Theory and Review of a Design Failure Mode and Effect Analysis

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Abstract

The DFME(C)A is a design tool used to systematically analyze postulated component failures and identify the resultant effects on system operations. The analysis is sometimes characterized as consisting of two sub-analyses, the first being the failure modes and effects analysis (FMEA), and the second, the criticality analysis (CA)Successful development of an FMEA requires that the analyst include all significant failure modes for each contributing element or part in the system. FMEAs can be performed at the system, subsystem, assembly, subassembly or part level. The FMECA should be a living document during development of a hardware design. It should be scheduled and completed concurrently with the design. If completed in a timely manner, The FMECA can help guide design decisions. The usefulness of the FMECA as a design tool and in the decision-making process is dependent on the effectiveness and timeliness with which design problems are identified. Timeliness is probably the most important consideration. In the extreme case, the FMECA would be of little value to the design decision process if the analysis is performed after the hardware is built. While the FMECA identifies all part failure modes, its primary benefit is the early identification of all critical and catastrophic subsystem or system failure modes so they can be eliminated or minimized through design modification at the earliest point in the development effort; therefore, the FMECA should be performed at the system level as soon as preliminary design information is available and extended to the lower levels as the detail design progresses.

Keywords - FMECA, FEA,CADD,PDM,DEN,CATIA, Effect, Design

Introduction

When first envisioned, Design Failure Mode and Effects Analysis (DFMEA) considered potential failures modes and their causes. It was first used in rocket science. Initially, the rocket development process in the 1950's did not go well. The complexity and difficulty of the task resulted in many catastrophic failures. Root Cause Analysis (RCA) was used to investigate these failures but had inconclusive results. Rocket failures are often explosive with no evidence of the root cause remaining. Design FMEA provided the rocket scientists with a platform to prevent failure. A similar platform is used today in many industries to identify risks, take counter measures and prevent failures. DFMEA has had a profound impact, improving safety and performance on products we use every day.

DFMEA is a methodical approach used for identifying potential risks introduced in a new or changed design of a product/service. The Design FMEA initially identifies design functions, failure modes and their effects on the customer with corresponding severity ranking / danger of the effect. Then, causes and their mechanisms of the failure mode are identified. High probability causes, indicated by the occurrence ranking, may drive action to prevent or reduce the cause's impact on the failure mode. The detection ranking highlights the ability of specific tests to confirm the failure mode / causes are eliminated. The DFMEA also tracks improvements through Risk Priority Number (RPN) reductions. By comparing the before and after RPN, a history of improvement and risk mitigation can be chronicled.

Risk is the substitute for failure on new / changed designs. It is a good practice to identify risks on a program as early as possible. Early risk identification provides the greatest opportunity for verified mitigation prior to program launch. Risks are identified on designs, which if left unattended, could result in failure. The DFMEA is applied when.

- There is a new design with new content
- There is a current design with modifications, which also may include changes due to past failure
- There is a current design being used in a new environment or change in duty cycle (no physical change made to design)

This paper describes the design and development of new mounting bracket replacing the old one. Commander Control station (CCS) is one of the accessories for the Armoured Fighting vehicle (AFV) sighting system and it is fitted on the mounting bracket in front of Commander's station at turret roof plate of the AFV. It displays the thermal images of the Gunner's main sight which is to monitor the Gunner Line of sight continuously by the Commander. During the trial, it was noticed that the existing ccs electronics units are malfunctioned. To know the cause of malfunction, it was planned to conduct the vibration analysis on the locations of cCs electronics units Subsequently the level of vibration on all the locations were recorded and analyzed for various operating track profiles. The spectrum plot of CCS location for all these track profiles shows the overall vibration levels in the frequency band of 20- 2000Hz are well within the qualified limit. Finite Element method is carried out applying shock load of 50g for 18ms in three different directions separately. It is found out from the shock analysis, when the shock load is applied in the Z direction, the maximum stress occurs as 177.6 MPa, which is less than the yield stress (210 MPa) of the mounting bracket material. It appears to be safe and the factor of safety is 1.2. Similarly Response spectrum analysis is also carried out the for the random vibration, with the PSD inputs. This simulation also shows that the design of mounting bracket is safe[1].

The usage of engine mounts is the best solution for dampening the effect of vibrations and transmitting forces between the engine and the automotive body structure. This paper deals with the topology optimization of engine mounting bracket of 'Chevrolet beat' using the tools CATIA V5R20 for modeling and Hyper works for finite element analysis. The main objective of the work is to minimize the weight of the engine mounting bracket by considering the design and material layout. For different material layout and different designs the stresses and weights are computed and compared to arrive ate the best model under prescribed conditions. It is observed that the maximum stress for all designs did not exceed the ultimate tensile strength for the corresponding materials. Based on the comparison of the weight reduction achieved in the three optimized designs, it can be concluded that the highest weight reduction has been obtained in design[2]

Radiator and engine, the major components of the generator are mounted on the base frame with the help of mounting brackets. These brackets are subjected to vibration during the working of the generator. Noise related problems that occur in mechanical structures are mostly due to vibrations. Excessive vibration results in structural damage. The structure itself has certain internal properties and it is important to understand its characteristics. This paper focuses on the derivation of transfer function of radiator brackets to express their dynamic vibration characteristics. The approach to derive the same comprises of finite element modelling of the radiator bracket, model validation, parameter identification based on sensitivity study and design of experiments to derive the transfer function. In this paper, transfer function for the first two bending frequencies of the bracket is developed with parameters that would significantly affect the fundamental frequency as inputs. The first two bending frequencies obtained from analytical method are compared with that from the finite element models and found to have good agreement. The transfer function developed will avoid expensive testing and time consuming simulations. It will also form a base to develop a more robust design.[3]

Abbreviation

Symbol	Description
CATIA	Computer Aided Three -Dimensional Interactive Application
FEA	Finite Element Analysis
FEM	Finite Element Method
SAE	Society Of Automobile Engineer's
MATLAB	Matrix Laboratory
CAD	Computer Aided Design
CADD	Computer Aided Design & Drafting
EDA	Electronic Design Automation
MDA	Mechanical Design Automation
CAGD	Computer Aided Geometric Design
DPD	Digital Product Design
PLM	Product Lifecycle Management
CAE	Computer Aided Engineering
CNC	Computer Numerical Control
PDM	Product Data Management
KE	Kinetic Energy
BP	Braking Power

Problem Statement

Optimization of weight has been very critical aspects of any design. It has substantial impact on vehicle performance, and in spin minimizes the emissions. This dissertation would focal point on the design gap offered by the element practical even as crucial the scenery and scope of the weight optimization more the areas acknowledged during design optimization.

Objective

1 To define and guide a logical design process.

2 To identify, quantify and reduce design risk.

3 To provide a traceable document for design and development.

4 To justify design activities.

5 To provide a means for continuous product improvement.

Responsibility & Scope

The DFMEA is a team function

- All team members should participate.
- Multi-disciplinary expertise and input is beneficial
- Input from all engineering fields is desirable.
- Representatives from all areas (not just technical disciplines) are generally included as team members.

The DFMEA is not a one meeting activity

- The DFMEA will be refined and evolve with the product.
- Numerous revisions are required to obtain the full benefit of the DFMEA.
- The DFMEA includes all systems, sub-systems, and components in the product design.

DFMEA Methodology

There are 11 steps to complete DFMEA.

1) Design Review.
2) Brainstorm Potential Failure Modes.
3) List Potential Failure modes.
4) List potential effects of failures modes
5) Assign the severity ranking.
6) Assign the occurrence ranking (1 to 10)
7) Assign detection ranking
8) Calculate SOD.
9) Develop action plan.
10) Implement the improvement identified.
11) Cakculate RPN and Do mistake proofing.

DFMEA Inputs

Product Design Requirements-

- Design requirement document.
- Legal and technical regulations.

Bill of Materials (BOM) and Specific Hardware.

- List of components
- Components and/or samples as supplied by the customer.

Product Definition

- Drawings, sketches, animations, and simulations
- Description of systems and components - What are the functions of the components listed on the BOM?

Previous Experience (Lessons Learned from Others)

- Experience with similar concepts, designs, and DFMEA
- Customer and supplier inputs.
- Design guides and design standards (for example ASME codes).

DFMEA Outputs

RPN: Risk Assessment Number

- RPN (Severity) x (Occurrence) x (Detection)
- Identification of both systems and components with high RPN values represents a summary of high risk items.
- Ranking of RPN to provide guidance on critical design issues Address the highest RPN items first.

Identification of Critical and Significant Characteristics

- This is also normally required by a customer.

The DFMEA is an Output to the Customer

- Be aware that the customer may be internal or external
- Internal customers may include other engineering groups or non-technical groups such as procurement, manufacturing, safety, etc.

Benefits

1) Identifies foreseeable failure modes and ranking failure according to their impact on the product

2) Analyzes product design before it is released to production.

3) It analyzes systems and subsystem's in early concept and design stages

4) It provides critical input for the planning of effective design test and development postage

5) It provides an open issue format for recommending and tracking risk reduction actions.

Clauses

1) Not understanding the DFMEA scope and objective.

2) Not going through the process of design control.

3) Only identifying problems, not solutions.

4) Having no control plan in place when a solution exists.

5) Not separating failure mode, cause and effect.

6) Ranking criteria too closely.

Conclusion

DFMEA is carried out, to list out all possible failures of the components, its causes and effects. Along with the severity of the failure modes, its likelihood of occurrence and detection are also determined.

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