



producing results

Solving the mysteries of the fin pass

Part II: Why don't they work the way they should?

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Editor's Note: This article is the second part of a two-part series about fin passes. Part I, which appeared in the March issue, discussed their location, what they do, and how they do it. Part II focuses on troubleshooting.



resulting from improper presentation of the formed section to welding.

Solution 1: Inspect Roll Shaft Shoulder Alignment

Proper roll shaft shoulder alignment is critical to the tooling setup. A tube mill is a toolholder. The alignment of the tool set from one forming pass to the next is ensured by the proper roll shaft shoulder alignment (the registration surface of the roll shaft).

You might have perfect tools and a perfect tool installation per the roll drawings, including the roll flange gaps, and be dead in the water on weld quality because the roll shaft shoulders are not aligned. Shoulder alignment must be true both vertically (top shaft to bottom shaft) and from pass to pass along the entire mill.

The minimum alignment criterion for material less than 0.030 in. thick is less than 0.003 in.; that's the *total* amount of shoulder misalignment allowed, or tolerance. As material thickness increases, the total error also may increase, but generally never should exceed 0.005 in. for quality tube production.

While you can't see misaligned roll shaft shoulders, it is possible to surmise that their alignment is incorrect without using sophisticated tools. Roll shafts that exhibit looseness or droop when the outboard stands are removed most likely are misaligned. If you can shake hands with any of the roll shafts (in other words, if you

can move the roll shaft up and down or around with the outboard stand removed), the shaft probably is out of alignment.

The simple act of replacing worn-out bearings, reshimming to reset preload, or replacing worn roll shafts without performing an alignment is almost guaranteed to cause shaft shoulder misalignment.

Last, tool life records and scrap production records can indicate a need to perform an alignment. If roll wear accelerates, if changeover time requirements from prime to prime (assuming the same work force) increase, or if the scrap production rate increases, it is time to align the mill.

Check alignment of welded tube mills that have frequent changeovers and multishift operations at least quarterly. If you perform any repairs, align the mill shaft shoulders as part of the repair.

Solution 2: Look for Physical Property Changes in the Material

In our ground rules, we assumed that the strip slit width and gauge are within limits, but we did not say the material came from the same steel supplier, or that the material is of the same grade. Why are these important?

Remember, we said that we must present the proper strip width to the fin tooling so the section compression exceeds the material's elastic limit. What is the proper strip width? Calculating proper strip width depends on the tube diameter, strip thickness, and material yield strength.

First, some ground rules (assumptions) for the arrangement before we discuss some possible reasons for poor-quality seam welding and their solutions:

1. You are working with a new set of rolls and spacers. We assume that the rolls are manufactured correctly. This eliminates from the equation the possibility that worn tooling is at fault. The roll tooling and spacers are installed according to the roll drawings, and all the flange gaps are correct.

2. The strip width and gauge are within the limits set by the roll drawing design.

3. Weld quality is inconsistent. Destructive testing shows fractures on the weld centerline. The weld seam shows unequal extrusion of weld bead to inside and outside or uneven edge heights.

Two main culprits are misaligned roll shaft shoulders and changes in the physical properties of the material.

Weld faults also can result from improper adjustment of weld heat, but for this discussion we will ignore this and concentrate on weld faults

The simple rules for determining strip width are:

1. The thinner the wall, the wider the strip width (for tubes with the same OD). Conversely, the thicker the wall, the narrower the required strip width (for tubes with the same OD). We assume the roll designer followed his normal practice in recommending a strip width, so we are not looking here for the problem.

2. A slightly different rule applies for increased yield strength and hardness. The calculated strip width will need to be increased in direct proportion to increases in yield and hardness. In other words, to make the same OD and wall tube but with a higher yield strength, more strip width is required.

An aberration as shown in example 2 is the far more likely culprit of poor weld quality.

You may find a clue that this is your problem simply by referring to the design specification for the tube rolls. A yield strength and hardness reading should be included in this information.

What this suggestion boils down to is to look for hardness changes in the slit coil. Are they different than the last time you ran the tube? Are there significant differences in hardness for the lead, middle, and tail of the coil?

Material with increased hardness, increased yield strength, or both will require more strip width than normal. Your setup (roll tool arrangement on the mill) may be on the ragged edge, meaning that it has sufficient compression for the part of the coil exhibiting the lower hardness but not enough for the coil ends.

One way to check this assumption is to reduce the flange gap in the fin pass rolls. In all probability, you also will have to close up the gaps in the weld forge and sizing steps to confirm the results of a more stable weld. This

Strip Width Reduction to Compress Steel to Its Elastic Limit			
Deformation calculations based on unit stress			
Yield Strength (PSI)	Modulus of Elasticity of Steel	Amount of Compression per Inch of Strip Width to Reach the Elastic Limit (Inches)	Suggested Reduction Rate to Ensure Sufficient Cold Work to Overcome All Residual Yield Strength Variation in a Typical Coil* (Inches)
30,000	30,000,000	0.0010	0.0025
40,000	30,000,000	0.0013	0.0033
50,000	30,000,000	0.0017	0.0042
60,000	30,000,000	0.0020	0.0050
70,000	30,000,000	0.0023	0.0058
80,000	30,000,000	0.0027	0.0067
90,000	30,000,000	0.0030	0.0075
100,000	30,000,000	0.0033	0.0083
110,000	30,000,000	0.0037	0.0092
120,000	30,000,000	0.0040	0.0100
130,000	30,000,000	0.0043	0.0108
140,000	30,000,000	0.0047	0.0117

* This is the amount of compression multiplied by 2.5.

Definitions:

The author chooses to use 30×10^6 PSI as the typical modulus of elasticity for general low-carbon steel grades. Published literature shows a range of 28×10^6 to 30×10^6 for steels.

Yield Strength: The maximum stress (in this case, measured in PSI) that can be applied without permanent deformation.

Modulus of Elasticity (Young's Modulus): The ratio of unit stress to unit strain within the proportional limit of a material in either tension or compression.

Additional reference books:

- *Machinery Handbook, 24th Edition* (Eric Oberg, Franklin D. Jones, Holbrook L. Horton, and Henry H. Ryffel, Industrial Press, Inc.; 1992; ISSN 1056-4802)
- *Roark's Formulas for Stress and Strain, Sixth Edition* (Warren C. Young, McGraw-Hill, Inc; New York, NY; ISBN 0-07-072541-1)

This table shows the effect of yield strength on the amount of cold work required in fin and sizing forming passes in typical welded tube mill operation.

As the yield strength of material increases, additional compression is required to raise the section, either the open profile in the fin passes or the closed profile in sizing, to a point at which unit stress exceeds the material's elastic limits.

For example: If the strip width used to produce a tube from steel with a yield strength of 50,000 PSI is 2.035 in., then a tube with the same OD and wall but at 90,000-PSI yield strength would require a strip width increase as follows:

$(0.0075 - 0.0042 = 0.0033$ inch per inch) or $2.035 \times 0.0033 = 0.0067$ in. width increase at every reduction pass.

If the tube mill has three fin passes and three sizing passes, the additional strip width required is 6×0.0067 in., or 0.040 in. total.

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Figure 1

will result in a tube too small in diameter and, in all probability, out of round to some degree, so it is not a running solution. This is just a way to confirm the need to increase strip width.

In real-world terms, the compression force reached in the fin pass must exceed all of the variations encountered in the feedstock. This means that you must apply a safety factor of

approximately 2 to 2.5 times the maximum anticipated compression level when calculating the strip width. This ensures consistent strip edge forming and sound welding.

Figure 1 illustrates the factor yield strength plays in determining recommended strip width.

Remember that the welded tube process actually is a sinking process

akin to drawing. The effect of compression (as occurs in fin and sizing passes) or sinking is twofold; both elongation (growth in length) and wall thickening do occur. Therefore, another way to verify that sufficient cold work has been accomplished in the fin forming passes is to measure wall thickness buildup carefully. An increase in wall thickness is a clue that enough cold work has occurred. A discernible thickening at the 3 o'clock and 6 o'clock positions of the tube wall, which can be difficult to measure, is an indicator of sufficient cold work.

Mystery Solved!

These two solutions are not exhaustive, but they are part of the total mill setup and troubleshooting process. The measurement of increased wall thickness indicated in the last test method is controversial, because the production goal always is to make a welded tube at

its minimal wall thickness. However, this requires some give and take. Making a tube with minimal wall is easier when the beginning wall is thinner.

The intent is to experiment with the strip width and the resulting reduction in the fin and sizing sections to increase the wall thickness so that it just exceeds the minimum. The trade-off is a reduction in residual elongation in the finished product. We get into trouble, however, when we step over the line in either direction, and we encounter one of two problems: Selling tube that does not meet the customer's minimum wall specification or selling tube that has less than the minimum residual elongation. These are equally bad problems.

Poor weld quality is the result of shaving the strip width to reduce wall thickness growth and, in the end, creates a far worse problem. Successful tube production is a matter of finding the balance, which is facilitated by

maintaining process mechanics (shoulder alignment and proper roll tooling installation and adjustment) and working closely with material suppliers.

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