Guidelines for Allowable Roller Misalignment

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David Roisum, Ph.D.
Finishing Technologies, Inc.
Why is Alignment So Important?

Affects the Web:

- Flatness: Bagginess and apparent Bagginess
- Position: Path and Registration (e.g. Printing)
- Runnability (Web Breaks)
- Winding: Roll Quality
- Wrinkles
- Costs money if standards are:
  - Too loose or
  - Too tight
Two Views of Alignment

- **Mechanical**
  - Level
  - Square
  - Common Centerlines

- **Web Handling**
  - In-plane (bending)
    - Path control
    - Web breaks
    - Wrinkles
  - Out-of-plane (twisting)
    - Web damage/breaks at edges
    - Center wrinkle
  - Offset Centerlines
    - Guide runs off center
    - Web runs off center
Hand Tools - Types

Machinist Levels

Graduations are
.0005" to .005" per foot
40-400 microns / meter

Trammels

Pi Tape

Figures Courtesy of Oasis Alignment Services
Hand Tool - Limitations

- **Level**
  - At best good to 0.001”/foot (100 microns per meter)
  - (Optics can be 20X tighter)

- **Square**
  - There is no squaring tool
  - Parallelism Problems
    - Doesn’t help square vertical spans (1-2 and 3-4)
    - Accumulation of error

- **Level and Square**
  - Large Tendency to Sloppiness
Hand Tool – Application

• **Step 1** – *I might* have an alignment related problem
  – Path Control
    • Printer Registration
    • Wound Roll Edge
  – Web Breaks
  – *(Diagonal)* Wrinkling

• **Step 2** – Verify working hypothesis that problem *might be* exacerbated by misalignment
  – Level by level
  – Parallel by Pi Tape

• **Step 3** – Align rollers using precision tooling
  – That specific area or
  – Entire machine
Similar to surveying equipment, but > 10X more precise

Figures Courtesy of Oasis Alignment Services
Baseline Installation

• Alignment means
  – Establishing ‘offset centerline’ for alignments
  – Look for ‘monuments’ (small plugs) in floor

Figure Courtesy of Oasis Alignment Services
Centerline Survey

• Alignment means
  – Level,
  – Square, AND
  – Middle of Rollers on Same Centerline

Figure Courtesy of Oasis Alignment Services
Squaring With Optics

- Precision Square w.r.t. Baseline
- Uses a pair of TTS
- Precision right angles

Figure Courtesy of Oasis Alignment Services 72.10
Other High Tech Alignment Tools

Laser Shaft Alignment
The standard for motor to roller alignment

Laser Trackers

Coordinate Measuring Total Station

Gyro – Fast setup and position readout

Gyroscope

Figures Courtesy of Oasis Alignment Services 72.11
Alignment Details - Preparation

- $$$ for Downtime
- Machine Builder
  - Standards & Instructions
  - Alignability
- Maintenance
  - Remove Excess Rollers
  - Roller Maintenance
  - Dowel/Mark
- Align Crew
  - Plug Lines
  - Report with before & after readings
- Design for Service (alignability)
  - Individual rollers easily moved
  - Preserve Level
    - Shear ledge
    - Jack bolts
- Match Drilled Frames?


Alignment Challenges

- **Bearing Housings**
  - At an angle
  - Bolt bound designs (e.g., match drilled frames)
  - No shear ledge

- **Rollers - General**
  - Flimsy frames
  - Flimsy foundations
  - Loose mounting

- **Rollers – Specific**
  - Pivoting / translating
  - Skewable
  - Curved axis (bowed spreaders)
  - Segmented

- **Alignment**
  - No line of sight
  - Flimsy floors
  - Hand tools

- **Procedural**
  - Lack of guidance
    - Which rollers
    - How close
  - Not enough time

- **Special**
  - Foil
  - Close packed rollers
  - Narrow rollers (wheels)
Two Views of Alignment

• **Mechanical**
  - Level
  - Square
  - Common Centerlines
  - See Web101.72
  - Roller Alignment - Mechanics

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    • Guide runs off center
    • Web runs off center
In-Plane Bending

- a.k.a, i.e.
  - Not parallel
  - Not trammed
- THE MOST SERIOUS RISK
  - Path Control
  - Web breaks
  - Wrinkling
  - etc
In-Plane Bending: Stresses-Strains

- **Physics:**
  - **Normal Entry Law:**
    - Web enters a roller in traction at a right (normal) angle

- **Explains**
  - Guides
  - Roller Misalignment
  - Spreaders
  - etc

- **Can Cause**
  - Web Breaks
  - Slack Web
  - Wrinkles
  - Path Change
  - etc
Out-of-Plane Twisting

• a.k.a, i.e.
  – Twist

• Very Tolerant
  – Difficult to Overstress
  – No path change

• Applications:
  – Displacement Guide
  – Some Dual Spreaders
Out-of-Plane Twisting: Stresses-Strains

- No Path Change
- High Stresses at Edges
- Center MD Bagginess/Wrinkle possible
**Emergency Alignment**

- Wrinkles are found at roller #3 and cause the web to break
- Question: **Which roller** (1-4) should be moved in **which direction** (horizontal, vertical, other)?

![Diagram showing roller alignment with labels Unwind, Ctr, Dryer, Winder, and Unwind Winder Dryer Wrinkle Ctr 2 3 4 1 4 3 with arrows indicating movement directions.]

**Hint:**
Smart Alignment

• Which rollers and directions is alignment most needed?
  – Level – easy
  – Square – requires optics
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Current Art/Craft/Science

- **Paper Industry**: 0.002” or 0.003” per 100” width, 0.005” maximum
- **Converting Industry**: 0.001” / foot
- **Most Common By Far**: nothing whatsoever
- **Models** for wrinkling and web breaks
- Despite decades of research, most everyone is getting the answer wrong

Commercial tolerances that are relatively easy to achieve with a bit of care.
In-Plane Bending

- a.k.a, i.e.
  - Not parallel
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- THE MOST SERIOUS RISK
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Practical Alignment

- **One number** for maximum allowable

- **Worst case** for a machine or plant
  - In-plane bending (versus out-of-plane, level and square)
  - Material (thin, high modulus)
  - Machine (short spans, short L/W span ratios)
  - Rollers (traction)

- **With Practical Exceptions** such as
Calculation Based

- For Each Critical/Typical Roller, Web and Direction
  - Path Control
  - Web Breaks (Critical Angle to Inside Edge Slackness)
  - Wrinkling (Critical Angle to Diagonal Shear Wrinkle)

Gehlbach, Lars S. and Good, J.K and Kedl, Douglas M. 
TopWeb – Roller Align etc
WP AbbottApp

Wrinkle Predictor AbbottApp

• ‘Wrinkle Predictor’ runs on any computer and smartphone that has a modern browser
Empirical

- For Each Critical/Typical Roller, Web and Direction
  - Wrinkling (Critical Angle)
- Move roller while running, observe when diagonal wrinkle starts
### Parametric Analysis:

36 cases from paper, paperboard, PET, PE and AL foil

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Paper/Paperboard - PM Winder & Converting Rewinder

- Paper is fussier than paperboard
- Narrow converting rewinder fussier than full width PM winder

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<th>Case</th>
<th>Describe</th>
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<th>Misalign</th>
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</table>
# Converting Rewinder - Other

- Tension, Width, Span, Wrap, Friction, Caliper, Modulus, Slack or Wrinkle

| Case       | Describe     | Hair's Breadth | Tension Misalign | Width Span Diameter Wrap Friction Thickness Modulus Slack Notes |
|------------|--------------|----------------|------------------|------------------|---------------------|---------------------|------------------|
| 4.00 Paper Rewinder | 3 500 15 60 30 8 90 0.3 3 0.8 Both | Wrinkle | | | | | |
| 4.01 Tension Study | 4 700 21 1.5X | | | | | | |
| 4.02 Tension Study | 2 266 8 0.5X | | | | | | |
| 4.03 L/W Study | 6 1000 30 2X | | | | | | Slack: Low tension worst |
| 4.04 L/W Study | 2 266 8 0.5X | | | | | | Slack: Short L/W worst |
| 4.05 Diameter | 3 500 15 3X | | | | | | Both: |
| 4.06 Diameter | 3 500 15 0.5X | | | | | | Both: NC |
| 4.07 Wrap | 3 500 15 0.167X | | | | | | Both: NC |
| 4.08 Friction Study | 3 500 15 3X | | | | | | Both: |
| 4.09 Friction Study | 3 500 15 0.3X | | | | | | Both: |
| 4.10 Caliper Study | 2 300 9 1.2X | | | | | | Slack: Thick Caliper Worst* |
| 4.11 Caliper Study | 2 300 9 0.8X | | | | | | Wrinkle |
| 4.12 Modulus Study | 2 333 10 | | | | | | Both: High Mod worst |
| 4.13 Modulus Study | 6 1000 30 | | | | | | Both: |
| Paper Worst | | | | | | | |
| 4.14 Case | 1 83 2.5 30 30 15 8 90 0.3 3 1.2 Slack | | | | | | low tension, short span, high mod |
| Paper Worst | 1 167 5 30 30 15 8 90 0.3 3 1.2 Both | | | | | | Both: |
Paper Industry Summary

• ½ Hair’s breadth good enough for most of the rollers in the paper industry*

• ½ Hair’s breadth is the VERY tight end of commercial tolerances

• Irony: the paper *mill* winder (where tight tolerances originated) can tolerate 100X**
  converting winder (which has no specs)

• * Sectional roller gaps and other special situations excepted

• ** ‘Guide roller’ can be misaligned 300 mils
Industry Summary – Hair’s Breadth

• 100 - Board Mill
• 50 – Paper Mill
• 1.0 – PE Convert
• 0.5 – Paper Convert
• 0.2 – Foil Convert*
• 0.1 – PET Convert

• Large difference between needs and practice in converting
• Education
• Tolerance
  – Few rollers
  – Slippery surfaces
  – Light wrap angles

*Walker’s foil study indicates models are too conservative
Outgoing Suggestions

• Outgoing *(Should rollers be moved?)*
  – Response to known misalignment problems
    • Path
    • Web Breaks
    • Wrinkles (diagonal)

• Calculate or Measure ‘threshold of pain’

• Safety factor of 4-10
  – Similar to tension

• Classes
  A – < 20 micro-radian tooling, brittle webs
  B – 20 micro-radian paper, metal
  C – 100 micro-radian converting
  D – 1000 micro-radian rubber, textiles
  F - > 1000 micro-radian web handling fail
Questions?

Answers:
David Roisum, Ph.D.

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