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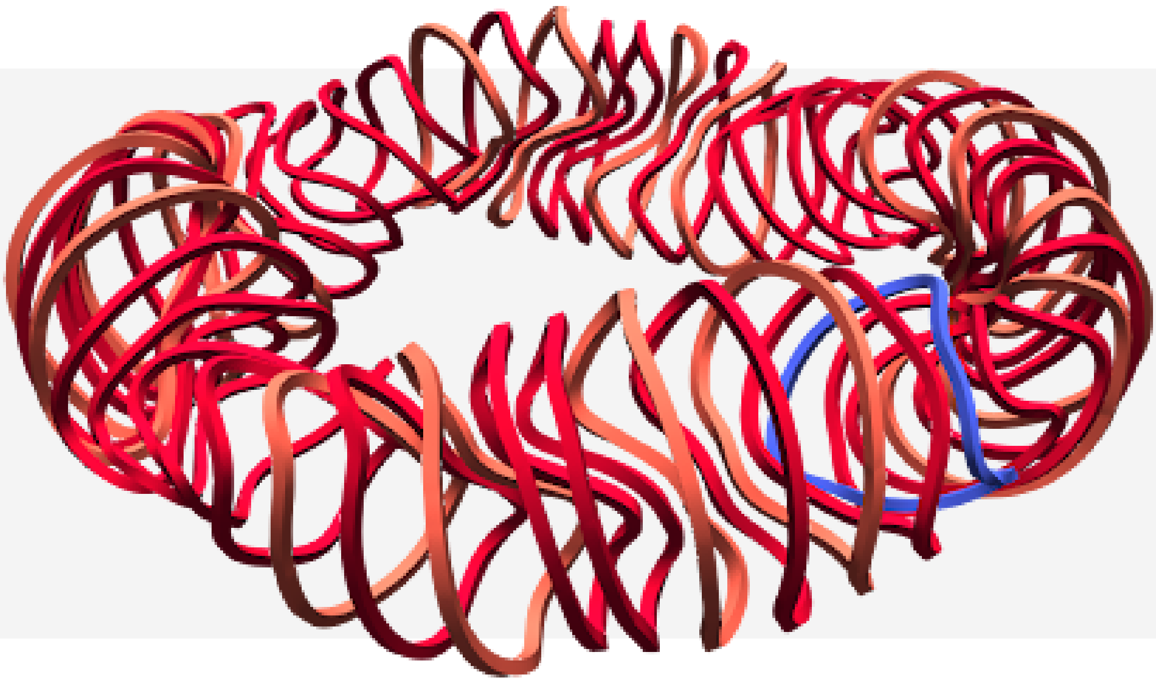


Quanscient Webinar 26th Sep 2024 | Executive summary

Accelerating fusion reactor design with cloud-based multiphysics simulations

See how cloud computing and modern formulations enable more efficient stellarator and HTS magnet design

Contents

Overview

This webinar covered the complexities and solutions associated with designing HTS magnets and stellarators for fusion reactors. Participants gained insights into the transformative role of cloud computing in managing large-scale simulations and overcoming the challenges posed by time-consuming design workflows, high aspect ratios and intricate geometries where symmetries can't be exploited. Through a live demonstration, the webinar also highlighted the advantages of the thinshell method, allowing for efficient modeling of thin layers in complex geometries without the need for explicit volume meshing.

Dr. Nicolò Riva from Proxima Fusion presented the real-world applications and outcomes of cloud-based multiphysics simulation software, Quanscient Allsolve, demonstrating the practical impact of advanced simulation tools and automated workflows in fusion research and development.

WATCH THE WEBINAR RECORDING

About the speakers

Dr. Mika Lyly

Senior Solutions Specialist, Quanscient

Dr. Mika Lyly has an extensive background of more than a decade in the field of applied superconductivity and more than four years of experience in electricity distribution. Mika's work has included developing FEM formulations in areas such as electromagnetics, device design, and experimental research.

Dr. Nicolò Riva

Magnet Engineer, Proxima Fusion

Dr. Nicolò Riva is a leading researcher in applied superconductivity, specializing in the development of HTS magnets for fusion energy. With postdoctoral experience at MIT, collaborating with Type One Energy and Commonwealth Fusion Systems (CFS), he brings a deep understanding of HTS applications in fusion.

Challenges and introduction to the thinshell method

FULL 14-MINUTE SECTION ON YOUTUBE

Modeling challenges in fusion applications

Dr. Mika Lyly discussed the difficulties in simulating fusion devices due to high aspect ratios and complex geometries, which often lead to computationally expensive simulations.

The thinshell method as a solution

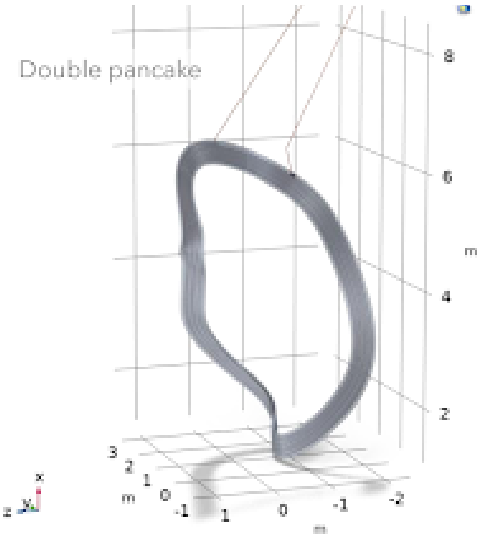
He introduced the thinshell method in Quanscient Allsolve, which simplifies geometry and meshing by representing thin 3D volumes as surfaces or 2D surfaces as lines.

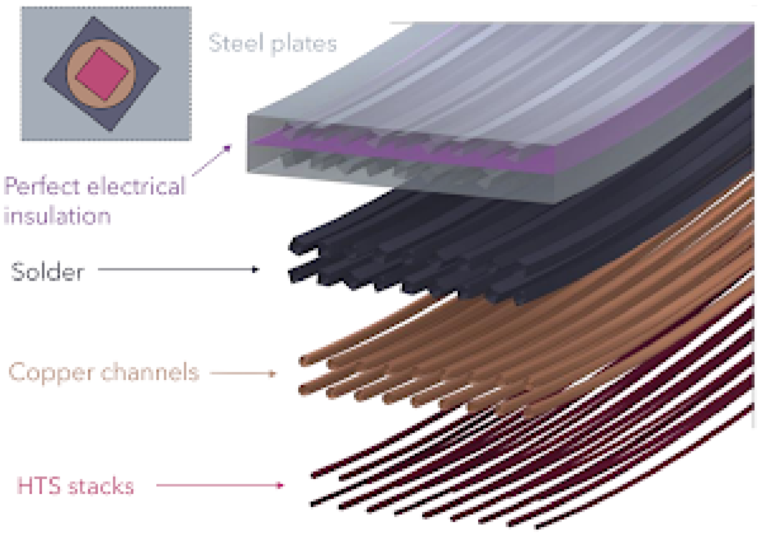
Benefits of the thinshell method

- Significant reduction in mesh size and computational time
- Maintains good agreement with volume-based models for significant quantities

Conclusion

The thinshell method offers a promising way to overcome the challenges of modeling complex fusion devices, enabling more efficient and accurate simulations.





Stellarator coil geometry

Open presentation slides by Dr. Lyly

Live demo
Thinshell simulation

FULL 20-MINUTE SECTION ON YOUTUBE

Objective

To demonstrate the impact of thinshell conductivity on magnetic field ramp-up dynamics in a partially insulated coil.

Process

Dr. Lyly conducted a live demonstration within Quanscient Allsolve, showcasing the setup and analysis of a simulation involving a partially insulated coil. He explained the geometry, material properties, physics definitions, and simulation parameters, highlighting the software's flexibility in handling complex geometries. A sweep over the thinshell conductivity was performed to observe its effects on current distribution and losses.

Results

The simulation results showed how different conductivity values influenced the magnetic field ramp-up time and the distribution of currents and losses within the coil. This emphasized the importance of considering partial insulation in stellarator design.

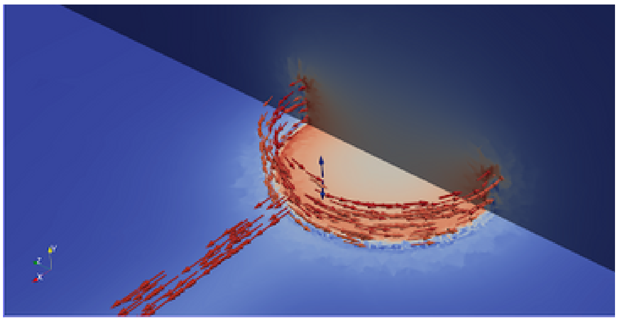
Key benefits demonstrated

Efficiency: The thinshell method simplified the model and reduced computational time compared to traditional volume-based approaches.

Accuracy: The simulation results provided valuable insights into the impact of thinshell conductivity on the system's behavior.

Flexibility: Quanscient Allsolve's ability to handle complex geometries and perform parameter sweeps allows for efficient exploration of design options.

Visualization: The platform's visualization capabilities enabled clear representation of current density and magnetic flux density distributions.



How Proxima Fusion leverages cloud computing in fusion reactor design 1/3

FULL 19-MINUTE SECTION ON YOUTUBE

Proxima Fusion

About Proxima Fusion

4-MINUTE SECTION ON YOUTUBE

Proxima Fusion is a spin-out from the Max Planck Institute for Plasma Physics, building on six decades of fusion R&D. Their work on HTS stellarators is built on advancements in stellarator research (such as the W7-X results) and HTS technology (notably the MIT SPARC program).

Proxima Fusion recognizes the role of HTS in enabling high magnetic fields and compact fusion reactors, making it a commercially attractive technology. The company prefers stellarators over tokamaks due to their inherent operational stability, despite the challenges associated with their construction.

Proxima Fusion's timeline includes a recently completed conceptual reactor design, ongoing magnet design and hardware prototyping efforts, and goals of building a demo magnet by 2027, a prototype by 2031, and ultimately, realizing the first fusion power plant, Stellaris, based on stellarator HTS technology by the mid-2030s.

Challenges of modeling HTS stellarators

3-MINUTE SECTION ON YOUTUBE

Dr. Nicolo Riva's presentation highlighted the challenges involved in modeling HTS stellarators for fusion reactors.

Key challenges:

Multifaceted nature of HTS coils: The design and modeling of HTS coils involves a range of challenges, including achieving high engineering current densities, ensuring mechanical strength and winding accuracy, mitigating quench risks, and managing the impact of neutron flux on HTS materials.

Multiscale and multiphysics modeling: The vast difference in scales, from the reactor's overall dimensions to the microscopic layers within HTS tapes, coupled with the need to consider multiple physical phenomena (electromagnetic, thermal, mechanical), makes modeling a complex undertaking.

Non-Insulated coil design: The choice of non-insulated coils for Stellaris, while offering advantages in terms of DC behavior, necessitates large-scale, high-fidelity numerical simulations to accurately capture quench behavior and other phenomena.

Open presentation slides by Dr. Riva

How Proxima Fusion leverages cloud computing in fusion reactor design 2/3

FULL 19-MINUTE SECTION ON YOUTUBE

Overview

The process of stellarator modeling is intricate, demanding various models like magnetostatics, structural analysis, and quench behavior assessment. It involves close collaboration with the stellarator optimization team, requiring frequent iterations and evaluations of multiple configurations.

Quanscient API

5-MINUTE SECTION ON YOUTUBE

To address the challenges of this iterative process, especially the complexities of magneto-mechanical model integration, Proxima Fusion has been utilizing the Quanscient API.

Dr. Riva presented the key features, workflow, and the main benefit of the API being an "(almost) one-click solution for magneto-mechanical study of any coil in any stellarator configuration."

Key features

Handles various tasks: From sanity checks and error handling to full stellarator B-field and high-fidelity coil magneto-mechanical analysis.

User-friendly: Requires user input of CAD model, mesh, and script.

Efficient: Automates simulations using Python scripts, enabling batch processing and customization.

Comprehensive output: Exports results like field maps and mechanical data.

Workflow

User sets up: Python environment, API keys, mesh, and JSON file with proper tagging.

Quanscient Allsolve executes:

- Estimates DOFs for resource optimization
- Runs coil orientation checks and fixes misalignments
- Simulates background field using N-1 method and exports field maps
- Analyzes Full Fidelity Coil (FFC) with fine mesh under background field
- Automates simulations using Python scripts
- Exports results including field maps, mechanical data, etc.

How Proxima Fusion leverages cloud computing in fusion reactor design 3/3

FULL 19-MINUTE SECTION ON YOUTUBE

Case study

Non-Insulated Non-Planar Double Pancake

4-MINUTE SECTION ON YOUTUBE

To demonstrate the use of Quanscient Allsolve in real-world scenarios, Dr. Riva presented a case study focused on a non-insulated, non-planar double pancake coil designed for a stellarator reactor. This coil design, favored for its DC performance, required detailed modeling to understand its quench characteristics.

Coil design and simulation setup

The coil featured a unit cell composed of HTS, copper, solder, and steel, with an insulation layer between the pancakes

The simulation involved a three-step process:

1. Ramp-up of current using linear material properties for faster charging
2. Transition to non-linear material properties to have stable initial conditions for quench simulation
3. Introduction of a localized defect to initiate a quench, followed by a controlled ramp-down of the current

Key findings

Defect positioning: The defect, strategically placed in the first turn, triggered a quench event.

Magnetic field persistence: Quanscient Allsolve revealed that despite the current ramp-down, the magnetic field initially remained relatively constant due to the energy stored in the coil.

Temperature rise and hotspot: The simulation showed a localized temperature increase, creating a hotspot primarily concentrated in the top pancake. The maximum temperature reached approximately 170 K.

Quench avalanche: The simulation effectively captured the non-insulated nature of the coil, demonstrating a quench avalanche effect, with the current redistributing among the turns. The turns closest to the current leads experienced a decrease in current, while others picked up the current, further propagating the quench.

Safety concerns: The simulation results highlighted potential safety implications due to the high hotspot temperatures, indicating the need for careful quench detection and management strategies in such coil designs.

This work was conducted in collaboration with Atled Engineering

Modelling of a large-scale non-insulated non-planar HTS stellarator coil using Quanscient Allsolve®, **Tara Benkel et al** (Submitted IEEE TAS)

Q&A

> **"As a researcher, sticking with older methods may lead you to miss out on groundbreaking innovations like this, which can simplify your workflow and automate repetitive tasks."**
>
> **- Dr. Nicolò Riva**

In the Q&A section of the webinar, Dr. Riva was presented with the following question:

"How would you encourage engineers and researchers, who are often hesitant to invest time and energy in learning new simulation software, to try a new platform like Quanscient Allsolve?

Dr. Riva acknowledged that people can be hesitant to switch from familiar software. However, he pointed out the following advantages of Quanscient Allsolve:

Specialized capabilities: Quanscient Allsolve is well-suited for the challenges of stellarator coil design.

Efficient workflow: Quanscient Allsolve offers a streamlined workflow and automation, which can save time and increase productivity.

Improved versatility: Learning new tools like Quanscient Allsolve is an investment in versatility in a competitive landscape.

Dr. Riva concluded by encouraging the audience to view trying Quanscient Allsolve as an investment in their own development and a gateway to more efficient and effective simulation solutions.

2-MINUTE SECTION ON YOUTUBE

Summary and key takeaways

This webinar provided a comprehensive overview of the challenges and solutions in designing high-temperature superconducting (HTS) magnets and stellarators for fusion reactors. It highlighted the crucial role of cloud computing and advanced simulation tools like Quanscient Allsolve in overcoming these complexities and accelerating fusion reactor development.

Cloud computing enables efficient simulation of complex fusion reactor designs.
Cloud-based platforms can handle the large-scale simulations required for these intricate geometries and high aspect ratios.

The thinshell method simplifies complex geometries while maintaining accuracy.
This leads to reduced computational time and more efficient simulations, as demonstrated in the live simulation.

Quanscient Allsolve offers specialized capabilities for magneto-mechanical analysis of HTS stellarator coils.
This includes a user-friendly interface, automation, and a streamlined workflow for increased productivity.

Proxima Fusion's use of Quanscient Allsolve demonstrates the value of advanced simulation tools in fusion research.
This real-world example highlights the practical benefits of such tools.

Adopting new technologies like Quanscient Allsolve is essential for progress in fusion energy.
These tools drive innovation and improve the efficiency and accuracy of the design process.

Tell us about your use case!

We want to hear from you and let you know how we could help.

Just fill in the form from the button below, and we'll:

- Assess the compatibility of Quanscient Allsolve with your use case and existing workflows
- Discover how Quanscient Allsolve could enhance your current simulation workflow and open up new possibilities
- Evaluate the cost-effectiveness for your use case

Our experts will review your case and be in touch within 1 business day!

Get in touch

QUANSCIENT

quanscient.com

info@quanscient.com

linkedin.com/company/quanscient