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First IQ Batch Furnace Certified to Carburize Wind-Turbine Gears

James Caton and Mike LaPlante – Flame Metals Processing Corp., Rogers, Minn

Working together, a Minnesota commercial heat treater, a Michigan manufacturer of atmosphere heat-treating furnaces and an Ohio furnace-controls company have developed the first integral-quench batch furnace in the U.S. approved for carburizing critical gears for wind-turbine applications. The Minnesota company is now certified to carburize gears to this rapidly growing energy market.

Flame Metals Processing Corp., Rogers, Minn., is a 23-year-old company that heat treats ferrous and nonferrous components in atmosphere and vacuum furnaces at two locations in the Twin Cities area. Today, the company also is a certified supplier of carburized gears for wind-turbine applications.

In 2006, Flame Metals was approached by Columbia Gear, Avon, Minn., a gear-manufacturing company servicing a number of original equipment manufacturers. One of its customers was a large international manufacturer of wind turbines looking for a commercial heat treater capable of meeting its performance standards. Flame Metals saw this as an opportunity to become involved in a new market. To demonstrate its capabilities, a process-development and certification program was undertaken.

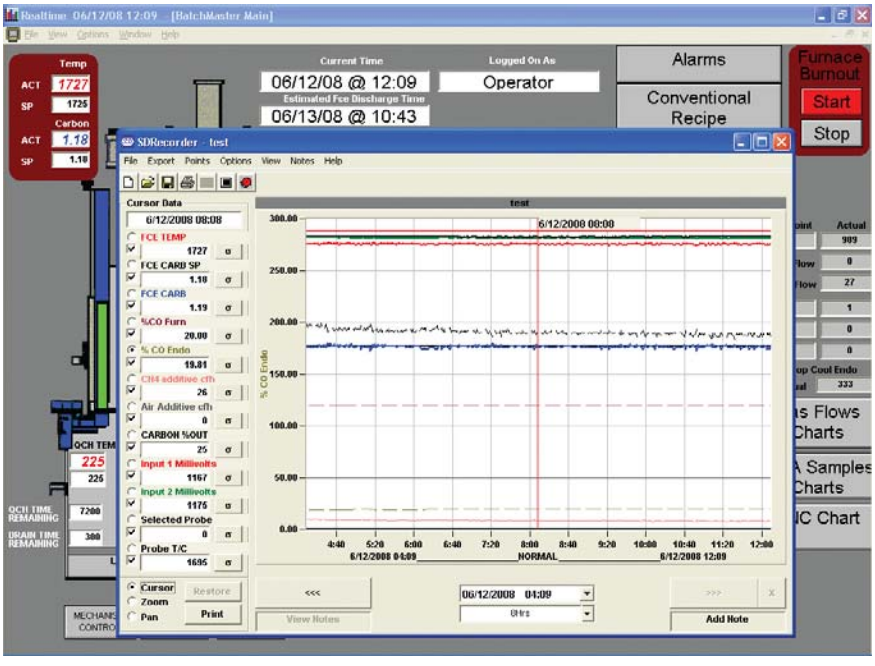
Application Requirements

Wind-turbine gears, shafts and splines must meet tough performance standards because equipment is 250 feet or more off the ground and usually located in remote areas to accommodate rotating blades that can have a 300-foot span. Because wind turbines are difficult and expensive to service, companies and individuals investing in this technology expect a service life of up to 40 years and are pushing for warranties of five years or longer on critical components. These requirements have made heat treating an increasingly important step in the manufacturing process.

The gears Flame Metals was asked to carburize range in size from 24-36 inches in diameter, weigh from 600-3,000 pounds and require long heat-treat cycles. The gears are made of high chromium, high-molybdenum steels like 4320, 4820, 9310 and 18CrNiMo7-6.

Furnace Selection

The first challenge facing Flame Metals was to determine the type of furnace it would use for the gear-carburizing program. Conventional thinking dictated a pit furnace. They are tight, simple to operate and can handle large loads. The



AFC-Holcroft worked with Super Systems, Inc. to modify its BatchMaster furnace management system to meet the wind-turbine gear-carburizing requirements of Flame Metals.

downside of pit furnaces is that loads have to be pulled from the protective atmosphere for quenching. This can contribute to decarburization on part surfaces, something Flame Metals was determined to avoid. Jim Caton, president of Flame Metals, decided to go in a totally different direction and develop its carburizing process around an Integral Quench (IQ) batch furnace. IQ furnaces are easier to automate and eliminate the need to remove loads from atmosphere for quenching.

The next challenge was to quickly acquire an IQ furnace that could be dedicated to the wind-turbine project. Caton found what he needed on a visit to the AFC-Holcroft plant in Wixom, Mich. AFC-Holcroft had IQ model Universal Batch Quench (UBQ) furnaces on the floor. Other than being larger than the 36-inch x 48-inch x 36-inch UBQ furnaces AFC-Holcroft builds for stock, the Flame Metals furnace was a standard product.

"One of the primary selling points of this furnace was its unique inner-door design," said Mike LaPlante, general manager of Flame Metals. "The design of the inner door ensures excellent temperature uniformity, ± 5°F out-of-the-box. It also heats up quickly, comes with an excellent atmosphere control system and offers processing flexibility."

Flame Metals purchased the AFC-Holcroft furnace, and over the next year worked with Bill Disler, vice president of sales and technology, and the controls supplier, Super Systems, Inc. (SSi), Cincinnati, Ohio, to develop the carburizing

Based upon the performance of its other AFC-Holcroft furnaces, Flame Metals designed its wind-turbine program around an AFC-Holcroft integral-quench furnace.

Wind-Turbine Manufacturing

Approximately 75% of the world's wind turbines are manufactured by four companies: Vistas Wind System (Denmark), Enercon (Germany), Gamesa Eolica (Spain) and GE Energy (U.S.). Other industry leaders include:

- **Acciona Energy (Spain)**
- **Bornay Wind Turbines (Spain)**
- **Clipper Turbine Works (U.S.)**
- **Goldwind (China)**
- **Mitsubishi (Japan)**
- **Nordex (Germany)**
- **REpower (Germany)**
- **Scanwind (Norway)**
- **Siemens Power (Germany)**
- **Sinovel (China)**

Most wind turbines installed in the U.S. are relatively small (rated capacity below 100 kW) and provide electricity to rural homes and farms, with excess capacity sold to local utilities. Worldwide, there are fewer than 100 manufacturers of small wind turbines. In the U.S., there are only about 20 manufacturers, a number of which are affiliated with overseas firms.

Based on projected growth, wind energy represents a huge market for U.S. manufacturers. To generate just 20% of U.S. electricity capacity by 2030, the installation of wind turbines will have to increase from 2,000 towers in 2006 to 7,000 towers in 2017.

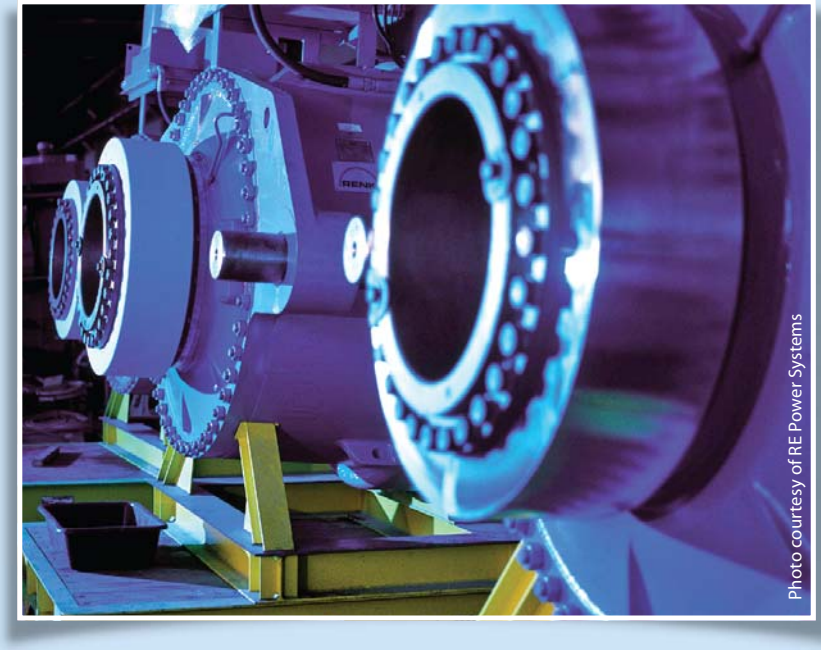


Photo courtesy of RE Power Systems

process. An integral part of the effort was the successful development of a method to purge the heat chamber of the furnace prior to loading and the use of a modified atmosphere gas to minimize intergranular oxidation (IGO).

Process Controls

The new furnace was equipped with an AFC-Holcroft BatchMaster furnace-management system based on the ProcessMaster® heat-treating supervisory system. AFC-Holcroft worked with SSi vice president of engineering, Scott Johnstone, and President Steve Thompson to modify and expand the capabilities of the BatchMaster system. Flame Metals' three staff metallurgists developed the recipe to carburize wind-turbine gears. SSi and AFC-Holcroft developed the controls hardware and software to make the recipes work to achieve the desired metallurgical results and make the process repeatable.

The type of controls and atmosphere-monitoring equipment needed to accurately control the carburizing process enabled experimentation, development and control of the low-temperature ferritic nitrocarburizing (FNC) processing using a combination of endothermic gas and ammonia. This involves calculating the nitriding potential and adjusting the atmosphere during processing.

"Meeting the requirements of the wind-turbine manufacturer was a bit different than traditional processes," said Thompson. "Some of our software and controls were standard, like installing four IR gas analyzers, mass flow meters and redundant probe packages to monitor and control endothermic gas, hydrogen, CO, CO_2 and CH_2. Our engineering was required to create a system that could automate the FNC process using additional algorithms, sensors and I/Os. The required process needed to account for gas flow rates, atmosphere, temperature, time and the precise measurements for FNC, including nitriding potential (Kn) and ammonia flow. We were able to provide a recipe structure to give AFC-Holcroft and Flame Metals the ability to control all aspects of the process and a data log of all the information for historical review. On top of that, we needed to provide a process controller that would allow the furnace to switch back and forth from atmosphere carburizing to FNC."

Process Certification

In 2007, the wind-turbine manufacturers sent an independent thermal-processing consultant to Minnesota to evaluate the Flame Metals process. In January 2008, based upon metallurgical examination of more than 20 sample gears, the process was certified as meeting all metallurgical requirements. In his report, the consultant said the process developed by Flame Metals was one of the best he had ever seen and, to the best of his knowledge, the first time a batch IQ furnace had been used in the U.S. to carburize wind-turbine gears. Today, four of the 18 heat-treating furnaces at Flame Metals are used to carburize wind-turbine components. This represents about 50% of its carburizing capacity. This segment of the business is expected to expand significantly.

Because its carburizing recipe and controls' modifications are proprietary, Flame Metals cannot reveal details of the technology. However, there have been discussions among the involved parties that some of the new technology may eventually be commercialized. Disler gives Flame Metals a lot of credit for its entry into a new market for carburizing.

"They have taken existing processes and pushed them to the next level, hence taking further benefit of some unique AFC-Holcroft bath-furnace design features," Disler said. "It has been great seeing them prosper by applying our equipment and raising the line in premium process capabilities in IQ furnaces."

Where to Find Wind-Turbine Farms

Wind energy is a rapidly growing global market, with the United States challenging Germany, Spain, India and China for on-line capacity.

U.S. wind-turbine electricity-generating capacity is growing by more than 30% a year. By 2030, it is expected to provide 20% of U.S. electric power, up from 1.2% in 2007. The total amount of electricity that could be produced in the U.S. by wind turbines is estimated at twice current output.

Wind turbines can be located on land or offshore in areas where there is sufficient space and an average wind speed of 13 mph. States which best meet these requirements include:

- **Texas**
- **Minnesota**
- **Washington**
- **Wyoming**
- **Kansas**
- **Illinois**
- **Montana**
- **New Mexico**
- **Michigan**
- **South Dakota**
- **Wisconsin**
- **Oregon**
- **California**
- **Iowa**
- **Nebraska**
- **Oklahoma**
- **Maine**
- **Colorado**
- **Idaho**
- **New York**
- **North Dakota**
- **Missouri**

Innovation and Teamwork

When word of the in-roads Flame Metals was making into the wind-turbine market began to circulate, there were people who suggested the company was lucky to be in the right place at the right time when the Minnesota wind-turbine industry took off. Caton disagrees.

Over the past 23 years, Flame Metals has purchased three heat-treating companies, an engineering laboratory, expanded its Rogers, Minn., plant by 22,500 square feet and quadrupled sales. Employment has increased to 100 people, including three staff metallurgists. In just the past five years, Flame Metals has invested more than $5 million in new equipment and is planning a third plant expansion. "It wasn't luck or coincidence that allowed us to become involved in the wind-turbine industry," Caton said. "We have been preparing for this opportunity for a long time."

"Finding the right furnace supplier and controls company was critical to the success of our wind-energy project," Caton said. "We did not own an AFC-Holcroft furnace until 2004. Today, we have four, with a fifth on order. The performance of these furnaces and the willingness of AFC-Holcroft and SSi to get involved in a risky project is why we selected them for the wind-turbine gear program."

Something to Think About

Caton believes wind energy represents a tremendous opportunity for North American commercial heat treaters. The in-house heat-treating capacity of turbine manufacturers, worldwide, already is taxed and, based on the value of the dollar, it now is less expensive to process parts in the U.S. than in Europe. The bad new is surprisingly few heat treaters are in a position to take advantage of these opportunities.

"Commercial heat treaters need to invest in better equipment and more skilled personnel," says Caton. "More engineers, including metallurgists, are needed on the plant floor to design and manage the processes necessary to meet wind-turbine specifications. Shops acquiring these capabilities are less likely to see work outsourced overseas based only on costs, even with a stronger dollar." **IH**

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Additional related information may be found by searching for these (and other) key words/terms via BNP Media SEARCH at www.industrialheating.com: wind turbine, IQ furnace, intergranular oxidation, carburizing process, ferritic nitrocarburizing, endothermic