The 5-Stand Tandem Cold Reduction Mill

a NUCOR-JFE company

CSI's Tandem Cold Reduction Mill was completely modernized in 1997 and typically processes seven out of every eight pickled coils. Its primary function is to reduce the thickness of the steel to between 1/2 and 1/10th of its hot-rolled gauge without first reheating it.

Capable of producing over a million tons annually at widths to 60" and finished gauges less than 1/100th of an inch thick, the mill supplies CSI's galvanizing lines and the Cold Sheet Mill, as well as CSI customers who purchase "full hard" unfinished cold roll. Because the coils are re-rolled at roughly room temperature, thinner gauges, tighter tolerances, and a superior surface quality are produced than can be rolled by the Hot Mill.

COLD ROLLING

CSI's cold reduction mill is a series of five rolling mills, or 'stands'; hence the name "5-Stand". Each mill stand has two work rolls about two feet in diameter, which are driven by powerful electric motors (totaling over 25,000 horsepower) and sandwich the steel to reduce the thickness. In what is known as a '4-Hi' arrangement, two back-up rolls around 4-1/2 feet in diameter prevent the work rolls from being distorted by the 1000+ tons of force that the steel exerts on them during rolling.

The 'roll gap', or space between the work rolls through which the steel passes, is adjusted by complex electronics to ensure the steel's thickness is being reduced the right amount (the 'draft') as it exits each mill stand. Because the individual iron crystals are being stretched with each rolling operation, the steel grows progressively stiffer and stiffer as it passes through the 5-stand until it reaches the 'Full Hard' condition, from which forming the steel further is likely to crack it. The degree to which the steel will resist deformation, including the 'work-hardening' described above, the geometry of the 'roll bite', and the speeds that will be required of each mill stand determine how much load will be placed on each motor.

A sophisticated automation system designs a 'draft schedule' for each product to avoid overloading equipment and to ensure that the last stand will leave a good texture on the product's surface. The first two stands' roll gaps are adjusted hydraulically, interacting with a pair of x-ray thickness gauges and laser velocimeters to remove variation in the hot-rolled coil; the latter stands employ large screws and electric motors to make fine-tune adjustments and to set up for new products.

A mixture of up to 5% oil in water, or 'solution', cools the rolls and lubricates the roll bite, reducing the loads on the motors and the abrasion of both work roll and steel. Prepared in one of three tanks, different concentrations are used for different products; scheduling coils together that require the same solution is desirable since a few coils will be rolled as the changeover stabilizes. Compressed air blows the solution off the steel as it is recoiled at the exit end to prevent it from staining the steel.

The 5-stand is operated at very high strip tension, approaching what could stretch or tear the steel, in order to reduce the vertical force in the roll bite and to remove any shape defects between stands. Significant tension is maintained even between the last stand and the coil being produced, and between the charged coil and the first stand, with the assistance of a set of five 'bridle' rolls that mesh together above and below the steel much like a leveler.

A complex system of position-, force-, speed-, and current-measurement devices feed information back to the computer, which then adjusts roll gap settings and motor speeds to maintain strip tension and produce the desired thickness. Precise tension control is critical in ensuring that over any given period of time, the same amount of steel exits the mill as is being drawn in; the consequences of not maintaining this condition are severe, resulting in 'strip breaks' and damaged rolls at the bare minimum. Because the steel is made thinner as it is rolled, it must exit each stand at a faster speed than it entered: the last stand is capable of 4500 feet per minute for some products, producing cold-roll sheet at over 50 mph.

THREADING AND TAIL-OUT

While the 5-stand is capable of producing precise gauges at very high speeds, cold reduction of coil heads and tails takes place much more slowly because tension cannot be maintained and because rolling solution is not applied at the very head-end to prevent the steel from slipping in the roll bite. The computer sets up the roll gaps and motor speeds to deliver the proper thickness to the tension reel, establishing strip tension as the coil is paid off of the 24" diameter entry reel and threaded through the 5-stand. Operators on the floor monitor this process, called 'sticking', steering the head-end into successive mills and positioning guides. Once the head-end is cinched on the 20" tension reel, the mills accelerate to their 'run speed', at which the bulk of the coil is rolled.

FLATNESS CORRECTION

The Hot Mill typically rolls material intended for cold reduction with a 'crown' of between two and three thousandths of an inch, a measure of how much thicker the center-line of the strip is than the edge. This is desirable for rolling mills, as it helps the strip to stay centered. If one edge is thicker than the rest of the strip, a condition called 'wedge', the coil has a tendency to 'run-out', folding over onto itself against a side-guide and damaging, or 'bruising', roll surfaces as the lapped steel passes between them. Whatever crown or wedge exists on the pickled band must be reproduced, proportional to the sheet thickness, through each stand or else the strip will not lay flat. To ensure cold-rolled steel is as flat as possible, the 5-Stand employs sophisticated equipment for measuring and correcting flatness defects.

A 'Shape meter' roll between the last stand and the tension reel measures the tension in the strip across its width, identifying flatness defects by the localized reduction in tension that accompanies them. This information is fed back to a computer that selects one or more actuators at the last stand to improve the shape.

The parameters that affect the shape of the steel are predominantly based on the roll force separating the work-rolls at the roll bite, so schedules are prepared with an eye toward minimizing the transitions between coils of different finished gauges and different hot band thicknesses.

FINAL PROCESSING

The cold-rolled sheet is recoiled at the exit end of the 5-stand on a 20" diameter 'tension reel' mandrel, using a 'belt wrapper' to cinch the first wraps and establish tension across the shape meter. Large 'built-up' coils with pickle-line welds may be split to fit the diameter and weight requirements of the Cold Sheet Mill.

Coils are automatically cinched around their circumference with one circumferential ('belly') band for lighter gauges, two for 14-gauge (0.075") and heavier, and eye bands, if necessary for Full-hard customers, are threaded through the middle of the coils by hand. Banded coils are typically loaded by crane onto rail-cars for transportation to the next production unit, or onto a coil handling system for transportation to the #2 CGL.

INSPECTION

From the control room, or 'pulpit', the Roller monitors the x-ray gauge readings of the coil's centerline thickness and the display from the shape meter, biasing the computer as necessary. A CCTV camera positioned above the tension reel allows for visual inspection of flatness, as well as of the quality of the top surface. A 'roll-out' is performed to inspect the bottom surface, and to carefully scrutinize the steel's quality. An unbanded coil is cradled between two driven rolls and fifty to a hundred feet of the tail is uncoiled onto a long, flat table. Flatness can be thoroughly evaluated, and any surface defect can be spotted and their origin pin-pointed.