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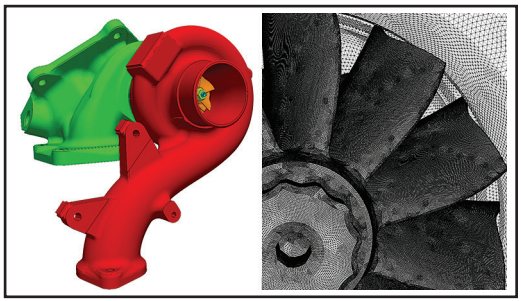
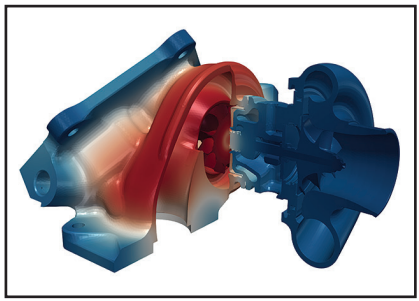
Nathan Sime is a post-doctoral research associate in the Department of Engineering at the University of Cambridge. He plans to use his prize fund to visit two collaborators – Mark Adams, at Lawrence Berkeley National Laboratory in California, and Barry Smith, at Argonne National Laboratory in Illinois. They are both developers of the PETSc library Nathan has used in his work.





The future of the internal combustion engine depends on dramatically increasing its efficiency. As European emission standards change, engines will need to be more fuel efficient. For motor vehicles, this means lower revving engines with turbochargers. Power stations and jet engines also rely on turbomachinery, where there is a strong incentive to increase efficiency.

Large industrial conglomerates need to constantly improve their turbomachinery component design. In particular, they want to decrease the amount of time needed for the design of new components. Our project has resulted in a dramatic decrease in modelling time needed for thermo-mechanical modelling of turbomachinery.

Thermo-mechanical modelling of a turbine uses a geometric mesh to define the shape of the turbine. A typical mesh contains hundreds of millions of points. The mesh can then be used to calculate properties such as heat transfer and thermal expansion and contraction.

The results are used to discover many properties of the turbine, such as:

- yield points,
- areas vulnerable to metal fatigue,
- the clearance of the blades from their housings

Our approach has been to use iterative “algebraic multigrid” (AMG) methods. This method allows for the solving of 100 million-point problems in only a few minutes. Making AMG work well on very large problems has only been possible by using ARCHER at large scale (up to 24,576 cores).

We tested the strong scaling of the solvers using a model of a turbocharger. Taking advantage of the good scaling of the method, we conducted a simulation where n = 3.3x109. Using 24,576 MPI processes over 1024 nodes on ARCHER, the total runtime for this simulation was 6 minutes and 37 seconds. The performance of these solvers enables the computation of large time-dependent thermo-mechanical simulations.