QUANSCIENT WEBINAR

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26th Mar, 2024

Faster steady-state results in MEMS simulations with harmonic balance

Learn how to reduce manual setup with harmonic balance enabling quicker, more precise results without transient analysis.

Overview

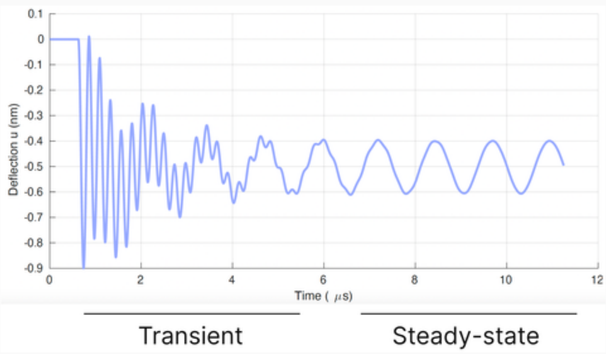
In this webinar, we covered the harmonic balance method in MEMS simulations. Our technical speakers, **Dr. Alexandre Halbach** and **Dr. Abhishek Deshmukh** covered the theory of the harmonic balance method and showcased its applications in three real-world use cases, demonstrating faster steady-state results and a simpler simulation setup. The cloud-based multiphysics simulation software Quanscient Allsolve was used for the demonstrations.

Theory of harmonic balance

Full section on YouTube

Harmonic balance approximates steady-state solutions to nonlinear periodic problems in the frequency domain.

Challenges with transient analysis



Achieving a steady-state periodic solution through transient analysis can be time-consuming and require manual intervention. Additionally, extracting frequencies from the transient signal using FFT may result in noisy data.

Key principle

$$\phi(\boldsymbol{x},t) = \sum_{k=0}^{N} \phi_{sk}(\boldsymbol{x}) \, \sin(\omega_k t) + \phi_{ck}(\boldsymbol{x}) \, \cos(\omega_k t)$$

The fields are decomposed using a truncated Fourier series that incorporates as many dominant harmonics as possible. The harmonics analyzed include not only those from the excitation field but also new harmonics that emerge due to the problem's nonlinearity.

About the speakers

Dr. Alexandre Halbach

CTO, Co-Founder

Alexandre is our CTO and simulation algorithms expert. He has developed our state-of-the-art multiphysics simulation algorithms and has years of hands-on R&D experience.

Dr. Abhishek Deshmukh

Team Lead - Application Engineering

Abhishek has more than nine years of experience in computational fluid dynamics (CFD) research and software development, especially for applications in high-speed compressible flows, turbulence, multiphase flows, and combustion.

Case examples

Thermoelectric AC simulation

Full section on YouTube

Objective:

A simple example for the demonstration of the key principle of the harmonic balance method

Process:

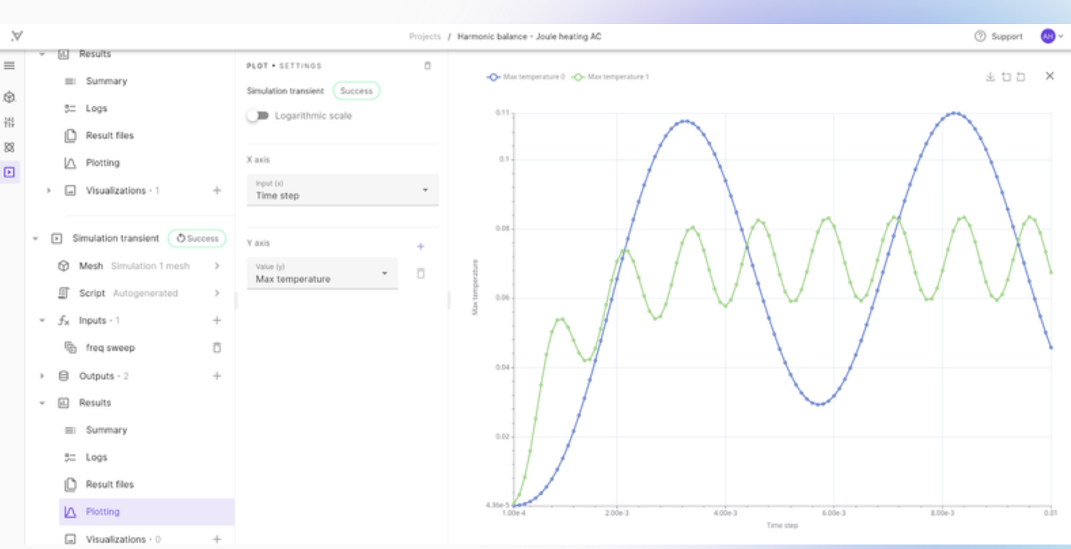
1. Walking through the problem setup in the GUI
2. Live execution of transient and harmonic balance simulations of heating a cable by AC current flowing through at two different frequencies

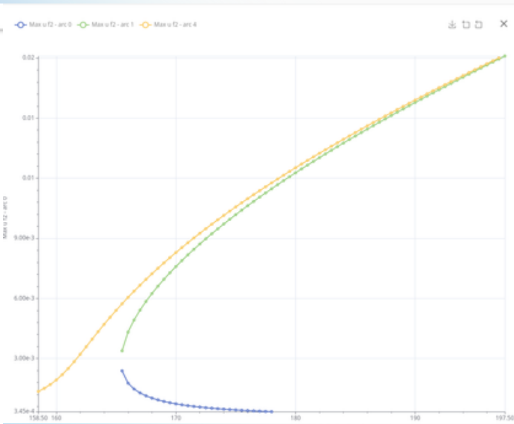
Key Benefits:

The transient simulation approach was compared with the harmonic balance method and the benefits of the harmonic balance approach were clearly demonstrated

Results:

- Plots shown: f0 = 100 and 400 Hz current flow through a cable
- Joule heating ∝ I^2
- Max temperature has DC + 2 f0





Backbone curve

Backbone curve

Full section on YouTube

Objective:

Demonstration of the capability of the harmonic balance in capturing the nonlinear behavior of the clamped-clamped beam

Process:

1. Walking through the problem setup in the GUI
2. Modification of the autogenerated script to write loops to simulate the different sections of the backbone curves

Key benefits demonstrated:

The ease of simulating nonlinear response using the harmonic balance method using Quanscient Allsolve

Results:

- Mechanical resonance in case of geometric nonlinearity
- Max displacement versus driving frequency
- The difficulty of transient analysis in this example

Microspeakers

Full section on YouTube

Objective:
Showcase more advanced multiphysics capabilities including mesh deformation on a complex application case of electrostatically actuated silicon-based microspeakers

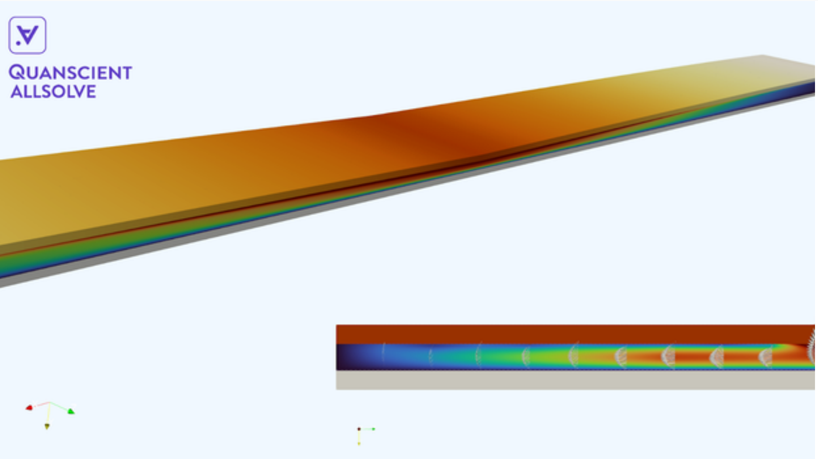
Key benefits demonstrated:
Harmonic balance method applied to a fully coupled multiphysics (electrostatics + solid mechanics + fluid dynamics) application including mesh deformation, geometric nonlinearity, and prestress

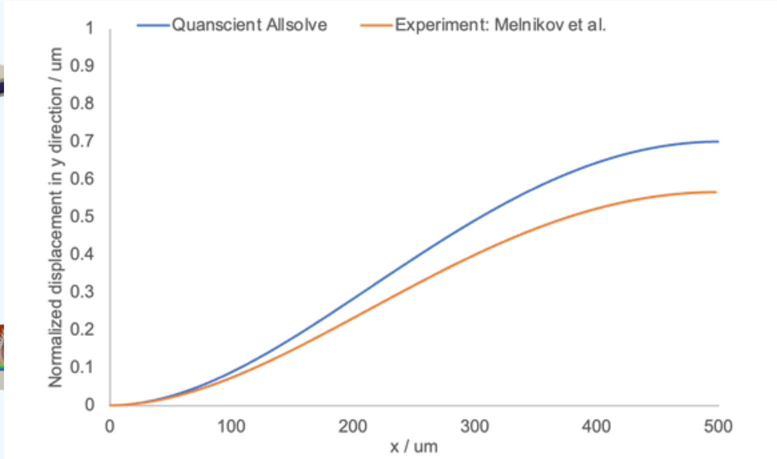
Process:

1. Walking through the problem setup in the GUI
2. Explanations of the couplings between different physics
3. Modification of the autogenerated script to account for the mesh deformation, geometric nonlinearity, and prestress

Results:

- Freq: 100 Hz, DoFs: 800k, Cores: 12, Runtime: 30 min
- Qualitative comparison showing contour plots of displacement and fluid velocity vectors
- Quantitative comparison of the displacement of the top microbeam along its length on the centerline with measured data from a published article





Introduction to Quanscient Allsolve

Other key capabilities covered

Full section on YouTube

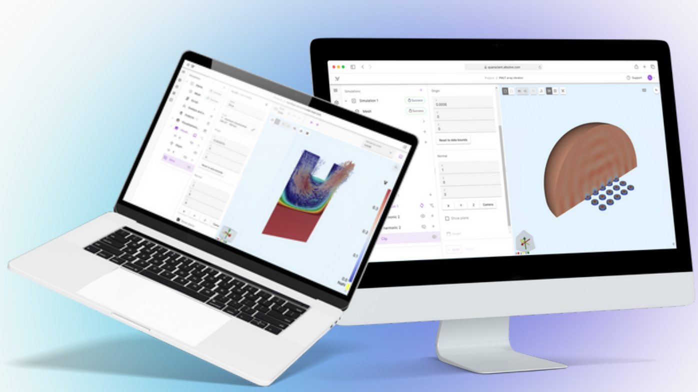
Cloud scaling
Practically unlimited amount of computational power and RAM on any device. Runtime from days to coffee breaks with unlimited parallel simulations.

No user limits
Unlimited number of users with every plan. No hardware requirements. Real-time collaboration easy as sharing a link.

Python scripting interface
Automatically generated Python scripts defining the entire simulation. Extensive multiphysics script libraries.

Usage-based pricing
Cost-efficient pricing for organizations of all sizes. Quota only spent when simulations running.

Support and materials
Support directly from our experts one click away. Tutorial videos; user guides; documentation.



Highlights from the Q&A

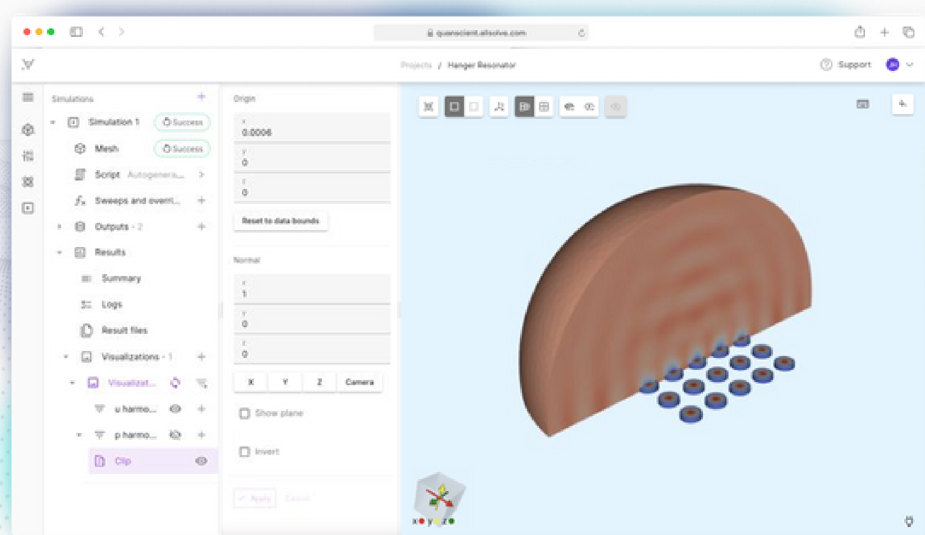
Full section on YouTube

Q: Is scripting always required when implementing the harmonic balance method?
A: No. In the micromirror demonstration, the mesh deformation had to be implemented through scripting, but that feature will be added to the GUI soon. The scripting interface allows for flexibility for custom or non-standard requirements.

Q: Does the continuation script have to be coded in Python, or are other languages supported (i.e. Julia)?
A: Currently, Python is the only supported scripting language within the product. Others, such as Julia bindings are not available at this time.

Q: Does Allsolve allow to run the harmonic balance in conjunction with a continuation algorithm?
A: Yes, Allsolve's Python scripting provides the flexibility to implement harmonic balance with continuation algorithms. The software supports simple to complex algorithms for this purpose.

Q: Does Quanscient support the simulation of piezoelectric materials?
A: Yes, piezoelectric materials can trivially be simulated in Quanscient Allolve.



Interested in Quanscient Allsolve?

If you're considering whether Quanscient Allsolve could be a beneficial addition to your workflow, we invite you to schedule a complimentary 30-minute consultation with us. This no-obligation call is an excellent opportunity to discuss your specific needs and see how Allsolve can be tailored to meet them.

Book your session now

Not ready for a call just yet but still curious? Fill out this form to describe your use case. Our technical team will review your information and respond within one business day.

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