More from the mill

Modern equipment has enhanced the production and quality of steel strip at a plant nearly a half-century old.

By Michael Valenti, Senior Editor
When Carpenter Technology Corp., began making specialty steel alloy strip at its Reading, Pa., mill in the mid-1950s, the launch of Sputnik transfixed the world. By incorporating advanced processing equipment, including a rolling mill, shape controller, annealing furnaces, wet grinders, and leveler with state-of-the-art automated control systems, Carpenter has improved the productivity and quality of its high value strip at a time when Space Shuttle launchings are taken in stride.

By incorporating advanced processing equipment, including a rolling mill with shape control, vertical annealing furnaces, wet grinders, and leveler with state-of-the-art automated control systems, the retooled mill can produce more than 10,500 tons of strip per year, in a greater range of sizes.

"We were capped at producing about 5,500 tons per year of specialty steel strip up to 13 inches wide, and our customers wanted more product," said Mike Shor, a metallurgical engineer and senior vice president of Specialty Alloy Operations, Carpenter's steel making subsidiary. "We also wanted to replace processing equipment that was nearly a half-century old with modern machinery that would increase both productivity and quality."

Only about 10 percent of the plant's output is precision strip; the remainder is bar and billet. However, the strip, ranging from a delicate, foil thickness of 0.0005 inch to a maximum 0.265 inch, and from 0.25 inch to 15 inches wide, fills high-value niches in burgeoning industrial and commercial markets. Precision steel strip is used to manufacture components for aircraft, household appliances, automobiles, computers, industrial controls, and telecommunications systems.

Over the years, Carpenter and other steel fabricators have developed different alloys of precision strip for specific applications. For example, cobalt-iron alloys provide a very strong magnetic field that is critical in making aircraft generators. Manufacturers use strips of cobalt-iron alloys to make high-strength rotors that deliver electrical energy to auxiliary power units and guidance systems on aircraft.

"Many of the nuts used to hold aircraft together are made of A-286 steel alloy strip. This alloy is made up of 26 percent nickel, enabling them to withstand temperatures as high as 2,000°F," explained Sunil Widge, a metallurgist.
who is vice president of technology and quality at the mill. Metallurgists also use the high nickel alloys to fashion prototype magnetic bearings, a promising component yet in its infancy. “The aerospace industry is interested in using magnetic bearings to develop noncontact shafting that will not wear. These alloys generate the high magnetic field and possess the low weight this application requires,” Widge said.

Anyone who has used a thermostat benefits from precision strip made of controlled-expansion alloys. The strip is typically bonded to stainless steel or another alloy. The difference in the rates of expansion produces the desired controlled reaction to temperature changes. Controlled-expansion alloy strip also has found a place in computer monitors and television sets.

The security requirements of retail stores have spurred the use of antitheft devices incorporating magnetic alloy strip. Manufacturers often stamp magnetic alloy strip into parts or laminations, stack them, and wind them with wire to make transformers for computer modems, small electronic motors, and telecommunications equipment.

Consumer electronics require ground fault interrupters to make them safe. The cores of the interrupters are made of a very sensitive nickel-iron magnetic alloy strip. Specialty stainless steel strip serves as knife blades, surgical implants, and golf club faceplates.

**CONTROLLING THE ROLLING**

The Carpenter specialty strip facility installed a cold rolling mill designed by Joseph Frohling GmbH of Olpe, Germany, in November last year, to increase rolling capacity and guarantee that the steel strip it produces meets the desired shape and thickness.

In the Frohling mill, strip passes between two working rolls that reduce its thickness to sizes between 0.150 and 0.008 inch, at speeds up to 1,500 feet per minute.

Each working roll is supported by nine rolls arranged in pyramid fashion, to transmit the required rotational speed and force. Mineral oil lubricates the process and cools the strip to prevent defects that are caused by uneven heating.

Carpenter uses the mill to roll high-tensile-strength, precipitation hardenable grades of steel up to 16 inches wide, 3 inches wider than its previous maximum.

Advanced instrumentation keeps the Frohling rolling process precise. A laser system designed by TSI Inc. of
The Ungerer stretch bend leveling machine at Reading flattens thinner steel strip and documents the flatness of the entire coil to reduce costly defects.

St. Paul, Minn., tracks the speed of the strip as part of the thickness gauge control system. The TSI system measures the flight time of a laser beam reflected by the surface of the steel strip.

“We had previously employed speed gauges whose wheels contacted the strip,” said Jim Andreas, an industrial engineer and the manager of strip finishing at the plant. “Although this was initially accurate, the wheels wore down over time and affected the accuracy of the readings. The noncontact laser eliminates this possibility, as well as the slipping and marking speed gauges sometimes caused.”

**MAINTAINING THE STRIP’S SHAPE**

The Frohling mill is also equipped with a system made by Friedrich Vollmer GmbH in Hagen-Berchum, Germany, to control the shape of the strip being rolled. The Vollmer system consists of two hollow rolls, each fitted with multiple transducers along its length that measure tension differentials, which reflect shape, as the steel strip passes. Signals are fed to a microcontroller that alerts an operator or closed loop controller to adjust the mill’s operation to maintain the requisite strip shape.

The Vollmer system also has three intermediate roll-bending controls that enhance shape and minimize parabolic defects. This characteristic reduces interruptions for roll adjustments and increases productivity. Two intermediate roll shifting devices control the movement of those supporting rolls to reduce wavy edges that can spoil strip shape.

In addition, a diamond tip position sensor contacts the strip to monitor its thickness continuously during the rolling process.

The readings from the TSI and Vollmer sensors are sent to a General Electric automatic gauge control system. The system monitors strip speed and thickness at entry and exit. It sends commands to the GE drive control system to maintain the desired thickness.

Carpenter technicians customized the Frohling mill’s data management system as a further hedge against variation in the cold rolled strip. To accomplish this, all of the mill’s rolling schedules are entered into a common database each day. Information includes the input parameters based on the incoming coil characteristics.

The data management system then predicts the schedule that is required to roll each coil. All of the process data are stored so that the mill’s operators can verify the accuracy of each prediction.

Carpenter wet grinds about 95 percent of the steel strip it rolls through the Frohling mill to prepare it for further processing. This involves using grinding belts covered with grit to remove oxide from the surface of the steel strip for processing. Previously, Carpenter ground one side of a strip at a time, but now a Hill Acme wet strip grinder prepares both sides of the strip simultaneously, doubling productivity. Hill Acme Co. is based in Gorham, Maine.

The Carpenter strip passes through three grit belts on each side while a water emulsion coolant is applied to the strip to extend belt life. Wet grinding enables Carpenter to use finer-grit belts and generate strip surfaces with an extremely fine finish. For example, the company can offer a photo-etch-quality strip for circuit boards. The wet grinder also enabled Carpenter to increase the maximum strip thickness at its plant from 0.187 inch to 0.265 inch.

The ground strip enters a cleaning tank contained in steel housing. Here, hot water is sprayed through nozzles.
to rinse coolant and particles from the steel, which is then dried by an air blower. In-line cleaning eliminates a stand-alone cleaning station.

**BELL FURNACE RAISES ANNEALING QUALITY**

The annealing process at the plant has also been revamped by new equipment. Carpenter installed a bell annealing furnace made by Ebner Furnaces Inc. of Wadsworth, Ohio, the American subsidiary of Ebner Industriefen-bau of Linz, Austria, in January of last year. The bell furnace can heat and cool up to 30 tons of semi-finished steel strip at a time, of any thickness, to provide requisite hardness. The furnace can anneal several coils made of the same alloy, or multiple coils of different alloys, depending on their heating cycle.

The furnace at the Carpenter plant comprises one heating bell, two bases, one cooling bell, and two inner covers. This equipment first raises and then lowers the temperature of coiled steel strip to adjust its hardness and grain structure. Carpenter work crews stack coils of steel strip on one of the bases and lower the heating bell over it. The steel is heated up to 880°C for eight to 12 hours in a hydrogen atmosphere.

"An added benefit of the vertical furnaces is that they allow for more compact package," said Andreas. "Those rolls sometimes scratched the strip." Another precaution against scratching is the roller exit seal.

Carpenter uses a stretch bend leveling machine made by Ungerer GmbH & Co. in Pforzheim, Germany, to flatten its thinner steel strip, document that flatness for an entire coil, and reduce costly defects.

Ungerer equipped its leveler with a shape measurement roll, similar to the multiple transducer roll of the Vollmer unit, which measures tension, and thus shape, in five zones across the width of the strip. This information is sent to an operator, or to computer controls, to adjust the stretching and bending process to maintain the required flatness of the strip.

Carpenter management installed a Frohling precision slitter at the plant in January this year to increase slitting efficiency for strip less than 0.015 inch thick. The slitter is equipped with upper and lower series of knives, which can cut 35 separate steel strands simultaneously, more than double the 16 strands of its predecessor. The knives' positioning is precisely regulated by computerized numerical control to reduce burring and twisting that can result from inaccurate positioning.

A turnstile enables operators to position a second set of knives for a new job while the slitter is operating on its current job. "This means we can change the tooling over in five minutes," Andreas said. "With the old slitter, we had to shut down to reset the knives, which took a half-hour to an hour."

**START WITH SUPERIOR INGOTS**

The higher quality of some of the precision strip being rolled by Carpenter relies on premium-grade ingots made by a vacuum induction melting furnace. Carpenter also owns 17 vacuum arc remelting furnaces that can produce premium-quality ingots.

The vacuum induction melting, or VIM, furnace that Carpenter uses was designed by ALD Vacuum Technologies Inc. in Erlensee, Germany. According to Widge, "We melt up to 20 metric tons of scrap steel, such as turnings from part making, or virgin alloys, depending on the application, into a refractory-lined crucible under a vacuum induced by pumps."

Induction coils outside the crucible create an electrical field that heats and melts the metal. The vacuum refines the steel, removing unwanted nitrogen and oxygen to only a few parts per million to produce a cleaner alloy.

Operators tilt the furnace to pour the molten steel into molds that form cylindrical ingots up to 36 inches in diameter or into slab molds for the production of strip.

The quality of the VIM furnace ingots is controlled by carefully selecting the appropriate feedstock for the alloy being made, and adjusting the temperature and vacuum of the melting process.
Some of the VIM ingots destined for the precision strip line are further refined by the three vacuum arc remelting, or VAR, furnaces. “We use the VAR process to make steel for applications that require high purity and uniform microstructure requirements such as magnetic alloys,” Widge noted.

The VARs each possess a freestanding, stationary base that consists of a copper crucible housed in a water-cooled steel jacket, and an upper, movable steel head. Carpenter welds an adapter at one end of a cylindrical ingot, and places it on end into the copper crucible, which serves as the VAR mold. Operators lower the furnace head over the base, seal it, and activate the diffusion pumps to induce a vacuum.

An electromechanical ram drives the welded electrode into the crucible. The adapter sends a direct current of up to 20,000 amperes through the ingot, which serves as an electrode. This causes an arc to form between the bottom of the ingot and the copper crucible, or anode, that generates intense heat to melt the steel at a gradual, predetermined rate.

“By remelting the ingot by electric arcing in a vacuum, we are able to produce a cleaner alloy by reducing oxygen and nitrogen in the original ingot, and remove unwanted nonmetallic substances such as clusters of alumina or carbon nitrides,” Widge explained. “We are remelting the ingot at a rate we control virtually droplet by droplet, and solidify the metal pool under closed conditions, giving the finished product a more uniform structure.”

Three VAR furnaces were made by Consarc Corp. of Rancocas, N.J. Carpenter finished installing the furnaces in August 1997. The Consarc engineers provide their VARs with coaxial current paths to prevent the stray magnetic fields that can interfere with the formation of ingots.

A key concern in vacuum arc remelting is positioning the ingot to control the gap between the arc and the ingot surface. Video cameras are installed to capture images of the furnace interior through small viewports in the furnace head, and transmit them to television screens. The furnace operators watch the screens to ensure that the melting is proceeding as planned.

Load cells continuously weigh the steel during the melting process and send their findings to an automated control system. The latter uses this data to calculate the melt rate of the steel batch, compare it to the desired rate, and regulate the process to optimize the melting, in order to provide the quality that is required by precision strip applications.