SELIM A. CHACOUR – ELECTED TO NATIONAL ACADEMY OF ENGINEERING

Mr. Chacour, who is an outstanding businessman and a dynamic leader of people, considers himself first and foremost a designer of hydraulic turbines. Working as a young engineer for Allis-Chalmers his natural abilities for artistic structural design and standard mechanical analysis served not only to create sound designs but also to highlight our inability to accurately calculate the stresses in these massive machines. His professional life from then on was dominated by a unique ability to understand an engineering need and to develop the advanced computational tools necessary to provide the engineering analysis. Mr. Chacour is certainly one of the most prolific developers of advanced engineering computer analysis of our times. His genius is in his understanding of the theory, ability to program incredibly fast, and in applying the results to advance engineering designs.

In the late 1960's Mr. Chacour became aware of a new technique to predict structural behavior. Rather than looking at an entire component, that component was subdivided and deflections were calculated for each "finite element". He recognized the power of this new approach, studied it, and by 1970 had personally developed a complete three-dimensional finite element code ("Danuta"). This static and dynamic structural analysis was so powerful that it is not only used today in the hydro turbine industry, but it was licensed by Allis-Chalmers in the 1970's to McDonnell-Douglas for aircraft analysis and to the Canadian Nuclear Power Industry for analysis of nuclear power plant components. The cubic subparametric element developed by Mr. Chacour is so powerful that comparisons with commercial codes today show that his finite element grid can have many fewer elements and yet provide more accurate results.

Mr. Chacour now had the tool he needed and throughout the 1970's he pioneered the use of the finite element method to design and analyze the massive structures that are hydro turbines. His design interest centered on the most sophisticated type of hydro unit, the pump-turbine. One pump-turbine can provide up to 500 megawatts of power with heads over 1200 ft. The turbine components such as inlet valves, stay rings, headcovers and runners have to hold these high pressures and safely transfer enormous loads. Mr. Chacour developed numerous unique concepts to optimize the structural design of such important pump-turbine power plants as Rio Grande, Bath County, Raccoon Mountain and Bad Creek, as well as the 700 megawatt Grand Coulee Francis turbines. His designs were not only structurally sound but also advanced the techniques the industry used to design more functional units.

The finite element code provided a means to understand deflections and how the unit would behave under load. Mr. Chacour led the industry by designing turbine components such that they would provide optimum performance in their deformed state. As an example, his design for spherical inlet valves for high head pump turbines is based on the deformed shape of the rotor. The stationary seat ring is machined to cancel the rotor's deflected shape thus presenting a flat surface to the mating seal ring. In older designs much of the closing energy actually went into bending the seal ring against the deformed rotor seat. The new design reduced the closing effort required to achieve complete seal contact.

With component mechanical design well in-hand, Mr. Chacour turned his attention to the turbine/generator interaction. Powerful Francis and pump-turbines sometimes had surprising instabilities in their bearing systems. These instabilities could not be predicted with the bearing analysis available at that time. To supplement linear static and dynamic analysis in his "Nathalie" program he developed a new computer code for non-linear shafting system analysis. The "Anne" program utilized a unique finite difference solution to shafting system dynamics. This program was used by Mr. Chacour to analyze complete shafting systems including the non-linear bearing support in the design of new installations and to solve existing vibration problems in units such as Helms and Raccoon Mountain.

Another operational challenge which accompanied "pushed" pump turbine technologies involved fluid inertia in penstock systems and its effect on turbomachine and powerhouse structures. Mr. Chacour studied the state-of-the art techniques for evaluating waterhammer pressure associated with time dependent flow through a network of penstock conduit. Using the powerful "method of characteristics", he developed his general purpose hydraulic transient program, CORA. This tool accurately models the reservoir-to-reservoir flow in and out of the interconnecting waterpassage segments, valves, surge tanks, pumps and turbines. He further customized the analyses to predict the associated transient reservoir elevations, distributed flow, surge tank capacity, pressure and speed rise, hydraulic thrust, wicket gate and valve torques and their associated fatigue damage. The static and dynamic response of any or all of these parameters can be evaluated at any point within the modeled segments. This computer program is used to avoid fluid resonant vibration and identify unstable operating regimes at design stage. Also, it has been used to diagnose cause and prove solutions for instabilities encountered at several high head generating and pumping stations.

In the late 1970's, Mr. Chacour recognized that the same solution technique he developed for mechanical design was applicable to optimize hydraulic designs especially for the critical runner blade shapes. He developed the three-dimensional finite element flow analysis code "Anthony" and proceeded to revolutionize the way runners were designed throughout the hydro turbine industry. Mr. Chacour realized that the finite element flow analysis would only be useful as a design tool if the program input was automatic. He accomplished this by writing the "Lilly" program that is an interactive design program to develop runner geometry. Combining the "Lilly" and "Anthony" codes, Mr. Chacour now had a system that allowed a runner designer to optimize the blade shapes with immediate feed back on how the runner performed. Mr. Chacour has developed hundreds of runner designs using this approach. Notable examples are the Bad Creek, Yards Creek, and Taum Sauk pump-turbines and the Aswan High Dam, Hoover Dam and Smith Mountain Francis turbines.

This computerized design and analysis not only led to much higher performance designs but Mr. Chacour directed Allis-Chalmers into a whole new concept for the hydraulic industry. Before 1980, any new runner was refined using physical model testing. This was a tedious, expensive and crude means to develop high performance runners. In 1981 Mr. Chacour directed that each new runner would be fully optimized through computer design. The accuracy of the computer tools was so good that Allis-Chalmers would guarantee performance for a fully optimized runner that had never been model tested. This concept was particularly important for the upgrade of existing hydro plants. It has resulted in much higher performance from our hydroelectric stations. Over the next 20 years it revolutionized the way the hydro industry worked. It has taken 20 years for some major hydro turbine manufacturers to develop the technology and change their culture to adopt this new approach to the hydro turbine industry.

In 1986 the hydro turbine division of Allis-Chalmers was sold to the German firm, Voith. This would have marked the end of any significant hydro turbine design and manufacturing in the United States. Mr. Chacour felt that this industry deserved a U.S. supplier and founded American Hydro Corporation. He recognized that the new firm had to be not only the best in design technology but also in manufacturing technology. This was (and is) especially true if U.S. manufacturing was to be cost competitive with the European technique of third world sourcing.

Once again Mr. Chacour utilized the computer to gain the advantage. He developed five axis milling codes to machine blade shapes. He developed plate cutting and nesting codes to minimize the plate usage and run the flame and plasma cutters. He integrated manufacturing techniques with the hydraulic designs to provide optimum hydraulic performance at minimum cost.

As a result of Mr. Chacour's leadership, business sense, and technology, American Hydro has grown to be a leader in hydro turbine upgrades throughout North America. All manufacturing of the turbine components (with some weighing well over 100 tons) is done in York, PA. Using Mr. Chacour's integrated design and manufacturing system (AHRDS, the American Hydro Runner Design System) it is possible to take a new order, completely design a new runner, and begin cutting the blades all in the same day. Throughout the hydroelectric industry, deliveries are months instead of years, power increases for turbine upgrades are 20 to 50% instead of 10%, and turbine price increases over the last 22 years have not kept pace with the cost of living. In every area: delivery, performance and price, foreign competitors struggle to compete. The result is significantly more energy from our existing hydroelectric facilities nationwide, with minimal ecological impact, and reduced energy costs. These are the direct result of Mr. Chacour's engineering accomplishments for the past 22 years at American Hydro Corporation.