International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 160-163 22nd March 2014

Reliability Estimation using Fault Tree Analysis Method

[1]Sarfraz Ali Quadri, [2] Swapneel R. Zende, 3Dhananjay R. Dolas
[1, 2] M.E. (CAD/CAM),MGM's Jawaharlal Nehru Engineering collage, Aurangabad, MS., India
[3] Department of Mechanical Engg. GM's Jawaharlal Nehru Engineering collage, Aurangabad, MS., India
Corresponding Email: sarfrazaliquadri@gmail.com

Abstract— **Fault tree analysis (FTA) method was developed in1962 at Bell Laboratories by H.A Watson of U.S. Air force for the evaluation and estimation of system reliability and safety. In this paper we present the general procedure for FTA, its application in various fields and the modifications that have been made through the time to overcome the inadequacies of the method. For this work we consider the case-study of ball pen which we use for writing purpose & presented a simplified methodology to determine base cause failure of the system**.
.

.Keywords— **Fault tree Analysis (FTA), Ball pen, AND gate & OR gate etc**

I. Introduction

Fault Tree analysis translates the physical system into a logical diagram due to which it is one of the most favored method used these days by the people involved in reliability and safety calculations in industry. It was originated from aerospace industry and then adapted by nuclear power plant industry to qualify and quantify the hazards and risks involve in nuclear power generation. [1]. Fault tree analysis (FTA) is the most commonly used technique for causal analysis in risk and reliability studies. Fault tree analysis is a failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the field of safety engineering to quantitatively determine the probability of a safety hazard. Fault Tree Analysis (FTA) was originally developed in 1962 at Bell Laboratories by H.A Watson, under a U.S Air Force Ballistics Systems Division contract to evaluate the Minuteman I Intercontinental Ballistic Missile (ICBM) Launch Control System. The use of fault trees has since gained wide-spread support and is often used as a failure analysis tool by reliability experts. Following the first published use of FTA in the 1962 Minuteman I Launch Control Safety Study, Boeing and AVCO expanded use of FTA to the entire Minuteman II system in 1963-1964. [2]

Fault Tree Analysis (FTA) attempts to model and analyze failure processes of engineering and biological systems. FTA is basically composed of logic diagrams that display the state of the system and is constructed using graphical design techniques. Originally, engineers were responsible for the development of Fault Tree Analysis, as a deep knowledge of the system under analysis is required. [2] The generalized Fault Tree Diagram is as shown in Fig. 01.

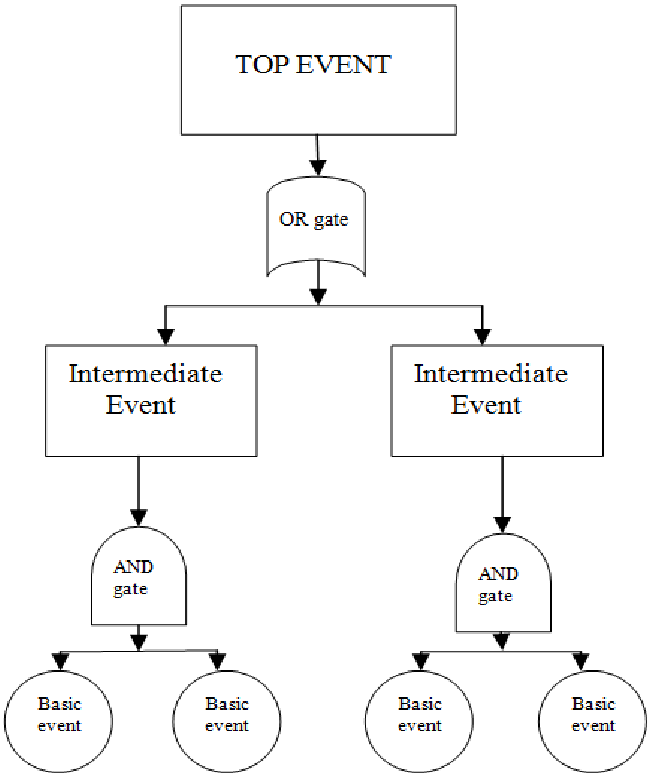


Fig.01 Fault Tree Diagram (FTD)

In the early design stage, formation of the fault tree allows the identification of potential failure modes; determine their causes and the connection between them. With the development of the project, fault tree is gradually developed and configured to cover all the changes in the project. Based on the results of FTA analysis, can be identified the critical elements of mechanical systems which have restrictive effect on reliable and secure operation of the system. Ranking of the critical components allows to the constructor to focusing attention on the elements that have the strongest impact on reliability. Therefore, he can easily take measures to minimize, or completely eliminate the cause of failure. In addition, the results can be also used in the abbreviated test for reliability assessment. [5]

II. Procedure of FTA

B.M. Ayyub the leading authority in the areas of risk analysis, uncertainty modeling, decision analysis, and systems

International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 160-163 22nd March 2014

engineering, describes the procedure for Fault-Tree Analysis in following 8 steps. [1]

- Define the system of interest: the boundaries of interest are defined in this step on which analysis is to be made along with the conditions of the system.
- Define top event of the system: Specify the problem on which the analysis will be made like shutdown, pipe rupture etc.
- Define tree top Structure: Define the events and the conditions that lead to the top event.
- Explore each branch in successive level of details: Determine the events and conditions that lead to the intermediate event and keep repeating this process at different successive levels unless the fault tree is completed.
- Solve the fault tree for the combination of events contributing to the top event: Examine all the event and conditions that are necessary for the top event to occur and develop a minimal cut set.
- Identify important dependent failure potentials and adjust the model appropriately: Study the event and find the dependencies among the event that can cause single or multiple events and conditions to occur simultaneously.
- Perform quantitative analysis: Use the past statistical data to evaluate or predict the future performance of the system.
- Use the results in decision making: Find the conditions in which the system is at most potential hazard and place appropriate measure and recommendations to counter with such risk.

III. Theoretical considerations & Symbols

Analytical trees are graphic representations or pictures of a project or event. They use deductive reasoning in that they start with a general top event or output event and develop down through the branches to specific input events that must occur in order for the output to be generated. Analytical trees are called trees because their structure resembles a tree, narrow at the top with a single event symbol and then branching out as the tree is developed. Negative analytical trees or fault trees are excellent troubleshooting tools. They can be used to prevent or identify failures prior to their occurrence, but are more frequently used to analyze accidents or as investigative tools to pinpoint failures. When an accident or failure occurs, the root cause of the negative event can be identified [2]. Each event is analyzed by asking, “How could this happen?” In answering this question, the primary causes and how they interact to produce an undesired event are identified.

This logic process continues until all potential causes have been identified. Throughout this process, a tree diagram is used to record the events as they are identified. Tree branches stop when all events leading to the negative event are complete. Symbols are used to represent various events and describe relationships:

There are five types of event symbols

Rectangle - The rectangle is the main building block for the analytical tree. It represents the negative event and is located at the top of the tree and can be located throughout the tree to indicate other events capable of being broken down further. This is the only symbol that will have a logic gate and input events below it.

Fig.02 Rectangle

Circle – A circle represents a base event in the tree. These are found on the bottom tiers of the tree and require no further development or breakdown. There are no gates or events below the base event.

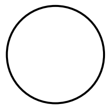


Fig.03 Circle

Diamond – The diamond identifies an undeveloped terminal event. Such an event is one not fully developed because of a lack of information or significance. A fault tree branch can end with a diamond. For example, most projects require personnel, procedures, and hardware. The tree developer may decide to concentrate on the personnel aspect of the procedure and not the hardware or procedural aspects. In this case the developer would use diamonds to show “procedures” and “hardware” as undeveloped terminal events.

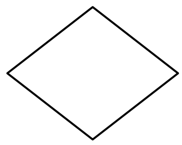


Fig.04 Diamond

Oval – An oval symbol represents a special situation that can only happen if certain circumstances occur. This is spelled out in the oval symbol. An example of this might be if switches must be thrown in a specific sequence before an action takes place.

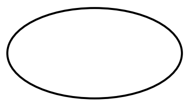
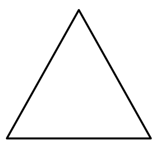


Fig.05 OVAL

Triangle – The triangle signifies a transfer of a fault tree branch to another location within the tree. Where a triangle connects to tree, everything shown below the connection point transfers to another area of the tree. This area is identified by a corresponding triangle that is connected to the tree with a vertical line. Letters, numbers or figures identify one set of transfer symbols from another. To maintain the simplicity of the analytical tree, the transfer symbol should be used sparingly.



International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 160-163 22nd March 2014

Fig.06 Triangle

AND gate - represents a condition in which all the events shown below the gate (input gate) must be present for the event shown above the gate (output event) to occur. This means the output event will occur only if all of the input events exist simultaneously.

Fig.07 (A) AND Gate, (B) OR Gate

OR gate - represents a situation in which any of the events shown below the gate (input gate) will lead to the event shown above the gate (output event). The event will occur if only one or any combination of the input events exists.

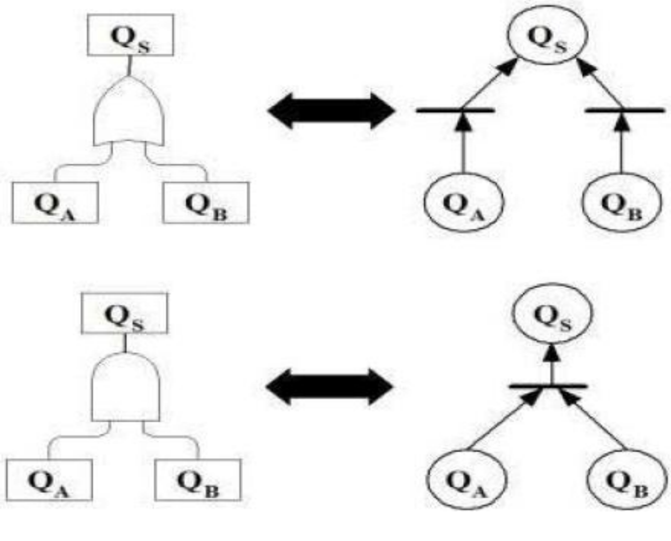


Fig.08 Basic Path of Logic Gates [5]

IV. Methodology & implementation of FTA for Ball pen

Many researchers have studied the reliability of different complex systems using FTA such as J. Negri & Dias has studied the reliability of Electro-Hydraulic system using FTA [6], Amit Kumar & Sneh Lata has studied reliability of piston manufacturing system using FTA [7] & B.B. popovic has studied reliability of A/C & ventilator system using FTA.

In this paper we have presented a case study & implementation of FTA to a simple writing ball pen to find out the basic elements of failure for the problem statement. In this we have followed the following steps:

1. We have decided the problem statement i.e TOP EVENT.
2. We studied the system thoroughly and distinguished the mode of failure viz. External and Internal problems separately.
3. We pick out the main elements of the system and distributed them in the mode of failure accordingly as INTERMEDIAT EVENTS.
4. In the last step we try to reason the intermediate events with accurate reasons viz. BASIC EVENTS.

The Fault Tree Diagram for the ball pen with the actual images of its basic components & accurate basic events of failure are shown in the following figures.

Fig.09 Full view of ball pen

Fig.10 Basic components of ball pen

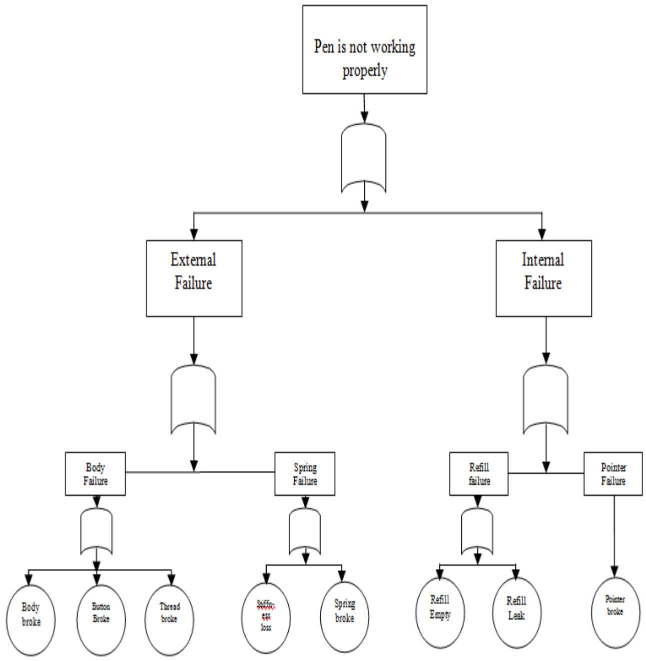


Fig. 11 Fault Tree Diagram

CALCULATION OF RELIABILITY FROM FAULT TREE

After having constructed the Fault tree for the Ball pen, the next step is the calculation of reliability of the system. To do this, we must remember that the events considered during the construction of the fault tree were the failures of the basic elements. Below we present the Reliability Block Diagram (RBD) of the Ball pen and its generalized formula to calculate the reliability of the Ball pen.

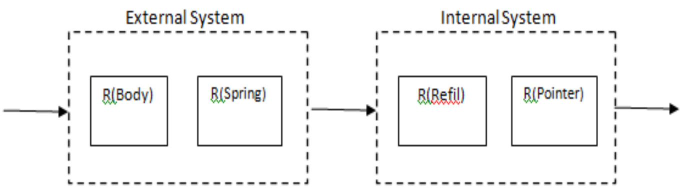


Fig. 12 Reliability Block Diagram (RBD) of Ball pen

As the above mentioned system is in series so the generalized formula to calculate the reliability of the system in series is,

$$R(System)_{series} = R(I^{st}\ System\ )\ X\ R(II^{nd}\ System\ )$$

Similarly in our case the reliability of the Ball pen is calculated by,

$$R(Ball\ Pen)_{series} = R(External\ System)\ X\ R(Internal\ System)$$

$$R(Ball\ Pen)_{series} = [R(Body)\ X\ R(Spring)]\ X\ [R(Refill)\ X\ R(Pointer)]$$

V. Conclusion

This paper presents the general methodology of Fault Tree Analysis for reliability assessment of engineering systems. FTA approach can be implemented for applications like writing Pen and to find the basic cause of failure of pen. This is top to bottom approach. FTA is useful tool for qualitative & quantitative assessment for Pen components & it is observed that in FTA the presence of reliability data is very important but its unavailability is a major problem for risk assessment. FTA method is more sensitive and effective than other reliability estimation methods.

Acknowledgments

We would like to thank our mentor Dr. Sudhir Deshmukh for their valuable co-operation & support, our guide D.R. Dolas for his understanding, kindness and humble guidance towards our research paper. All faculty members of Mechanical Engineering Department and especially the most, our families for their forever support.

REFERENCES

i. Ahmed Ali Baig, Risza Ruzli, and Azizul B. Buang "Reliability *Analysis Using Fault Tree Analysis: A Review",* International Journal of Chemical Engineering and Applications, Vol. 4, No. 3, 2013 pp-169-173

ii. Mohammad Sadegh Javadi, Azim Nobakht, Ali Meskarbashee, "*Fault Tree Analysis Approach in Reliability Assessment of Power System*", INTERNATIONAL JOURNAL OF ULTIDISCIPLINARY SCIENCES AND ENGINEERING, VOL . 2, NO. 6, SEPTEMBER 2011.

iii. E. Povolotskaya, P. Mach, "*FMEA and FTA Analyses of the Adhesive Joining Process using Electrically Conductive Adhesives*", Acta Polytechnica Vol. 52 No. 2/2012.

iv. Yi Zhang and Yan Bai, "*Reliability Analysis and Safety Evaluation of an Analog Output Module Based on FMEA and FTA*", 2011 International Conference on Computer and Automation Engineering (ICCAE 2011) IPCSIT vol. 44 (2012) © (2012) IACSIT Press, Singapore DOI: 10.7763/IPCSIT.2012.V44.11

v. B.B. Popović and N.J. Gligorijević, "*ANALYSIS OF CAUSES AND MODES OF FAILURE OF AIR CONDITIONER AND DC ELECTRIC-VENTILATOR, AS PARTS OF AUTOMOTIVE AIR CONDITIONING SYSTEM*", July 2013. Vol. 4, No. 1 International Journal of Engineering and Applied Sciences

vi. Gilson S. Porciúncula & Victor J. De Negri, "*RELIABILITY OF ELECTRO-HYDRAULIC EQUIPMENT: SYSTEMATIZATION AND ANALYSIS*", 18th International Congress of Mechanical Engineering November 6-11, 2005, Ouro Preto, MG

vii. Amit Kumar and Sneh Lata, "*RELIABILITY ANALYSIS OF PISTON MANUFACTURING SYSTEM*", Journal of Reliability and Statistical Studies; ISSN (Print): 0974-8024, (Online):2229-5666 Vol. 4, Issue 2 (2011): 43-55