# CRITICAL ISSUES IN ENERGY – 3

## WATER POWER, CO2 CAPTURE AND TURBOMACHINERY DESIGN

Wind turbines have been industrialized to the point where they are among the fastest growing renewable energy sources. Land or offshore wind turbines that are rated at 1.5 MWe to 2.5 MWe of power are not uncommon. However, the power output of such turbines is affected by the variability of wind velocities. A more constant natural energy resource are water waves. Oscillating Water Columns (OWC) are waterwave energy recovery systems designed to produce high air velocities in the order of 100 ft/sec to 150 ft/sec. This system requires a wind turbine design that can accommodate the constantly changing fluid velocities during each wave period.

The vast natural resource of water wave energy warrants the active study of advanced wind turbine designs that can accommodate these continually changing velocities and pressures. For example, Concepts NREC is researching the use of a self-actuating turbine blade that can respond to the changes in air velocity by using the aerodynamic forces that act on the blade. The challenge is to match the torsion stiffness of the blade with its necessary tensile strength. The result of a successful design will be the development of a wind turbine that has the efficiency of a variable pitch, unidirectional turbine with the inexpensiveness of a fixed-blade (i.e., Wells type turbine design) that tends to have a lower efficiency.

Meanwhile, the capture of $CO_2$ from the exhaust products of a conventional, fossil-fueled (particularly coal) power plant has been given increased interest with the advent of recent "Cap-and-Trade" legislation. Research has been funded by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) for methods of capturing and sequestering $CO_2$. Several of these studies have promoted the integration of $CO_2$ capture with power generation using coal as the primary fossil fuel.

An example is Advanced $CO_2$ Cycle Power Generation — a project funded by NETL and conducted by Foster Wheeler North America (Figure). The cycle combines power generation using fluidized bed technology and coal-to-syngas production to generate power while also capturing 100% of the $CO_2$. This cycle has the advantage of not requiring amines to absorb the $CO_2$ from the exhaust products of coal combustion. Of particular interest to the turbomachinery industry is a conclusion reached by Foster Wheeler:

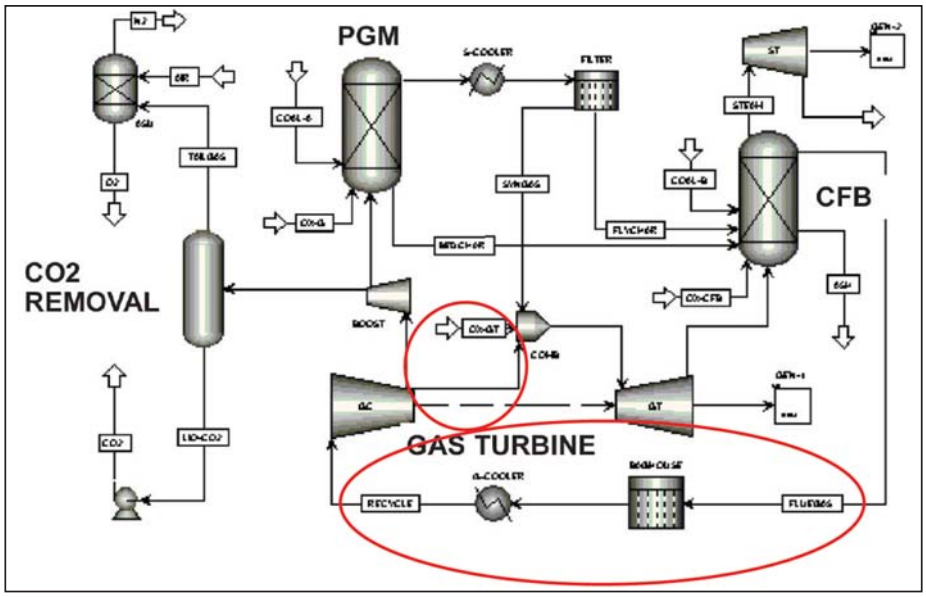


*Figure: A CO2 capture system that does not use amines*

"Currently available turbines would not be able to handle the $CO_2$ stream. Today's turbines operate on mainly nitrogen streams (from air combustion) and therefore were designed with different thermodynamic limits." The development of a $CO_2$-based gas turbine engine is facilitated by Agile Engineering including the current state-of-the-art Computational Fluid Dynamics (CFD) tools and 5-axs machining capability.

## Enabling turbomachinery

Clearly the analysis, design, and fabrication of the necessary turbomachinery is of paramount importance to the efficient recovery of waste heat. This is truly the heart of the engineering challenge for power generation and includes various turbines, compressors and pumps. The turbomachinery can be axial or radial, impulse or reaction. The choice depends upon the fluid operating pressure ratios and volume flow rates, and these in turn depend on the temperature of the available waste heat, temperature of the available cooling source, and power required.

Advances in machining technology include Computer Aided Machining software that can transform detailed engineering drawings of the advanced rotors almost immediately into machine code that can guide the 5-axis machining of the entire turbine or compressor or pump impeller. The technology has enabled even the most sweeping or contoured shrouded turbine or compressor blade to be manufactured without compromising the CFD solution for the blade shape in order to achieve maximum power recovery efficiency.

The common technical challenge that must be met for each of these turbomachines, in addition to the expert thermofluid analysis and design, is the proper selection of compatible materials between the working fluid of choice and the materials of construction for the high-speed turbine or compressor. While it is desirable to increase the operating limits of the rotor tip speeds to reduce the number of stages for a particular application (and thus reduce complexity and cost of the unit), the rotor materials must be chosen for their strength to survive the enormous centrifugal stresses while also maintaining compatibility with the working fluid. Thus the proper application of CFD and Finite Element Analysis in the design of the machine is necessary. TI

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