Design and Optimization of an Open Rotor Stage

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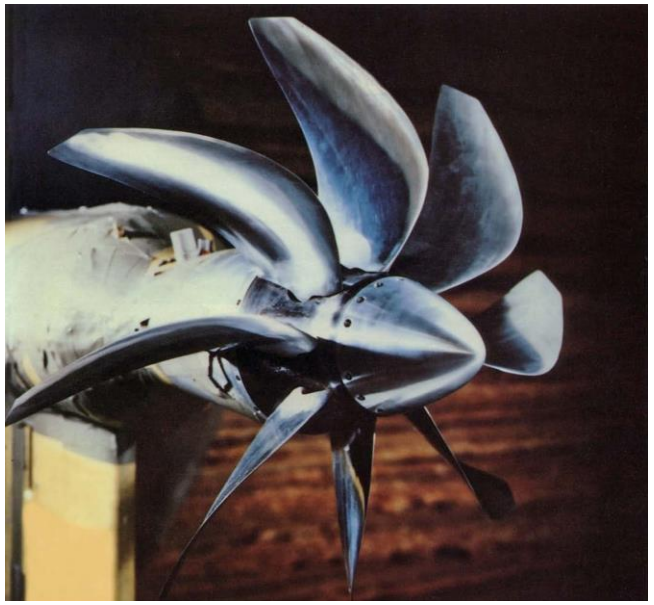
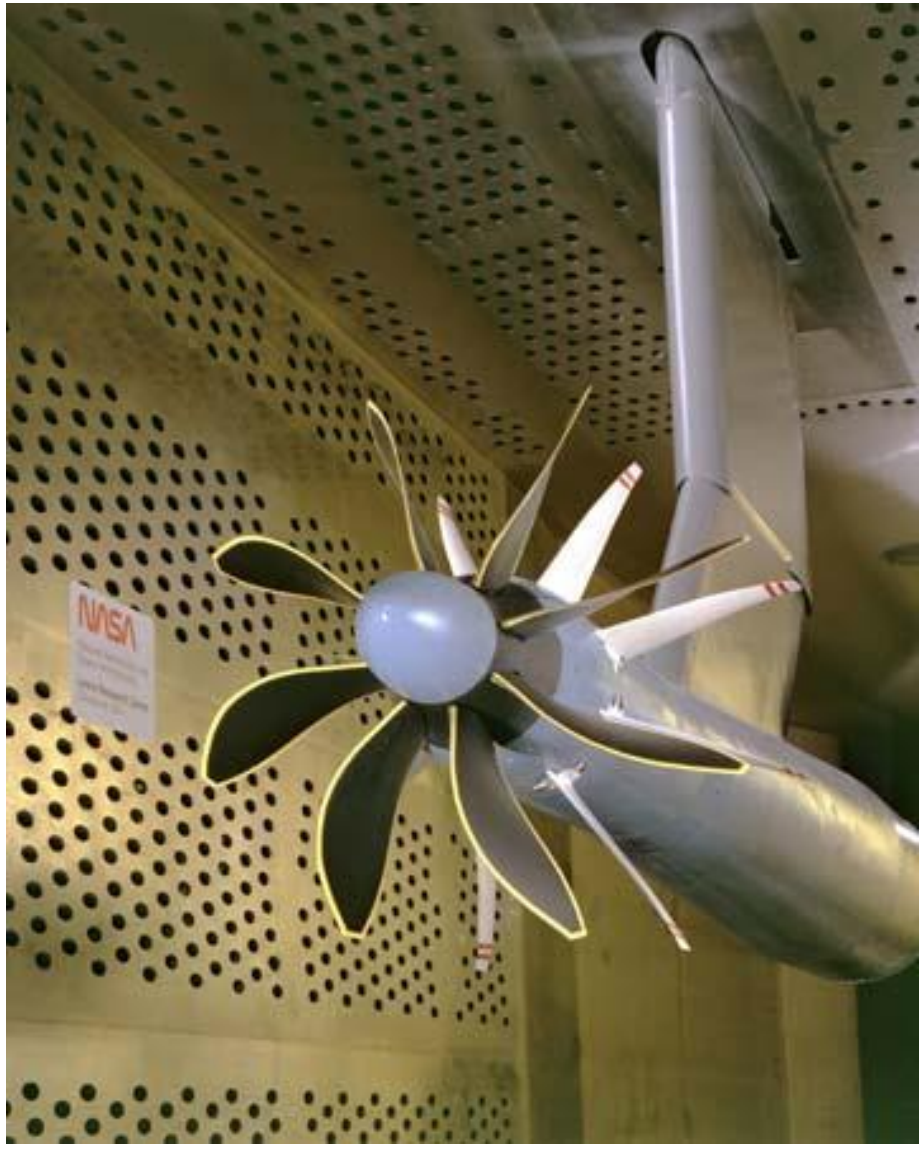
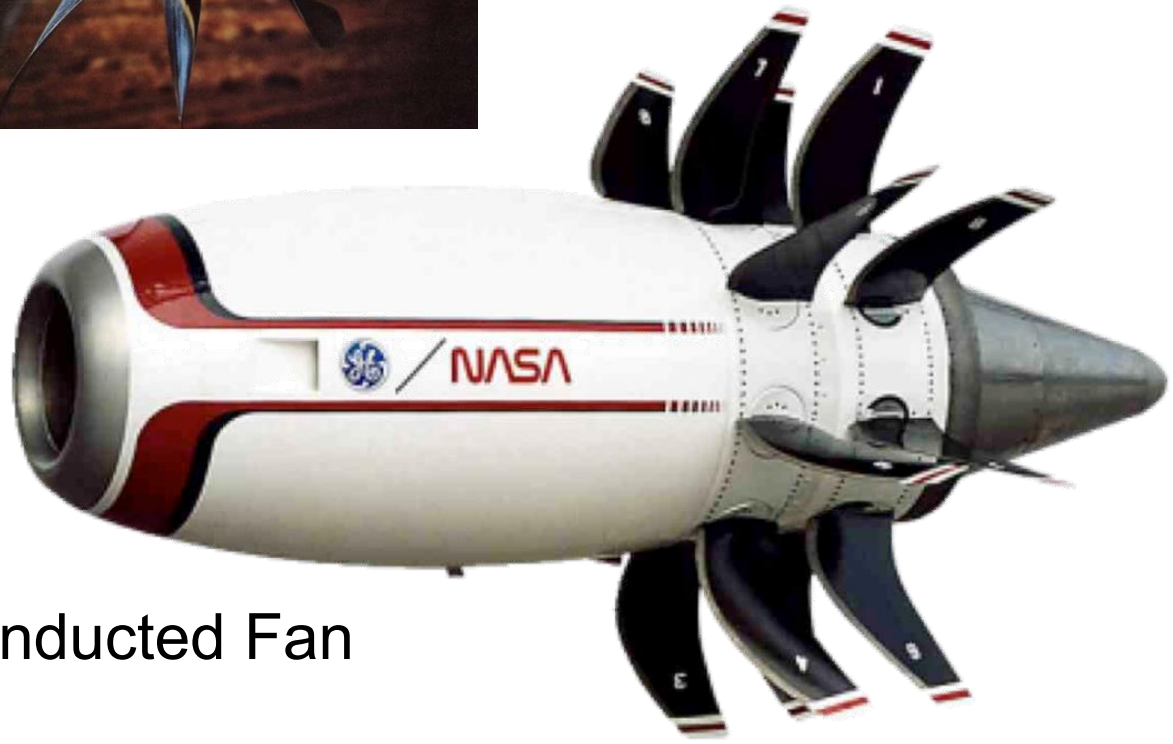
Open rotor propulsors have been of interest for a long time



SR-3

SR-7A with SRVs in 8x6 wind tunnel

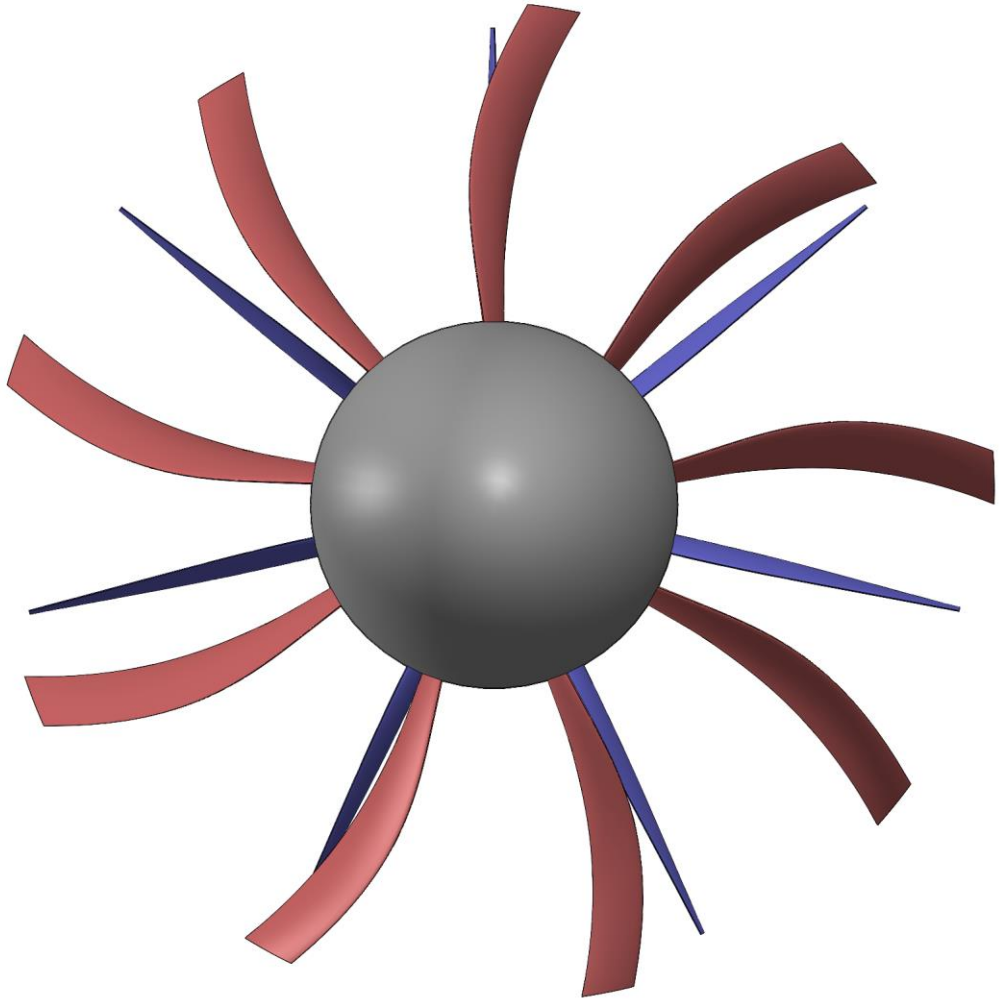




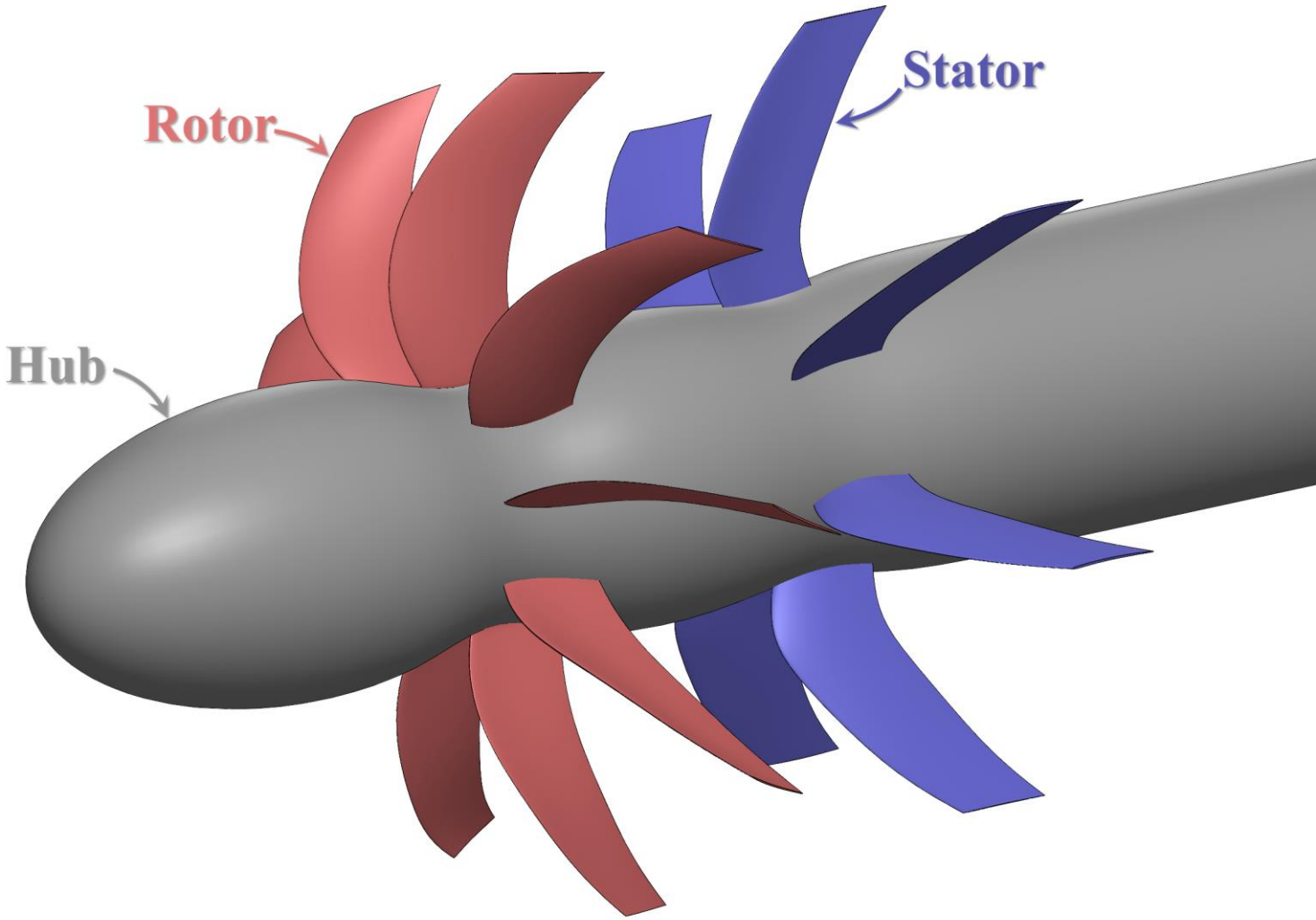
GE Unducted Fan

NASA is currently designing an “Open Rotor Stage”

$M_\infty = 0.785$

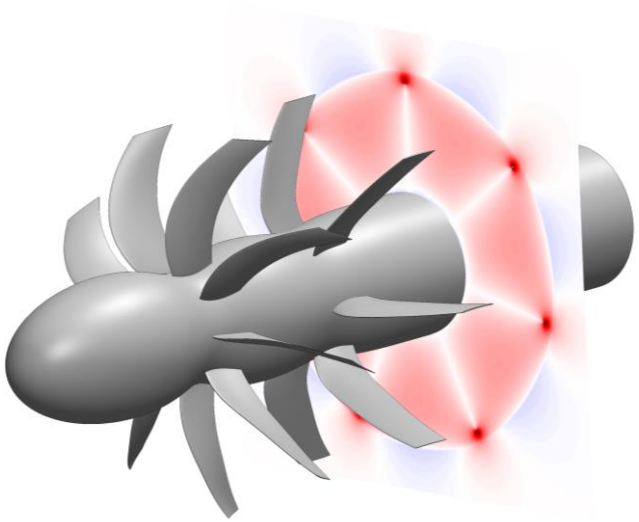


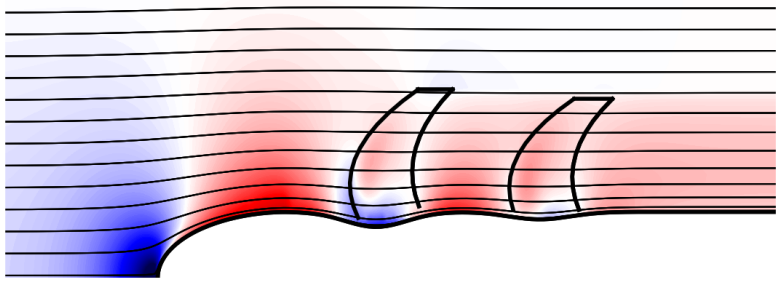
N-OPEN-1

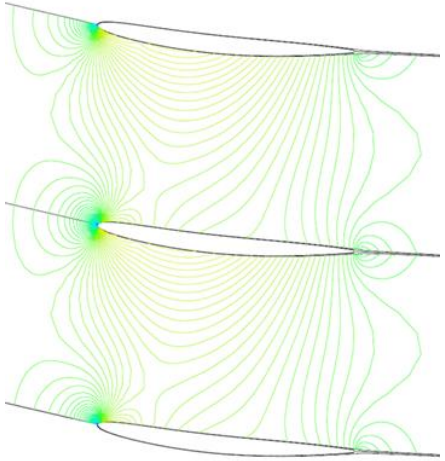


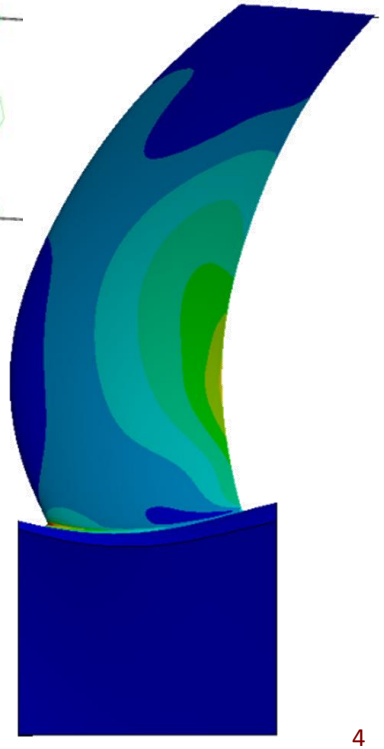
Preliminary design process has several steps

Trefftz plane analysis → Axisymmetric throughflow → Blade-to-blade CFD + structural FEA

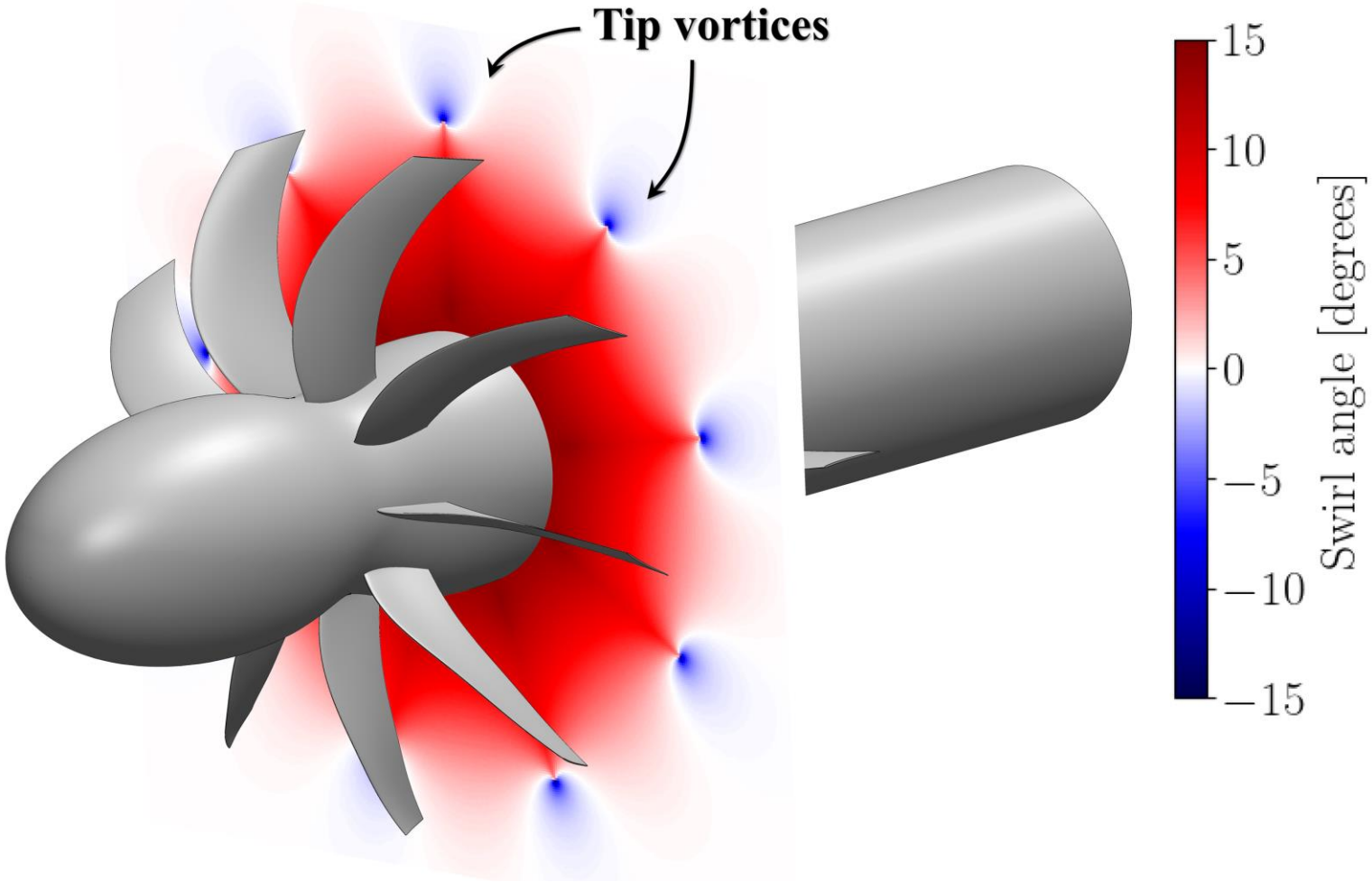




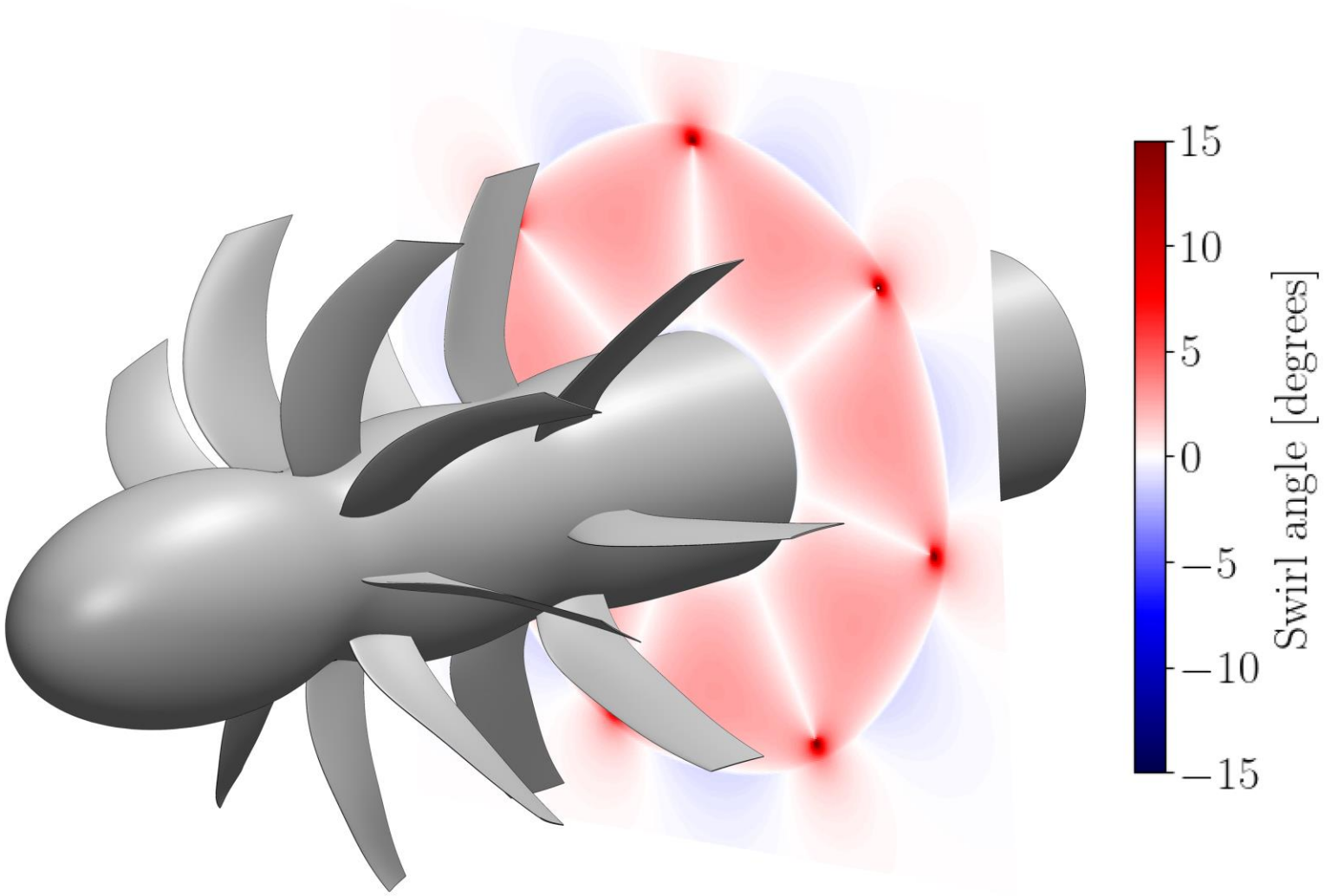




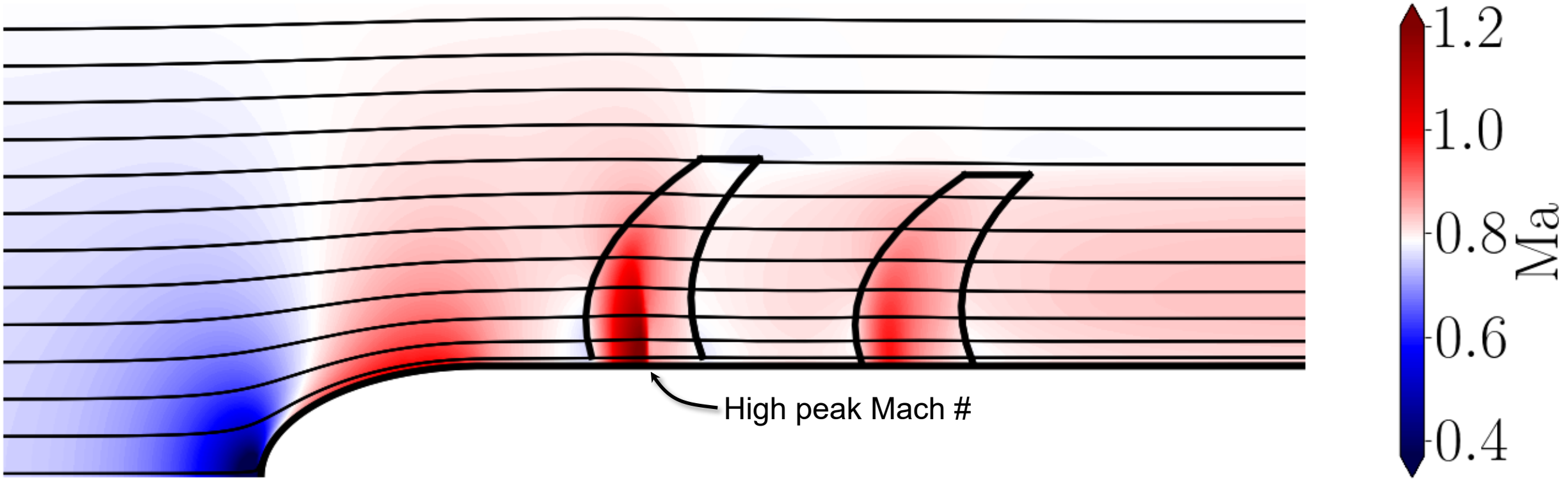
Work distribution considers tip effects



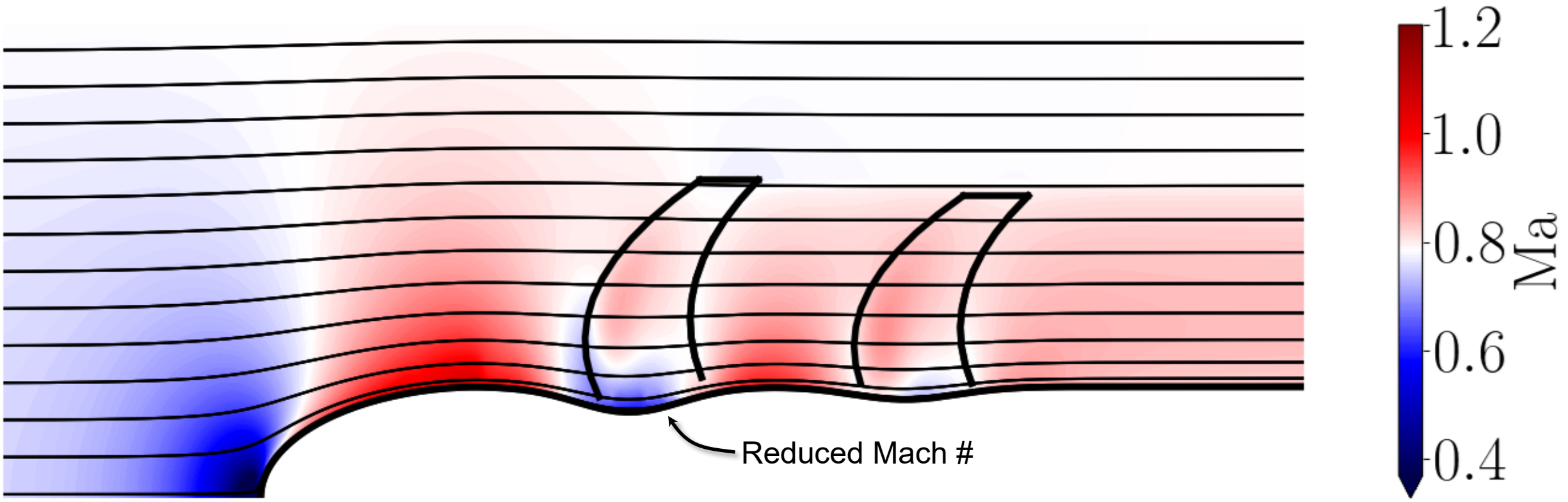
Stator removes most of the swirl from the rotor



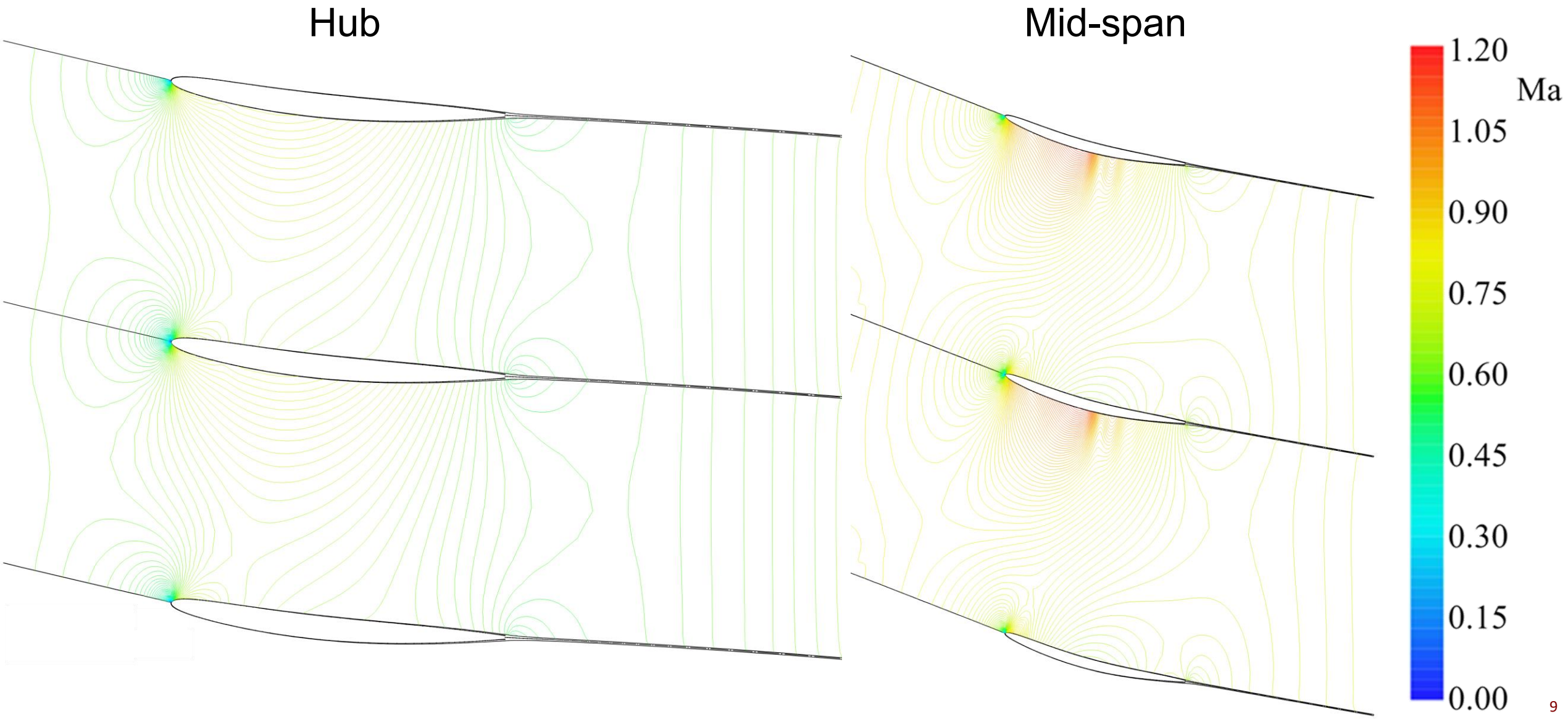
High blockage near hub can lead to high shock losses



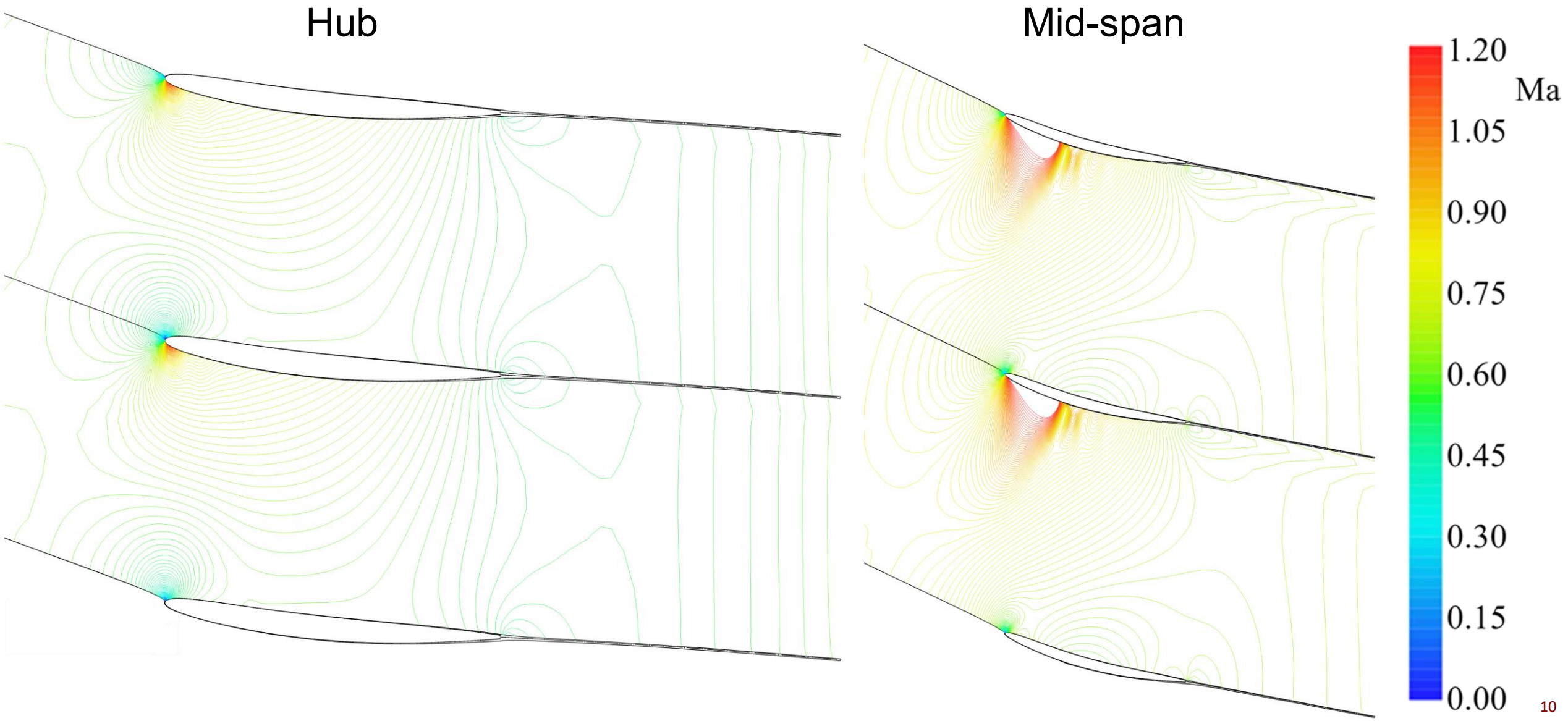
Hub contouring greatly reduces peak Mach number



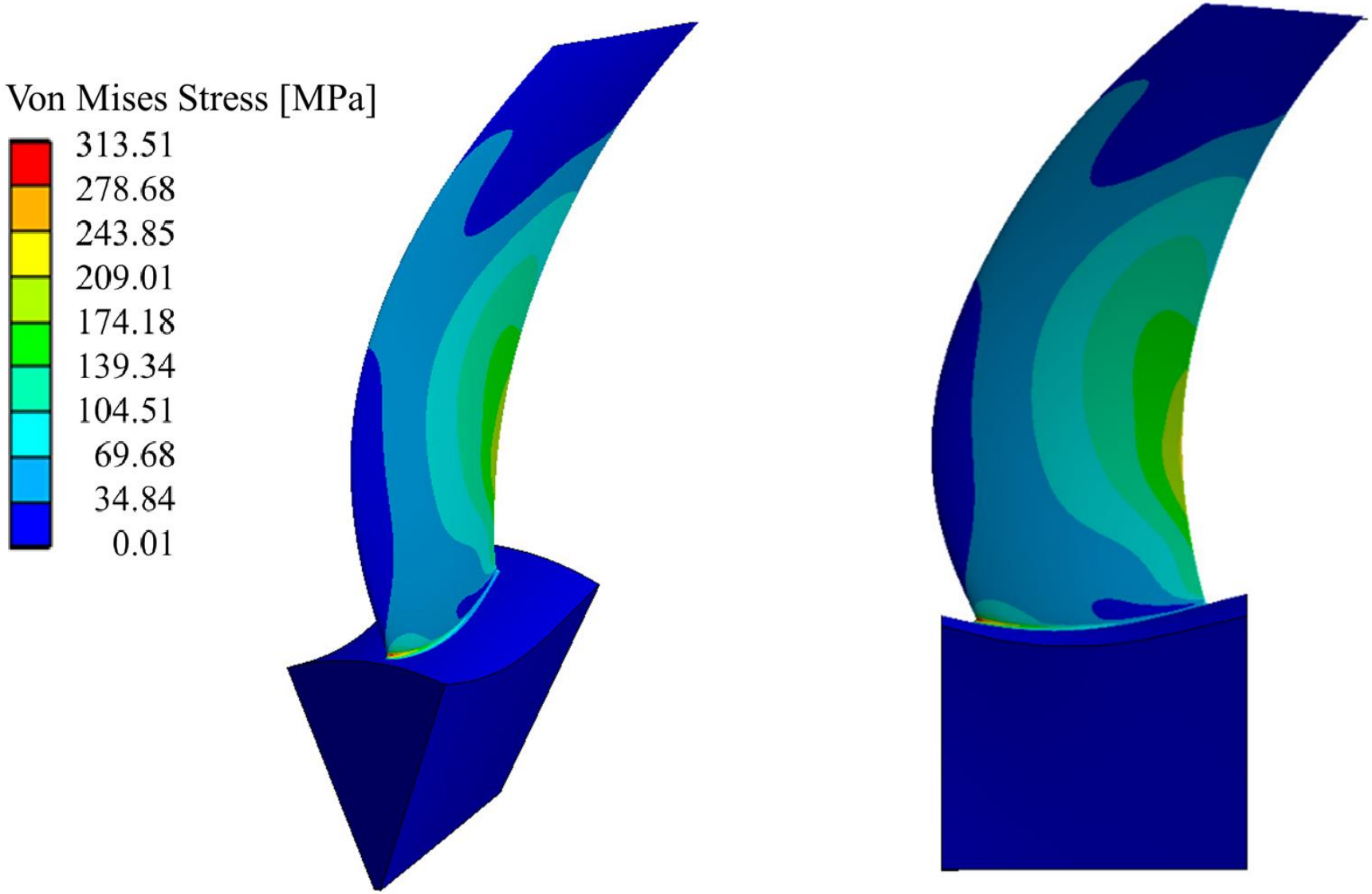
MISES ran on blade sections from hub to tip



Off-design incidence cases were also considered



Structural requirement met at takeoff rotational speed

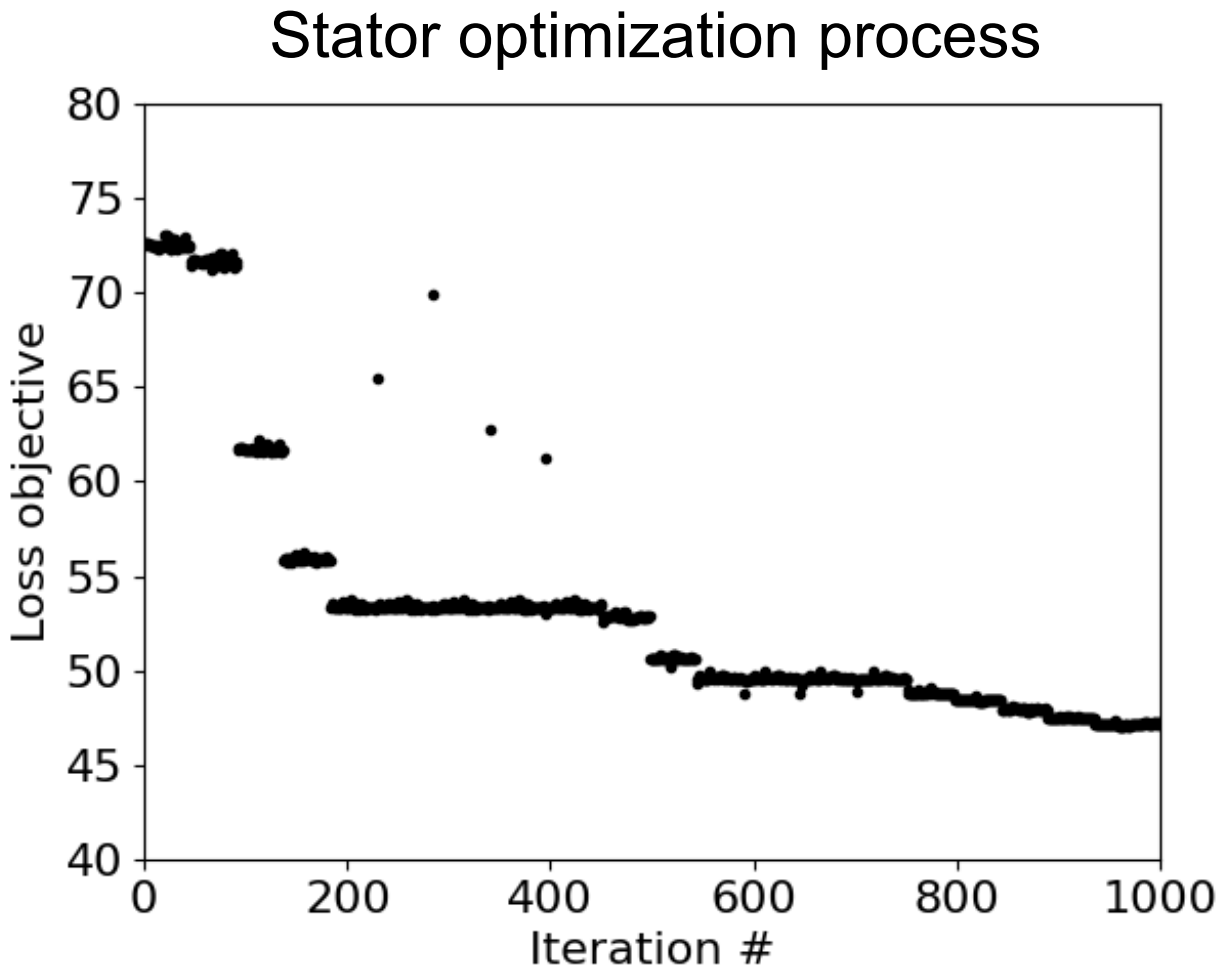


Successful joint aerodynamic and structural optimization

Rotor losses reduced by 9.4%

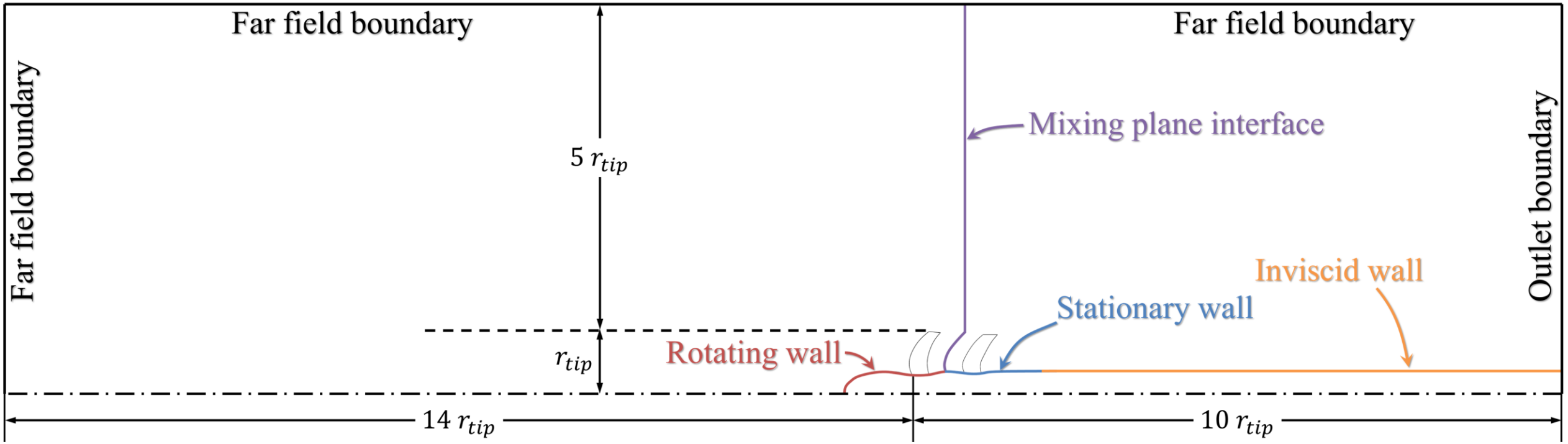
Stator losses reduced by 37%

Rotor FS increased from 1.32 to 1.70



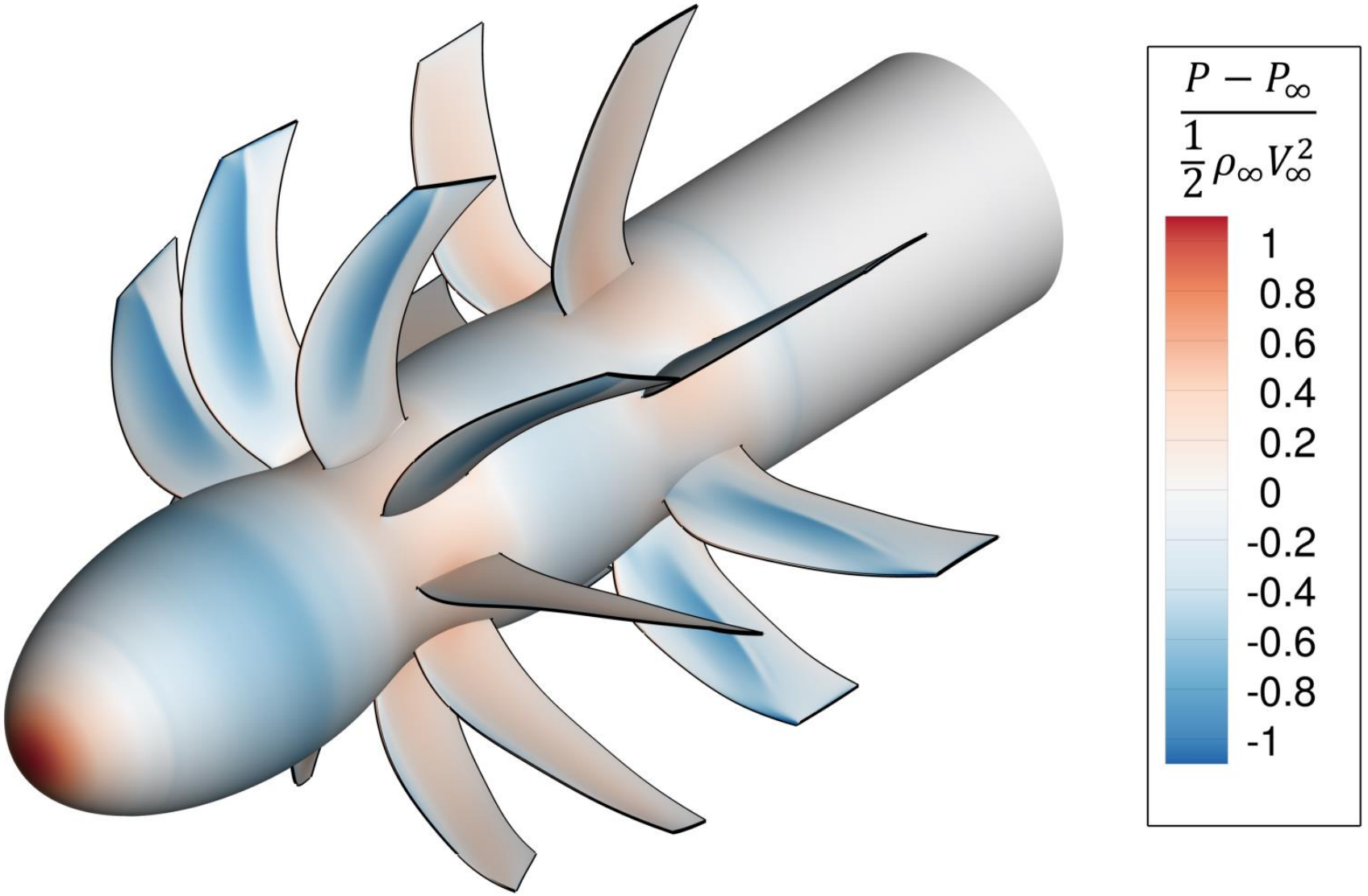
Optimized geometry was then analyzed using CFD

FINE/Turbo multigrid solver used, with multiple turbulence models

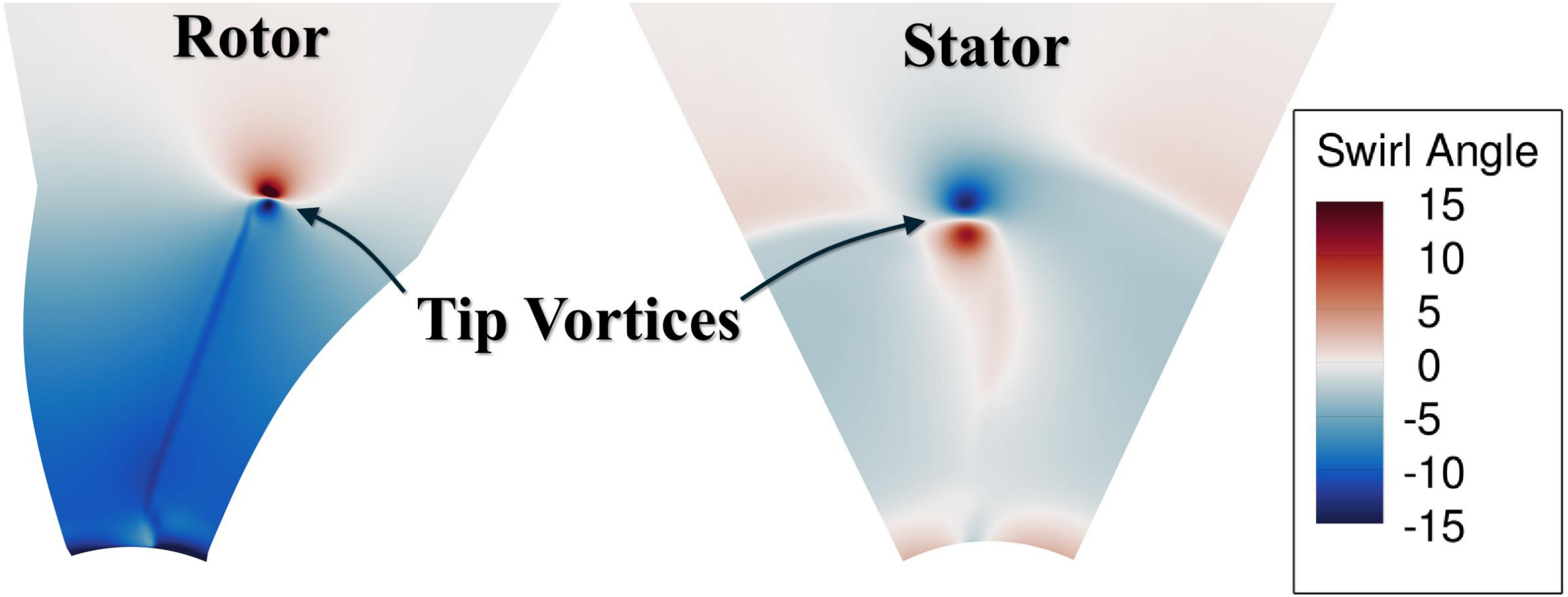


Net efficiency at cruise estimated to be 84.7%

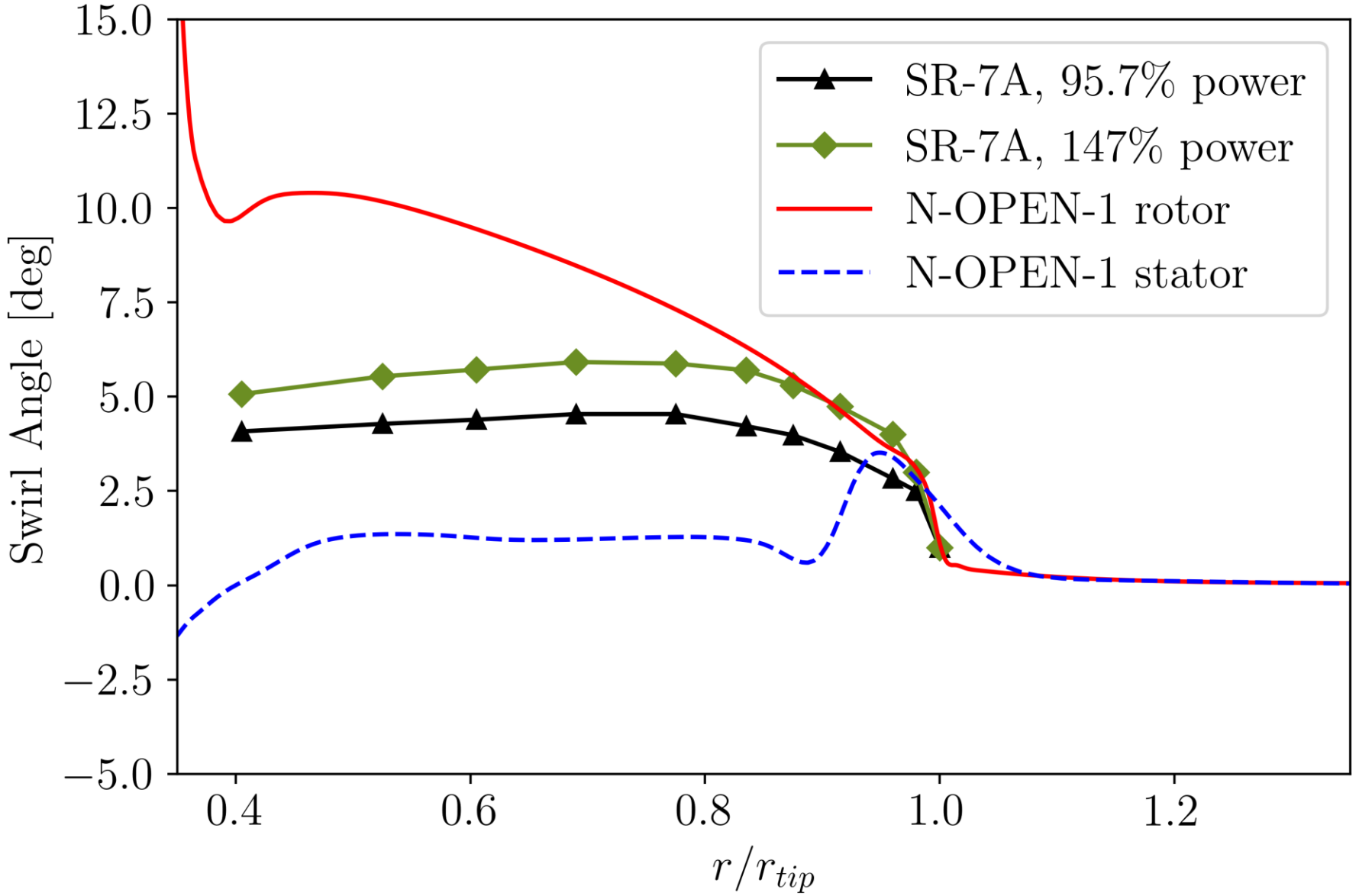
SST turbulence model with Menter-Langtry $\gamma - Re_{\theta t}$ transition model



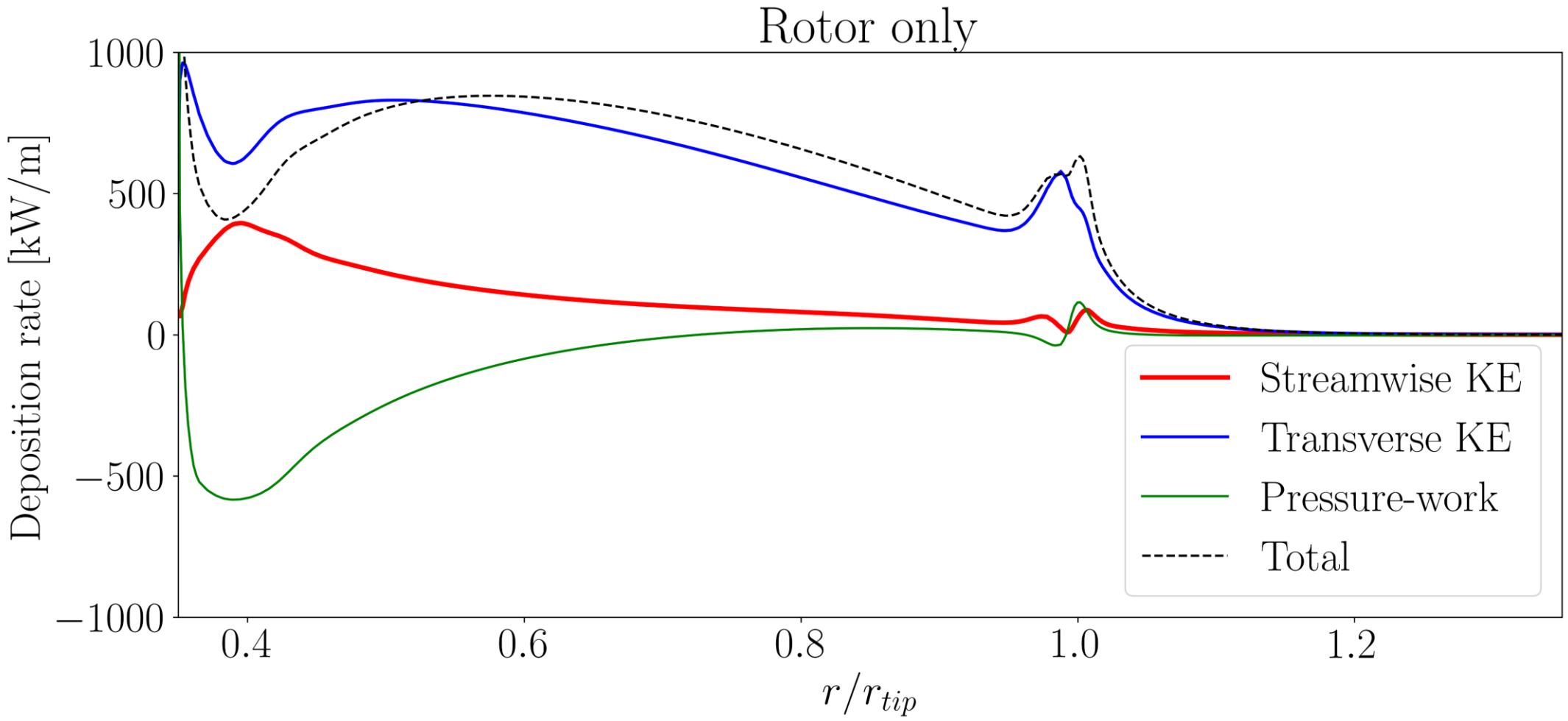
Tip vortices are clearly visible for each blade row



N-OPEN-1 swirl is very different than SR-7A



Induced losses decomposed using power balance



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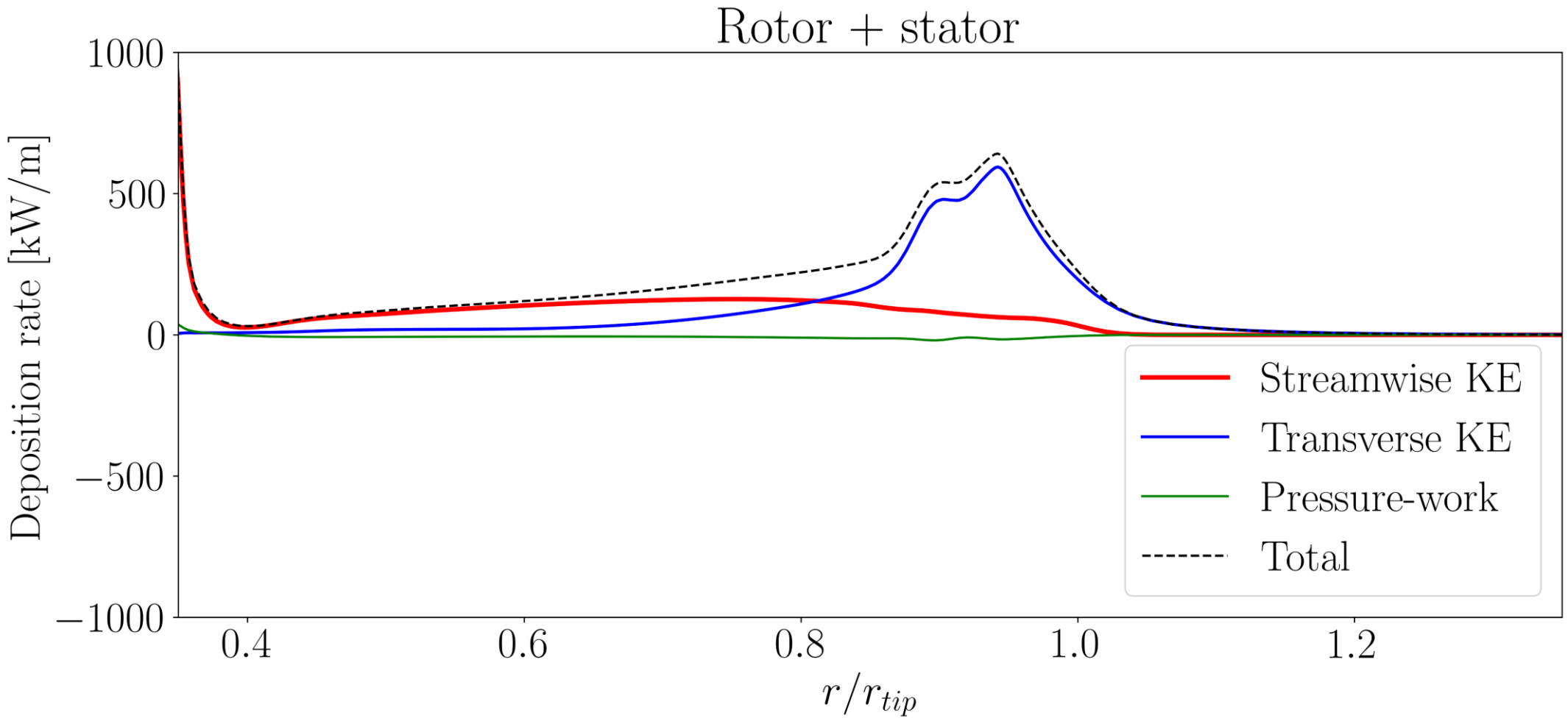
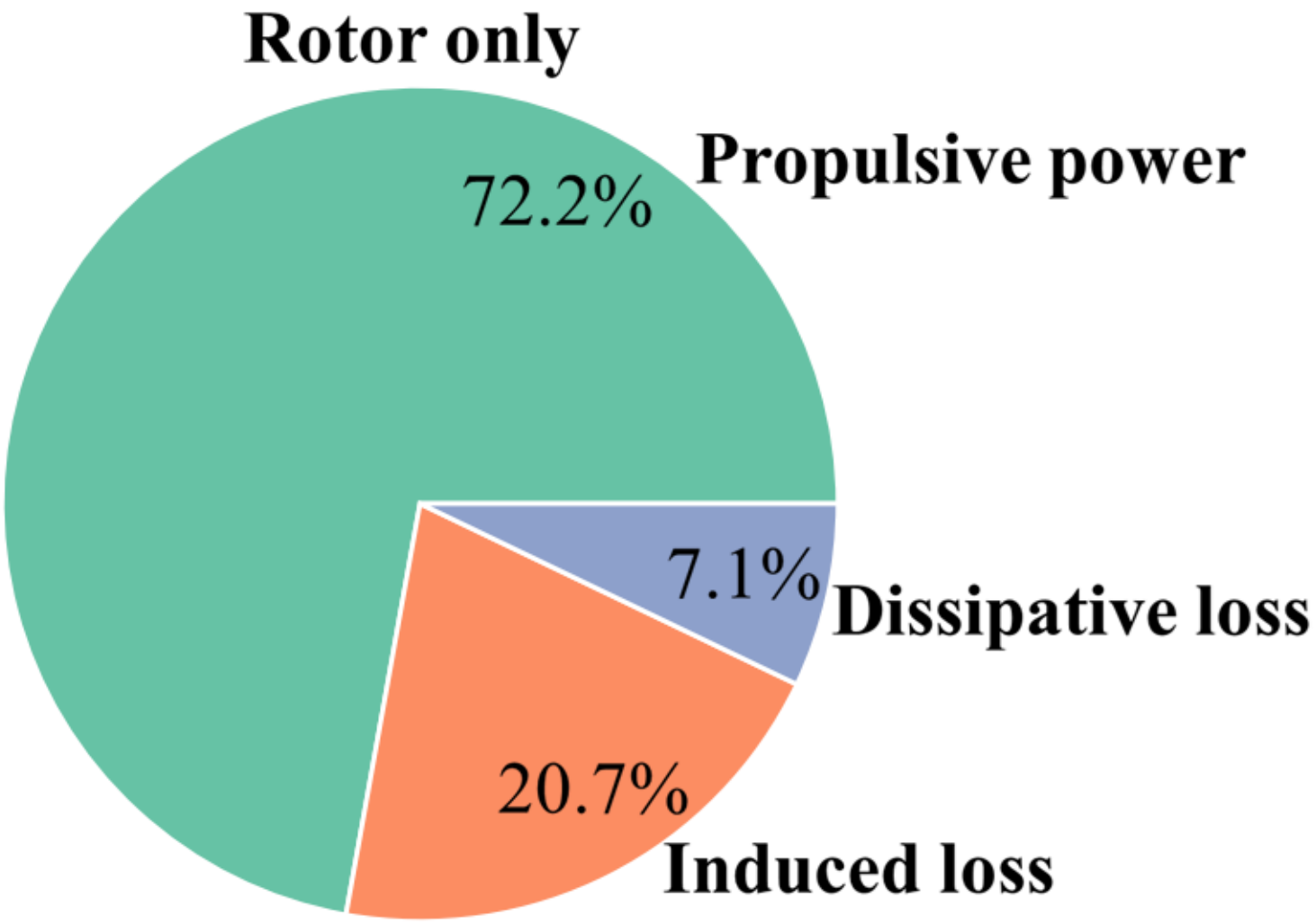
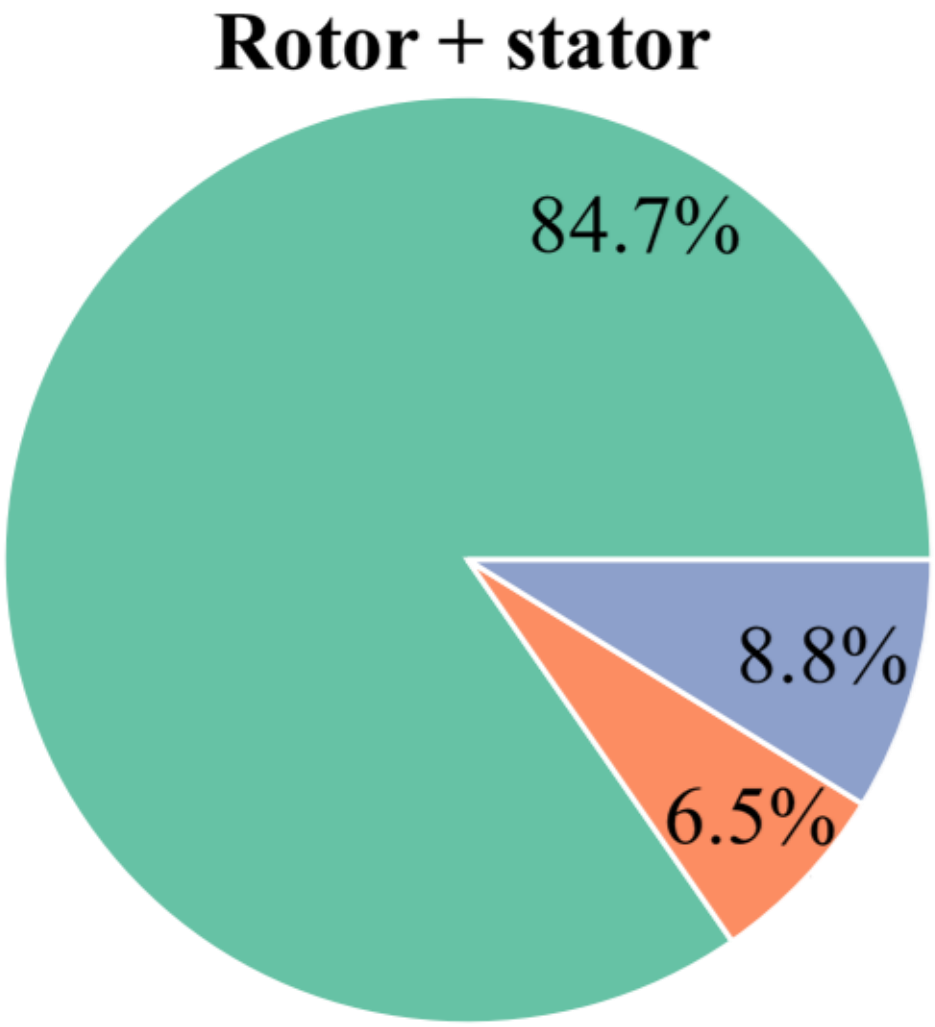


Stator greatly reduces induced losses

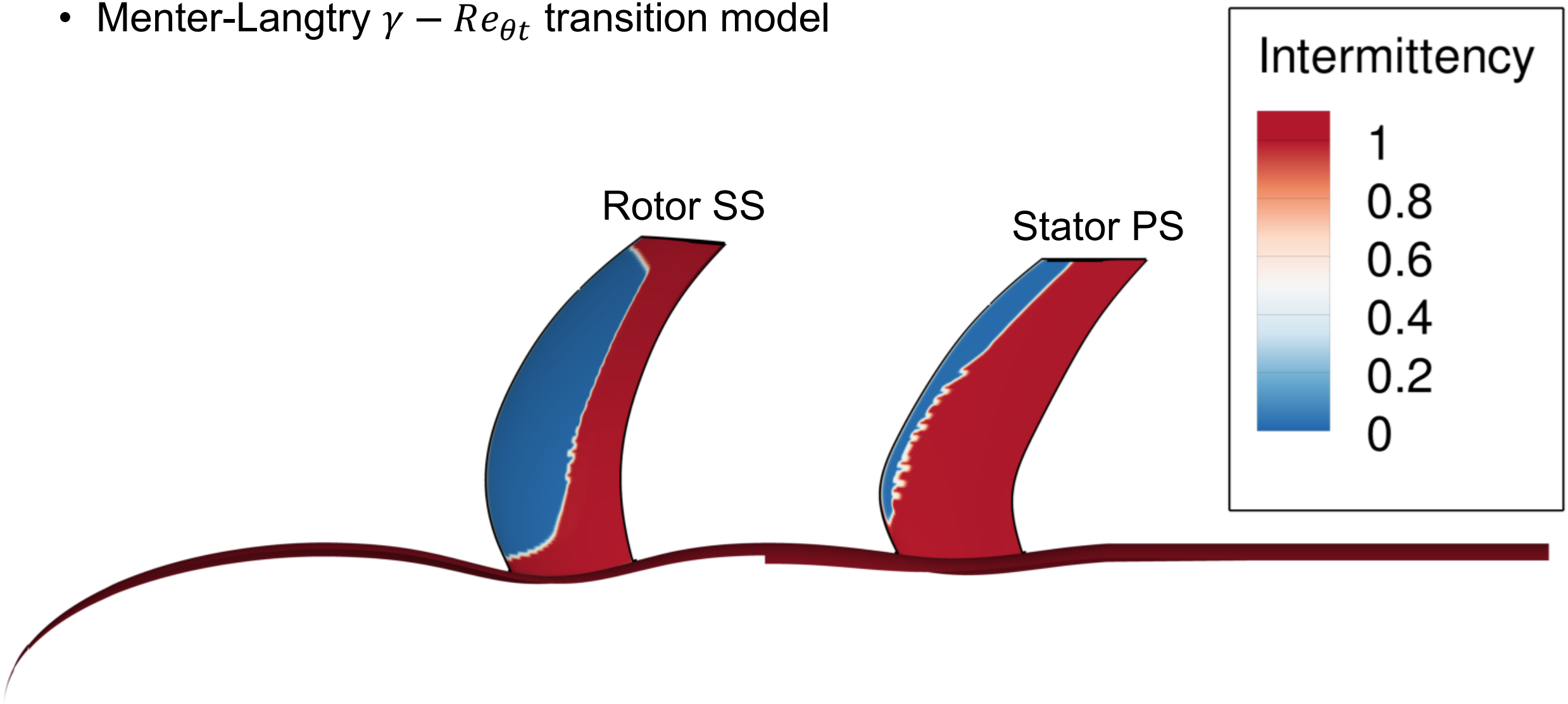




Laminar flow seen over much of the blade surface

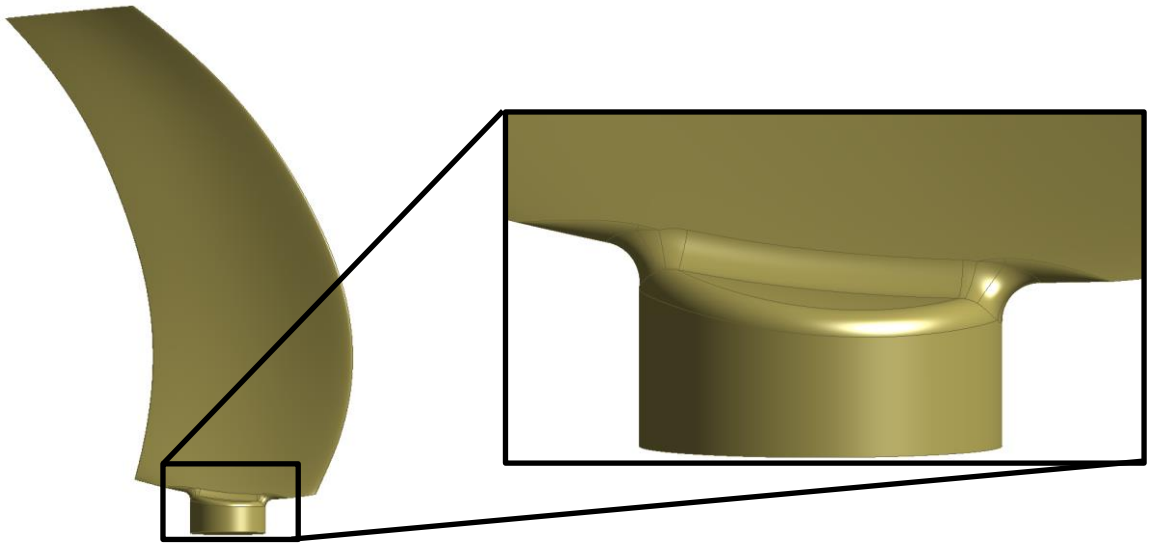
About a 1.7% efficiency benefit over fully-turbulent results

- Menter-Langtry $\gamma - Re_{\theta t}$ transition model

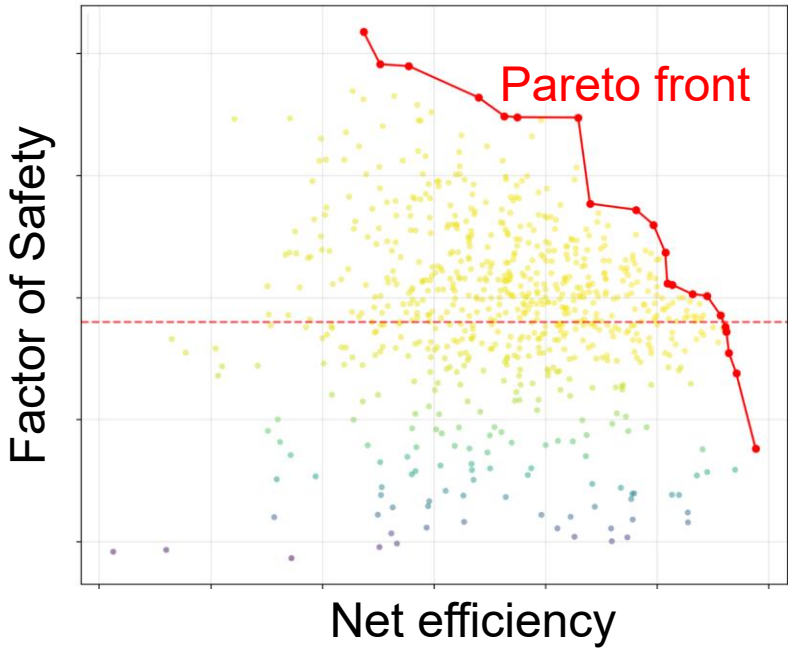


Future work is planned to build on these results

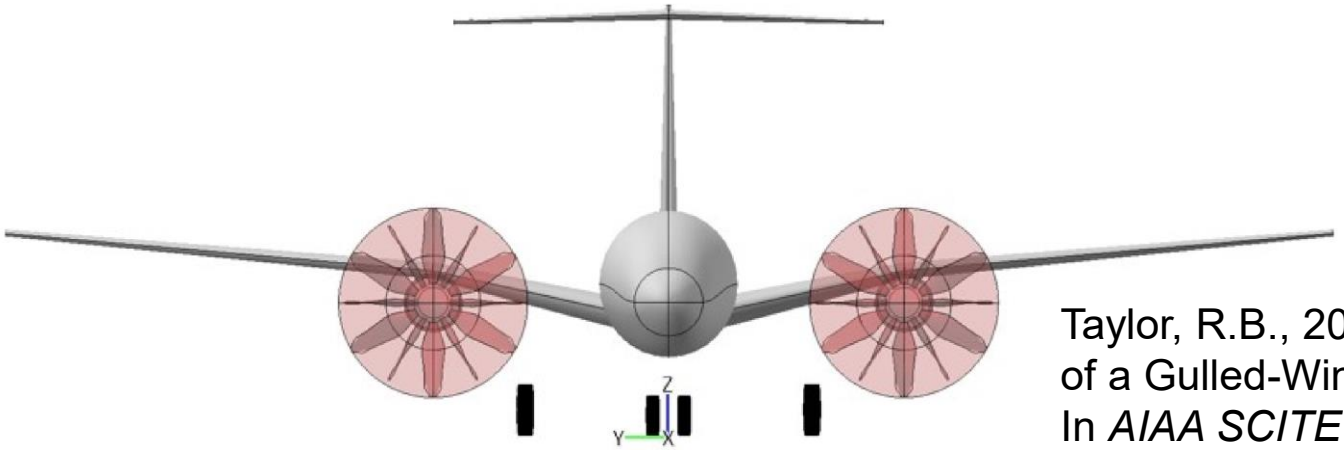
Realistic trunnion/button geometry



Optimization with 3D CFD



Propulsion-airframe integration



Taylor, R.B., 2025. Conceptual Design of a Gulled-Wing Commercial Transport. In *AIAA SCITECH 2025 Forum*

Questions?

Thank you to the Subsonic Vehicle Technologies and Tools (SVTT) Project for supporting this work