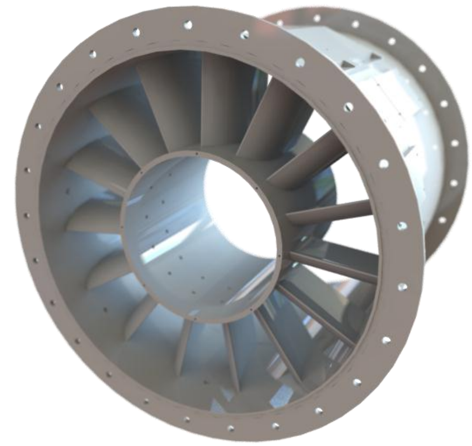
3D Optimization of the „TU Berlin TurboLab Stator"



The „TurboLab Stator" is a stator in a measurement rig at the TU Berlin in the TurboLab at the Chair for Aero Engines. A model of the stator assembly is shown on the right. An initial stator geometry has been designed based on a representative stator geometry as used in modern jet engine compressors. This initial geometry, as shown in fig. 2 below has to be optimized to reduce the total pressure loss over the incidence range stated below. A CAD model of the CFD domain will be provided in various formats (iges, step, parasolid). Details of the CFD domain, flow boundary conditions, optimization requirements and manufacturing constraints are stated below.

In order to participate in the optimization challenge, please register with Dr. Jens-Dominik Müller (j.mueller@qmul.ac.uk) and Prof. Tom Verstraete (t.verstraete@qmul.ac.uk) in order to obtain future updates and clarifications on the optimization setup, should those become necessary. With your registration you agree that the Chair for Aero Engines at the TU Berlin will be allowed to manufacture and test the optimized blade you submit to the challenge (pending availability of funding).

CFD Domain

Inner radius:	147.5 mm
Outer radius:	297.5 mm
Inlet axial position:	-180 mm
Outlet axial position:	540 mm

The CFD domain is shown in fig. 1.
The axial positioning of the blade in the CFD domain is shown in fig. 2. The „zero" position of the machine axis is the position where the camber line of the blade meets the leading edge.

CFD Boundary Conditions

All conditions stated below are constant values over the radial height, since measurement values are not yet available. An ideal gas model with a ratio of specific heats of 1.4 should be used if possible.

Inlet total pressure: 102713.0 Pa
Inlet total temperature: 294.314 K
Inlet whirl angle: 42°
Inlet pitch angle: 0°
Inlet turbulence intensity: 4%

Outlet static pressure: Adjusted to achieve a massflow of 9.0 kg/s (full annulus). A good initial guess to achieve this is p_exit = 101817.0 Pa

Stator Geometry

The initial stator geometry is shown in fig. 2. The task of the stator is to turn the incoming swirling flow with a whirl angle of 42° into axial flow with a minimal total pressure loss.

Optimization requirements

We have formulated two optimization criteria, stated in points (1) and (2) below, leading to a multi-objective optimization problem. In addition three operating points as defined in point (3) below have to be considered, leading to a multi-point optimization problem.

1) Minimize the total pressure loss between CFD inlet and CFD outlet under the constraint of keeping the mass flow at 9.0 +/- 0.1 kg/s (full annulus) over the whole operating range given in point (3) below. The total pressure loss is defined as
   loss = (p_total_in – p_total_out)/(p_total_in – p_static_in)
2) Minimize the flow angle deviation at the CFD outlet from the axial direction over the whole operating range given in point (3) below.
   The deviation is defined as the integral from hub to casing of the exit whirl angle squared.
3) The inlet whirl angle is allowed to vary by +/- 5°. Thus three operating points have to be considered, OP1 with 0° whirl angle and OP2&OP3 with +/- 5°. The weights are 50% for OP1 and 25% for OP2 and OP3 each for the optimizations targets (1) and (2) above.

Manufacturing constraints

It is allowed to change the profile shape of the blade and its 3D stacking. Additionally a hub endwall contouring in the domain as indicated in fig. 2 is allowed. The casing endwall can not be changed due to manufacturing constraints. We also have to take into account the following manufacturing constraints:

- The number of blades is fixed to n=15.
- The axial chord of the blade has to be kept constant.
- The thickness of the blade has to satisfy the following conditions:
  1) The minimum value for leading and trailing edge circle radius is 1mm.
  2) The two holes for the fixture in the middle of the blade have a radius of 2.5 mm and a depth of 20 mm. The blade thickness at these positions has to accomodate a cylinder of material with a radius of 5 mm and a depth of 20mm to allow cutting of the thread at both hub and casing, see fig. 2. The two holes can be placed arbitrarily inside the profile shape, but have to be at least 60mm apart from each other.
- The blade has to be mountable on a plate of dimensions 200mm x 80 mm as a part of the cylindrical casing, see fig. 3. On the hub there is no location or dimensional constraint for the fixture.
- The reduction of radius due to the hub contouring has to be 5mm or less and the increase of the radius due to the hub contouring has to stay below 10mm.

Note: The optimal blade will be manufactured using additive manufacturing (3D printing). This allows considerable freedom in the shape of the optimal blade, which you can use to your advantage!

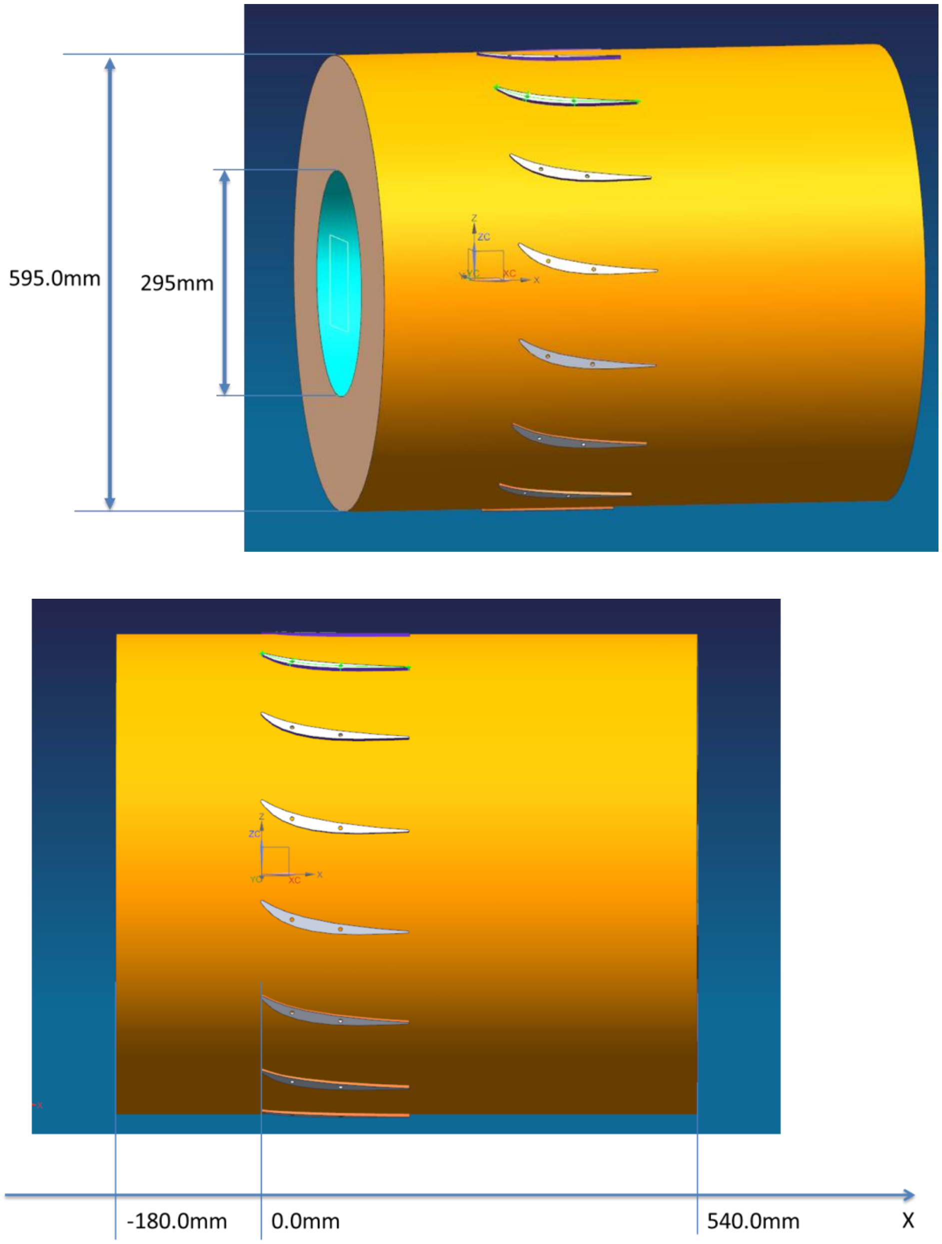


Fig. 1: CFD Domain

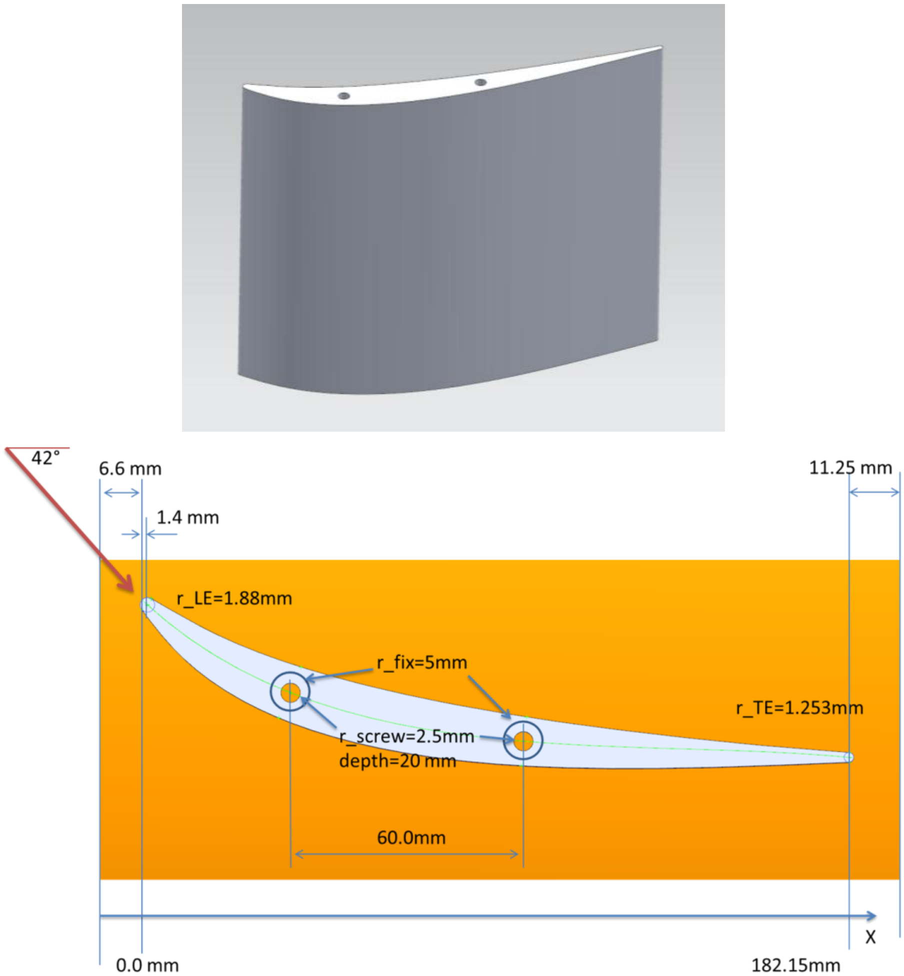


Fig. 2: Initial blade geometry (top) and axial positioning (bottom),
including yellow domain for endwall profiling and manufacturing constraints (bottom)

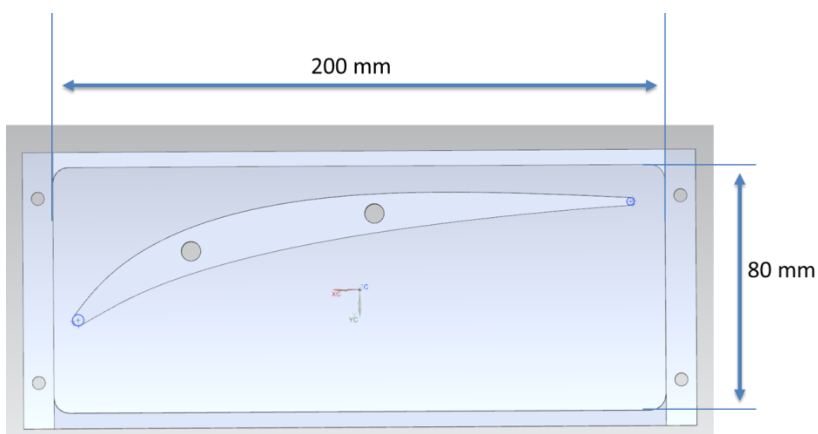


Fig. 3: Manufacturing constraints for the casing fixture