Diagnostic Methods

Model Based Diagnostic Methods
Fault tree (FT)
part 2

Outline

- Introduction
- Fault tree Analysis
  - Qualitative analysis
    - Example 1
  - Quantitative analysis
    - Example 2
  - References

Introduction

- There is a need to analyze all the possible failure mechanisms in complex systems
- This can be achieved by performing qualitative and quantitative analyses for the expected failures

Fault tree Analysis

- To perform the fault tree analysis, these steps should be applied:
- Definition of the system, the TOP event (the potential accident), and the cause-effect relationships
- Construction of the fault tree
- Identification of the minimal cut sets
- Qualitative analysis of the fault tree
- Quantitative analysis of the fault tree
- Reporting of results

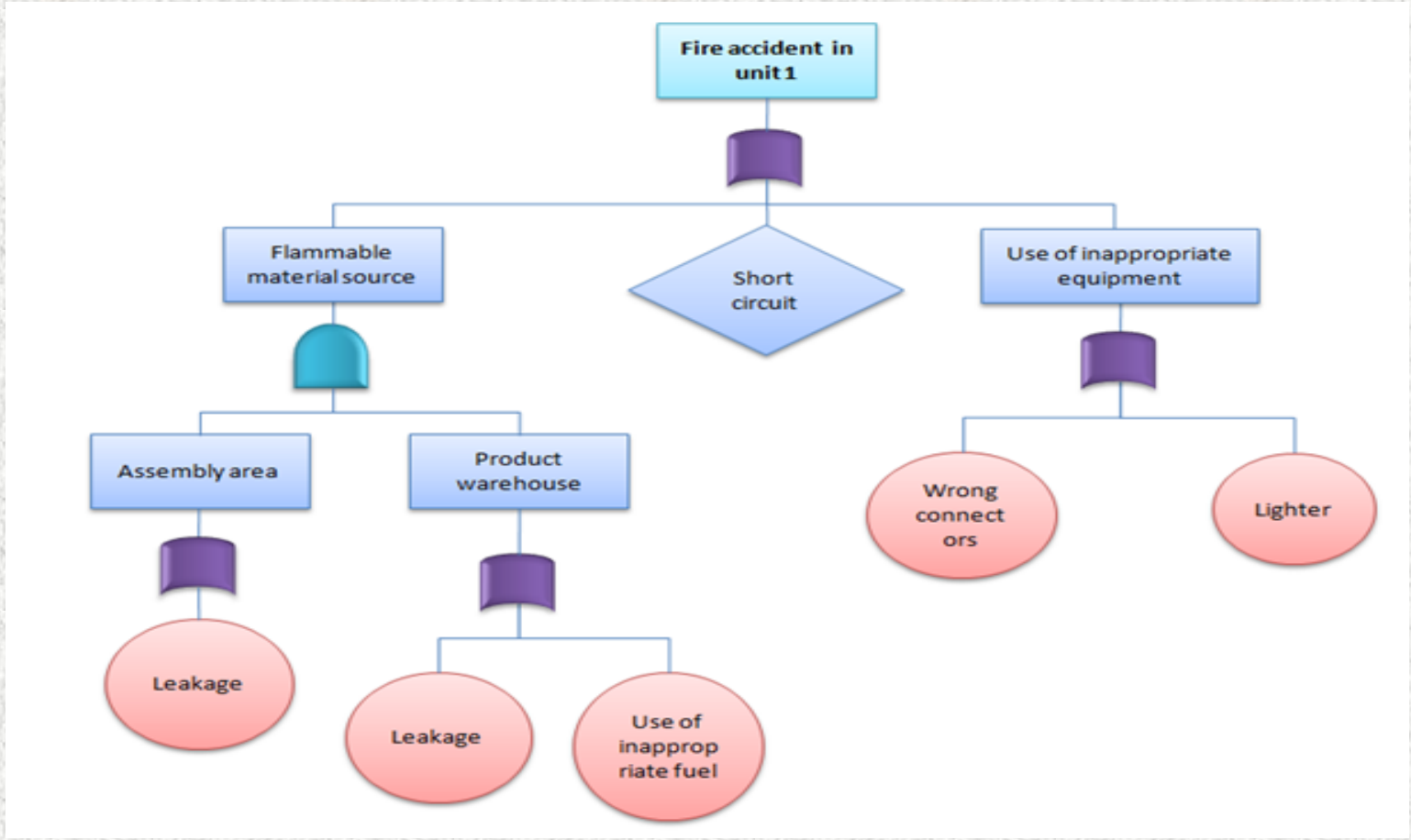
Fault tree Analysis

- A cut set in a fault tree is a set of basic events whose (simultaneous) occurrence ensures that the TOP event occurs
- A cut set is said to be minimal if the set cannot be reduced without loosing its status as a cut set
- The TOP event will therefore occur if all the basic events in a minimal cut set occur at the same time

Qualitative analysis

- The TOP event occurs if one of the minimal cut sets occurs
- The main challenge is therefore to identify the minimal cut sets
- Qualitative analysis of the fault tree may include:
  - Analysis of minimal cut sets to identify and verify any single points of failure
  - Review minimal cut sets up to check if there are dependencies

Example 1


Fire accident in unit1
Flammable material source
Short circuit
Use of inappropriate equipment
Assembly area
Product warehouse
Wrong connect ors
Lighter
Leakage
Leakage
Use of inapprop riate fuel

Example 1

- We can from this small fault tree identify the following cut sets:
  - C1 = {leakage}
  - C2 = {leakage, use of inappropriate fuel}
  - C3 = {short circuit}
  - C4 = {wrong connectors, lighter }
- With larger and more complex fault trees we need to use special tools (implementing algorithms for extraction) of minimal cut sets.

Quantitative analysis

- It uses top event reliability information to estimate failure frequencies and likelihoods, and relative importance of various failure sequences and contributing events
- Use statistical characterizations regarding the failure and repair of specific events and conditions in the fault tree model to predict future performance for the system.

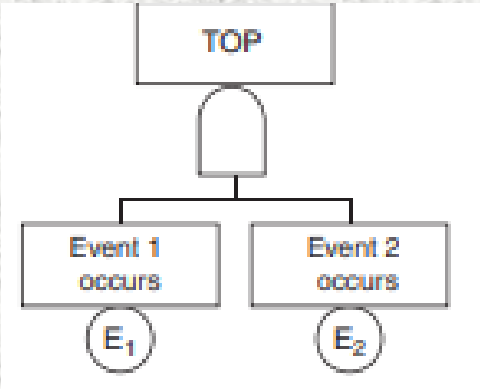
Quantitative analysis

- Single AND-gate

  $Q0(t) = Pr(\text{The TOP event occurs at time } t)$

  $Q0(t) = Pr(E1(t) \cap E2(t))$

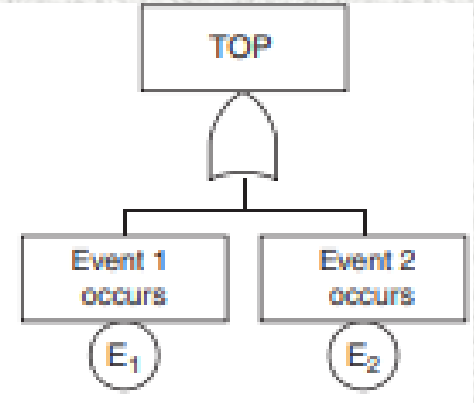
  $= Pr(E1(t)) \cdot Pr(E2(t))$



- Single OR-gate

  $Q0(t) = Pr(E1(t) \cup E2(t))$

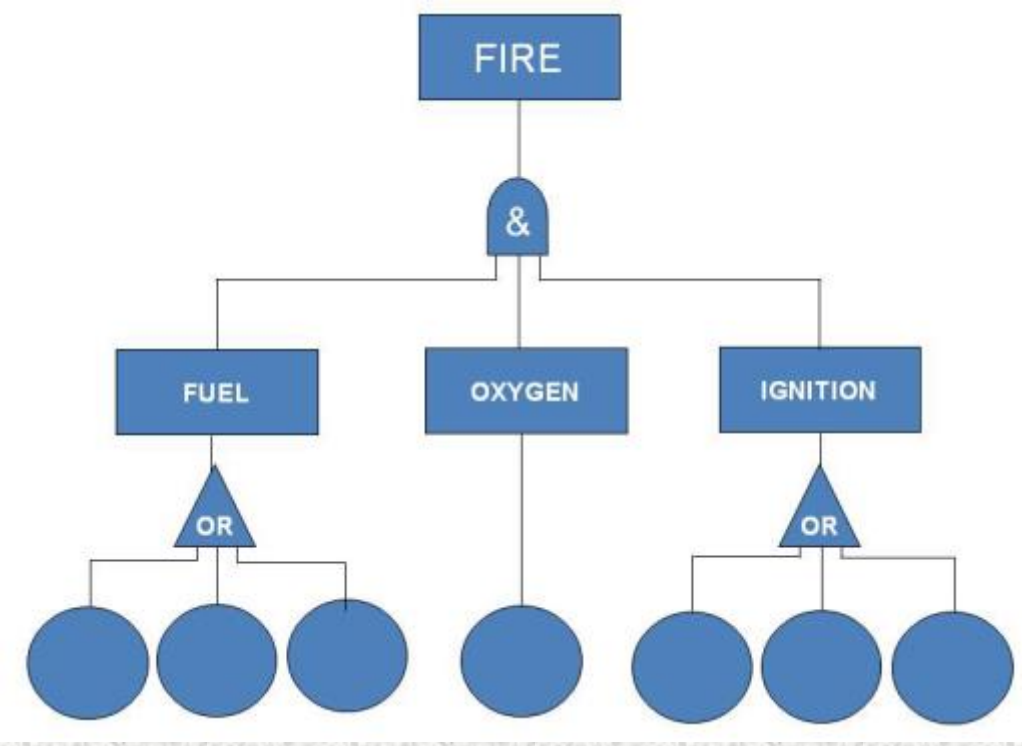
  $= Pr(E1(t)) + Pr(E2(t))$



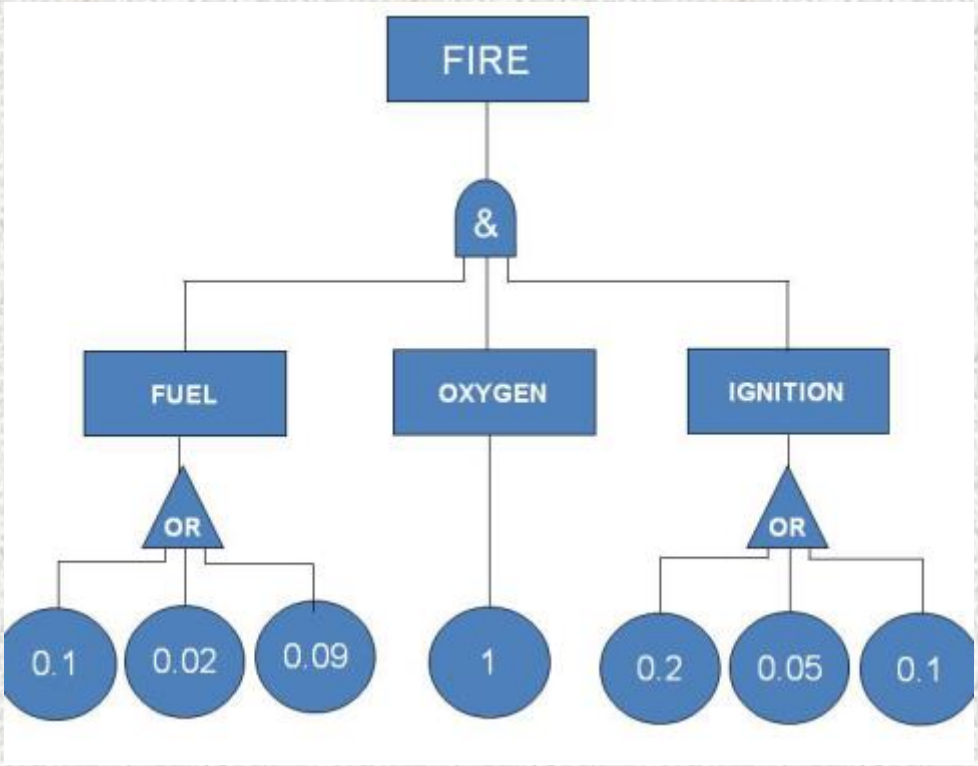
Example 2

- Construct a simple fault tree for a fire
- For the fire to occur there needs to be:
  - Fuel.
  - Oxygen.
  - An ignition source
- A probability for each of the primary failures being present or occurring can be established, is also provided

Example 2



Example 2

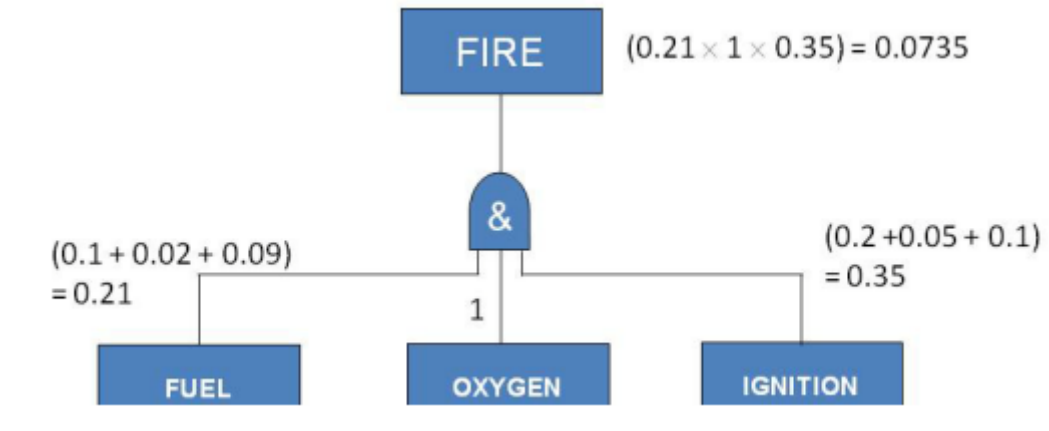


Example 2

- Add the probabilities which sit below an OR gate (this isn't strictly correct, but is a 'rare event' approximation).
- Multiply the probabilities which sit below an AND gate
- So, in this example, combining probabilities upwards to the next level gives:
  - Probability of FUEL being present = 0.1 + 0.02 + 0.09 = 0.21
  - Probability of OXYGEN being present = 1
  - Probability of IGNITION being present = 0.2 + 0.05 + 0.1 = 0.35

Example 2

- The probability of a fire to occur is 0,0735



References

- Slides related to the book:
  - System Reliability Theory Models, Statistical Methods, and Applications Wiley, 2004
- Training, R. R. C. "Identifying Hazards, Assessing and Evaluating Risks." *NEBOSH National Diploma in Occupational Health and Safety* (2010).