



Accelerating Acoustic Innovation with COMSOL Multiphysics®

Combining physics simulation with rapid prototyping is a powerful approach for transducer design. This work describes how COMSOL enabled a novel transducer architecture in the Sonos Arc Ultra.

A. Kozhevnikov¹ and S.G. Shankar¹
1. Sonos Europe B.V., The Netherlands

Engineering Challenges of the Novel Architecture

Traditional loudspeaker transducer designs centre the voice coil (and motor) on the moving diaphragm, creating inherent structural and dynamic stability. The novel Sound Motion architecture relocates multiple motors to the diaphragm perimeter to achieve distributed driving force, see Figure 1. This in turn enables opposing diaphragms in a much more compact form factor relative to a single conventional transducer of equal acoustic output.

These two architectural changes lead to the following engineering challenges:

- Traditional fabric “spider” suspensions cannot be accommodated
- Distributed masses and driving forces create a diaphragm rigidity challenge, compromising the range of rigid-piston behaviour^[1]

As a result, the spider was completely redesigned, and stiffening “ribs” were introduced to improve diaphragm rigidity.



FIGURE 1 – Conventional transducer on the left. Sound Motion woofer – centre and right.

Design & Optimisation

A transducer, and specifically the spider and ribs, face the following competing design objectives^[1,2]:

1. Achieve the right spring stiffness, moving mass and consequently the target resonance frequency, with stiffness remaining linear over the full displacement range.
2. Ensure natural modes fall outside the operational bandwidth, or are sufficiently damped.
3. Constrain motion of the diaphragm to linear axial translation only.
4. Withstand expected stress and strain at peak displacement without plastic deformation or fatigue failure over its lifetime.

COMSOL Solid Mechanics studies were used in the design iterations of the spider and ribs (see Figure 2). Additionally, Topology Optimisation^[3] was used to minimise rib mass while constraining bending displacement as a proxy for stiffness.

Validation

Rapid prototyping using 3D printing and CNC machining requires accepting differences in material grade and longevity relative to production parts, in exchange for iteration speed. These in-house prototypes validated COMSOL predictions to within $\pm 5\%$, at a fraction of the time and cost needed for production materials and processes.

Results

Simulation-driven optimisation enabled a single woofer to deliver the bass output of 16 of the woofers used in the predecessor Arc, while occupying the physical volume of 4 such woofers. This represents a 4x improvement in bass output per unit volume. This demonstrates how validated simulation supports confident engineering decisions to deliver a class-leading sound experience.

REFERENCES

- [1] L.L. Beranek and T.J. Mellow, Acoustics: Sound Fields, Transducers and Vibration, Academic Press (2019)
[2] W. Klippel and R. Werner, Loudspeaker Distortion – Measurement and Perception, Part 1: Regular Distortion Defined by Design, Klippel GmbH
[3] R. Christensen, Shape and Topology Optimization of Loudspeaker Drivers, Proceedings of the COMSOL Conference, Grenoble (2020)

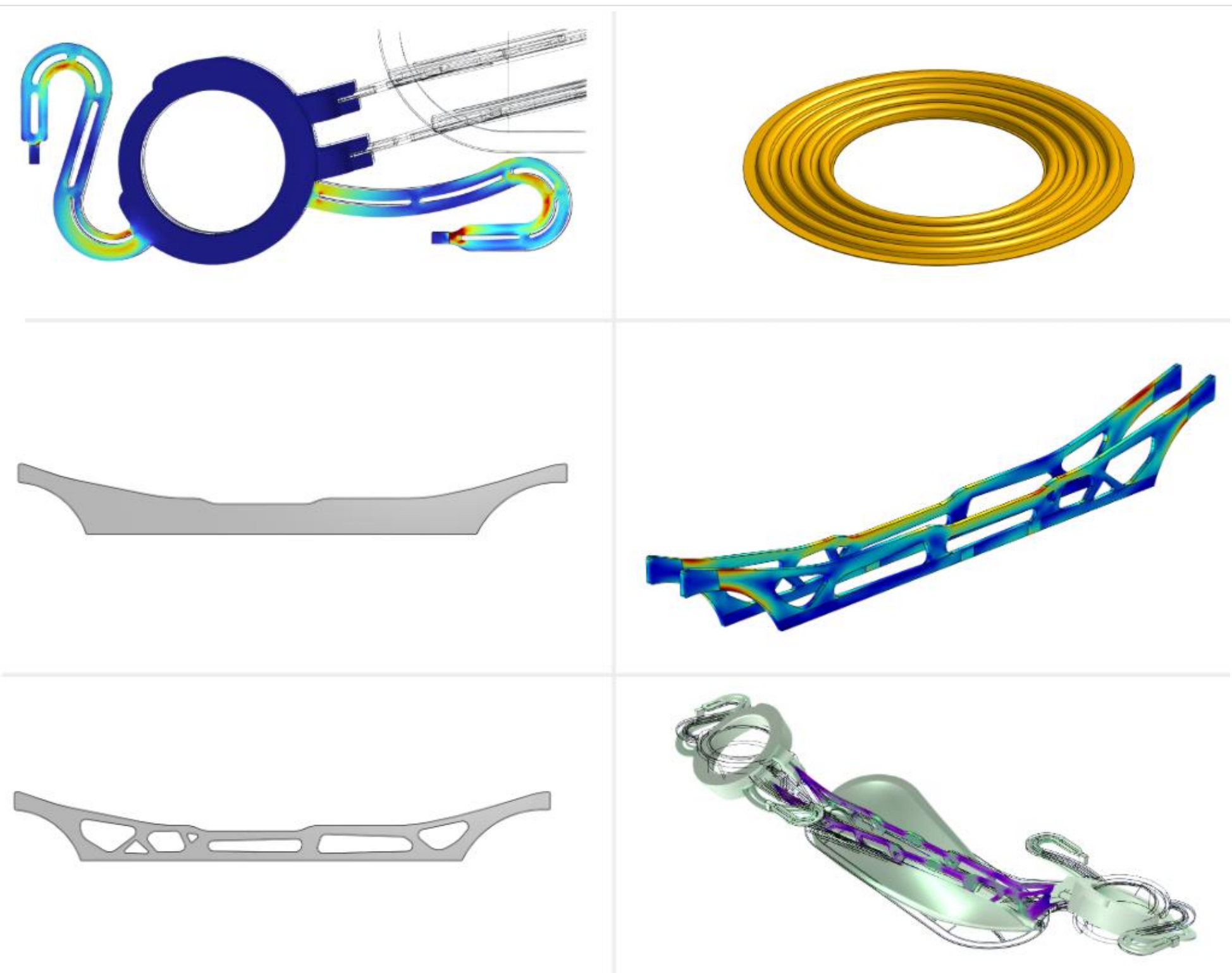


FIGURE 2 – Stress distribution in the redesigned spider (top left) compared with a conventional fabric spider's suspension geometry (top right). Rib profile before (middle left) and after (bottom left) topology optimisation, alongside the optimised rib's stress distribution (middle right) and full transducer mode shape (bottom right)

SONOS