RODON®

Tolerance Based Simulation & Automated FMEA generation in Aircraft Elevators

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How to improve supportability, affordable readiness & RTOC?

Our basic approach:

- Seamless math-based data flow from Engineering data to FMEA and Service Information

This leads to:

- Reduced costs
  - Lower development costs for FMEA & Service Information (FDI) generation

- Improved Quality
  - More complete and accurate FMEAs & Troubleshooting Procedures

- Reduced Lead times
  - Design validation early on in the development process
  - Early Availability of Service Information (FDI)
How can a math-based seamless data flow be achieved?

By using a software tool which allows

- To create a simulation model of a system based on its
  - Functional behavior

- To have analysis capabilities available for
  - Validation of functional design & Risk analysis
  - Diagnostics (FDI)
  - Non-functional attributes
    - like cost, mass for early on requirements analyses
    - Failure probability on component level for FTA

=> Both requirements are fulfilled by the model-based software tool RODON
RODON - Application Areas

RODON is a Software-Tool for System Integration based on the analysis of the functional behavior of the components.

**Requirements, Specifications** → **Design & Dvlpmnt.** → **Integration & Prototyping** → **Manufacturing** → **Maintenance, Operational Service**

**Simulation, Consistency Checks**

**Risk Analysis**
- FMEA
- SCA
- FTA
- other

**Requirements Analysis**

**Monitoring**

**Diagnostics**
- Model based (MBD)
  - On Board
  - Off Board
- Model supported (MSD)
  - Decision Trees
  - Diagnostic Rules
  - State Based Reasoning

**RODON**
Virtual Product Model VPM

**Engineering data base:**
Net lists, Communication Tables, Component behavior, ECU Behavior
RODON
Modeling I - Components

Model Visualization

Model Description - Transfer Functions
Highlights & Features:
- Description of **Nominal Behavior**
- Hierarchical Model Structure based upon BOM
- **Multidirectional Determination** of all Values of the System
- Qualitative and quantitative Values
- Representation of **Tolerances** as Intervals
- Steady State and Dynamic Analyses
- **Top-Down** and **Bottom-Up** Approach
- Definition of **Failure Modes** on Component Level
- Straight Forward Variant Handling
The RODON Process

- Generates Models Automatically from Design Data
- Generates all Analyses by calculation from one Model

Engineering data base
- Net lists
- Communication Tables
- ECU Behavior
- Component Behavior

RODON Modeling System

RODON Simulation System

RODON Compressor & Formatting System

Results of Analyses
- FMEA
- FTA
- SCA
- Decision Trees
- Diagnostic Rules

Generation of
- Risk Analyses
- Diagnostic Knowledge

Model Based Diagnosis

CAD Schematics

RODON System Model

RODON State Database

FMEA

RODON Decision Tree

Diagnostic Rules
Example: Project with Aircraft Manufacturer
Aircraft Elevator - Fly by wire system

System consists of:
- **Hydraulic** control loop
- Controller **Logic**
- **Electrical** Wiring
**Tasks:**
- Simulate maximum deviation of actual value from set point depending on tolerances & offsets of inputs
- Investigate impact of tolerances & offsets on behavior of monitors
- Investigate impact of failure modes on behavior of monitors

**Methodology:**
- Create RODON Virtual Product Model
- Simulation with Tolerances for time-dependent systems
- Failure-Mode-Simulations for time-dependent systems

**Additional benefits concurrently to the simulations:**
- Automated FMEA generation for dynamic systems
- Generation of Troubleshooting Procedures

**Example:** Aircraft Elevator - Fly by wire system
Example: Aircraft Elevator - Fly by wire system
Create RODON Virtual Product Model
**Example:** Aircraft Elevator - Fly by wire system

Tolerance-Simulations with RODON

- Sensor-tolerances
- Offsets

Elevator position versus time after stimulation with a step function.

Black: no offsets & tolerances
Yellow / cyan: upper boundary of tolerances & offsets
Red / green: lower boundary of offsets and tolerances

Servo-valve position versus time, controlling the elevator position.
Example: Aircraft Elevator - Fly by wire system

Failure Mode Simulations

Elevator position versus time. "Run-away" situation.
Failure mode is Enabling Valve EV1 "STUCK_ACTIVE".
Effect: Main Servo Valve is closed; no control possible. Elevator runs away due to air loads.

Servo Valve position versus time for all offsets and tolerances. Position of Servo Valve has no influence on elevator due to closed Main Servo Valve.
**Example:** Aircraft Elevator - Fly by wire system

**Excitation of Monitors**

Sensor-Monitoring of sensor LVDT of Servo Valve SV. Monitoring behavior as expected.

Black curve: Simulation with no offsets and tolerances.
Colored curves: Simulations with offsets and tolerances.

Position-Monitoring of Servo Valve SV. Monitor activated due to offsets and tolerances.

*Unexpected Monitoring behavior!*
Example: Aircraft Elevator - Fly by wire system

Results of the analysis

- Maximum deviation of actual value from set point due to the offsets and tolerances were larger than specified

- Offsets & Tolerances have significant impact on Monitoring for both
  - the nominal behavior mode
  - failure modes
**Example: Aircraft Elevator - Fly by wire system**

Additional benefits - **FMEA**

System **FMEA** for dynamic- and tolerance-based systems; generated automatically out of the same RODON Virtual Product Model.

FMEA was used to check the controller's self diagnostics and monitors for about 300 failure modes.

**Potential Effects:**
- Observable and measurable variables of the hydraulic system

**Indications:**
- Monitors
- Diagnostic Trouble Codes
Example: Aircraft Elevator - Fly by wire system

Additional benefits - **Simplified Fault Trees**

- Elevator too high
- Elevator too low
- Elevator stuck

**Simplified Fault Trees:**
Symptom -&gt; possible causes relationship
Example: Aircraft Elevator - Fly by wire system

Additional benefits - Troubleshooting Procedures

Automated generation of Troubleshooting Procedures (Decision Trees) out of the same RODON Virtual Product Model.
Additional benefit - Compliance checks for integration and test phases

Compliance checks between specifications and the real, physical system according to the “V”-Model can be performed by using RODON’s Model-Based Diagnosis (MBD) - Function.
RODON supports the following tasks using the same RODON Virtual Product Model:

- Analysis of the design
- Automated Risk Analysis: FMEA, simplified FTA, Sneak Circuit Analysis (SCA)
- Automated generation of troubleshooting procedures and diagnostic rules
- FDI analysis of the design
- Coverage analysis in the design stage
- Subsystems’ integratibility tests by Virtual Prototyping
- Identification of fault conditions for ECU
- “Executable" FMEA with Math Based Model
- **Reduces Effort**
  - To generate FMEA, FTA and diagnostic Information
  - Creates “Technical Memory” over successive programs

- **Improves Quality:**
  - More complete and accurate results by using math based process

- **Reduces lead times** by early analysis of design
  - Getting Errors out Early

- **Early Availability:**
  Diagnostic Information available at Integration & Test phase
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