Dry Temper Mill Work Roll Heating and Expansion Just Outside Strip Edge - Analysis of Causes and Solution Results

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Introduction

Surface Conditioning Mills on Pickle Lines have traditionally run relatively Heavy Gauges of Mild Steels at relatively Low Elongation. Recently, to meet market demand, Mills have been adapting to running Lighter Gauges, Higher Strength, and Higher Elongation. While doing so they have run into Shape Issues while within Roll Bending and Roll Force limits. Thermal imaging revealed significant Work Roll heating appearing just outside of the material width. One solution to this is to invest the capital to install a Tension Leveler to achieve the desired Elongation without Shape Issues. Before investing the capital in new equipment we wanted to define (and possibly correct some of) the limiting factors in the existing Surface Conditioning Mill. In this paper we will explore the theoretical causes of the observed Work Roll heating patterns and possible solutions to successfully run the material in question on the existing Surface Conditioning Mills.

History
As with many other Surface Conditioning Mills, Shape Issues began to occur when running light gauges to a higher Elongation. Typically the operators would prioritize Shape over Elongation and run the Mill in Constant Force Mode.

Unsuccessful Trial
While IPSI was onsite for another project, the customer had several light gauge high elongation coils to run on their Pickle Line that had created difficulties in the past. The operator ran the coils up to the edge of Shape Issues, where we observed simultaneous Edge-Wave with Center-Buckle. The operator changed Roll Force to show where reducing Roll Force made the simultaneous Edge-Wave and Center-Buckle vanish. The operator then increased the Roll Force to the point that simultaneous Edge-Wave and Center-Buckle reappeared and showed that increasing or decreasing Roll Bending made either the Center-Buckle or Edge-Wave worse.

Unsuccessful Trial
3764652 1607261450.xlsx 1018 0.068" Thick 49.82" Width

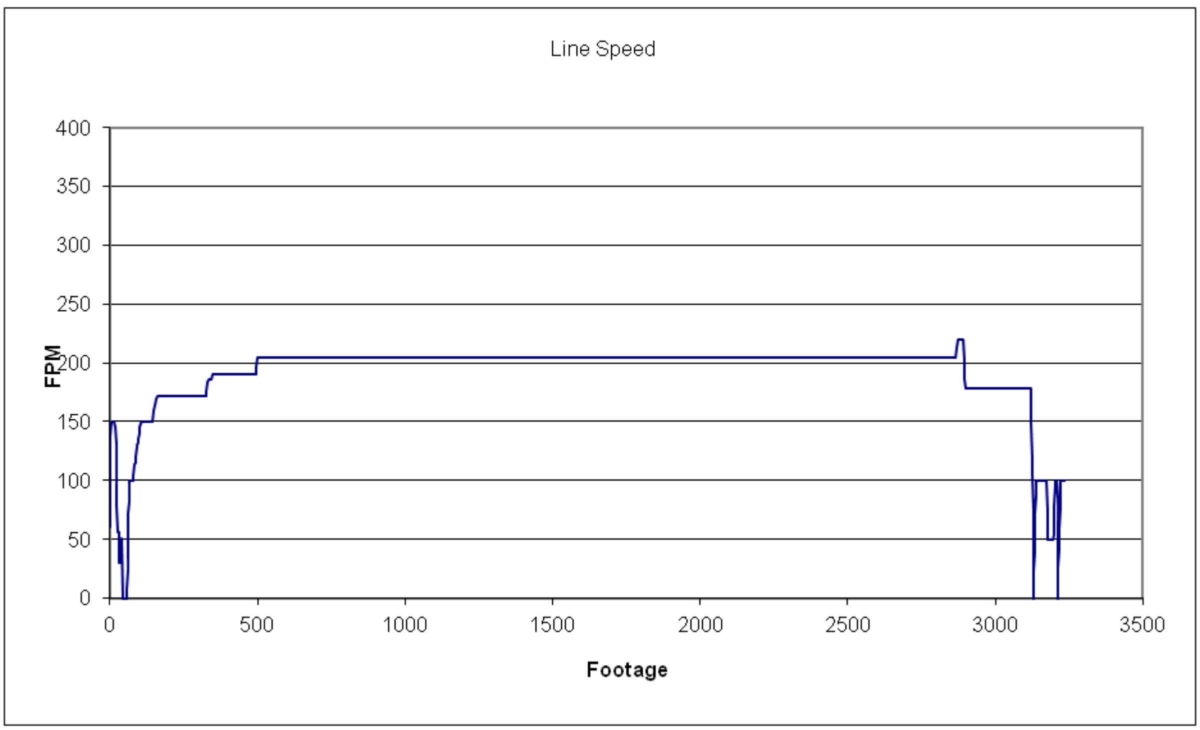

Figure 1. Unsuccessful Trial – Speed vs. Footage

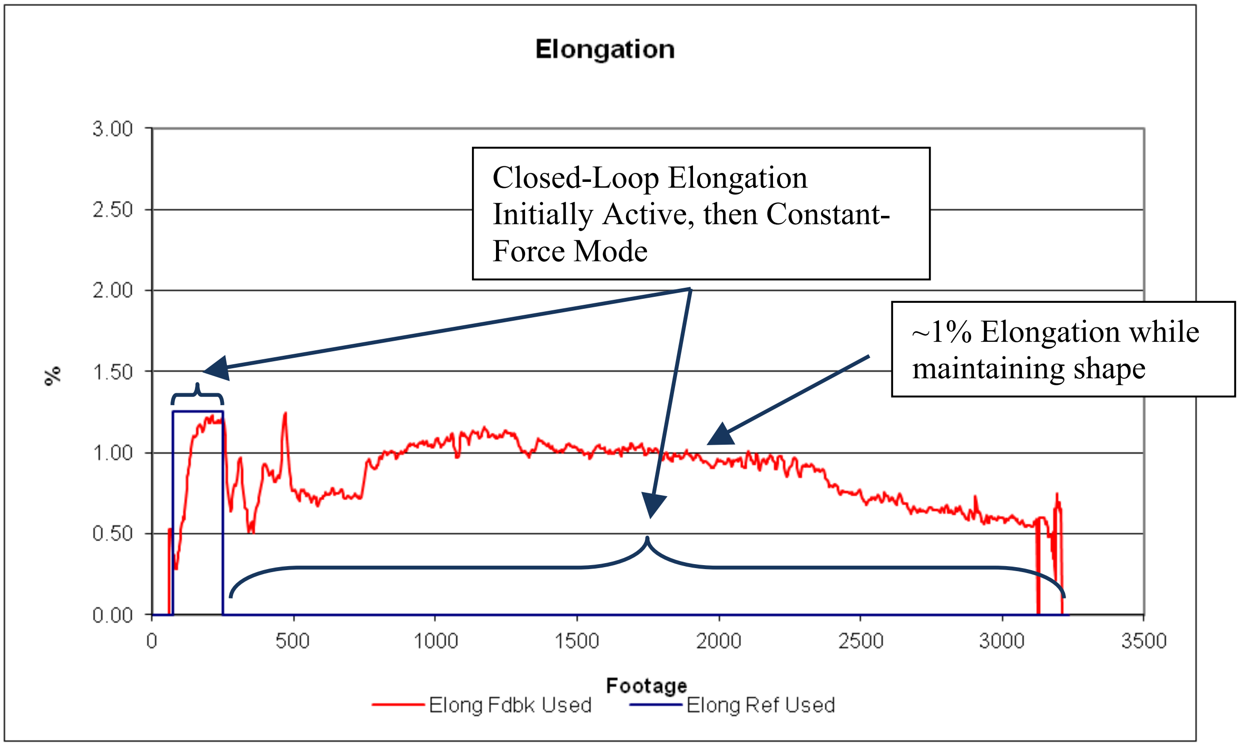

Figure 2. Unsuccessful Trial – Elongation vs. Footage

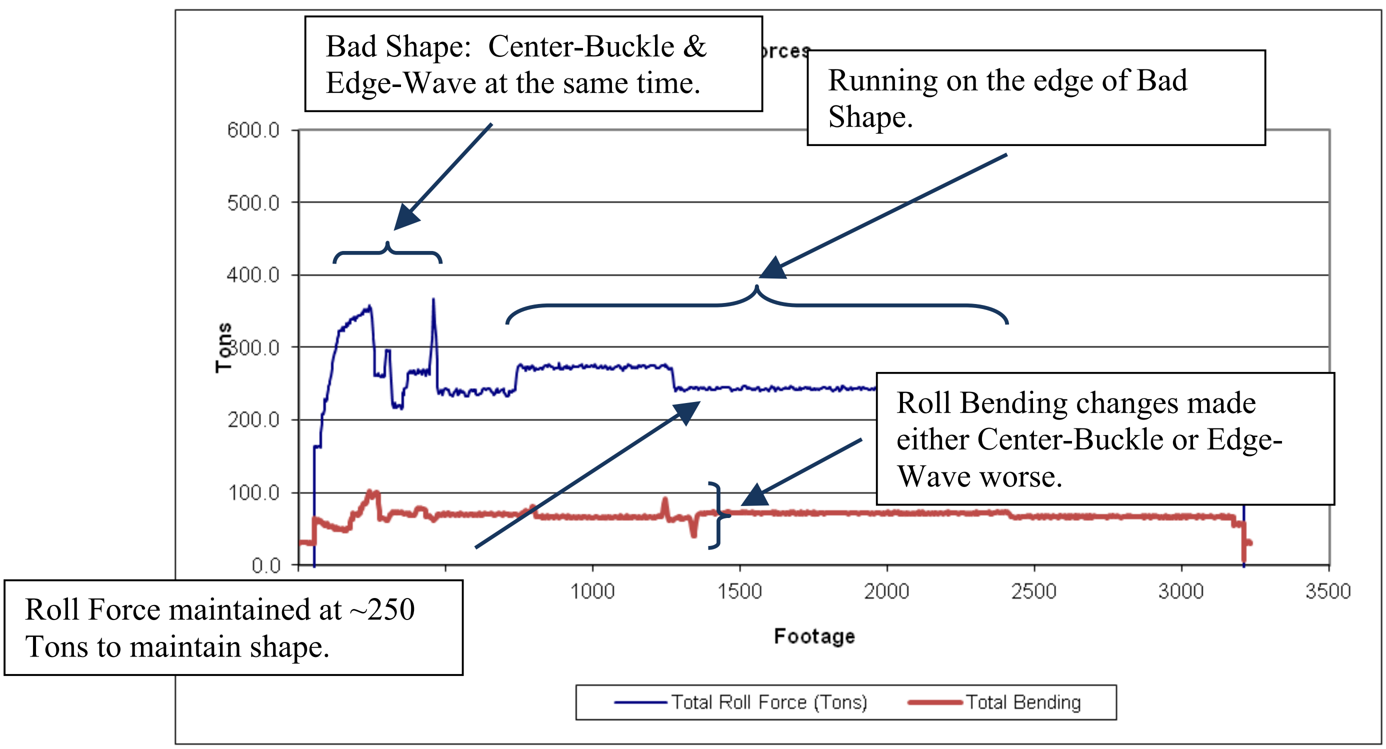

Figure 3. Unsuccessful Trial – Roll Force & Roll Bending vs. Footage

Unsuccessful Trial – Thermal Imaging

The simultaneous Center-Buckle and Edge-Wave condition made us suspect an asymmetric Work Roll profile. We obtained a Thermal Imaging camera to get thermal images of the Work Roll surface temperature profile.

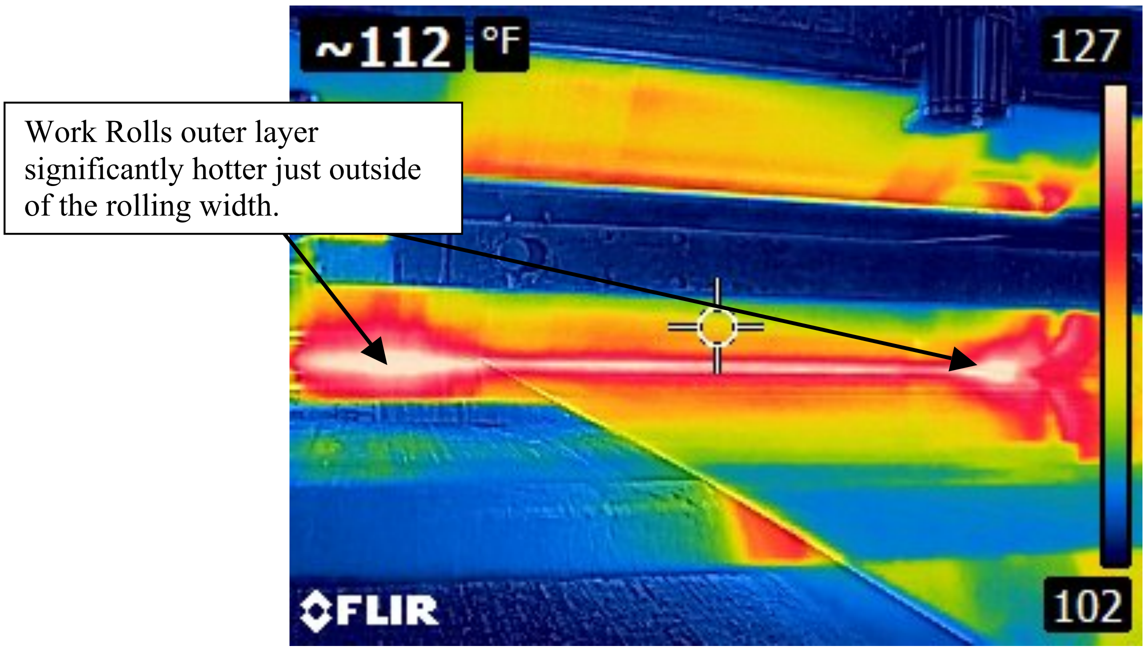

Figure 4. Unsuccessful Trial – Thermal Imaging while running

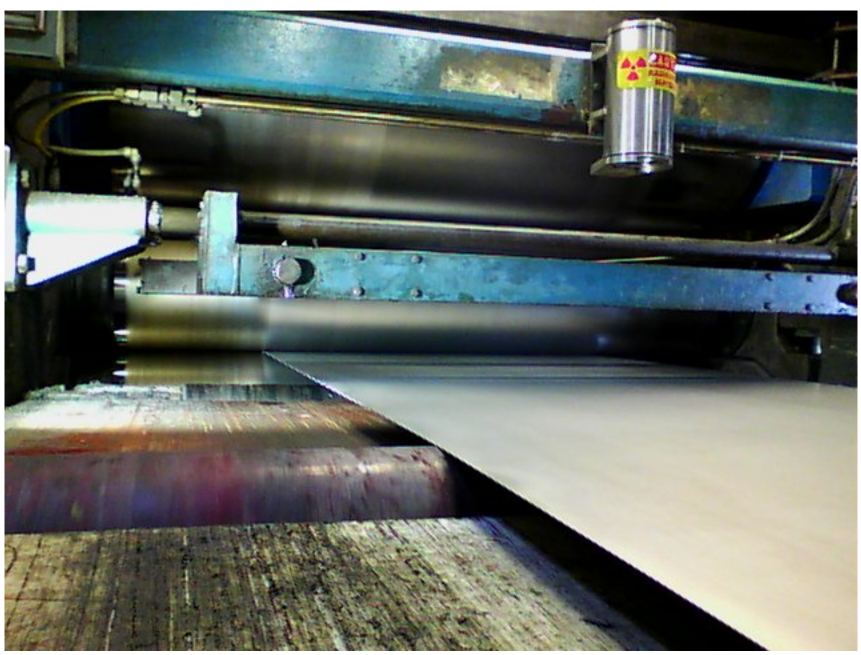

Figure 5. Unsuccessful Trial – Visual Imaging while running

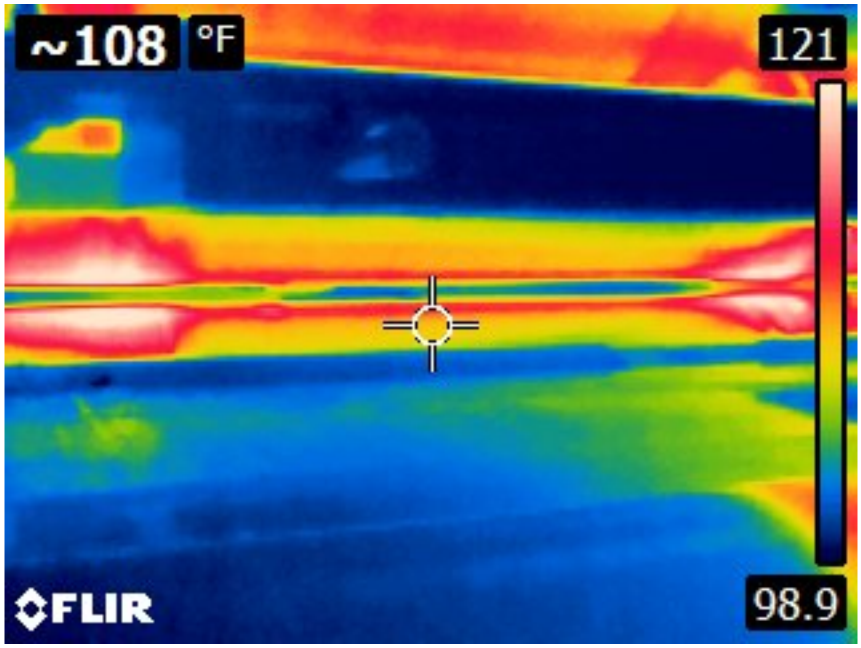

Figure 6. Unsuccessful Trial – Thermal Imaging between coils


Figure 7. Unsuccessful Trial – Visual Imaging between coils

Unsuccessful Trial – Thermal growth diagram

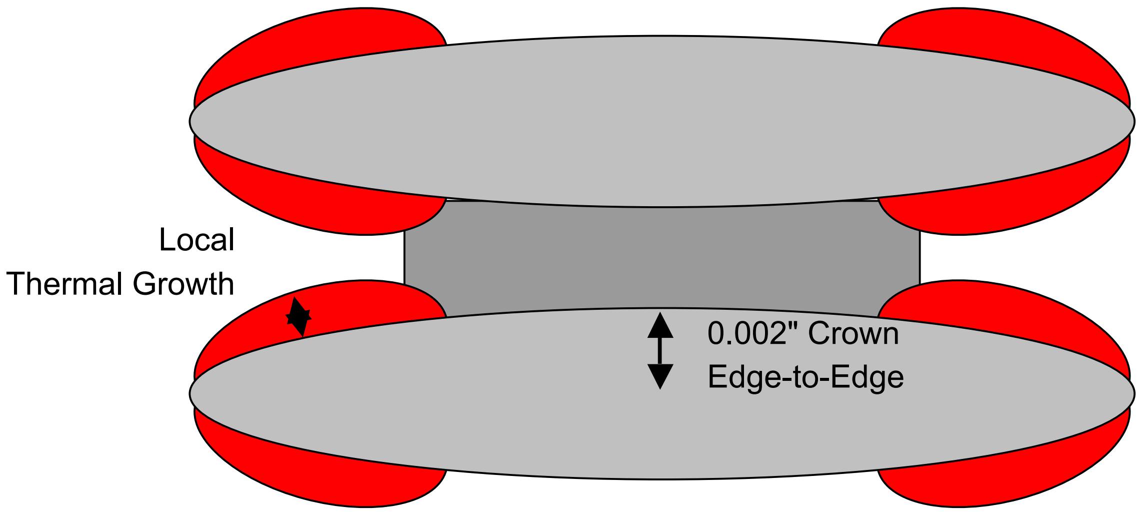

Figure 8. Unsuccessful Trial – Thermal growth diagram

The irregular roll profile from the localized thermal growth explained the Shape Issues present while attempting to run the light gauge high elongation material.

Successful Trial
The next day we ran a very similar coil on fresh, cold rolls.

3758417 1607271633.xlsx 1018 0.072" Thick 53" Width

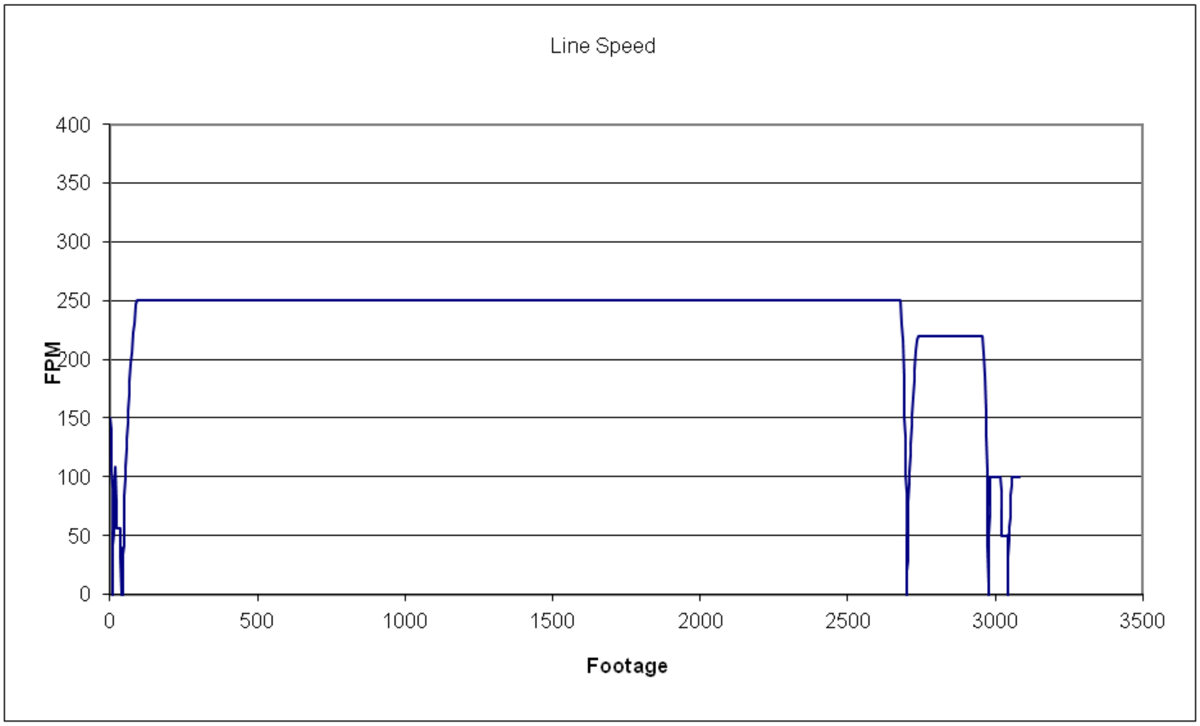

Figure 9. Successful Trial – Speed vs. Footage

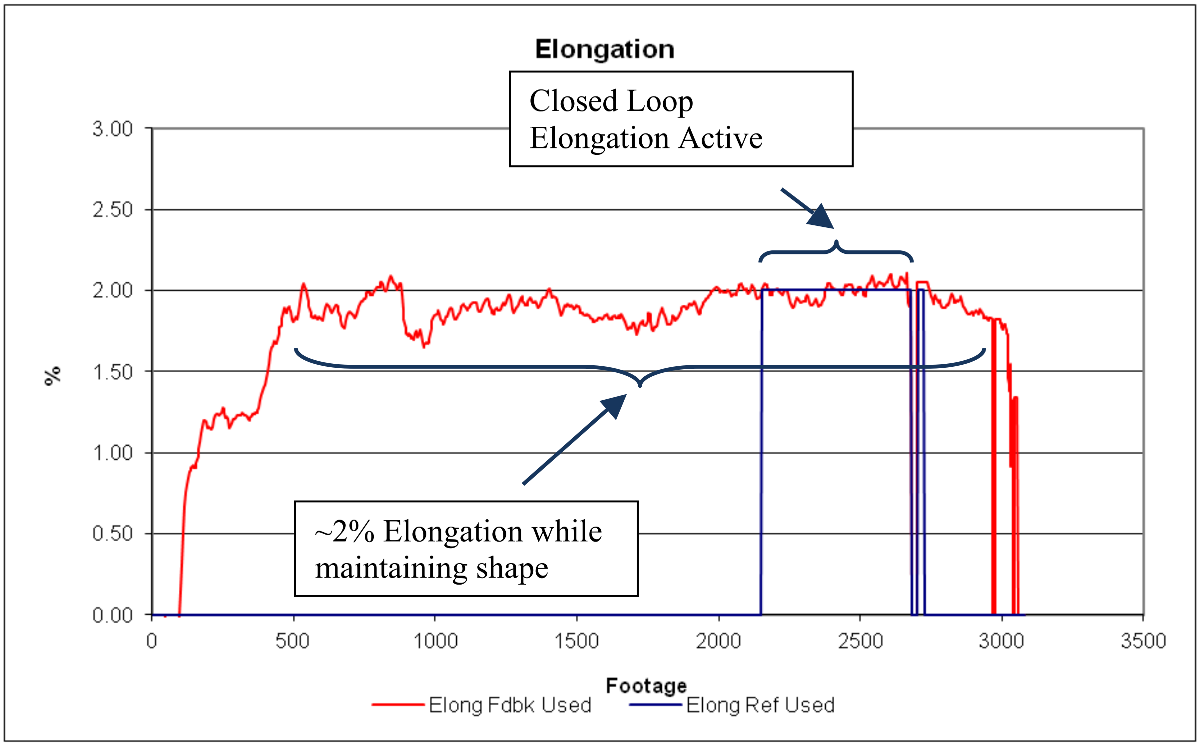

Figure 10. Successful Trial – Elongation vs. Footage

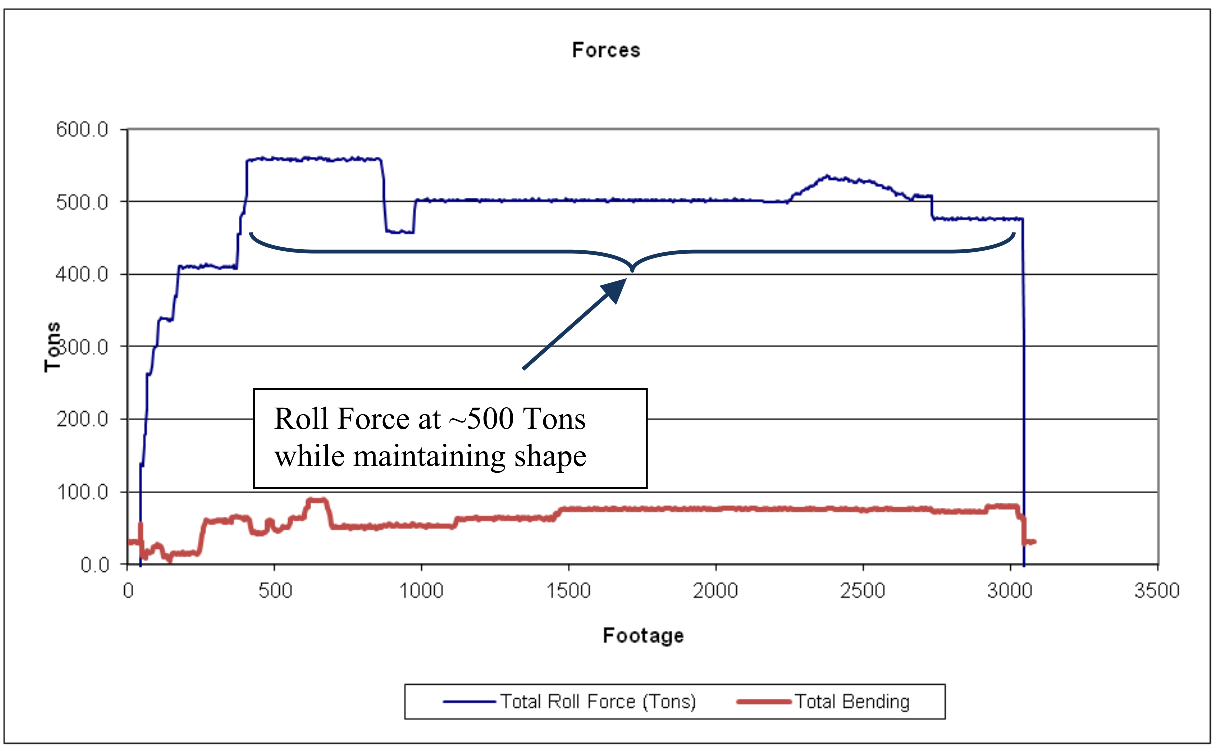

Figure 11. Successful Trial – Roll Force & Roll Bending vs. Footage

Successful Trial – Thermal Imaging

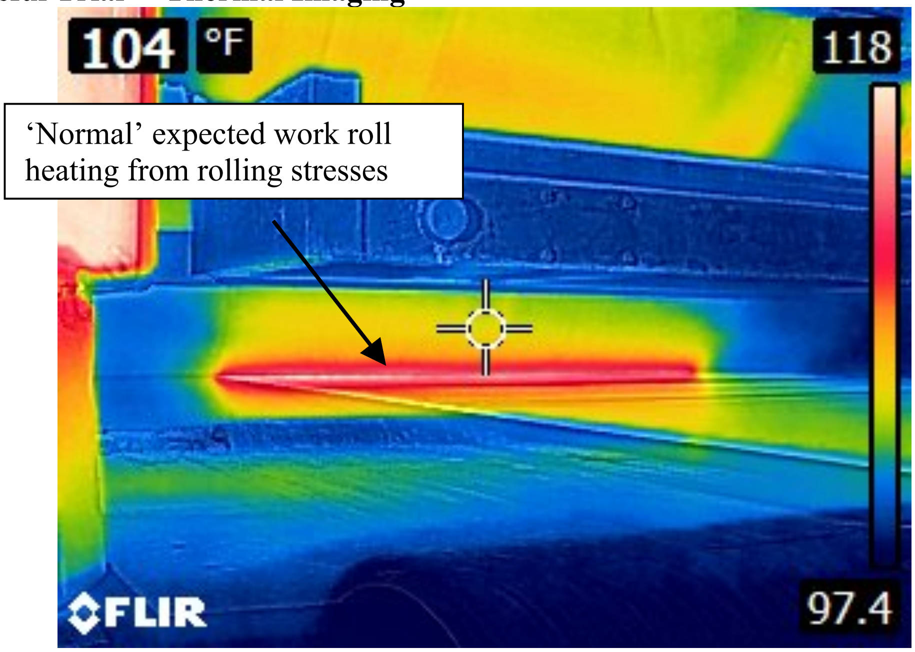

Figure 12. Successful Trial – Thermal Imaging while running

Figure 13. Successful Trial – Visual Imaging while running

Successful Trial – Thermal Imaging between coils

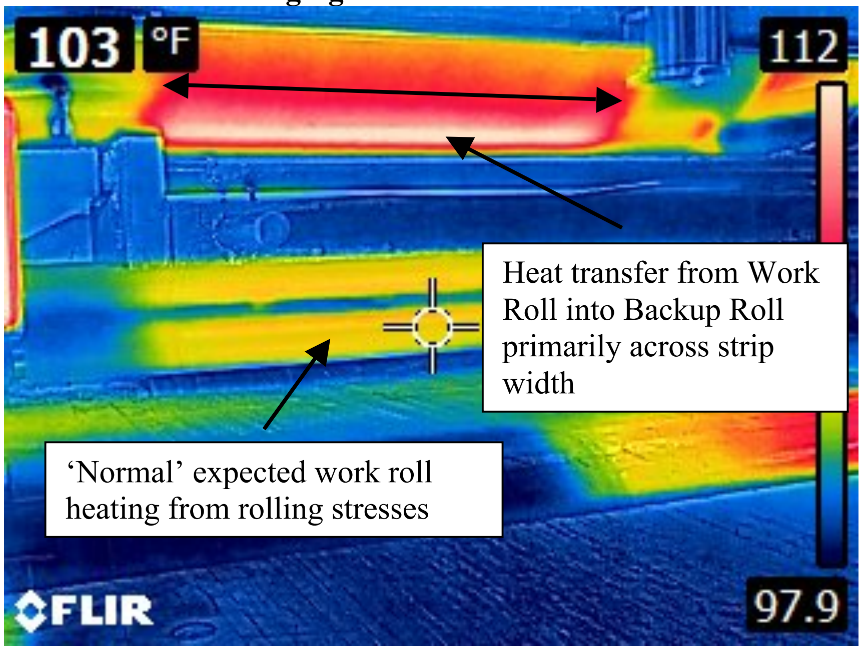

Figure 14. Successful Trial – Thermal Imaging between coils

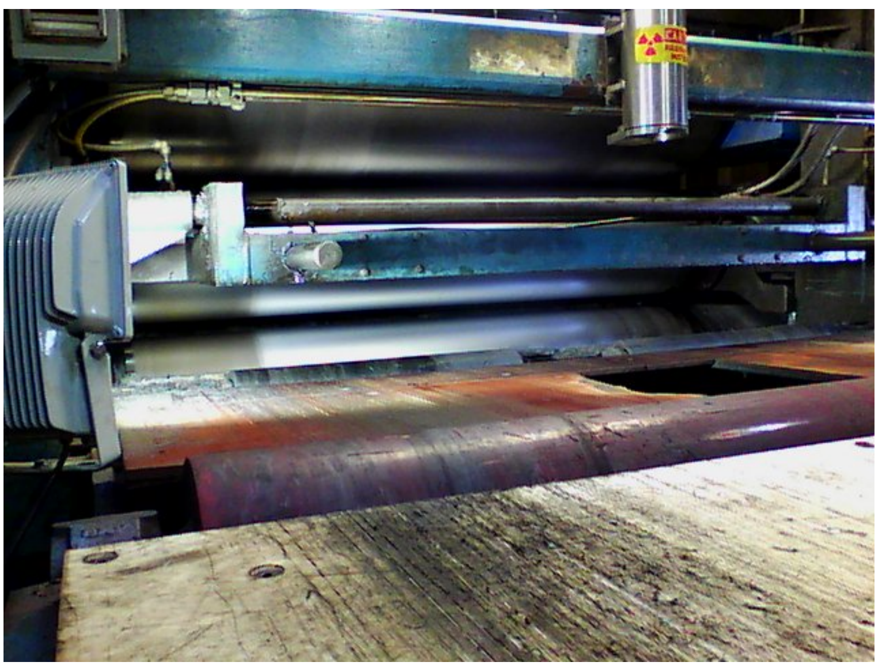

Figure 15. Successful Trial – Visual Imaging between coils

Thermal Growth Pattern

Over the course of the next several coils the rolls appeared to have a ‘thermal bloom’ just outside the rolling width.

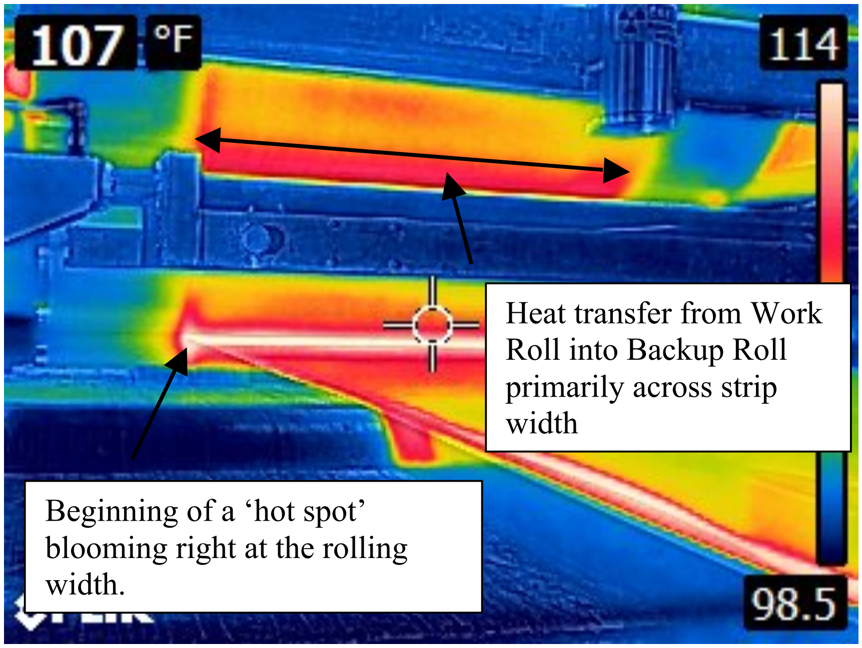

Figure 16. Thermal Growth Pattern – Thermal Imaging between coils

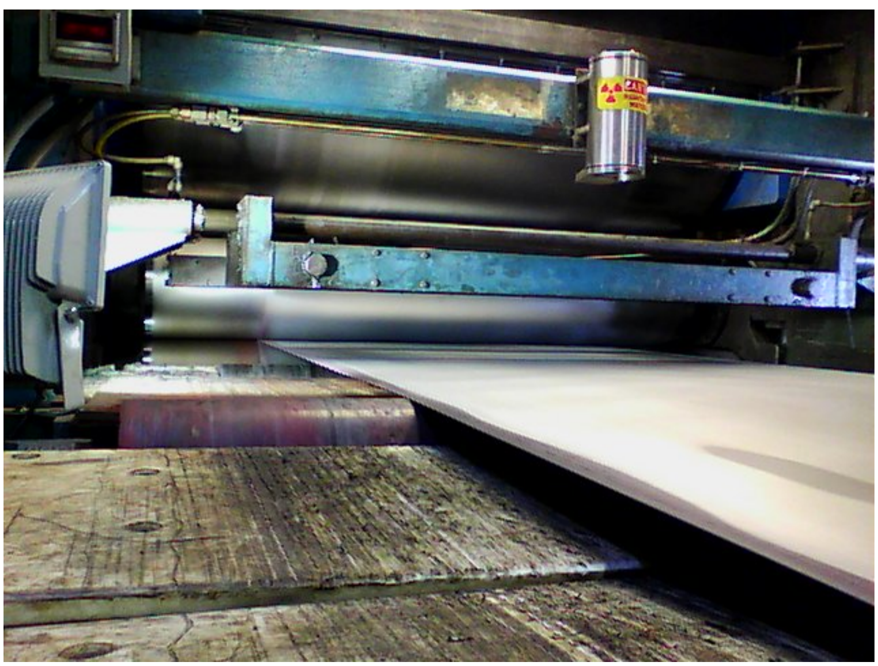

Figure 17. Thermal Growth Pattern – Thermal Imaging between coils

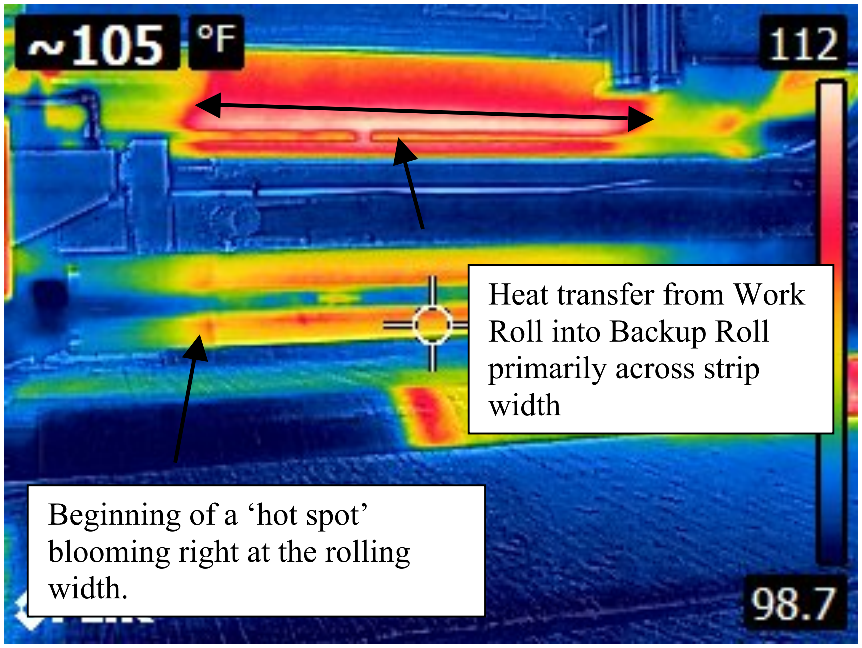

Figure 18. Thermal Growth Pattern – Thermal Imaging between coils

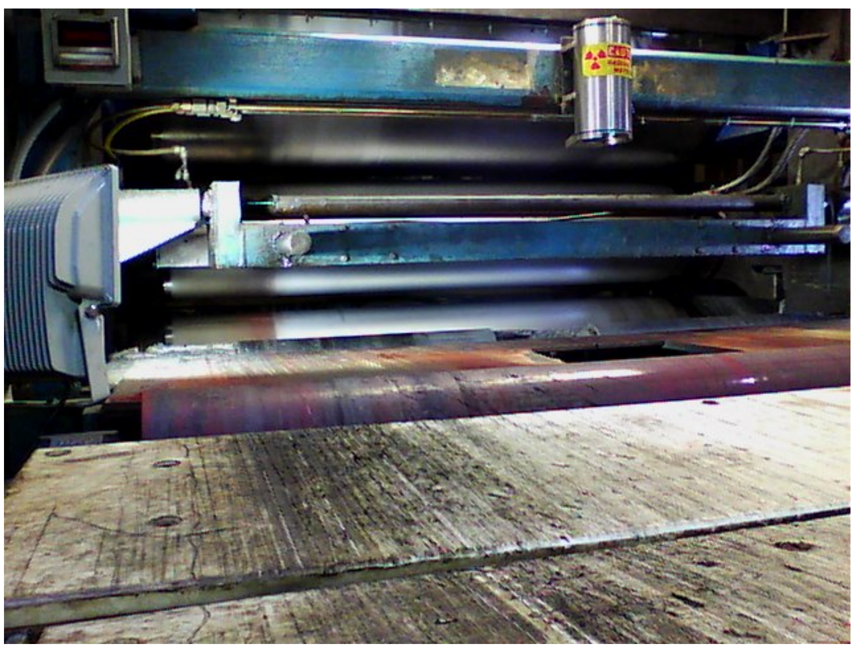
Figure 19. Thermal Growth Pattern – Thermal Imaging between coils

After 45 minutes of rolling.

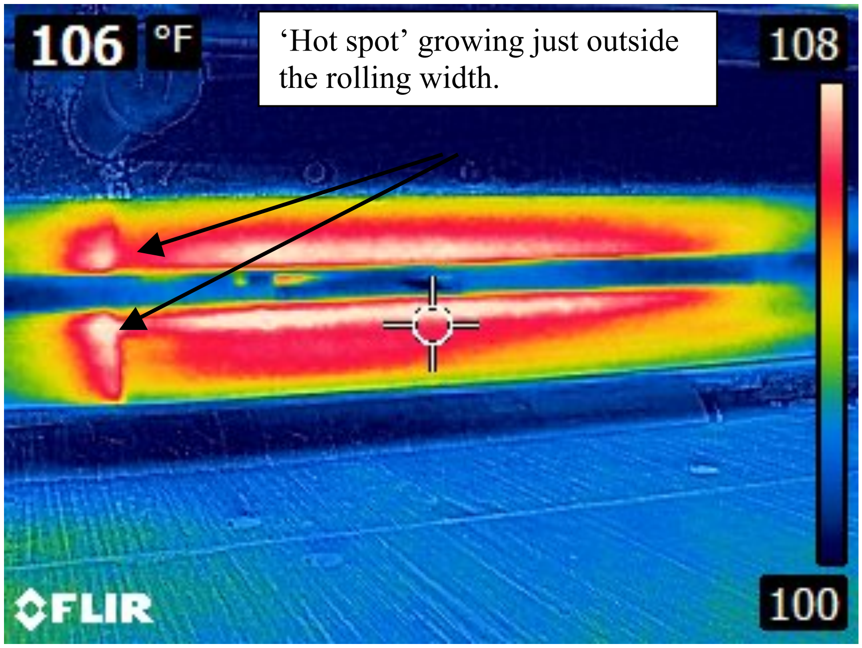

Figure 20. Thermal Growth Pattern – Thermal Imaging 45 minutes later


Figure 21. Thermal Growth Pattern – Visual Imaging 45 minutes later

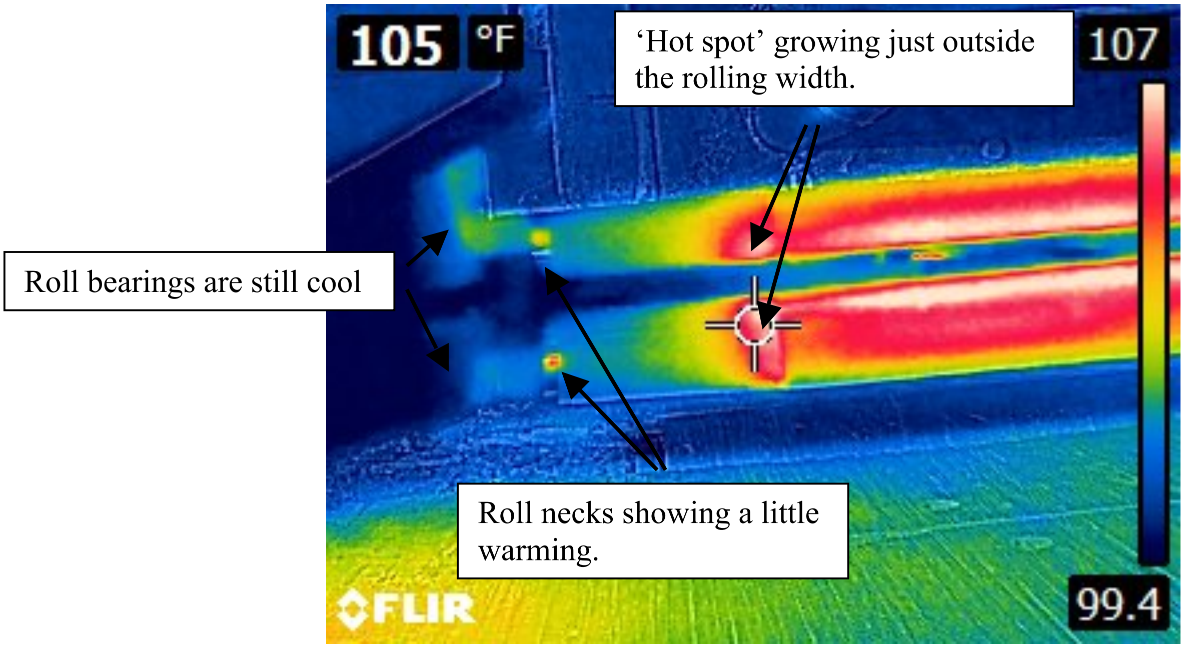

Figure 22. Thermal Growth Pattern – Thermal Imaging 45 minutes later


Figure 23. Thermal Growth Pattern – Visual Imaging 45 minutes later

After 20 hours of rolling.

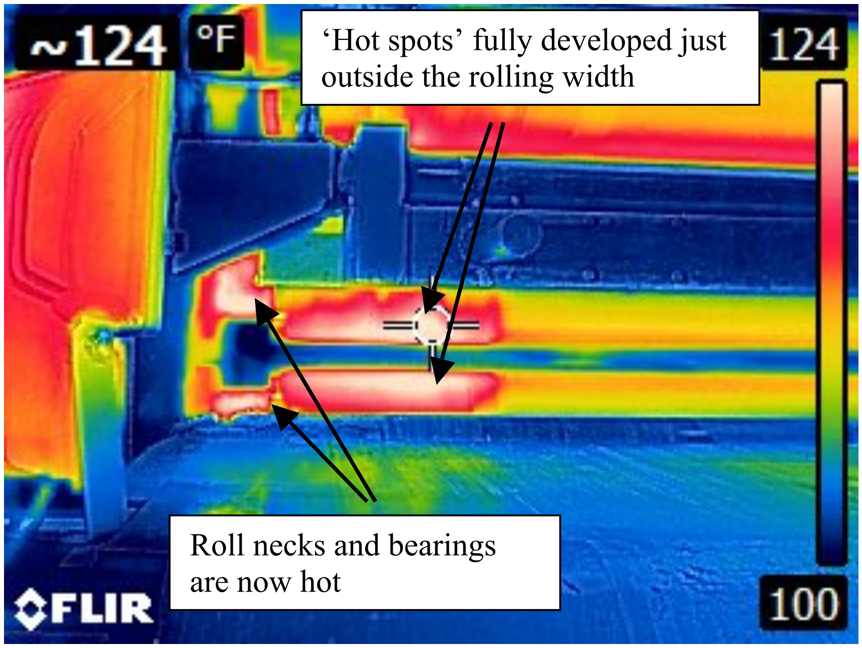

Figure 24. Thermal Growth Pattern – Thermal Imaging 20 Hours later

Figure 25. Thermal Growth Pattern – Visual Imaging 20 Hours later

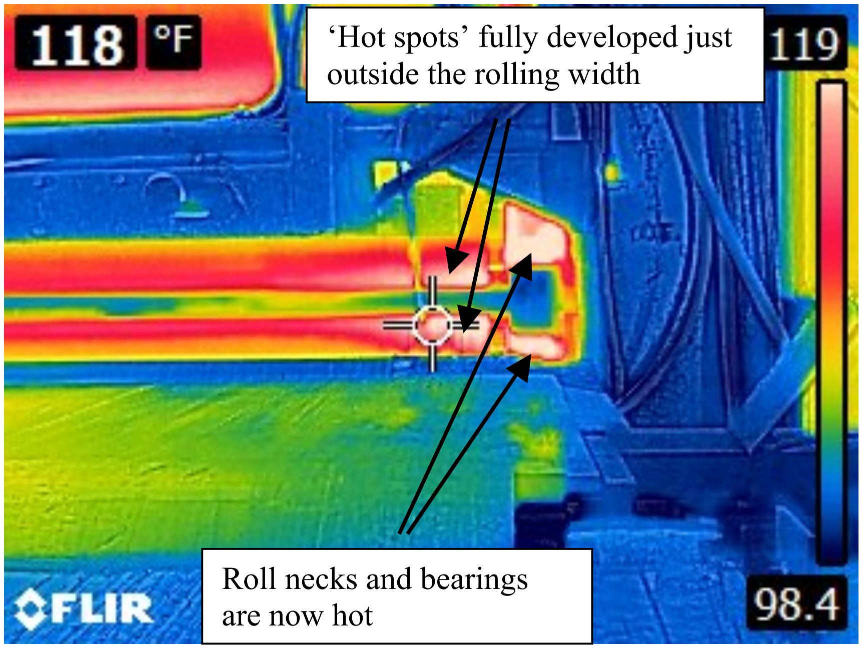

Figure 26. Thermal Growth Pattern – Thermal Imaging 20 Hours later

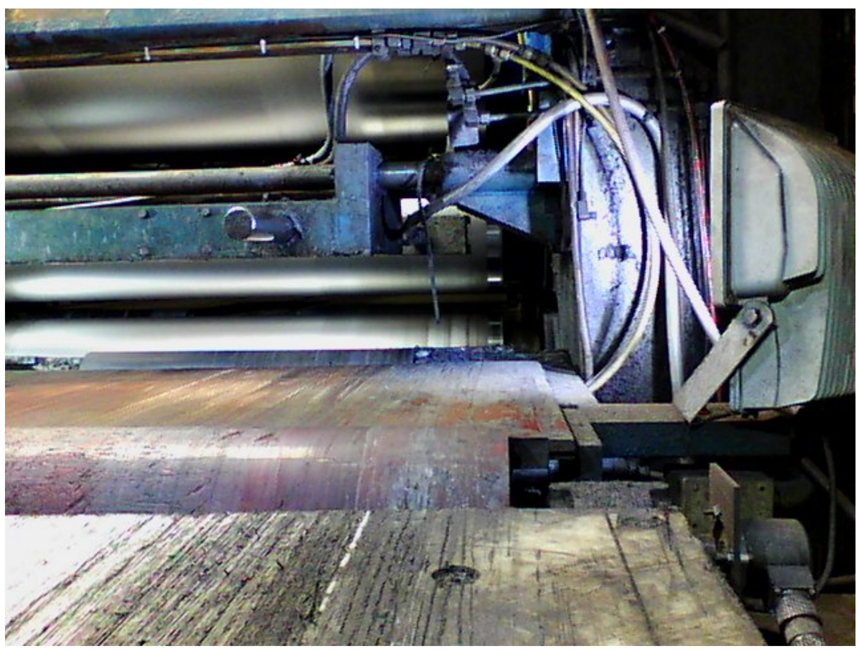
Figure 27. Thermal Growth Pattern – Visual Imaging 20 Hours later

Work Roll and Backup Roll non-contact region

For the 'normal' material, the Mill runs with relatively low Roll Force (~200 Tons) and relatively high Negative Roll Bending (~-70 Tons). This combination with the ground-in Work Roll Crown results in a region where the Backup Rolls and Work Rolls do not touch during normal rolling operations.

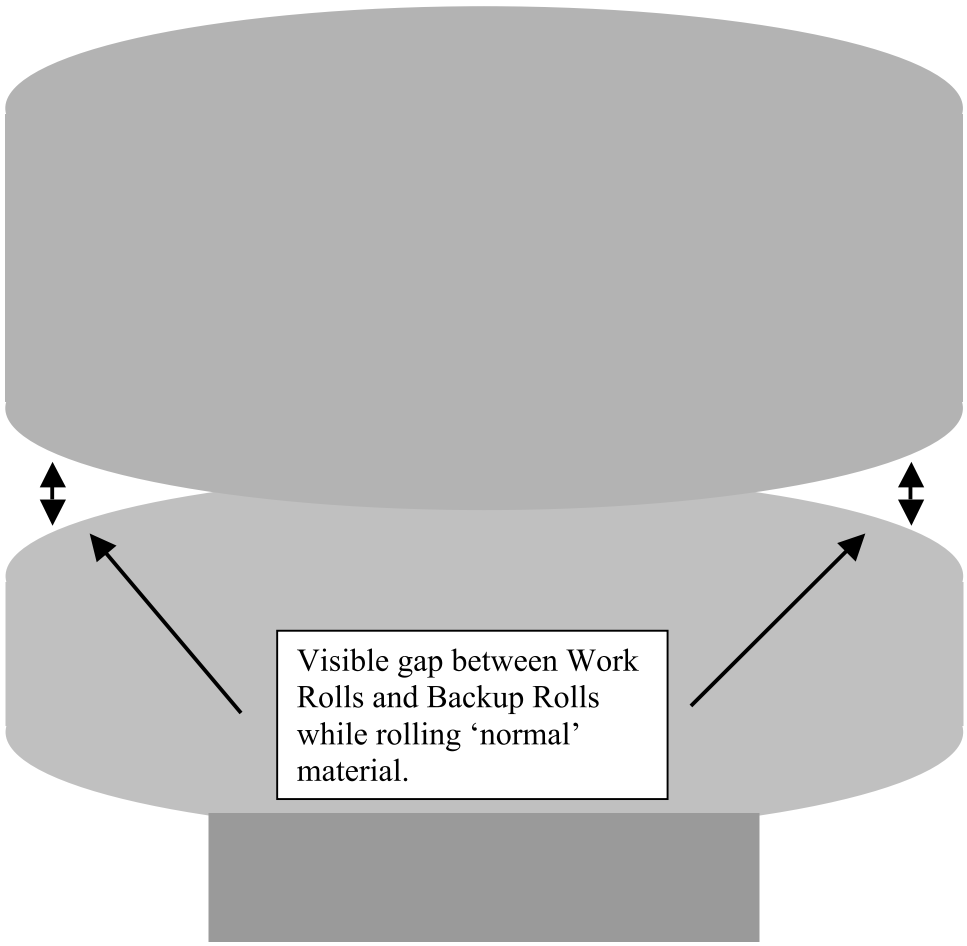

Figure 28. Work Roll and Backup Roll non-contact region diagram

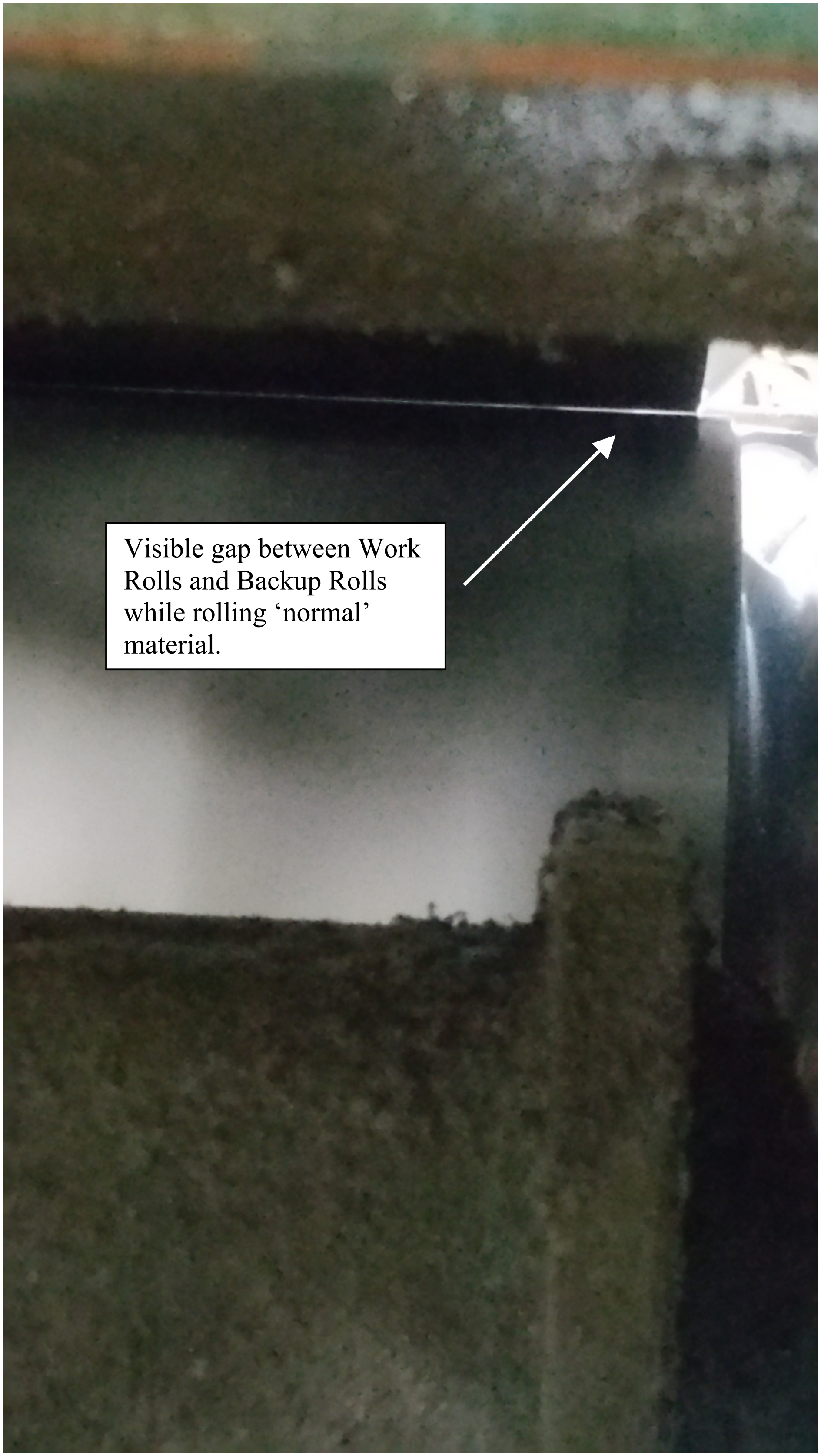

Figure 29. Work Roll and Backup Roll non-contact region picture

Heat Generation and Transfer

1. Heat is generated at the entry of the Roll Gap and transfers efficiently into the Work Roll surface and into the Material surface.
2. Heat transfers efficiently into the Work Roll ends from the Bearing Chocks.
3. Heat transfers efficiently from the surface into the Work Roll interior.
4. Heat transfers poorly to the outside environment from the non-contact region of the Work Rolls via Radiation and Passive Ambient Air Convection.
5. Heat transfers efficiently from Work Rolls to Backup Rolls in ~Material Width Region of Contact.

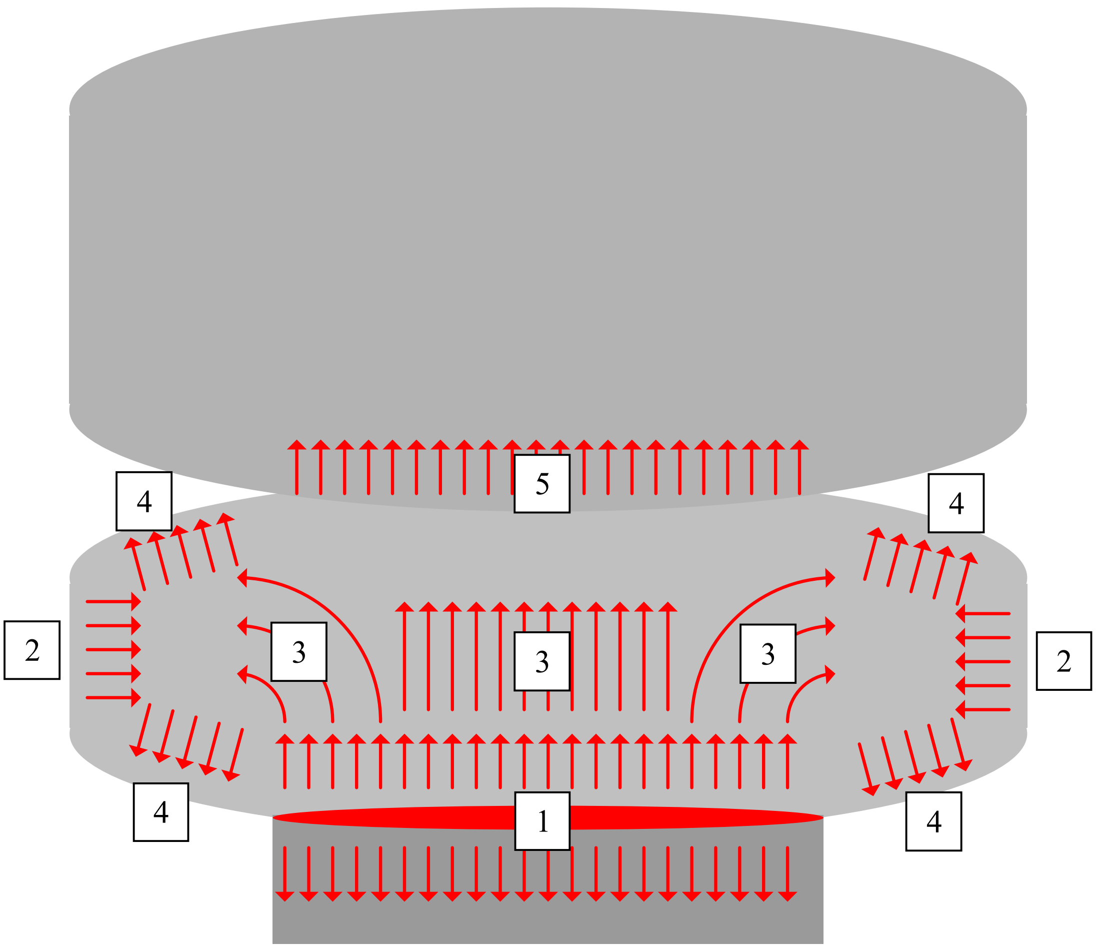

Figure 30. Heat Generation and Transfer

Heat Accumulation

Poor heat transfer in the region ~outside the material width leads to accumulation of heat and undesirable thermal profile and subsequent profile of the Work Rolls.

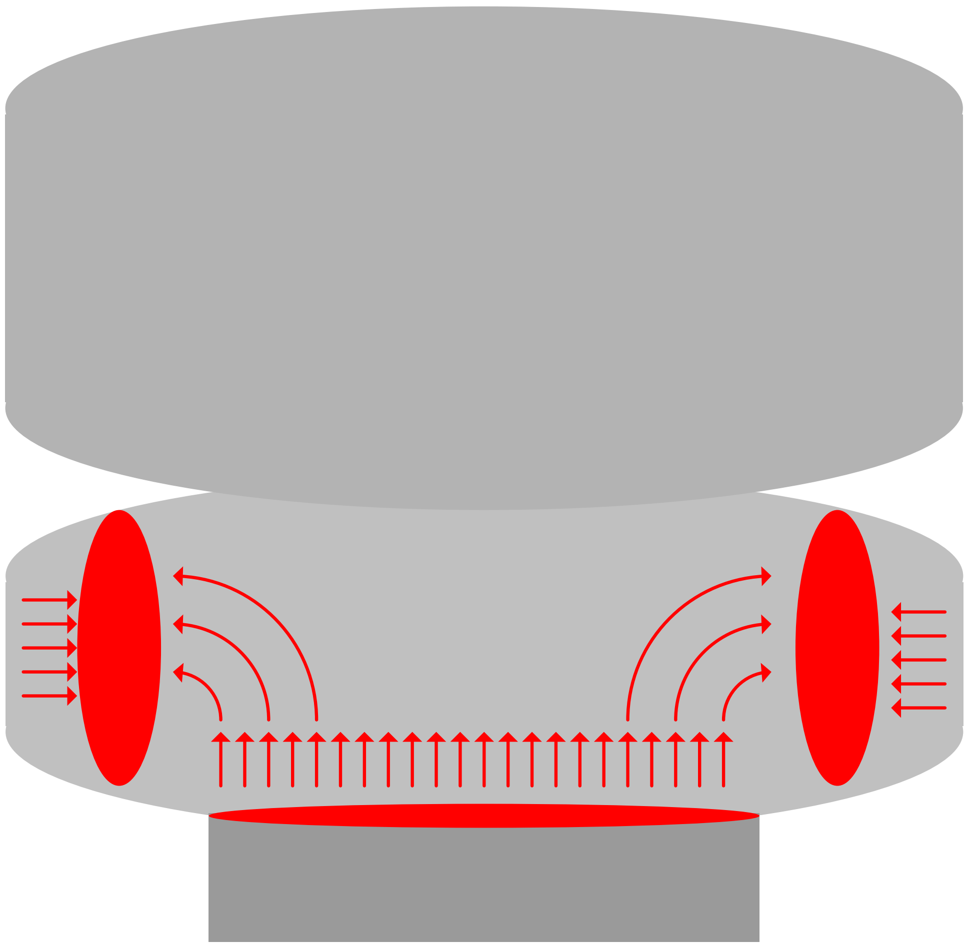

Figure 31. Heat Accumulation

Corrective Action(s)

Online Monitoring

Plans are in place to install several FLIR AX8 thermal cameras to monitor the Work Roll outer surface temperature and pass the information to the operators and to the PLC.

Air Cooling

Although Thermal Conductivity of Air Cooling is several orders of magnitude less than Water Cooling or Metal-to-Metal direct contact, Forced Air Cooling should work better than Passive Air Cooling and not create process issues (ie already dry strip immediately before the Oiler and Recoiler.

Scheduling

Pickle Lines in general can be scheduled as orders come in, just grouping coils in a given order together, with ‘transition’ coils as necessary for gauge and width changes while using a stitcher.

As long as the Higher-Strength Lighter-Gauge Higher-Elongation coils are relatively few, Work Roll changes could be scheduled for those coils, but this adds expense in Roll Inventory and loss of productivity.

Wet Temper

A Wet Temper system could be installed to help thermally manage the rolls, but this would be relatively expensive, but less so than a Tension Leveler.

References

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