DESIGN PROCESS IMPROVEMENT FOR ELECTRIC CAR HARNESS

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Abstract. In an automobile parts design company, the customer satisfaction is one of the most important factors for product design. Therefore, the company employs all means to focus its product design process based on the various requirements of customers resulting in high number of design changes. The objective of this research is to improve the design process of the electric car harness that effects the production scheduling by using Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) as the main tools. FTA is employed for root cause analysis and FMEA is used to ranking a High Risk Priority Number (RPN) which is shows the priority of factors in the electric car harness that have high impact to the design of the electric car harness. After the implementation, the improvements are realized significantly since the number of design change is reduced from 0.26% to 0.08%.

1. INTRODUCTION

Electric car harness is an equipment that connects to the automobile central nervous system. It consists of various wires bundled together, with which each individual wire is responsible for carrying the electric signals and energy used in the vehicles such as engine, lights, meters, navigation systems, power windows, doors, etc. This research is focuses on the problems occurred in the electric car harness design company in Thailand which is the designer of the electric car harness for Japanese and European passenger cars. The product named "electric car harness model 17M type T1" as shown in Fig. 1 is selected in this study since its designs are changed most frequent. At present, the company faces downward trend of the market share. Two key reasons come from customers are not satisfied with the products (measured by the customer satisfaction survey) and the design of the products is not match with customer needs. These two reasons are the key factors that lead to high number of design changes (1). Currently, the percentage of design changes per year is 0.26% which is higher than the 0.10% target set by the company. As a part history, the company has to improve the design process and eliminate the root causes to reduce the number of design changes so as to meet the target set by the company.
Figure 1. An example of the electric car harness designed by the company (Source: http://www.sws.co.jp/en/product/wireharness)

The historical design defect data from customer satisfaction survey reported between April 2015 to March 2016 illustrated by the Pareto chart (Fig 2) shows the major proportions of defects that effects to the high number of design change, including wrong wire size 15.29%, wrong electrical connection 10.59%, wrong type of wire and broken conductor 9.41%, protection part mistake 8.24%, protection part broken 7.06% and vibrating surface testing 7.06%. These problems are subjected to the improvement. The appropriate tools that are employed in this research are FTA (Fault Tree Analysis) [2] and FMEA (Failure Mode and Effect Analysis) [3] because they are the tools that can be easily used and cautiously analysed the problems.

Figure 2. Pareto chart of defects
Upon reviewing literature, FTA and FMEA techniques are two approaches that could be used to discover and prioritize root causes of failures. The analysis of the causes and modes of failures of the collector electro motors, used for cooling systems of motor vehicles, is presented in the paper. Vehicle cooling system is one of most important system for internal combustion engine security and safety. It provides that engine’s working temperature is in permit limits and without breakdown. Based on a detailed review of the structure and operation modes of the observed object and other relevant data, a fault tree for collector electromotor is formed. Thus, a logical relation between the peak event and the basic initiating events from the fault tree is established. In conclusion, the paper presents possible applications of the achieved results [4].

Now a days Reliability of any mechanical system is the most important factor of the product design, so the need for reliability estimation & prediction of critical modes of failure for mechanical system became the talk of the town. Lead acid battery which has been in use for different applications for over 13 decades. Their areas of application have transcended the traditional areas of automotive vehicle and have spread to newly developed area such as in traction of hybrid-electric vehicles, in un-interruptible power supply units and in telecommunication system for standby duties. The objective of this paper is to present the failure mode, its severity and effects on the service life of Lead Acid Battery. The Risk Priority Number (RPN) of the automobile battery based upon the failure data from a battery. This is very useful to understand Battery faults & maintenance [5].

2. IMPROVEMENT METHOD

To reduce the number of design changes, FTA and FMEA are applied for this research study. The purpose of applying FTA is to analyze in details for root-cause analysis and developing appropriate measures to prevent the recurrent of the problems. FTA uses a graphical representation to show the information about the faults that could be occurred in terms of logical probability. It enables to find causes-and-consequences connections of the breakdown elements. With the help of FTA, it is possible to analyze reliability for improving the defects related to design changes. The FTA of the aluminium electric car harness model 17M type T1 is shown in Fig. 3 which illustrates the causes of design changes found in the trial prototype of the car assembly process. From the causes of faults, we can determine the appropriate approach to improve the design of the products.
Figure 3. FTA of the design changes in the electric car harness

FMEA is a proactive analysis tool, allowing engineers to define, identify and eliminate known and/or potential failures, problems, errors and so on from the design process. Furthermore, FMEA is an inductive approach to support risk assessment studies and correction of defects. The risk priority number (RPN) is a mathematical product of the seriousness of a group of effects (severity), the likelihood that a cause will create the failure associated with those effects (occurrence), and an ability to detect the failure before it gets to the customer (detection). In the equation form, RPN = S*O*D, where S - Severity; O - Occurrence; and D - Detection. Severity is an assessment of the seriousness of the effect of the potential failure mode after it has occurred. The severity of the failure should be predicted and recorded on a 1 to 10 scale, which is called severity rating. Since the severity rating is based solely on the effect, and not the cause of the failure, it always remains the same, regardless of its possible causes. The “occurrence of failure” is related to the risk evaluation. In other words, occurrence is the probability that the failure mode will occur as a result of a specific cause. The estimate of the probability of the failure occurrence must be recorded by using all available knowledge and it would be ranked on a 1 to 10 scale. Detection is the probability that a potential failure will be detected before it reaches the customer. The detection rate should also be estimated based on a scale of 1 to 10. The meaning of different ranking scales used in FMEA is shown in Table 1 [6]. The working team of the company including head engineer, engineers and project leader discusses the rating scales of failure modes. With the approval of the section manager, the RPN with scoring higher 100 must be improved. The results of the FMEA meeting is shown in Table 2. The recommendations for corrective actions to improve the design process of the electric car harness are also discussed in the meetings.
Table 1. Severity Ranking, Occurrence Ranking & Detection Ranking

| Rank | Severity Ranking | Occurrence Ranking | Occurrence Ranking | Criteria | Criteria | Criteria |
|------|------------------|--------------------|--------------------|----------|----------|----------|
| 1    | No               | No effect          | Almost never       | Failures unlikely | Almost Certain | Proven detection methods available in concept stage |
| 2    | Very Slight      | Customer Not annoyed | Remote             | Very few Nos of failures likely | Very High | Proven computer analysis available in early design stage |
| 3    | Slight           | Customer slightly annoyed | Very Slight | Few Nos of failures likely | High | Simulation and/or modelling in early stage |
| 4    | Minor            | Customer experiences minor nuisance | Slight | Occasional High Nos of failures likely | Moderately High | Test on early prototype system element |
| 5    | Moderate         | Customer experiences Low | Medium Nos of failures likely | Medium | Test on preproduction |
| 6    | Significant      | Customer experiences discomfort | Medium | Moderately High Nos of failures likely | Low | Test on similar system components |
| 7    | Major            | Customer dissatisfied Moderately High | Moderately High Nos of failures likely | Slight | Test on product with prototypes and system components installed |
| 8    | Extreme          | Customer very dissatisfied | High | High Nos of failures likely | Very Slight | Proving durability test on Test on product with system components installed |
| 9    | Serious          | Potential hazardous effect | Very High | Very high Nos of failures likely | Remote | Only unproven or unreliable techniques available |
| 10   | Hazardous        | Hazardous effect | Almost Certain | Failure almost certain | Almost impossible | No known techniques available. |

Table 2. FMEA of design process for electric car harness.

| Failure Modes | Effects            | Causes | S | O | P | RPN | Recommendations |
|---------------|--------------------|--------|---|---|---|-----|-----------------|
| Use difference standard | Method broken conductor | 8 | 6 | 5 | 240 | Use documented design standard for work |
| Work standard is not setting | Method wrong type of wire | 4 | 9 | 7 | 252 | Use documented design standard for work |
| Tolerances are not consistent | Method protection part broken | 5 | 6 | 7 | 210 | Use documented design standard for work |
| Materials import | Material protection part mistake | 8 | 4 | 7 | 224 | Requiring the use of raw materials in a system control plan |
| Knowledge | Man wrong electrical connection | 8 | 8 | 4 | 256 | Use form of quality control to check by work flow |
| Skill | Man wrong wire size | 8 | 8 | 5 | 320 | Focusing on training of employees to comply with design standard |
| Tools defect | Machine vibrating surface testing | 5 | 6 | 5 | 180 | Check the computer program daily and control by annual maintenance plans |
3. RESULT AND DISCUSSION

The working team use FTA and FMEA are applied to reduce the number of design changes of electric car harness model 17M type T1. The results show that is very helpful to find the significant factors and analysis of the failures occurred in the design process of the electric car harness. The results of FTA indicate that the “defects” such as Man, Method, Machine and Material are the most critical components [7]. The RPN determined by FMEA is used to prioritize the failure modes that are urgently needed for corrective and preventive actions [8, 9]. In this case study, those failure modes with RPNs more than 100 are subjected to take actions immediately. The improvements could be performed by developing a new design working standard, control the procurement process of the raw materials from abroad, quality control of the design process to comply with the standard work flow, provide appropriate training to the designers, check the computer program daily and perform annual maintenance of the computers. After the improvement, the design change data are collected for 4 months. It is found that the design changes are reduced substantially from 0.26% to 0.08 % (Fig. 4 and 5). In addition, the designers understands the importance of controlling these processes to ensure that the performance is maintained or further improved in the future.

![Defect before Improvement process](image1)

**Figure 4.** The number of design changes before the improvement

![Defect after Improvement process](image2)

**Figure 5.** The number of design changes after the improvement
4. CONCLUSION

The objective of this research is to apply FTA and FMEA to reduce the number of design change occurred in the design process of the electric car harness. It is found that FTA and FMEA are effective tools to identify the significant factors and prioritize the root causes of the failure modes, as well as being a useful media to facilitate the recommendations for the improvements. The results indicate that the number of design changes is reduced from 0.28% to 0.08%, which is lower than 0.10% target set by the company. In addition, this results could be assessed in terms of the market share improvement of 5% increasing.

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