Introduction to

Solid Wood Bending

overview and present applications

GHE bavaria

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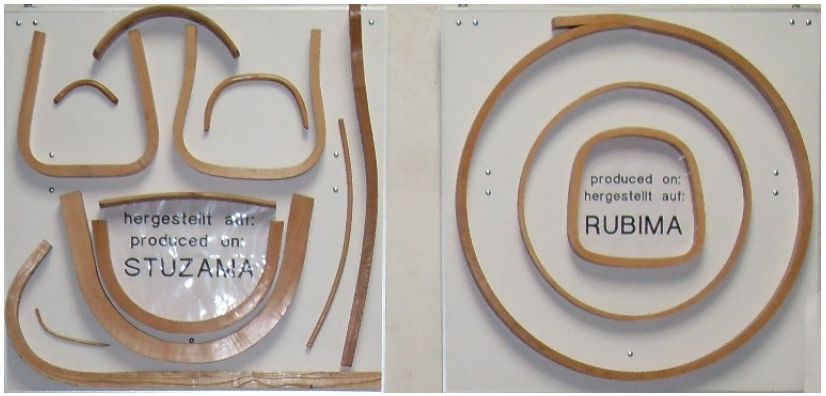
Introduction

- Family operated, est. 1870
- Today main business ***Solid Wood Bending*** equipment
- Further activities in renewable energies
- Bending machines for open (U) and closed (O) shapes
- Softening plants: steam generator & autoclaves
- Export worldwide



Overview: Past to Present (1)

- Michael Thonet and his Chair No. 14
  - 1796 – 1871 German cabinet maker
    - 1841 moving from Boppard to Vienna
    - 1849 developing solid wood bending (Thonet Method), because laminating results not satisfactory (glue)
    - 1859 designing chair Thonet No. 14
      - First mass product of industrialisation
      - Until 1914 > 50 mio. produced
      - Modular design for making multiple versions

Overview: Past to Present (2)

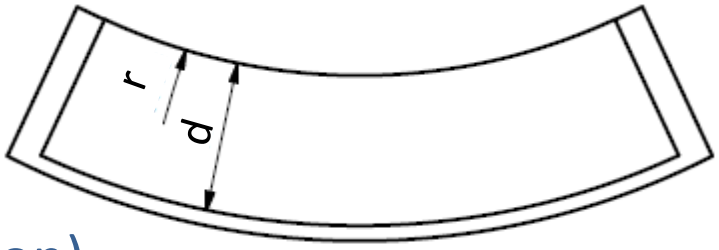
- Wood Bending Applications of the Past:
  - Chairs
  - Sleighs (and related)
  - Frames of many kinds
    - Suitcases
    - Ships (vertical frames)
    - Airplanes (wood constructions until 1950ies)
  - Wheel rims, steering wheels etc.

Overview: Past to Present (3)

- Wood Bending – Present Use:
  - Chairs
  - Sleighs (and related)

Wood Bending – How does it work (1)

- Softening
  - Initial moisture, optimum: 18% ± 2%
  - in steam, T ≈ 100 … 110 °C, t ≈ 1min/mm
- Bending
  - Bending ratio $s = \frac{r}{d}$ depending on wood species (degree of tolerated densification)



- Stabilizing
  1. t ≈ 30 … 90 min with strap & clamp
  2. Drying in frame to H < 12%
  3. No more spring-back (see Norimoto)

Wood Bending – How does it work (2)

- Tensions in Bentwood
  - Wood allows tensile elongation only to ≈ 1,5%
  - Further elongation causes breaking
  - Softened Wood: Compression uncritical
  - System of Metal Strap with End Stops & Softend Wood
    - Tensile Stress covered by Strap
    - Compression Stress to densify softend wooden cells

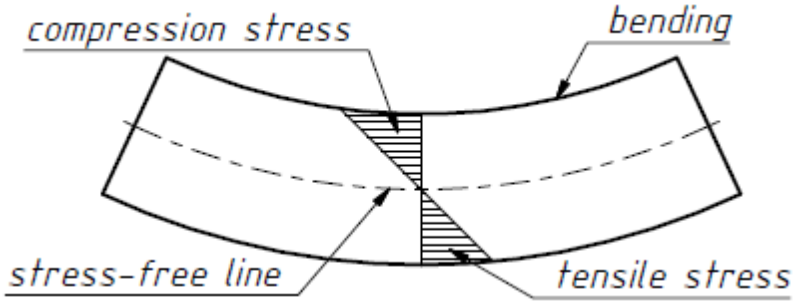


Fig. a) General Bending

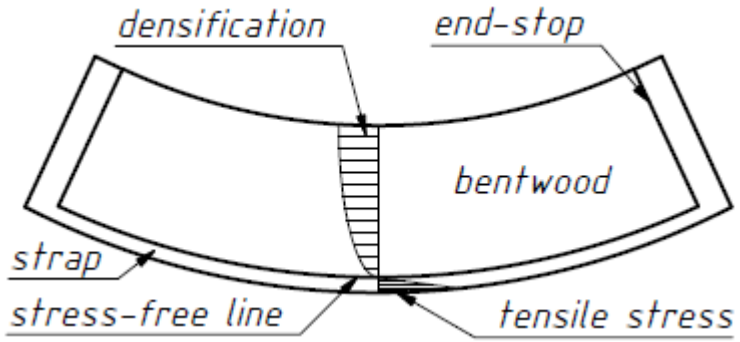


Fig. b) Wood Bending

Stress Relaxation of Wood after Bending

- Burger-Kelvin-Model

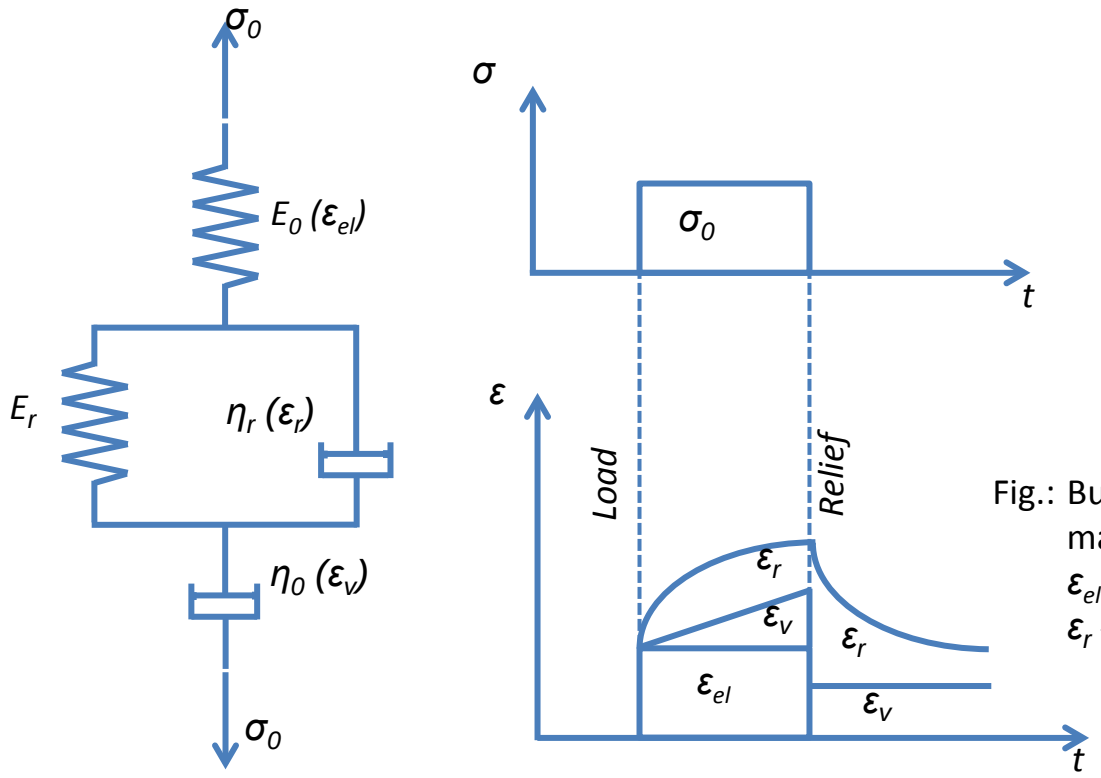


Fig.: Burger-Kelvin Model of viscoelastic material behaviour [Sae92], with: ε_{el} - elastic; ε_v - viscous; ε_r - *viscoelastic (relaxing)*

Stress Relaxation of Wood after Bending

- Viscoelastic properties of wood

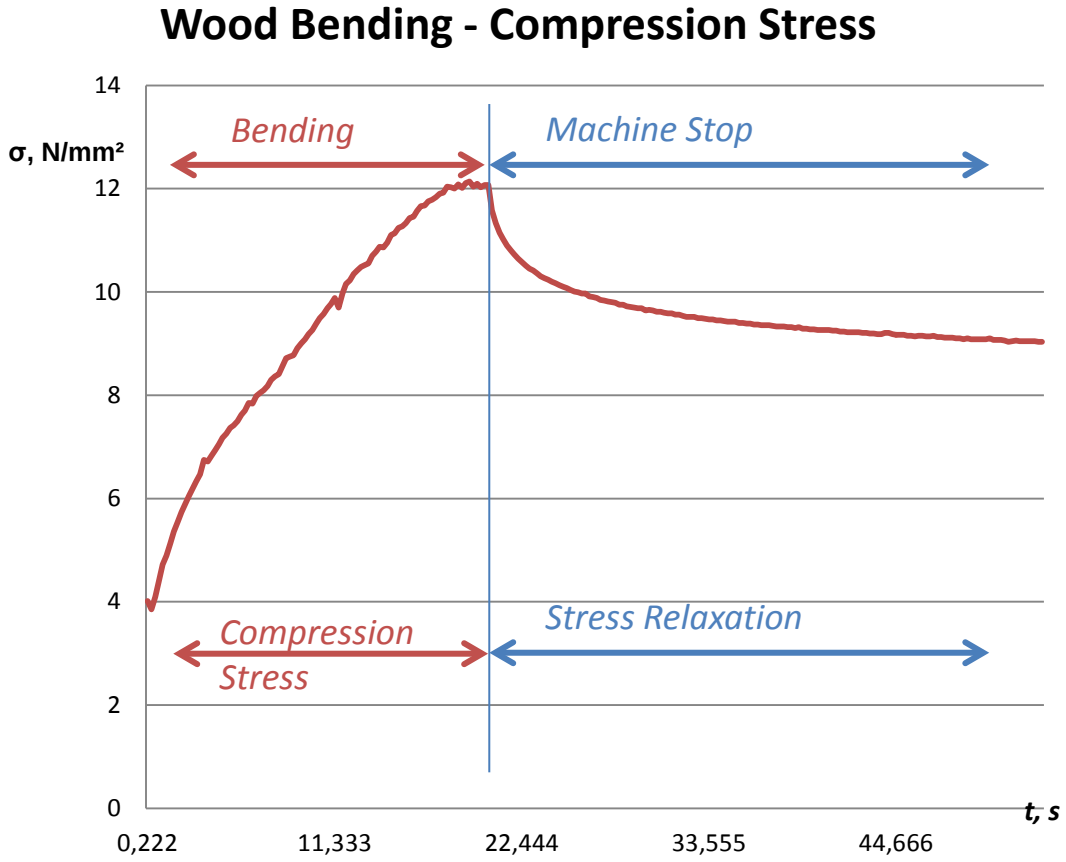


Fig.: Compression stress relaxation of solid wood during bending process [Egg95]

Stress Relaxation of Wood after Bending

- Practical Application
  - Bentwood needs to stay in the strap (end-stop), until tensile stress is relieved.
    - Cutting on relaxation time = increased productivity

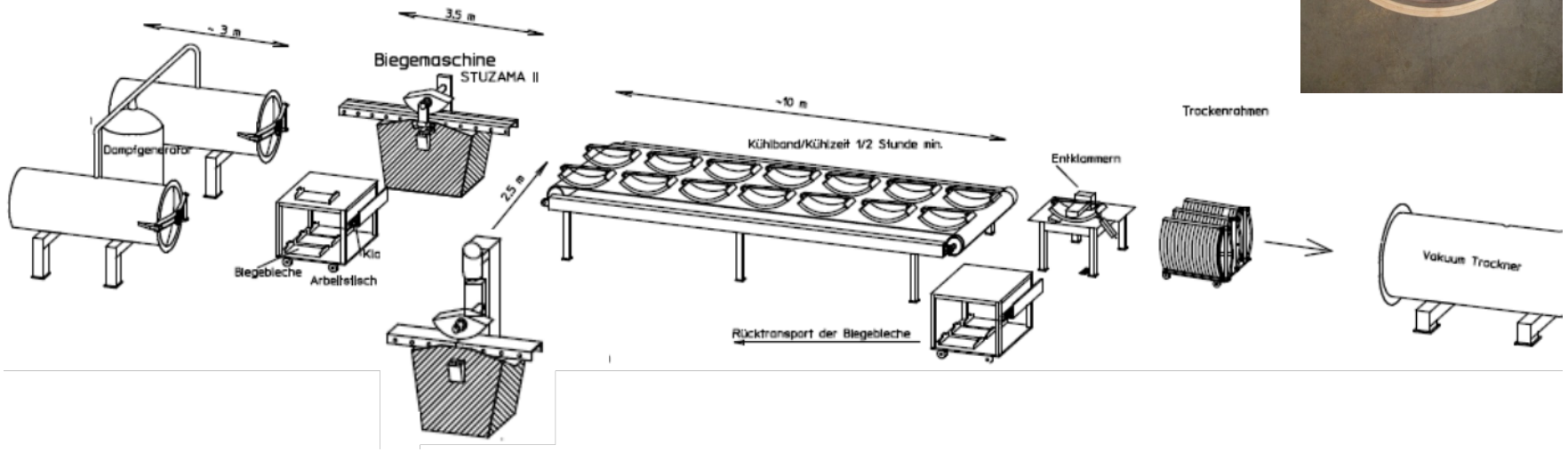


Fig.: Production flow of Solid Wood Bending line in a chair plant [Egg95-2]

Thank You

More videos available at
http://www.youtube.com/user/GHEbavaria

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