Utilizing CAESES' Parametric CAD Engine in ANSYS' Workbench

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Summary

The difficulty of parametrically defining complex geometries and pre-processing CAD models for flow and structural simulation has driven the development of FRIENDSHIP SYSTEMS' CAE platform CAESES over the last decade: the built-in parametric CAD kernel is geared towards simulation-ready geometries that can easily and robustly be varied. Exports are provided in various formats, either derived from imported and modified CAD models or from geometries entirely defined in CAESES.

Controlling CAESES from within the ANSYS Workbench for assessing the parametric geometry has recently been implemented as a push button solution. Using the CAESES ACT Extension, the user has the flexibility of using the parametric geometry for different scenarios in the ANSYS Workbench.

The approach will be presented in a case study, in which a mirror blank for an airborne optical sensor made from glass ceramics and with a dynamic operation behavior is optimized for minimum deformation and weight. A fully parametric model of the mirror blank's shape in created in CAESES and then analyzed and optimized within ANSYS Workbench, using the coupled connection between the two software packages, modal and static structural systems.

Keywords

Optimization, Parametric CAD, ACT Extension, Static Structural, Modal

1. Introduction

As simulation tools are becoming increasingly suited for being used as a design rather that just an evaluation tool, as well as for process automation, additional complementary CAE tools are needed, which take care of other tasks required for the complete automation of the process: control of the optimization process, including variant and data management, and generation of the geometry variants that should be evaluated, providing the input for the simulations. Especially the latter category – i.e., dedicated tools for shape variation – seems to be a frequent bottleneck. Traditional CAD systems often do not fulfill the given requirements well when dealing with complex geometries, e.g., based on free-formed surfaces, and a specialized CAD approach is called for instead.

1.1 The Bottlenecks with Traditional CAD Tools

Traditional CAD packages are very powerful systems that accompany the complete design process and fulfill many different tasks, e.g. constructing production-level geometry models, creating complex assemblies, producing BOMs and manufacturing drawings, as well as managing PLM data. They are, however, often detail-centric, meaning that the geometry models include many details that are relevant for the final product, but not necessarily for the simulation. When pre-processing the models for grid generation, they have to be de-featured and the geometry has to be cleaned up (e.g., making it watertight). Also, and most importantly, these tools are often not predisposed for quick variation of complex geometry. Changing properties of the shape can involve a lot of manual effort and is not necessarily robust, leading to many failed variants when attempts are made to automate the variation.

Another aspect that characterizes traditional CAD is the typical user group. Usually, a dedicated CAD department will be in charge of operating the CAD system, handing over geometries to the simulation department. When the people in the simulation department want to try variations of the geometry or suggest some changes, they have to request a new geometry from the CAD department, which often leads to delays and an inefficient process. Obviously, process automation is hardly possible in this set-up.

1.2 The Case for a Specialized CAD for Variation and Simulation

A specialized CAD tool like CAESES, on the other hand, is a modeler that focuses on the modeling of the relevant geometry only, providing it in a state that can directly be used for simulation. It has a strong focus on geometry variation, so that, once a model has been parameterized accordingly, it can robustly provide geometry variants just by simply changing the model parameters, be it in a manual or an automated process.

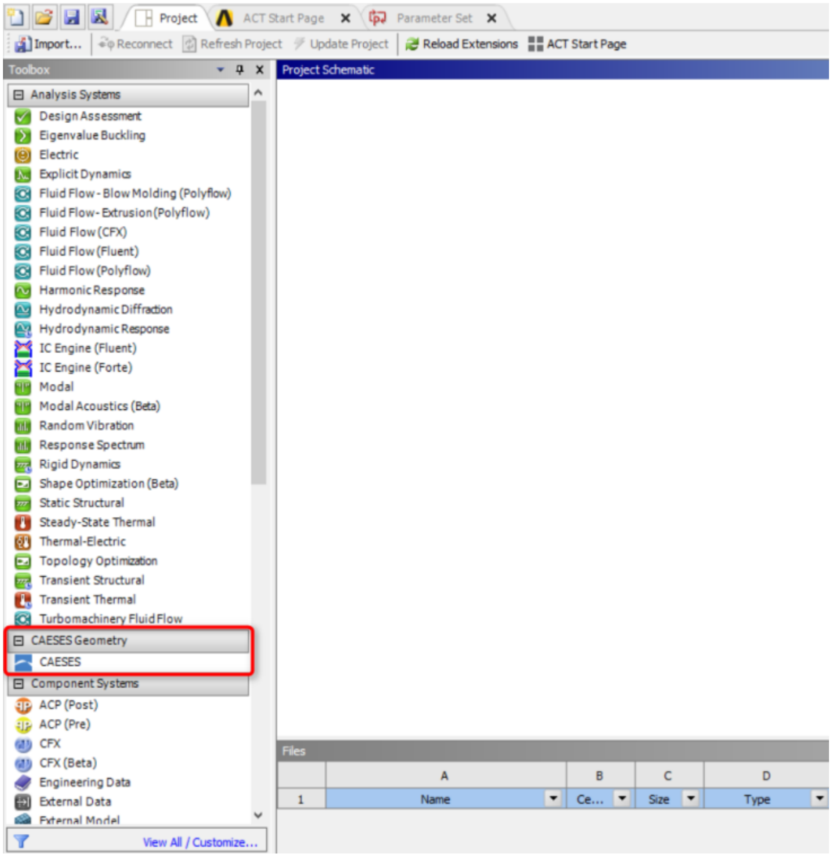
The requirements fulfilled by such a CAD tool for variation and simulation can be summarized as follows:

- Geometries should be defined and controlled by as few parameters as possible, thus reducing the degrees-of-freedom. The optimization effort scales with the number of free variables (often in a quadratic fashion); therefore, a low number is highly desirable.It should be easy and fast to vary the geometry by controlling the values of previously defined parameters. These parameters should be independent from each other and it should not be required to change multiple parameters in a concerted way, just to obtain a specific change in shape.
- Geometry generation should be robust with a minimal amount of failed variants.
- The generated geometry should be provided in a state and format that can directly be used for the simulation tool involved in the specific process.
- The system should have the ability to manage constraints and even build them right into the model, so that the creation of infeasible variants is prevented or at least minimized.

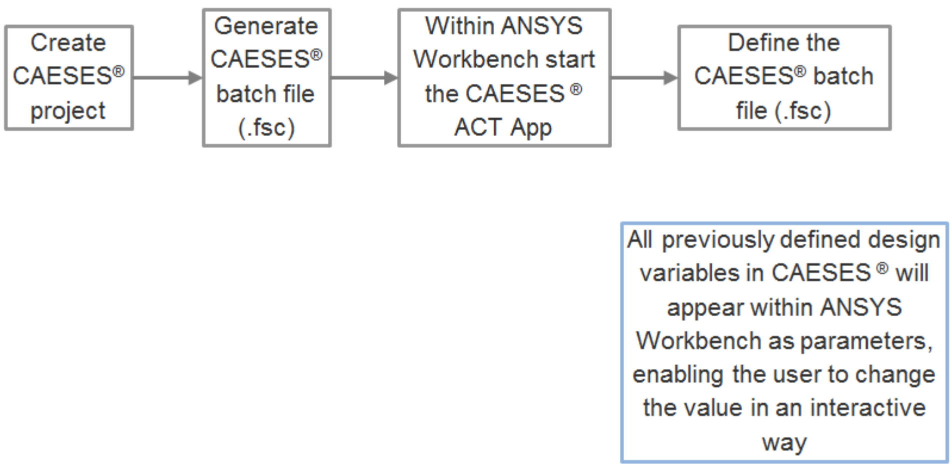
In contrast to a traditional CAD package, this is meant as a tool for the simulation engineers, giving them the ability to generate geometries and variants on their own, even at a stage where the design is not progressed so far that the CAD department can actually hand over geometry files.

2. CAESES ACT Extension

The CAESES ACT Extension has been developed with the above mentioned concerns to provide the ANSYS users the full capability of the CAESES parametric geometry modeling and variation within ANSYS Workbench platform. The ANSYS user has to download the CAESES ACT App from the ANSYS App Store and install it within ANSYS Workbench.



After the installation, the app will appear within the toolbox of ANSYS Workbench as a separate component system. It includes the CAESES Geometry, ANSYS Geometry and ANSYS Meshing components.

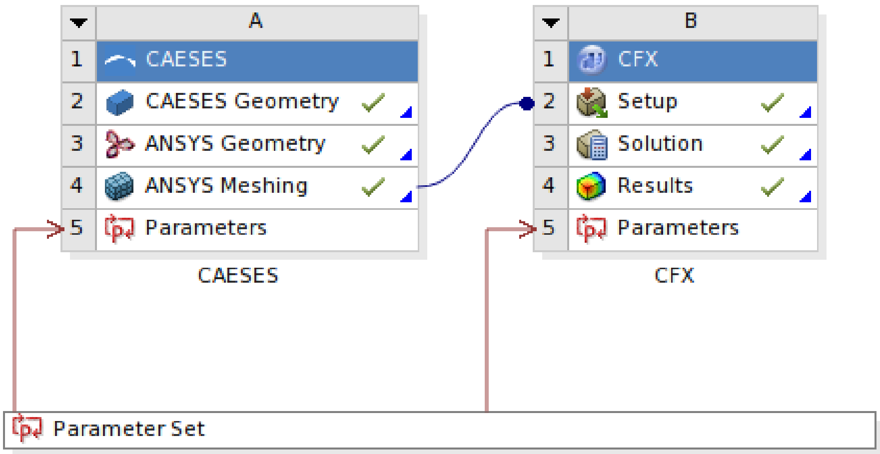


As an input, the CAESES ACT App requires the CAESES batch script file (.fsc file) where all necessary information needed for the project is described; like geometric design variables, CAESES binary, export type, project file location, named selections, etc. Optionally, the user has the flexibility to use another version of CAESES, if desired.

Properties of Schematic A2: CAESES Geometry

	A	B
1	Property	Value
2	General	
3	Always Include in Design Point Update	☐
4	Component ID	id_geom_task3
5	Directory Name	C_GEO-1
6	FSC file	\
7	CAESES Binary	\
8	CAESES Geometry file	/
9	Shared Topology	☑
10	2D Geometry	☐
11	Notes	
12	Notes	
13	Used Licenses	
14	Last Update Used Licenses	

After defining the necessary inputs, the CAESES ACT App is ready to serve as the parametric geometry creator within the ANSYS Workbench. Depending on the specific project scenario, the created parametric geometry can be linked to other components.

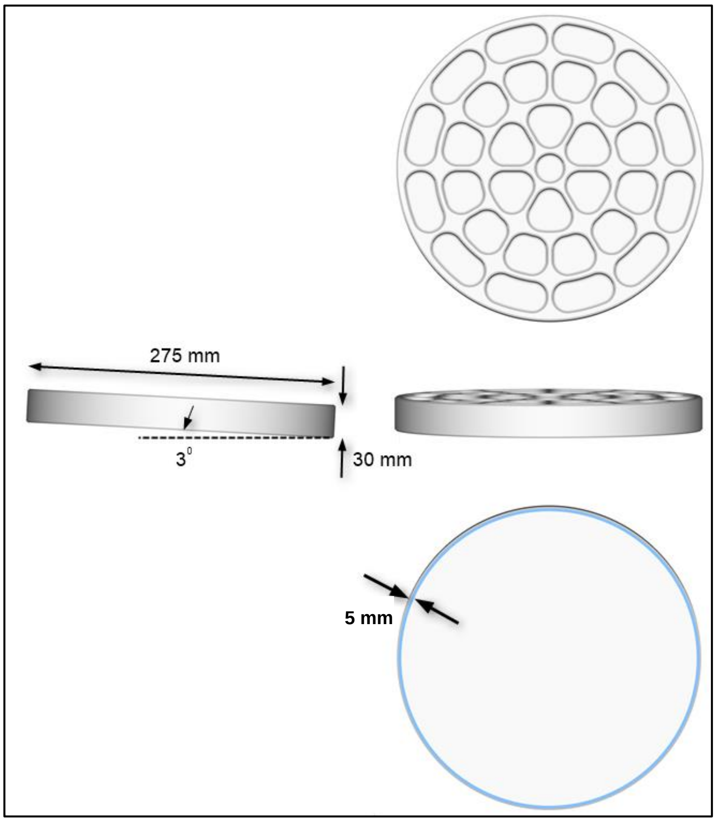


As a restriction, the created CAESES batch file is computer specific and includes the CAESES binary location used to execute CAESES in the background, if not otherwise defined in the options, as well as the CAESES project file location. Hence, it is recommended to re-generate the CAESES batch file, if the set-up is to be used on another machine.

3. Example Case: Optimization of a Mirror Blank for an Airborne Optical Sensor

The mirror blanks for the presented optical sensor are made from glass ceramics with an extremely low thermal expansion and dynamic operation behavior, in which geometrical shape and displacement must be kept within very small limits under working conditions. Moreover, for an airborne application as presented in this case study, the weight of the mirror blank needed to be minimized. Both requirements – the minimum deformation during operation and the low weight – dominate the design of the product. The aim of this study was to provide a fully parametric model of the mirror blank's shape in CAESES, analyze and optimize the model within ANSYS workbench using a coupled connection between the two software packages. The parametric model defined in CAESES was made available to the workbench as described above and linked to Modal and Static Structural systems. The results of the optimization process are presented such that they can be used as an aid to selecting the most favorable design for the envisioned mirror blank application.

3.1 Object of Study



The mirror blank has a radius of 275 mm with a thickness of 30 mm.

The top surface normal has a 3 degrees deviation from the axis of rotation that passes through the center of gravity of the object.

The object is supported by a 5 mm wide ring support at the bottom, where it is attached to the mechanism.

The total mass of the mirror blank is 2.48 kg

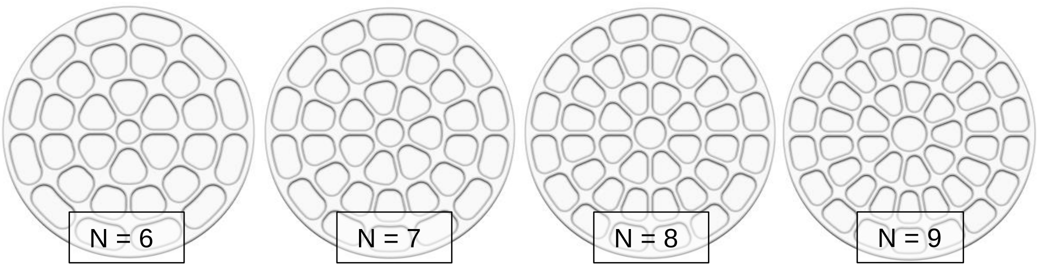
Properties	ZERODUR®
Density [g/cm³]	2.53
Young's Modulus E [GPa]	90.3
Poisson's Ratio µ	0.24
Knoop Hardness [HK 0.1/20]	620
Coefficient of thermal expansion α CTE (0°C; 50°C) [10^{-6}/K]	0 ± 0.100 (class 2) 0 ± 0.050 (class 1) 0 ± 0.020 (class 0) 0 ± 0.010 (SPECIAL) 0 ± 0.007 (EXTREME)
ZERODUR® TAILORED	TAILORED ± 0.020 ppm/K Optimized for application temperature profile
CTE (0°C; 50°C) Homogeneity	< 0.01 – 0.03*10^{-6}/K
Heat Capacity cp (20°C) [J/(gK)]	0.80
Thermal Conductivity $\lambda_{90°C}$ [W/(mK)]	1.46
Max. Application Temperature [°C]	600

The blank is made from ZERODUR. The material properties were included to the Engineering Data, to be used as material for the simulations.

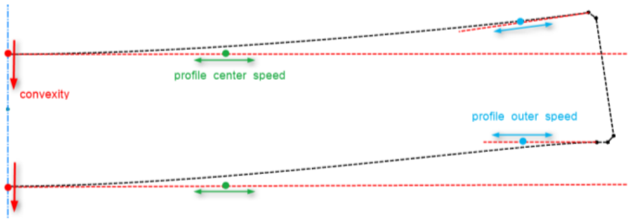
3.2 Parametric Geometry

A total of 7 design variables were picked for the study;

1) number of holes
parameter, defining the number of holes in the inner row on the mirror blank (other rows N*2)

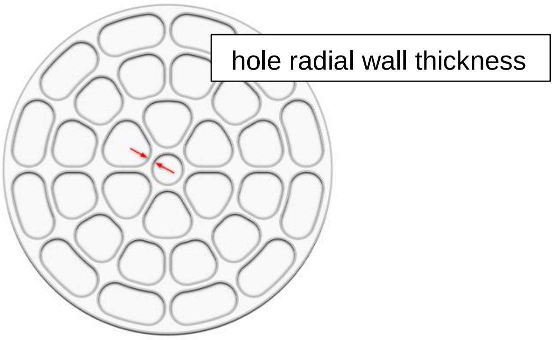


2) convexity
parameter, defining the convexity of the profile, used to counteract deflection when in rotation

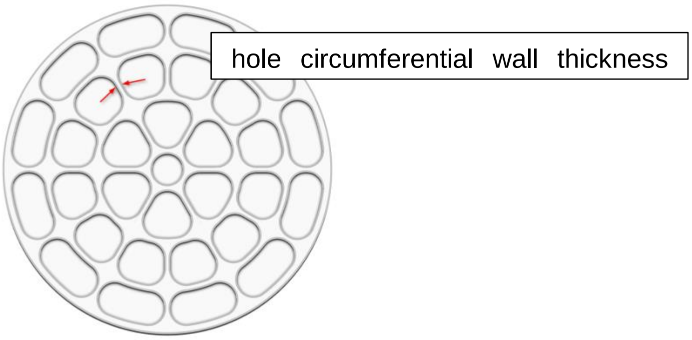


3) profile center speed
4) profile outer speed
parameters, further defining the defining the shape of the mirror's crossection (see above)

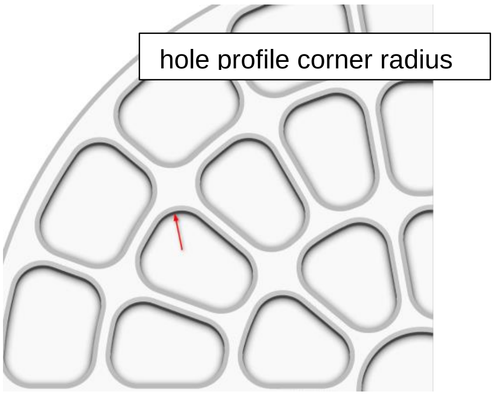
5) hole radial wall thickness parameter
parameter, defining wall thickness between holes in radial direction



6) hole circumferential wall thickness parameter
parameter, defining wall thickness between holes in circumferential direction



7) hole profile corner radius
parameter, defining the hole corner radius (as well as the size of the inner hole)

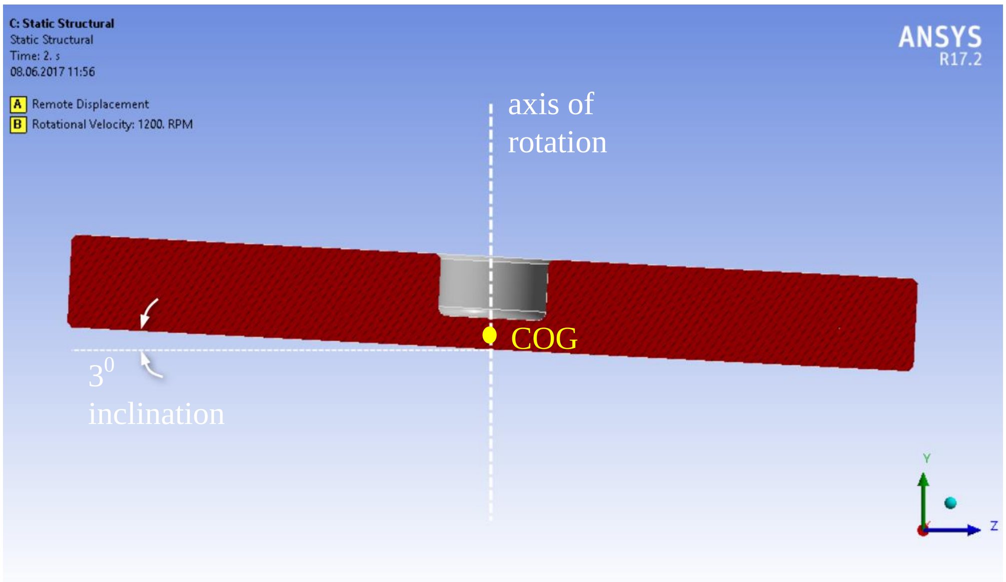


3.3 Finite Element Model and Boundary Conditions

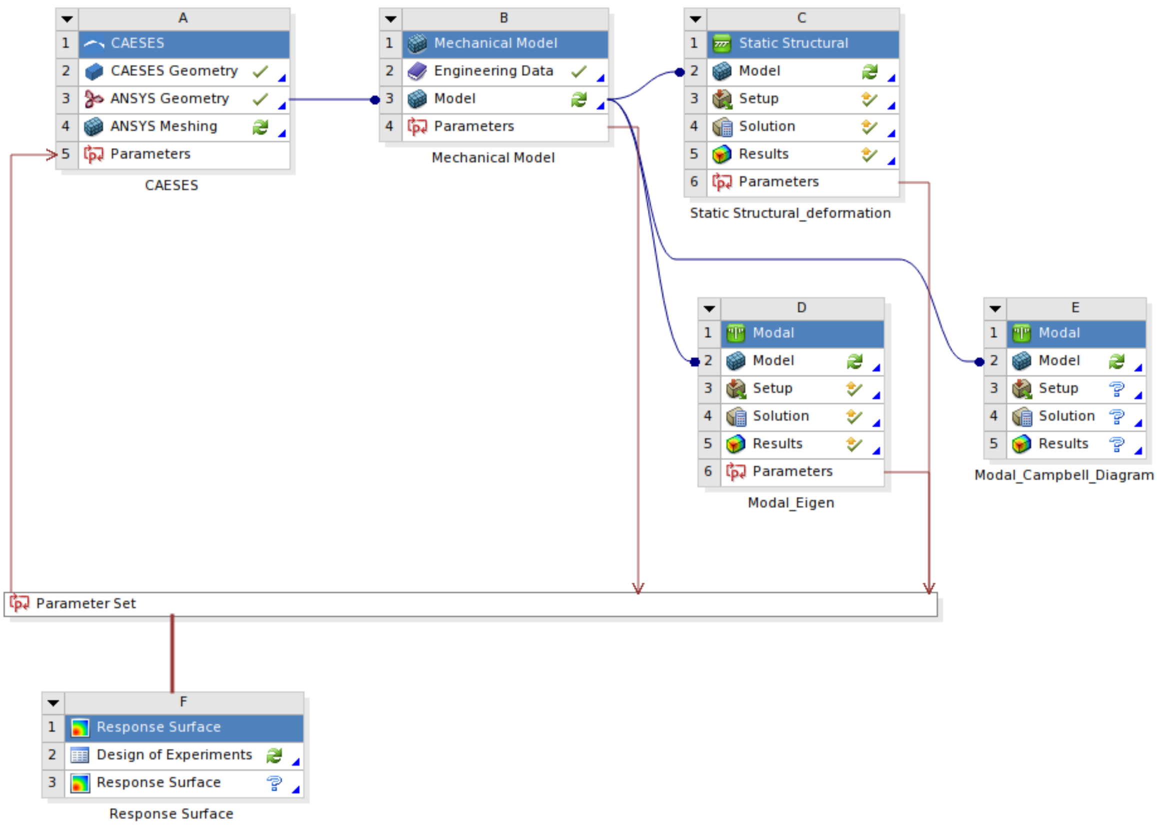
Higher order 3-D 20-node solid elements (Solid186 element type) were used in the meshing process, resulting in a mesh with ~150,000 elements and ~250,000 nodes.:

The top surface normal has a 3 degrees deviation from the axis of rotation that passes through the center of gravity of the object. The object has a rotational velocity of 1200 rpm.

A remote point attached to the ring support was defined and used for the remote displacement definition.



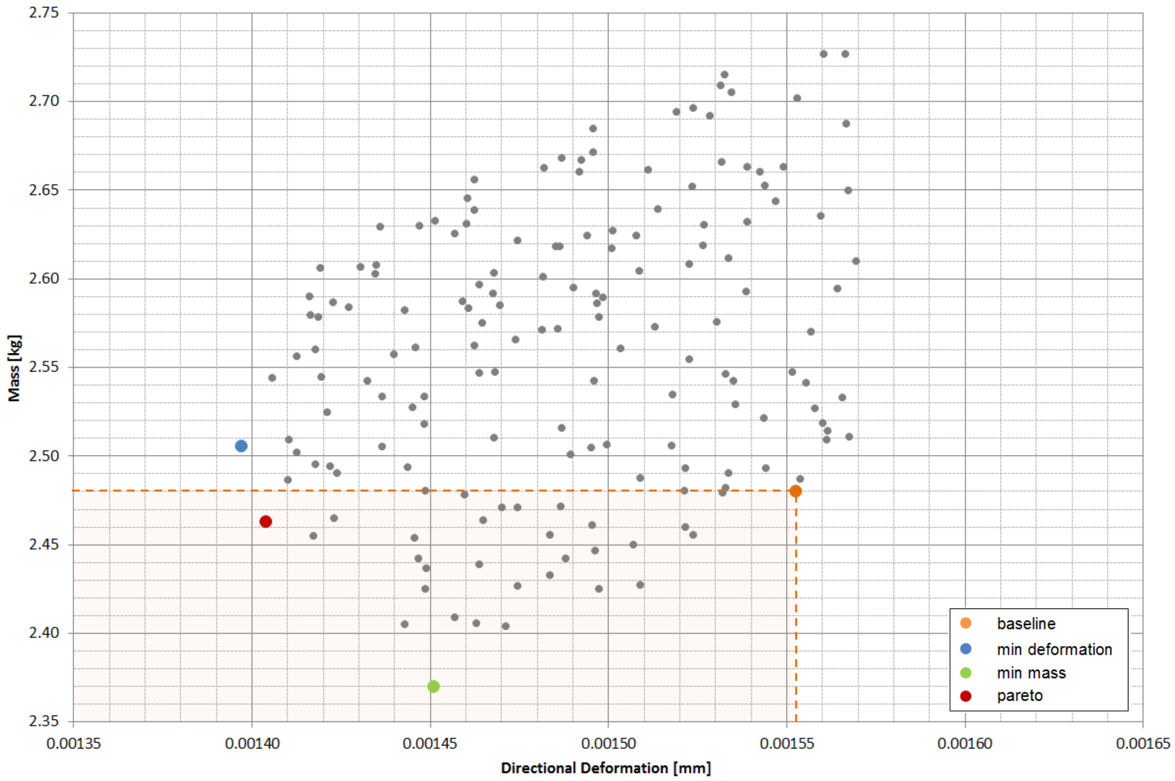
3.4 Workbench Workflow



Within the used workflow, the parametric geometry, obtained through the CAESES ACT App with the current set of geometry parameters, is transferred to the Mechanical Model component, where the material is defined and remote point, local coordinate system and mesh are created. The obtained data is then directed to the Static Structural analysis, Modal analysis for obtaining eigenmodes (resonance frequencies) and finally Modal analysis for obtaining the Campbell diagram to get the critical velocities, if any, within the search range.

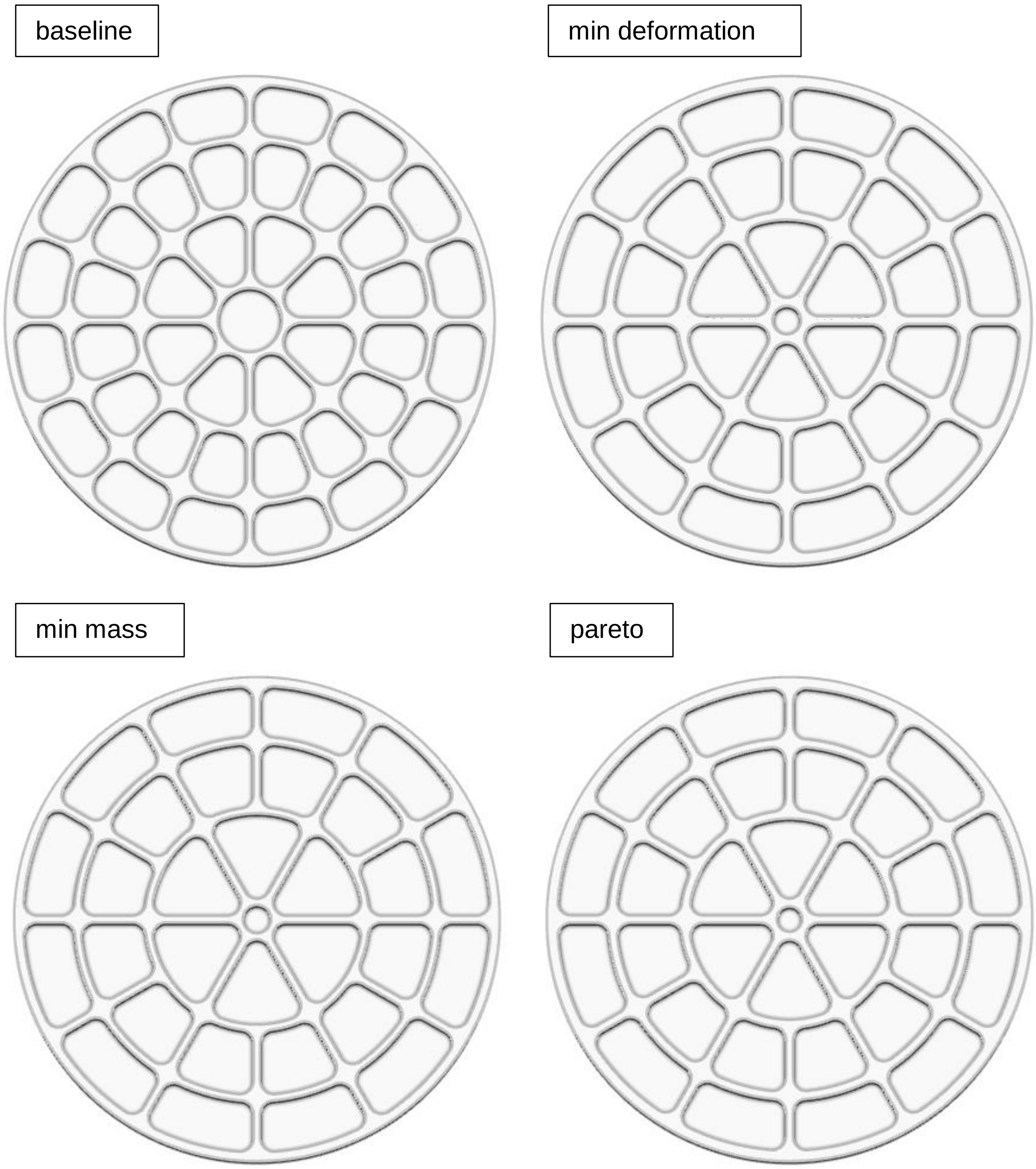
3.6 Results

A Design of Experiments (DoE) was run with the previously described geometry variables and set-up, resulting in 220 design variants. Although no formal optimization had been performed at this point, a first, sparse, "Pareto frontier" was recognizable from the cloud of design points plotted for the two objectives. Also, it was evident that a multitude of designs were able to improve upon the baseline design with respect to both considered objectives.



From this "Pareto frontier", three different designs were selected: the one with the lowest deformation, that has a slightly increased mass, the one with the lowest mass, that also has significantly lower deformation and finally, a compromise design that has a very low deformation, but also a slightly lower mass. This selection should simply illustrate that it is possible to select different designs from the generated database, depending on the emphasis in terms of the two considered objectives.

Design	Directional Deformation Maximum [mm]	Mass [kg]
baseline	0.0015523	2.4805
min deformation	0.0013969 (-10%)	2.5058 (+1%)
min mass	0.0014507 (-6.5%)	2.3704 (-4.5%)
pareto	0.0014037 (-9.5%)	2.4633 (-0.7%)



From the pictures above, it is surprisingly apparent that the three selected designs are quite similar in terms of geometry. All of them have a very small inner hole, and therefore hole corner radii, and all have 6 holes in the inner ring, while the baseline has large corner radii and 8 holes. Among these designs, the differences are mainly caused by different wall thicknesses between the holes and a different convexity, i.e., cross-sectional profile.

4 Conclusion

The case-study described above demonstrated that, by using the newly developed ACT Extension, CAESES can be used as an integrated and robust geometry engine to perform automated design studies and optimizations within the ANSYS Workbench, irrespectively of the used solver (fluid or structural). The performed DoE resulted in 220 new designs, with no geometry update failures, many of which were significantly improved in comparison with the baseline. As a next step, an actual optimization will be performed to further improve the design.