Inline gauge control in welded tube production

Reducing conversion losses

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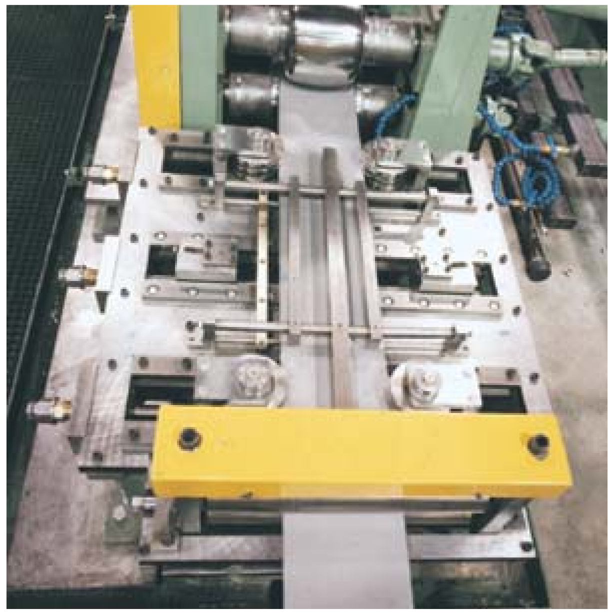
Reducing scrap when converting strip to finished tube is a huge step in bettering your bottom line.



In welded tube production, the conversion of strip to finished tube always produces some loss of raw material. These conversion losses have many causes, including scrap generation because of poor forming (mill setup or adjustment), poor welding, tube straightness, off-tolerance length, or poor OD/ID bead control. These areas are all within the control of operations, and for the most part, the majority of producers manage these types of losses well.

The balance of conversion losses are related to the raw material itself. All tube producers work with their strip suppliers to buy the right material required for production, but the reality is that tube wall thickness is almost always over tolerance.

Why? The principal reason is that companies buy from multiple suppliers who have different standards, practices, and equipment capabilities. Also, the materials bought for one job are often substituted for another if the finished tube will at least meet minimum gauge requirements. This means that the production department can never perfectly match the tolerance window with the materials provided for production. In other words, the silently accepted practice is to accept such losses as unavoidable and attempt to make up the difference in volume.

Setting aside strip chemistry, anneal conditions and related processes--those normally controlled by the steel producers (pickling, oiling, etc.)--there remain two causes of conversion loss. The first is strip camber, a result of material shape or poor slitting practices. The second cause of conversion loss is the variability of wall thickness "build" in the actual tube. In round and reshaped-from-round tube production below 6 inches in diameter, wall thickness generally increases (thus the term "build")in varying degrees.

Cambered strip creates strip guidance problems, welding faults (rolled-over seams), OD/ID weld bead scarfing failure, and out-of-alignment seams in shaped tube. Many operators simply lose the outer and inner coil wraps because the adjustments needed in the mill to accommodate the changes are impossible to make at today's mill speeds. In addition, heavy ends further magnify camber.

Build variations result from the difficulty of duplicating mill setup, operator preference (no two operators run the mill in the same way), slit width variation, and material physical characteristics such as thickness, hardness, yield, tensile, and related chemical/processing makeup from heat to heat or one supplier to another. The principal culprit is thickness.

Traditionally, sorting materials by production heat, supplier, and physical characteristics has been the only way to reduce the effect of these variations.

Improvements in steel rolling technology have reduced some of the gauge variation problems. Tension leveling, roll shape control, and steel production by continuous cast-versus-billet processing all have contributed to improved consistency of steel quality. The integrated and mini-mill producers are investing millions of dollars to improve their capabilities.

While it is true that many mills and rerollers offer temper-rolled master coils, this helps gauge control only partially. A premium must be paid for the steel. A tube mill or steel warehouse must increase stock levels because it will need different tolerance strip for different products.

Camber still exists as a result of slitting stress relief, and wall thickness "build" still occurs in the tube mill.

Even with the millions spent to date on rolling mill improvements, in the end, all steel producers are not equal. Companies will continue to buy from more than one source, and unless the tube producer pays a healthy premium, pays for complete heats from only one mill, and runs only one gauge on only one tube diameter, conversion losses will only improve, not go away.

Cambered strip and off-gauge raw material remain the uncontrolled variables in welded tube production and the principal reason for loss of profit. Neither variable has anything to do with the skill of the operator, mill equipment capabilities (assuming good mechanical repair and roll surfaces), or the basic principle of welded tube production.

Mill operators, supervisors, or production superintendents will say that they can only do their best with the material they are provided. The problem is not the people, their desire, or their old or new tube mill equipment. It is that a tool is missing.

When looking at the available tools, it can be noted that welded tube mills provide excellent control of outside diameter (OD) only. Previously, the only way to produce controlled wall and inside diameter (ID) was by controlling incoming material thickness and by employing the expensive secondary process of drawing over a mandrel.

What is In-Line Gauge Control?

In-line gauge control, the application of temper rolling in line with the tube mill, can actively adjust incoming raw material thickness and correct camber to maintain minimum wall production despite the variability of the incoming material. The operator-controllable process maintains thickness of material as it enters the tube mill. With noncontact thickness measurement at the exit of the tube mill, a closed-loop control can automatically adjust entry strip thickness.

After being set by the operator, the self-correcting thickness control adjusts for both variation in strip thickness and hardness. It can also reduce strip camber problems while correcting thickness variation.

Why Use Gauge Control?

Gauge control can help reduce roll wear and setup time by providing uniform strip thickness with reduced camber variation. This allows the purchase of commercial grades rather than close-tolerance thickness, and in some cases material grades can be substituted (for example, HRS-P&O for CRS).

Tube walls can be made to ±0.0005 inch of the desired wall. The process converts over-gauge material to thinner and longer sections. On strip widths common to small tube production, the vast majority of material growth is to length, with normal gauge reductions being 10 percent or less. **Figure 1** shows a rolling study performed on 6- by 0.257-inch-thick, low-carbon, hot-rolled steel. The width growth for a gauge reduction of 8 percent is +0.1 to 0.2 percent. As strip width increases, the increase in width becomes less. The bottom line is that gauge reduction does not adversely affect tube production.

Comparison: Length-to-Width Change as Result of Gauge Control		
Reduction %	Length Delta	Width Delta
18%	+20.6%	+0.4%
23%	+27.1%	+0.7%
28%	+35.8%	+0.8%

Figure 1: The results of a rolling study that indicate that as strip width increases, the growth in width decreases.

Production Objectives Through In-Line Gauge Control

In-line gauge control can provide the following advantages in tube production:

1. Reactive control of tube wall in electric resistance welded (ERW) tube production enables the operator to change the incoming gauge and correct camber conditions.

2. Consistent production of high-quality tube products. The operation that does not provide quality products will be gone.

3. The use of alternative raw materials reduces raw material cost. Upgraded hot-rolled gauge tolerances can be substituted for cold rolled when surface finish is not a requirement. Upgraded HRS P/O gauge tolerances can be substituted for cold rolled where surface concerns are an issue. Low carbon steel can be upgraded to the strength requirements of a higher carbon, or a medium carbon to that of high-strength, low-alloy (HSLA).

4. Reduced production cost and increased profits help to maximize use of available personnel skills and raw material. In addition, waste can be reduced and production can be increased.

Applying Gauge Control to Correct Thickness/Camber

Two possible methods can be used to correct thickness/camber. Both methods are assumed to process strip after slitting because corrections for both gauge and camber are needed.

Off-line. As the name implies, this is a separate self-contained line where individual (previously slit) mults are passed through the gauge and camber correction process, recoiled, and then taken to the welded tube mill. Typically, the off-line equipment includes an entry coil car, uncoiler, peeler, coil end joiner, gauge control stand, free loop (for camber detection), tension stand, crop shear, recoiler, exit coil car, and control console.

This arrangement can serve more than one line, since operation is independent of the conversion process. However, it requires more equipment at higher operating speeds than the in-line arrangement. It also requires more floor space and one or two people to run it. Immediate adjustment to accommodate mill operating conditions cannot be made.

In-line. Here, the gauge and camber control process is installed in the welded production line, between the exit of the accumulator and the entry of the tube mill. The equipment involved includes a gauge control stand and a control console. This arrangement requires no additional labor and little additional floor space. Thickness/camber correction can be made in real time with the operating conditions of the mill. However, this arrangement can only serve one line, so the in-line gauge control process must be applied to each tube production line.

Thickness Control / Limitations

Thickness control is possible to ±0.0005 inch of the target gauge when closed-loop feedback is used to update the hydraulic screwdown settings.

This capability is based on a raw material maximum rate of change of ±0.0005 inch per 1 foot and maintenance of rolls, bearings, and connected mechanical components to hold a total roll stack TIR of less than 0.0005 inch.

Process capabilities can accommodate change rates greater than this with some degradation of performance (within the design limits of the gauge control stand). By using good quality hot-rolled, coil-heavy ends, coil end weld joints, and material-variable hardness conditions, about 95 percent of the material can be recovered to the target gauge window.

If material entering the process causes the mill operating force to exceed preset limits, the mill's hydraulic screwdown (hydraulic cylinders) will permit an incremental opening of the roll gap, thus automatically protecting the equipment from overloading. The work rolls are always loaded against the strip surface to prevent skidding and roll damage.

In cases where end welds are expected to be thicker than parent materials, a noncontact eddy current probe is placed immediately in front of the gauge control stand to provide a signal to reduce the mill operating force in anticipation of the end weld passage.

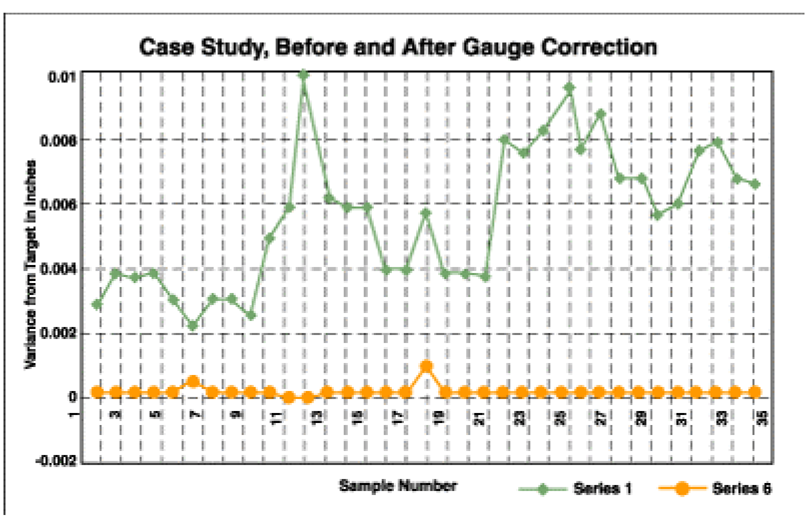


Figure 2: A recap of actual measured thickness readings before and after gauge correction.

Once the overload condition passes, the gauge control stand returns to preset operating parameters without operator attendance. The mill operator must calibrate the thickness gauges, confirm that the thickness gauges are operating within acceptable limits, set target gauge either by entering specific thickness and alloy date, or calling up presets from the materials library.

Figure 2 shows a recap of actual measured thickness readings before and after gauge correction. The upper graph depicts variation of the strip before gauge correction. The lower graph shows the result of gauge correction.

Reduction in thickness capabilities is a function of the design limits of the equipment and the cold workability of the raw materials. In general, for common low-carbon steels, the low limit of reduction is about 2 percent, with a maximum of less than 10 percent without intermediary annealing. Staying below the 10 percent reduction level generally will not adversely affect the finished mechanical properties of the welded tube.

Single pass reductions of 30 percent are possible on some materials, but this would almost always require an intermediary anneal. There are no limits on matching the capabilities of in-line gauge control to high-speed welded tube mill performance.

Cold reduction control technology is now routinely running tight tolerance strip at close to 3,000 surface feet per minute (FPM) with mechanical components loaded many times greater than they would ever be in a welded tube process. Thickness capacity is related to the mill mass (cross section), bearing capacities, and work roll material selection, with main drive sizing directly related to required separating forces and speed.

With a similar reduction percentage and strip width, the required horsepower is directly proportional to speed. If 200 HP is required at a speed of 150 FPM, then 400 HP is needed to achieve a line speed of 300 FPM on the same section.

Measuring Strip Thickness

Strip thickness is measured by contact and non-contact type gauges.

Contact gauges are typically precision floating rolls or roll and carbide button. Accuracy is ±0.0005 inch. They are prone to mechanical wear and strip marking and may be damaged by strip cobbles.

Noncontact gauges include inductance (±0.0001 inch), laser (±0.0005 inch), isotope (±0.0001 inch @ 0.250 inch maximum), and X-ray (±0.0001 inch on material from 0.005 to more than 1 inch), and are preferred for high-speed operations.

Converting Measurements to Motion Control

Measurements are converted to motion control in two ways:

1. After the Fact. In this mode, only an exit thickness gauge is employed. The process is based on the premise that the roll gap is the same as the thickness at the gauge (after rolling). Measurements are averaged, if different than the target, and a proportional change is ordered through the mill screwdown controls. Accuracy is ±0.001 inch.

2. Mass Flow, Feed Forward. Two thickness gauges are used in this mode. The basic formula is:

Lin x Tin x Win = Lout x Tout x Wout-IE--Volume in = Volume out.

The change in dimension is length. Therefore, speed increases to compensate for a thinner exit strip thickness. The closed loop feedback provided by the second thickness gauge enables accuracy of ±0.005 inch to be achieved.

Understanding Wall Thickness Standards

American Society of Testing and Materials (ASTM) A513-85 explains the wall thickness variations permitted for welded tubes as produced from hot-rolled and cold-rolled steels.

A range of 20.0 to 10.5 percent variation is permitted for welded tube made with hot-rolled steel, and a range of 18.9 to 9.4 percent is the permitted variation in similar tubes made with cold-rolled steel. While tube producers try to stay toward the light side of the permitted variations, welded tube is routinely produced to these standards.

The permitted variations in wall thickness might be seen as outdated by some because they represent the range of variation present in rolled steel produced in 1985. The ranges were selected to permit the use of the widest available raw material sources (as available from rolling mills) and still provide a common, acceptable description for tube production.

If it is considered that today's rolling mills can provide one-half tolerance materials, this still means that wall thickness variation can be in excess of 10 percent in hot-rolled steel and 9.4 percent in cold rolled. That is, if the welded tube producer can obtain and always use the lowest wall thickness materials to convert into acceptable, sellable product.

A welded tube made with in-line gauge control and OD/ID bead trim can be more uniform in its mechanical properties than the current best tube available--drawn over mandrel. In addition, a gauge-controlled tube can be made without multiple handling, secondary operations cost, and added labor power, and with the best possible cost of conversion.

Summary

In-line gauge control offers the welded tube producer a process which will consistently reduce conversion losses and improve profitability. Superior tubular products with potential sales opportunities in new markets are attainable without extensive capital investments. The process is not limited in its application to welded tube production by materials, by weld speed, or by material thickness.

In-line gauge control permits the use of a range of raw material sources (steel chemistry and basic physical quality must be similar), thereby permitting further flexibility in raw material purchasing. In some instances, the process offers further savings by permitting substitution of alternate materials (such as HRS P&O for cold rolled steel).

In-line gauge control offers the tube producer the ability to be more competitive and less dependent on its steel suppliers.

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