ACD Invested in Simulation Driven Design

Simulation-driven design enables ACD to reinterpret the process of design, while offering our customers tested products with confidence in design and evidence of performance. Unlike the past, when each design required a prototype for testing, simulation takes design to a whole other level. Simulation-driven design is defined as *"a design process where decisions related to the behavior and the performance of the design in all major phases of the process are significantly supported by computer-based product modelling and simulation"*.

ACD's integrated state-of-the-art simulation tools and solutions help to explain performance trade-offs at an incredible level of detail. This enables us to analyze a variety of conditions up front, review results and fine-tune the design prior to the full-scale prototyping and testing. Simulation-driven design gives us the ability to resolve potential issues before we put them in the design, thus preventing expensive field failures. The result is a better end product for our customers.

What are the benefits? Simulation provides several key benefits: Improving/increasing product quality, resulting in a reduced risk of failures and warranty issues; simultaneously improving the bottom line through reduced product and labor costs.

a) Timescales – ACD recognizes the power of building, testing and verifying their products using a virtual prototype rather than a physical prototype. This is more cost effective and offers lower risk, which in turn translates to reduced cycle times.

b) Evidence of Performance – Customers require evidence of performance and compliance to a variety of industry codes and standards. It is easier and more accurate to perform simulations rather than build the prototype and do destructive testing.

c) Failure Root Cause Analysis – In cases where you have a failed part, simulation allows us to analyze it and determine what the root cause of the failure was. Identifying the root cause of the failure allows for design modifications that can be implemented quickly and thus reduces equipment downtime.

d) Confidence in Design – Traditional approach to design is to perform hand calculations and sketch something out. There is little-to-no confidence in the design; the confidence comes from testing. Our state-of-the-art software tells us more about the design and provides that confidence without the time and expense of extensive physical testing or oversimplified calculations.

Simulation Software Applications

The various software tools available and in use at ACD for design simulations are:

Sizing and Selection Tools

- TESS: TurboExpander Sizing and Simulation – Our modern, networked, graphical software system designed and built in-house to support rapid selection and sizing of turboexpanders.

- SPAIX: Centrifugal & Reciprocating Pump selection and configuration – This software includes a rich database of specifications and performance data that helps us select the right pump for our end user.

Aerodynamic Design Codes

As a provider of turbomachinery solutions, ACD's competence lies in our skill and ability to design impellers customized to end user needs. The following aerodynamic sizing tools allow design and rapid analysis of the flow through the impellers.

- Aerodynamic 1D Sizing Tools ("Meanline" Analysis)
  - Vista Tools in Ansys - Includes design software such as CCD (Centrifugal Compressor Design), CPD (Centrifugal Pump Design), RTD (Radial Turbine Design)
  - Concepts NREC Compal

- Blade Geometry Design
  - Ansys BladeGen and BladeEditor
  - Concepts NREC

- Aerodynamic 2D Rapid "ThroughFlow" Analysis
  - Concepts NREC Axcent

- Turbomachinery Specific Mesh Generation Tools
  - Ansys TurboGrid
  - Numeca AutoGrid5

- 3D CFD (Computational Fluid Dynamics) Analysis Software
  - Ansys CFX & Fluent
  - Numeca Fine/Turbo

Structural Analysis Tools

- Mechanical Analysis - Static Structural, Modal, Thermal
  - Ansys Mechanical
  - SolidWorks Simulation

- Rotordynamics
  - XLRotor - For simulation of rotor bearing system dynamics.

Testing

- Experimental Modal Analysis (EMA) – To do full modal analysis on impellers and measure FEA-computed frequencies and mode shapes.
  - Data Physics Dynamic Signal Analyzer (DSA)
  - Vibrant Technology MeScope

- Labview 'Turbo Test' Software – Specialized software for cryogenic performance testing of compressors and expanders.

Computing Hardware

To support and run the simulation software, we have a full contingent of dedicated workstations for High Performance Computing (HPC). The computers are complete with high speed processors, RAM and storage capabilities and have been specifically tailored for CFD and FEA applications.

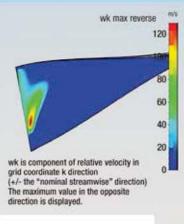## Examples of Simulation Driven Design

Impeller Modal Analysis

We at ACD perform FEA modal analysis on impellers to characterize impeller natural frequencies. The use of Campbell and interference diagrams, as well as animated mode shapes from FEA helps to visualize the potentially dangerous interactions of various impeller mode shapes and sources of excitation. The frequency analysis helps ACD avoid vibration-based failures by modifying geometry of the impeller hub and back disk including designing shrouded impeller if needed. All the geometry modification can be managed during the initial design phase thus avoiding costly rework and rejection after manufacturing and testing. After the impeller is manufactured, we perform full experimental modal analysis and our experience has shown very good correlation to analytical results.

Figure 1 - Impeller Modal Analysis

Aerodynamic Blade Design and CFD analysis

Figure 2 shows a compressor blade design in Bladegen. This in an example of a development effort that ACD undertook to improve impeller efficiency. Extensive 3-D Computational Fluid Dynamic (CFD) analysis was done on the existing wheel design to characterize the flow field. Several blade profiles were generated using the commercial codes Concepts/NREC and ANSYS BladeModeler. The CFD analysis was done using Numeca Fine/Turbo software with identical mesh settings for all designs and subsequent mesh refinements were done to get mesh independent results on the chosen design. CFD was primarily used to rank the designs based on stage total to total efficiency.
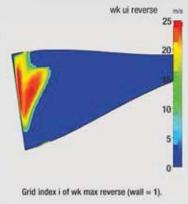
wk max reverse   m/s

120

80

60

40

20

0

wk is component of relative velocity in grid coordinate k direction (+/- the "nominal streamwise" direction) The maximum value in the opposite direction is displayed.

wk ui reverse   m/s

25

20

15

10

5

0

Grid index i of wk max reverse (wall = 1).

Figure 2 - Compressor Blade Design

Figure 3 - Pump Impeller Design - New Product Development

Frictional Contact Analysis

Our FEA capabilities allow us to design a part around the results of the Frictional Contact Analysis. One such example shown in Figure 4 is of an impulse liquid turbine that ACD designs. Because of the cyclic nature of the load, the impeller shroud came loose. FEA was used in failure root cause analysis and the design was modified to prevent such failure
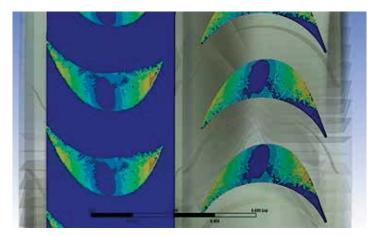

Figure 4 - Frictional Contact Analysis

Professional Analytical Staff

In addition to the investment that ACD made in simulation tools and methods development, we have an experienced engineering staff with years of experience in turbomachinery design and analysis. Without their expert knowledge it would be very difficult to understand and evaluate designs and leverage the capabilities of the software.

Simulation driven design combined with robust design practices, experienced staff and powerful high-performance computing enables ACD engineers to predict performance and solve product design challenges faster than ever with a high degree of confidence.

For more information, visit acdllc.com.

New Product Development - Pump Impeller Design and CFD

ACD's new product development department's mission is to constantly re-invent the company's products to maintain leadership in the ever-changing market. A simulation-driven product development approach helps in order to bring different ideas to the table, work with them and take the best possible solution to move further into the testing phase, faster and more efficiently. While working to get a new line of centrifugal pumps for the LNG market, CFD is being used by ACD to sort out the best designs for the hydraulic components. The variations include changes in number of blades, blade angles, wrap angles, passage heights, and gulping and trimming component among other options. A design of experiment study can be set up for the impeller, diffuser and inducer designs using the CFD software to get the best stage performance for the application. These designs can then be manufactured and tested in real-time to experimentally verify and approve for production. Using CFD has enabled exploration of ideas as a faster and more effective way of proving those designs before manufacturing and testing each design. Since there is a decrease in the number of physical prototypes made, there is a significant reduction in manufacturing and development costs.

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