probabilities. (Kritzinger, 2017) |
| **Applications** | RBD often used in system design and optimization to analyze reliability and performance through redundancy or fault tolerance. (B.Gissler, 2015) | FMEA is widely used in product development and manufacturing process to improve reliability and quality | FTA commonly used to assess system vulnerabilities, identify critical failure paths, and guide risk mitigation strategies. (Hessing, 2020) |
| **Complexity** | Graphical block diagrams are easy to understand. Hence it is less complicated than FTA and FMEA | FMEA can be complex for complex systems as it analyzes possible failure modes and their effect on system performance | FTA can be complex, as it requires detailed knowledge of system components and failure modes in large inter connected systems |

Conclusion

This assessment went through the historical development of the automotive industry to know about the opportunities and challenges in the automotive industry. It also conducted a detailed exploration of three methods used in reliability analysis: Fault Tree Analysis (FTA), Failure Mode Effects Analysis (FMEA) and Reliability Block Diagram (RBD). Comparison of these methods helped to understand that each method has unique precautions for mitigating risk and improving system reliability. The combined use of these methods helped identify potential failure modes, assess their effects on system performance, and prioritize countermeasures to effectively mitigate risks.

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