DAVID JAPIKSE BACK TO BASICS

THE VERITABLE STEAM TURBINE – 4

IMPORTANT STEPS IN THE DESIGN OF MODERN STEAM TURBINES USING VALIDATED DESIGN TOOLS

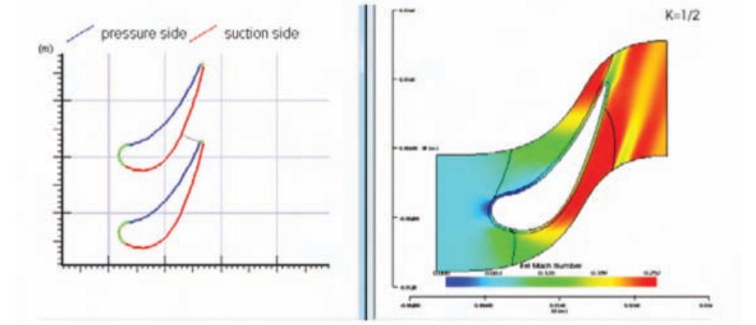

Figure 1. Sample blade section design problem: The vane contours on the left must allow for an efficient flow field on the right as shown by CFD.

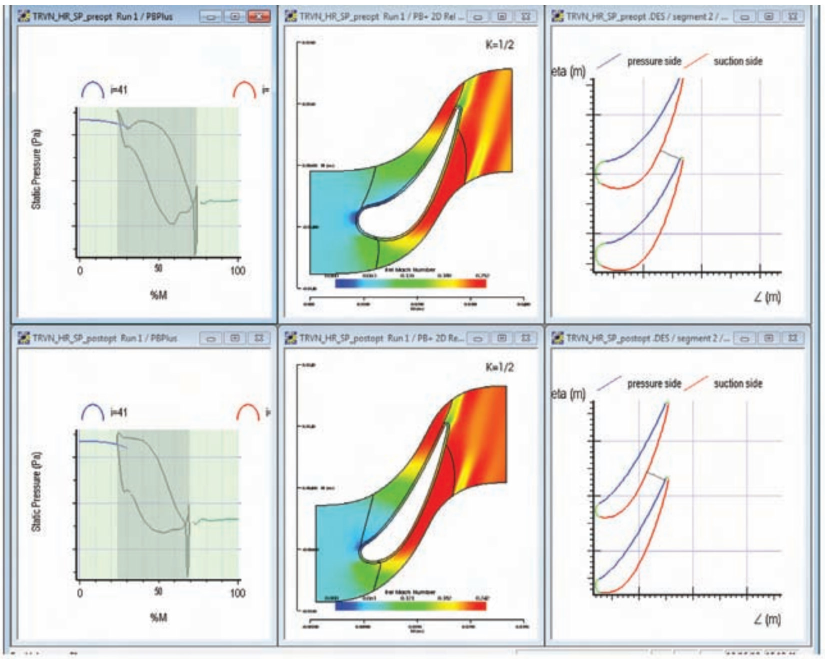

Figure 2. Optimized blade shape (below) and starting shape (above).

In Part 3 (Mar/Apr, p. 27) we probed deeper into the details of blade design and were ready to consider an optimization search method. For such work, the blade shape must be fully parameterized mathematically so that simple parameters can be changed sequentially or stochastically to find optimum results. One of the great advantages of such studies is that other important design conditions such as weight, inertia, root stress, life or Eigen frequencies can be easily added into a suitable variation of such design effort. The geometry of Figure 1 was taken as the starting point, and the geometry of Figure 2, below, is the final result. After nearly 235 trial shapes and computed CFD results, the maximum exit pressure (min. loss) was achieved.

Loading diagrams of surface static pressure are shown on the left of Figure 2 as a result (some methods require these as input – but *no one* could possibly describe the precise difference in these two diagrams *a priori*). Mach number distributions are given in the center; the peak value for the top case is 0.252 and for the bottom case is 0.242 showing dropped levels of Mach number which accompanied a rise in exit total pressure of 54 kPa! The blade shapes are shown in the right-hand side views (*n.b.*: old design on top and new optimized design on bottom of Figure 2).

This example focused on a first-stage design with a single-blade cross-section to be optimized. As explained in Part 3, latter stages have much larger variations in blade shapes from hub to shroud due to the lower values of r_{1h}/r_{1t} which follow the strong variation of local wheel speed, $U = 2\pi rN$ (sorry the pi was dropped in Part 3 while typesetting.)

Of course, the large blade lengths of the aft stages follow directly from the lower steam density, which occurs after the steam has been expanded, work has been extracted, and the resulting lower aft-end pressures are much lower. To design a stage for the aft-end, one must do the same work as just mentioned and repeat it at many sections along the blade length. This process can be helped by the optimization search methods just mentioned, but the end results and final section stacking had best be done or at least carefully reviewed by an expert designer to achieve a useful blade. Massive computerization can be a wonderful thing when carefully done, but an experienced eye is invaluable and can eliminate undue risk as technology continues to evolve.

The examples shown in this article both survey and illustrate important steps in the design of a modern steam turbine using validated design tools. In subsequent articles we will examine some of the special exceptions that occur in steam turbine design, making this part of the turbomachinery world unique, challenging, and rewarding to work with for future industrial designs.

It seems, however, that we should come back to this topic after we spend time on other areas, having now done four articles on steam turbines. Hence our next article will be on machining diverse turbomachinery blading followed by up to four articles on centrifugal compressors. Then we will come back to the veritable steam turbine to look at special topics. TI

Author

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