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Prevention of Corrosion Deposition in Heat Exchangers via Root-Cause Analyses

Multidisciplinary Deposition Analyses for Heat Exchangers

Framatome's multidisciplinary numerical root-cause analysis for local deposition of corrosion products on the heat transfer surfaces of heat exchangers delivers valuable input for mitigation measures.

Challenge

Heat exchangers such as boilers, evaporators, steam generators are part of many industrial processes in chemical or petrochemical plants. The **heat transfer surfaces** in those heat exchangers are subject to **deposition of corrosion products** with consequences in **maintenance**, **downtime** and component **failure**.

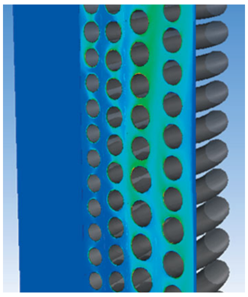
The complex **relationship** between the water chemistry, fluid- and thermodynamics and deposition of **particulate solids** acts as a barrier in understanding the **root-causes** of the **failure** or **low-efficiency operation** of the component. The assessment of the degradation phenomenon covers **multidisciplinary approaches** in which all interacting **parameters** are simultaneously **analyzed**.

Solution

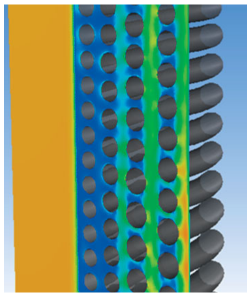
Framatome's methodology predicts the **local deposition** of corrosion products on **heated surfaces** of heat exchangers taking into account the effects of the **fluid- and thermodynamics, transport of the particulate deposits**, properties of the **water chemistry** and realistic geometry. The simulation of the complex three-dimensional **turbulent, two-phase and particle-laden flow** is performed with a extended state-of-the-art Computational Fluid Dynamics (CFD) code.

The calculated deposition location and behavior, distribution of key flow variables like: **velocity, temperature and heat flux, boiling behavior** combined with the water chemistry and particle properties provide an insightful **3D reproduction of the degradation** at current operation as well as enhanced information to derive potential causes.

Additionally, the impact of **individual parameters** on the deposition behavior can be analyzed in detail and **preventive measures** developed. Customers will be able to review their component design as well as to analyze invest and gains of adjustment measures.



Contours of Void-fraction



Flow Velocity

Flow variables (top) and deposition patterns (bottom) on the heat transfer surfaces of the coils of an oil-industry boiler.

Customer benefits

- Multidisciplinary expertise in numerical simulation of fluids, water chemistry, material corrosion, corrosion deposition and cleaning of steam generators.
- Long-term experience in numerical simulation of fluids and deposition of corrosion products.
- Gain access to cutting-edge cleaning techniques originating from worldwide nuclear steam generator cleaning projects.
- Derive mitigation actions to increase plant performance by knowledge of HX limiting operation phenomena and drawbacks.

Your performance
is **our** everyday **commitment**

Technical information

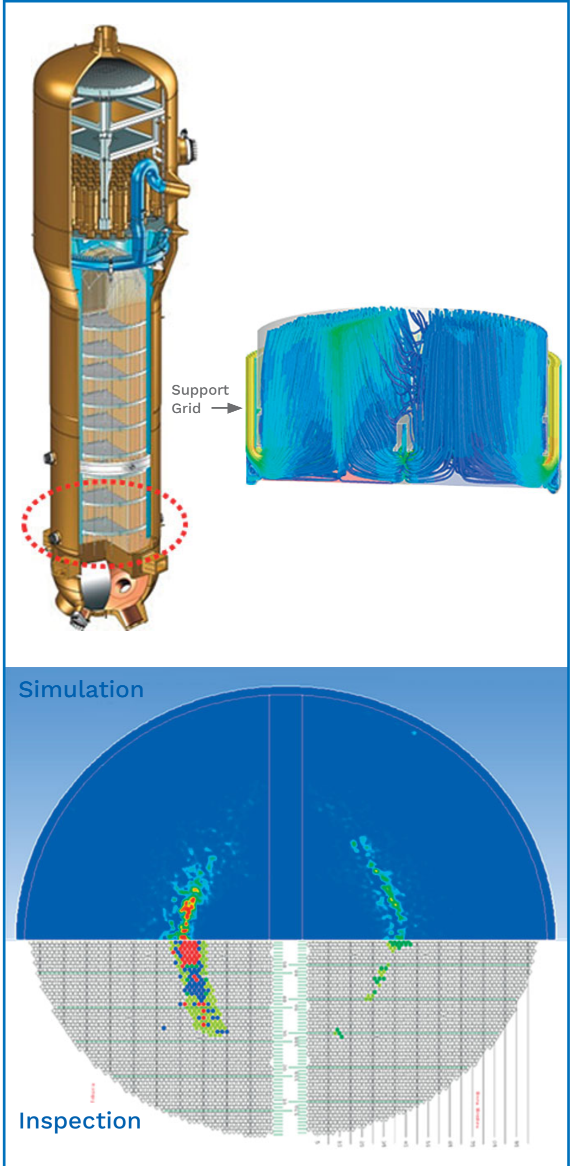
Fluid- and thermodynamics but also by the secondary-side water chemistry strongly affect the deposition of particulate impurities like corrosion products in heat exchangers. Therefore, the transport of insoluble magnetite is calculated with a multi-disciplinary approach of turbulent two-phase flow using an extended Computational Fluid Dynamics (CFD) code.

A state-of-the-art multi-phase Euler model and mass and energy transfer models are applied for evaporation and condensation in the two-phase flow calculation. The transport of the magnetite particles to the heated surfaces is calculated in a Lagrangian frame. The developed deposition criterion on the surfaces of the HX considers:

- Fluid dynamics: flow velocity, temperature, heat flux, void fraction
- Particle properties: density, size distribution
- Water-chemistry: electrostatic interaction energy between metal surface and particles using the DLVO (Derjaguin, Landau, Verwey and Overbeek) model.

DLVO model is based on the concept of an existing energy barrier caused by the double-layer interactions between particles and surface. Local effects of diffusion transport, boiling, gravity and removal forces on the deposition are included to the calculated deposition load in form of deposition coefficients. Water-chemistry properties like Zeta potential, ionic strength play a role in the deposition calculation.

The calculation method has been validated against data from inspections in steam generators with different designs and applied successfully to an oil-industry boiler.



Simulation of a nuclear steam generator with CFD. Flow velocity inside the tube bundle (top). Deposition patterns on the tube sheet (bottom)

References

- Multiple projects for nuclear steam generators in Nuclear Power Plants (NPP) worldwide with focus on cleaning, corrosion protection by Film-Forming-Amines (FFM) and water-chemistry optimization.
- Flow simulation and **deposition assessment** in NPP **steam generators** (Spain, The Netherlands)
- Flow simulation and **deposition assessment** in a **steam generating cooler** of petro-chemistry/refinery plant (The Netherlands)

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