Experience in developing Digital Twins to support operation and maintenance of French nuclear plants

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Overview

A set of mature technologies
- Numerical simulation
- Physical measurements
- Data processing

Enabling to create Digital Twins
- Main characteristics of Digital Twins

Example for O&M of nuclear power plants: containment building Digital Twin

Conclusions & Perspectives
Simulation

Some breakthroughs of the last 30 years

Non linear solvers
Transient algorithms
Advanced constitutive laws
Multi-phase flow
Mesh adaptation
Parallel computation
Multi-physics
Multi-scale
Probabilistic approaches
Data assimilation
Simulation platforms
Environments to develop/run/analyse

Air intake in a pump
Advanced simulation

A set of skills and tools for various applications

During the last 30 years EDF R&D and his partners has built a quite comprehensive advanced simulation capacity, based on numerical tools and methodologies.

This asset benefits to all group activities: electricity generation, distribution, services.

- Nuclear reactor applications

  - Tightness of the containment vessel
  - Resistance to projectiles impact
  - Seismic Analysis
  - Environmental impacts
  - Behaviour of alternators
  - Behaviour of turbines
  - Tightness of the primary loop
  - Control of nuclear reactions
  - Behaviour of the pressure vessel
  - Dismantling Waste Storage

- OPEN-SOURCE
- MULTI-PHYSICS
- HIGH PERFORMANCE COMPUTING
- INDUSTRIAL TOOL NEEDED TO BE APPROVED BY SAFETY AUTHORITIES
Physical measurements

No data analysis without data

Different kind of measurements

• For design: geometry, material properties
• For maintenance: actions correctives réalisées
• For process operation: pressure, temperature, flow rates…
  online
• For process monitoring: online or offline
• For control: non destructive control,…

With a lot of recent progress

• Development of scanners
• Development of tomography
• Development of wireless technologies
• Continuous improvement of sensors (representativeness, reliability, lifetime,…)
• Improvement of related tech: communication, storage, data analysis
Towards Digital Twins

All necessary components are available to build Digital Twins

Progress in Data technologies:
- Storage
- Data analytics
- Big Data
What is a Digital Twin?

No standard definition but a set of common features

The Digital Twin of an industrial component or system (« object ») is a digital image of it, based:

• On a virtual representation relying either on the physics (model centric) or on a data analysis (data centric), or on both
• On a connection with the real object, allowing the twin to be updated with the received data

The value raised by a Digital Twin comes from its own features:

• **Individualize** decisions according to *each* object
• **Extend** the observation domain (limited in the real world) to the whole model
• **Forecast** the future object behavior based on an optimal knowledge of its state at each time
Containment building Digital Twin
An example for O&M optimization of nuclear power plants

What is at stake?

- Containment shall respect leakage threshold
  - A test is performed every 10 years to measure containment leakage rate
  - A polymer coating can be placed on the surface of the internal wall to reduce leakage. Nevertheless, this preventive maintenance operation is expensive and should be optimized.

1000 m² ≈ 5 M€ + 15 working days

=> R&D program to bring an innovative solution
Digital Twin: a software ecosystem around VERCORS

3 specific tools were developed especially for VERCORS:
1) **SYSACC**: requirement for structuring (data models) and keeping the data (database)
2) **ARMORIC**: coherence and capitalization of the studies process
3) **CERVIN**: rapid accessibility to study and test results

An “interoperable” organization built around VERCORS to last until the end of the experiment
Results: forecasting the ageing and predict effect on leaks

- Ageing of VERCORS (Pre-stress, Decennial Tests)
- Leakage prediction of VERCORS

Extrapolation to real containment buildings to optimize maintenance works

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Digital Twins form a new stage of engineering and analysis tools, to tackle more and more complex systems

Already successfully used to support different objectives related to design/operation/maintenance/end of life of an industrial “asset”

A successful example has been shown in the field of maintenance optimization of big components of nuclear plants, others are currently under development

This raises new scientific, technical and organizational challenges
  - Handling and maintaining the inherent complexity (sensors, communication, data, simulation tools)
  - Beware of multi-purpose digital twin
  - Real time with detailed physical models
  - Capability to “update” the twin in real time
  - Acceptability: users, regulators