PERFORMING MACHINE AUDITS

REVIEWS MAY BE NEEDED DESPITE THE USE OF ADVANCED COMPUTING METHODS

Oh, how we have come to trust the computer! It has gained almost a sacred status for some and is cursed by others; yet no one doubts that it plays a key role in getting the right turbomachine for the right job.

The computer is a workhorse for all design, manufacturing, testing and development work before a new turbomachine arrives on site. The computer today has vast capacity and speed, making the challenging calculations of yesterday fast and economical now.

But it needs a critical resource that is challenging: Good software to handle tough performance challenges and an educational basis for managers and employees to understand just what the numbers mean. This is where the process is tantalizing: The computer beguiles us with its incredible power, fantastic color output plots, and detailed results with intriguing new insights, and yet we are not always sure if it is reflecting a sure reality or a new fiction!

Deciding a review

The OEM design process uses many computer codes. Sizing programs give the first choice of stages that might be used for a new process or refrigeration compressor or pump and then standard design stages can be used with confidence.

When there are questions about any quirk in the flowfield, Computational Fluid Dynamics (CFD) evaluations are usually added (CFD usually refers to full 3-D solutions to the complete Navier Stokes equations that govern viscous flow behavior). Finite Element Analysis (FEA) evaluations are, of course, to be applied to any component that has any stress, vibration of other life-limiting concerns.

For products that cannot be supported with standard stage designs, such as new generation gas turbines or specialized, high-performance industrial compressors or pumps, the first step in the design process is not a selection or sizing code, rather a full blown meanline analysis. This develops the critical stage characteristics on a station-by-station basis using fundamental, empirical physics models.

The average buyer of these machines is at some disadvantage to interpret all the OEM calculations and procedures. Both parties must be concerned when errors are made — colorful plots do not always tell the full picture and audits may be needed.

Figure: Rerated multistage, gear-driven centrifugal compressor. Various new impellers, diffusers, volutes and seals were introduced to meet new operating specifications

Independent machine audits should be made during manufacturing and for field problems. Although any tool used in the design process might be used at some point in an audit, the rational starting point is to use a meanline model to scope out the broad world of design issues before looking too deeply into any one area.

With today's powerful meanline tools, these audits may be conducted quickly and frequently turn up issues that should have received additional attention in the original layout process. Most stages are well conceived and will not need corrections, but from time to time an oversight passes through and the audit is well worth the effort.

These audits may be made by the customer or for them by an independent consultant. The codes used should have a significant degree of independence from the original design or selection work. The depth of an audit depends on the level of concern that a customer may have.

Usually, only the initial design type procedures need to be exercised to see if either fluid dynamic or structural mechanic concerns may exist. An exception would be rotordynamics wherein the audit should check all levels of design concern. If concerns are found, then deeper evaluation, perhaps all the way up to unsteady CFD, ought to be pursued.

All design procedures (usually codes) employed by a manufacturer are available to help evaluate field performance problems or to help plan for the future, either with increased capacity or reduced capacity (not uncommon during a recession) or to redefine a process layout to permit alternative machine strategies. For instance, recently, a plant operator wanted to rerate a gear-driven multi-stage centrifugal compressor for 12% higher capacity and greater efficiency, while eliminating a boost compressor (hence requiring greater head in some stages) and improving reliability. This was done without involving OEMs (Figure). The same design procedures were employed for the rerate as would have been used for the OEM!

The computer and the supporting design codes for turbomachinery also serve for "blue sky" (what-if) studies, as well. When a whole new application is proposed, one wants to open the doors of possibility and outline totally new options. Here good performance models are needed to get the process rolling with much detailed analysis for follow through.

Through all the options for performance analysis, errors can be made. It is always essential to form useful sanity checks. Simple hand calculations are useful to see if essential parameters are sensibly within bounds. Experienced human judgment is never to be dismissed. Calculations with alternative physical models or with competitive codes are useful. Uncertainty analysis can be applied to most situations and may be an eye opener. For any project, a combination of these approaches should provide a measure of safety for the customer.

Give thanks for the modern computer — no one in their right mind would want to go back to the (not so) good old days. But computer power has grown so vast that it is now time to carefully decide just how to exploit this asset best. It behooves us to continue our education in basic engineering and test all modeling with observations from nature so that we are able to evaluate computations with a physics-based understanding and not be beguiled by a modern Lorelei! Hopefully the ideas given herein start the process of review. TI

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