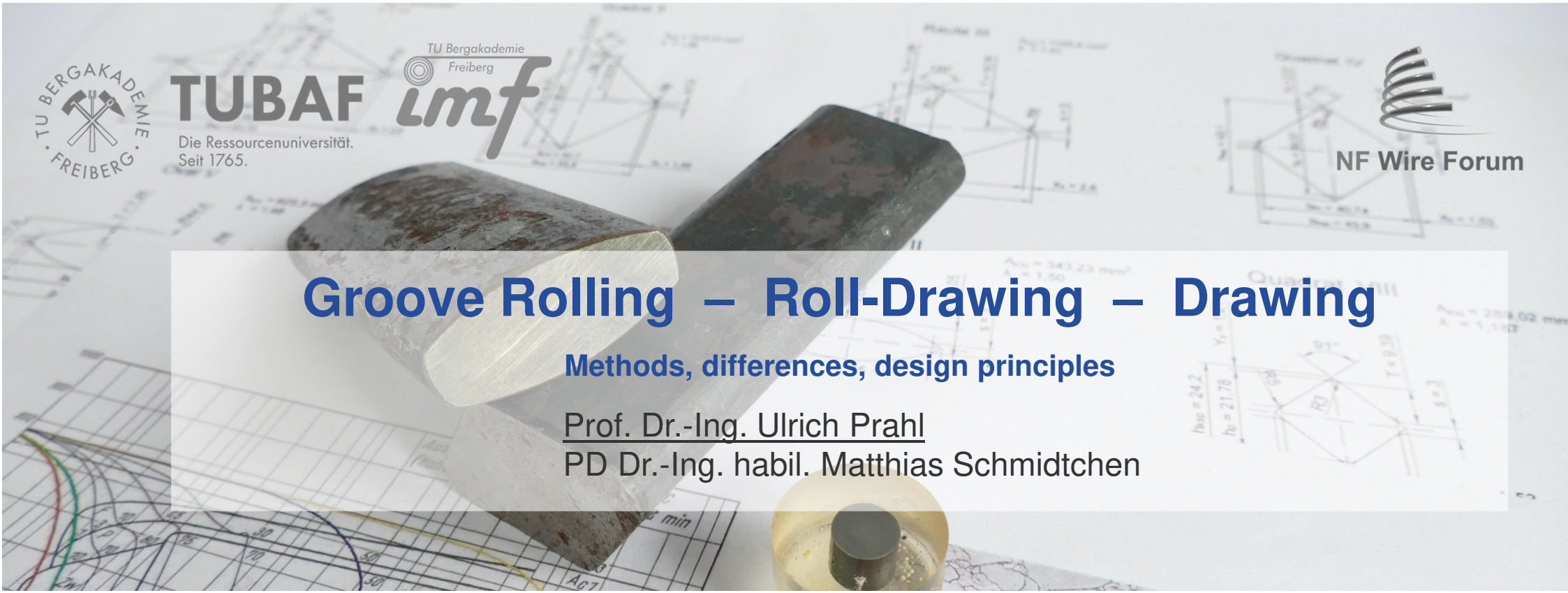


Groove Rolling – Roll-Drawing – Drawing

Methods, differences, design principles

Prof. Dr.-Ing. Ulrich Prahl
PD Dr.-Ing. habil. Matthias Schmidtchen

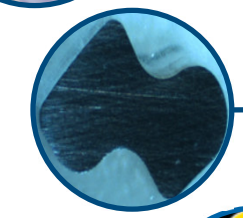
Agenda



1. Institute of Metal Forming (IMF) at the TUBAF
Who we are and what we offer



2. Rolling – Roll-Drawing – Drawing
Strain and stress state, temperature distribution,
Gripping condition, maximum strain, process limitations



3. Example Z-profile in different forming processes
Tensile stress, hardness, surface roughness



4. Open source simulation software PyRolL
IMF.PyRolL @ Github Python – groove pass simulation in a nut shell

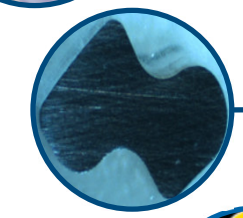
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Institute of Metal Forming

Working groups and research fields



Management



Prof. Dr.-Ing. U. Prahl

Director / Chair for Metal Forming



Dr.-Ing. M. Ullmann

Deputy Director, Administration, Finances



Dr.-Ing. S. Guk

Student affairs

Scientific Groups



PD Dr.-Ing. habil. M. Schmidtchen

Numerical Simulation



Dipl.-Ing. M. Zapf

Hot Forming Simulation



Dr.-Ing. M. Ullmann

Light Metals



Dr.-Ing. S. Guk

Steel and Heavy Metals

Methodical Approaches

Material and Technology Development

Technical Laboratory



Dipl.-Ing. M. Oswald

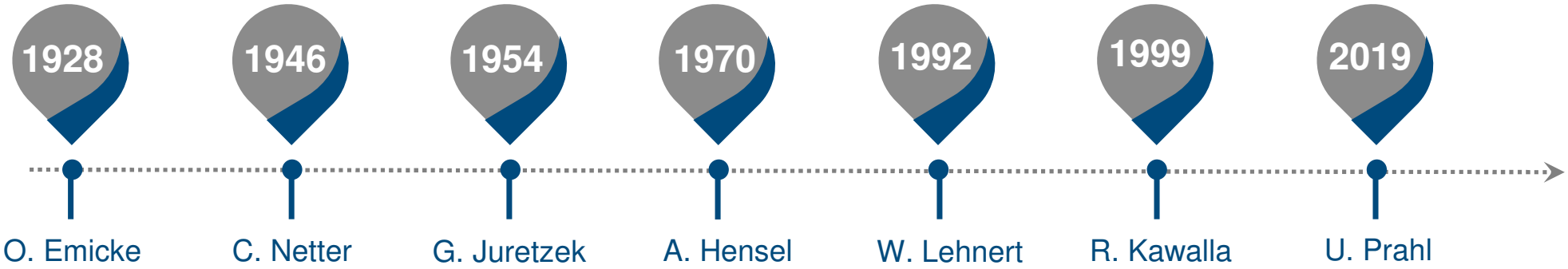
Validation

- Flat Products
- Long Products
- Forged Products

Institute of Metal Forming

More than 95 years of expertise in the development of metal forming technologies

NF Wire Forum



Key competences:

- **Integrating material science** into forming technology
- **Multiscale experimental and numerical simulation** of metal production chains
- **Cross-process optimization** of metal production processes and chains

Team:

- 47 employees
- 10 external PhD candidates
- 12 student co-workers

Funding:

- 2.5 Mio € per year (third-party funding)
- 25 % of that direct industrial funding

Equipment @ IMF

Induction melting furnace

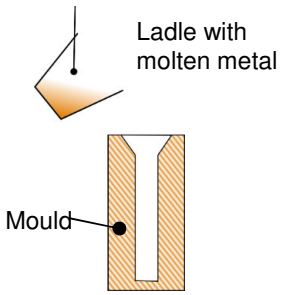
NF Wire Forum

Design of metallic materials:

- Numerical alloy design by thermodynamic databases (ThermoCalc, Dictra, MatCalc)
- Casting of laboratory special melts in vacuum furnace
- Coupling with hot rolling / direct rolling simulation
- Coupling with spectrometry

Process conditions and equipment:

- Max. volume 20 kg (currently 1 liter – approx. 8 kg steel)
- Max. melting temperature 1800 °C
- Vacuum, argon, adjustable partial pressure
- Thermocouple / pyrometer
- Water-cooled / heated mould
- Programmable casting process





VIM LAP 20-50

Equipment @ IMF

NF Wire Forum

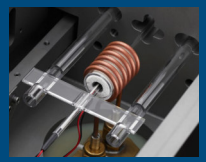
Experimental simulation and parameter identification towards technology design



Heat treatment furnaces



WUmSi
HOT Deformation Simulator



Bähr DTS
deformation dilatometer



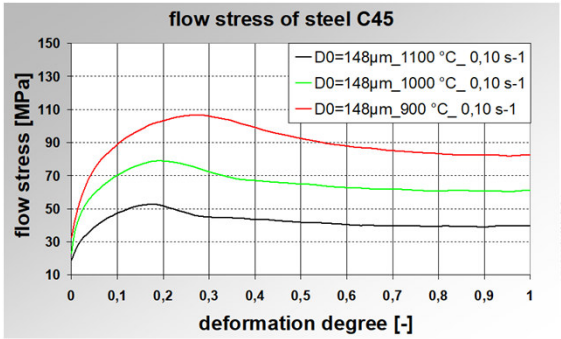
Bähr MDS 830
multi-directional simulator

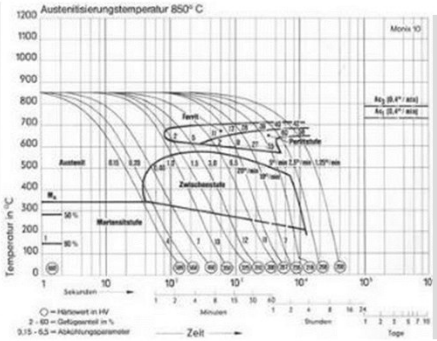


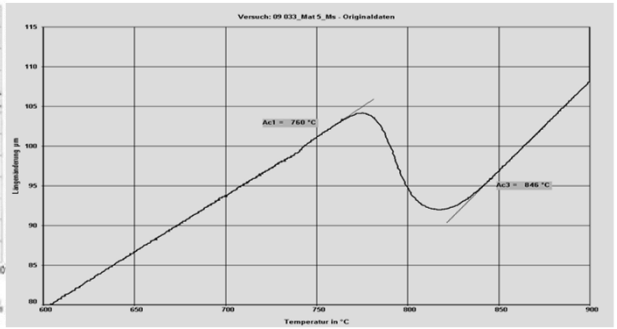
Gleeble HDS-V40
thermomechanical simulator



Bähr BTA 840
biaxial testing apparatus

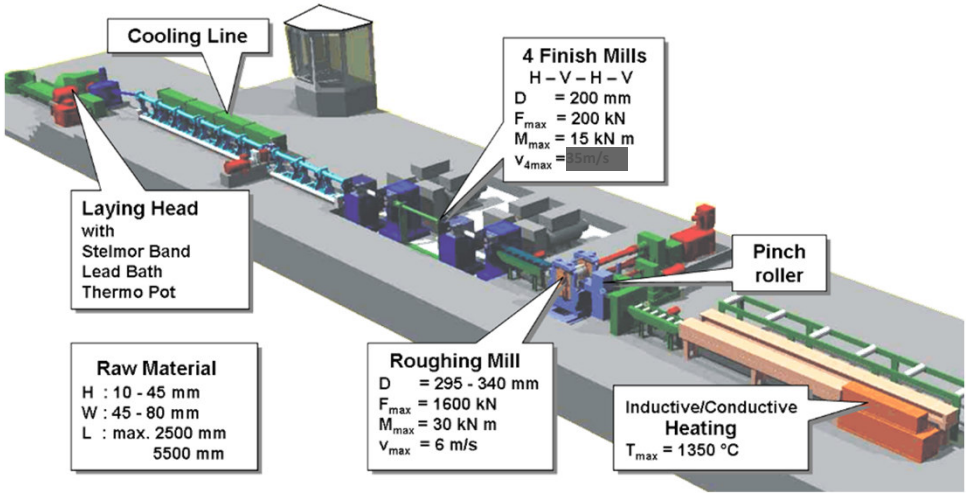


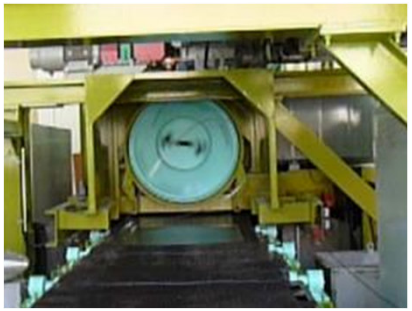




Equipment @ IMF

Hot rolling of wire and rod





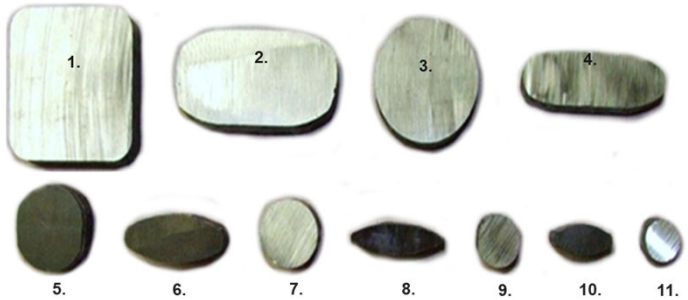






Trio groove pass rolling plant

NF Wire Forum



Possible processing routes

Equipment @ IMF

Heavy and fine wire drawing

NF Wire Forum



Heavy wire drawing

Fine wire drawing

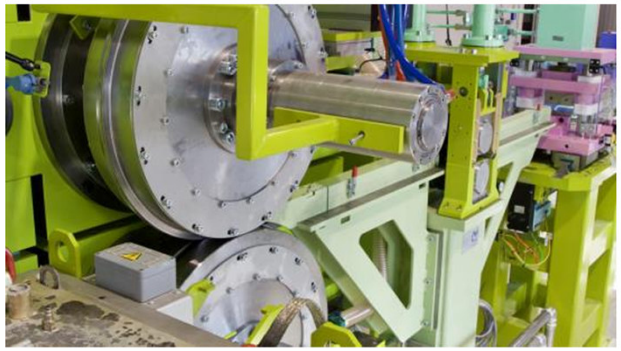


Technical data:

- Max. entry diameter: 10 mm
- Min. final diameter: 0,5 mm
- Drawing speed: max. 30 m/min
- Hot drawing max. 1000 °C
- For all drawable metals

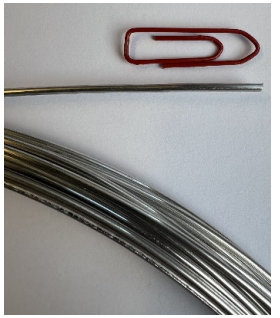
Equipment @ IMF

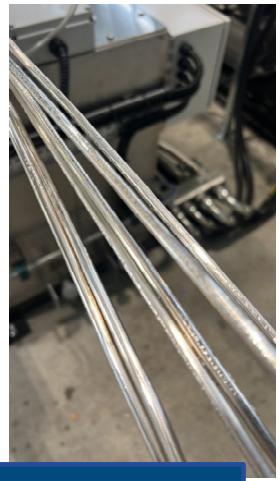
Wire twin-roll casting plant, Conform™ system











Wire twin-roll caster → Conform system → Products

Equipment @ IMF

Controlled atmosphere furnace

NF Wire Forum



- Heat treatment up to 1600 °C
- Removal temperatures for subsequent warm forming (rolling, forging) up to 1250 °C
- Diameter working chamber 800 mm, Height 500 mm, max. load 170 kg
- Heating capacity 60 kW / One heating zone
- Furnace atmospheres two gas lines → Nitrogen, Hydrogen
- Quick filling after evacuation with nitrogen
- Gas humidification with dew point sensor at the furnace inlet
- Vacuum system 10 mbar in the empty and cold furnace
- Control system Eurotherm 2704
- Safety systems: oxygen sensor, hydrogen sensor, electric igniter in the exhaust tract, additional pressure sensors

Equipment @ IMF

NF Wire Forum

Microstructure analysis and material characterization towards properties design



Zeiss, Keyence
(LOM, 3D DOM, DIC)



SEM/EDX/EBSD
hot/tension/
compression stage



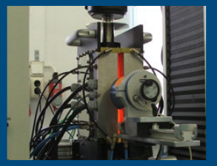
MiViA
AI based
analysis system



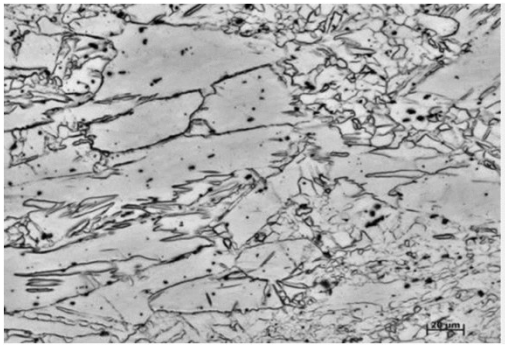
BUP 600
Sheet testing
machine

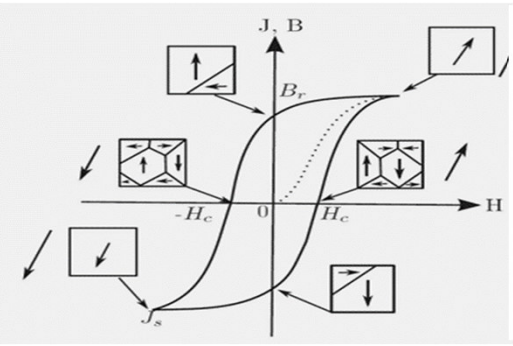


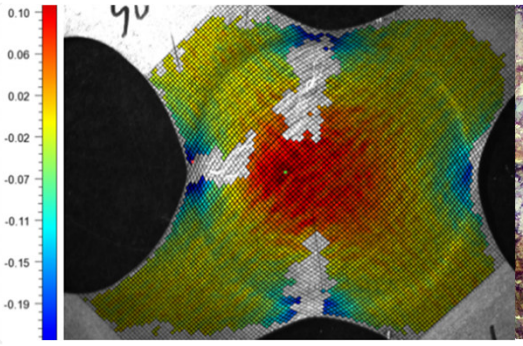
Notched bar
impact hammer

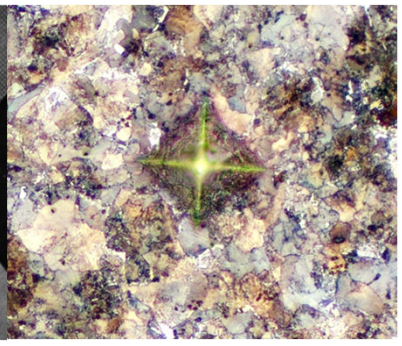


Instron AG 100
Universal Testing
Machine









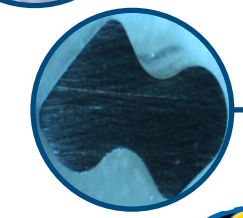
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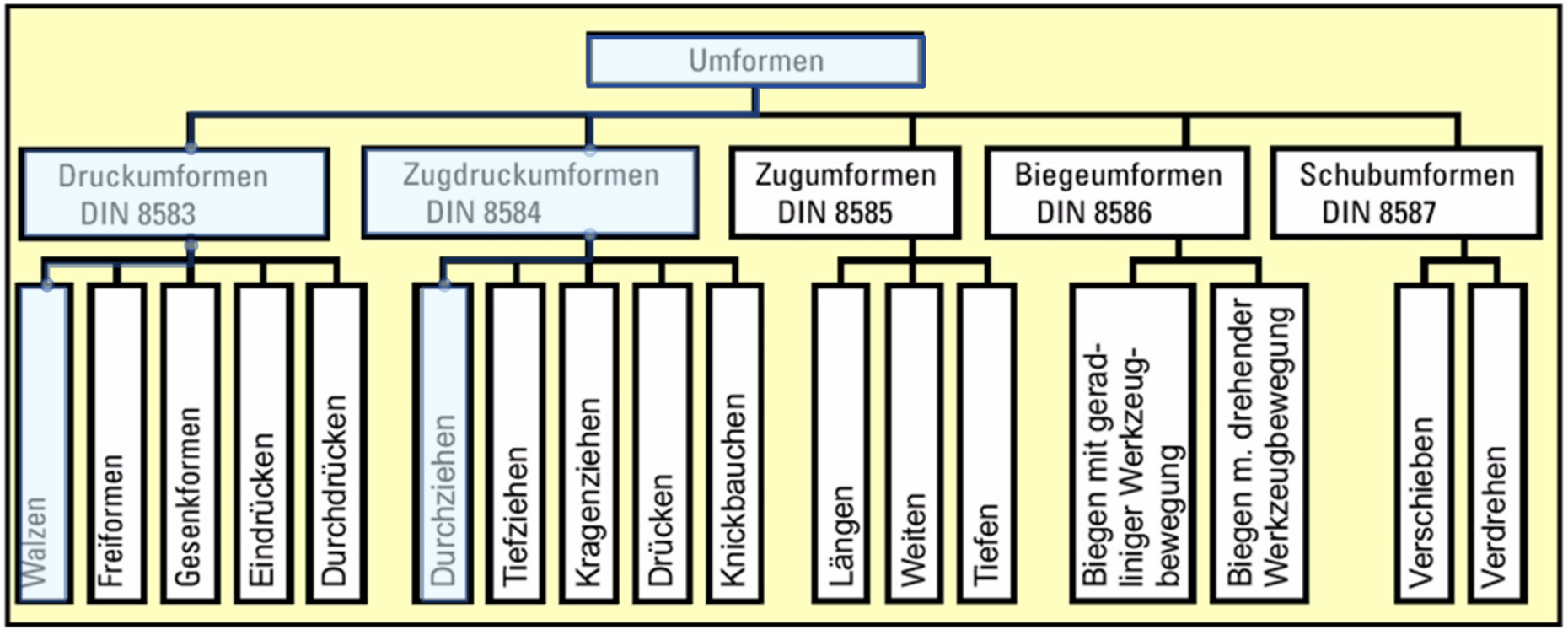


3. Example Z-profile in different forming processes
Tensile stress, hardness, surface roughness



4. Open source simulation software PyRolL
IMF.PyRolL @ Github Python – groove pass simulation in a nut shell

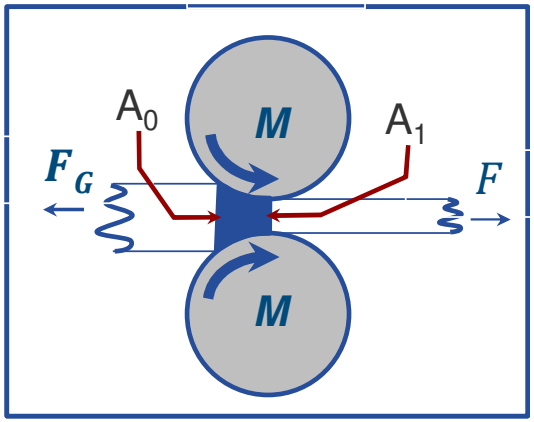
Production technologies



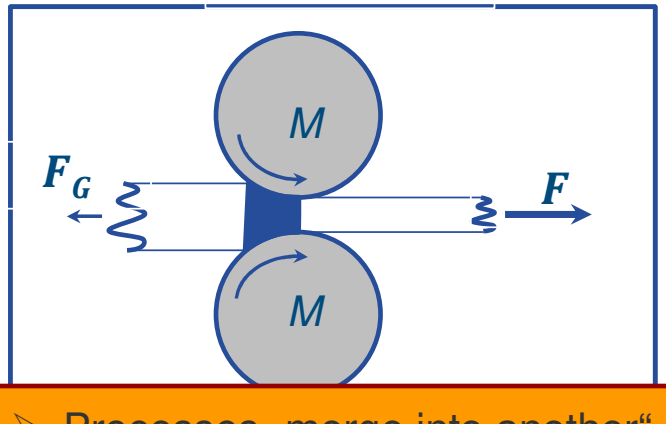
Comparison of manufacturing processes - similarity parameters

NF Wire Forum

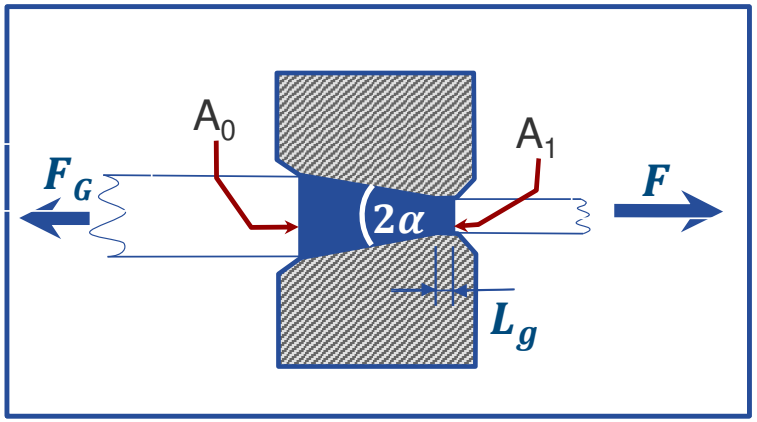
Rolling



Roll drawing

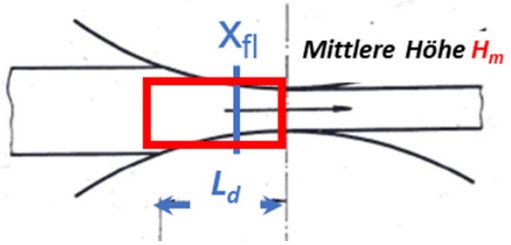


Drawing



➢ Processes „merge into another“

Walzspaltlänge L_d



Roll gap ratio

$$\frac{L_d}{H_m} = \frac{\text{friction forces}}{\text{Shear forces}}$$

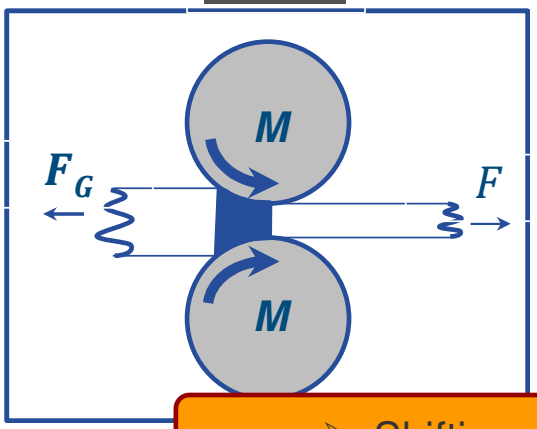
Friction μ
Strain φ
Strain rate $\dot{\varphi}$

Drawing angle α
Friction μ
Strain φ
Strain rate $\dot{\varphi}$

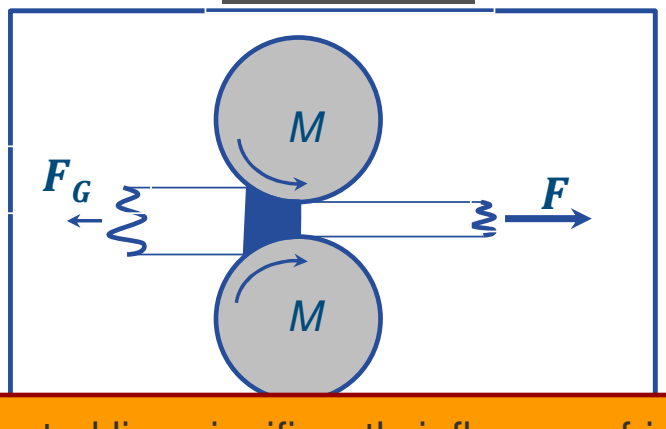
Comparison of manufacturing processes - Material flow and neutral line

NF Wire Forum

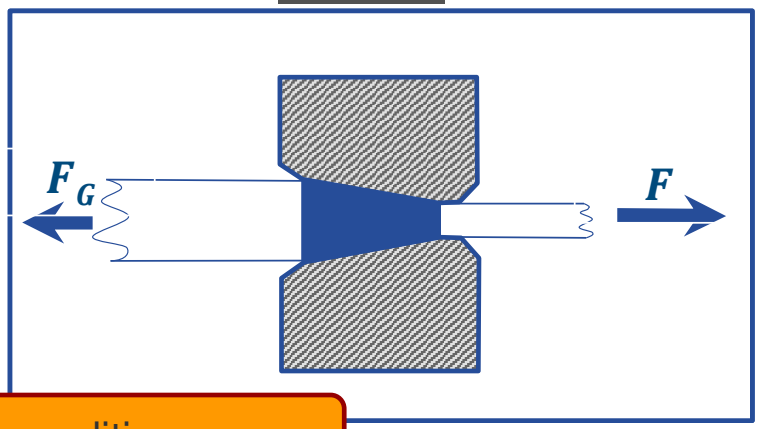
Rolling



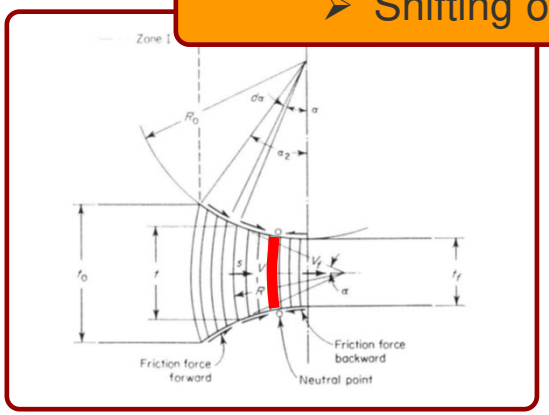
Roll drawing

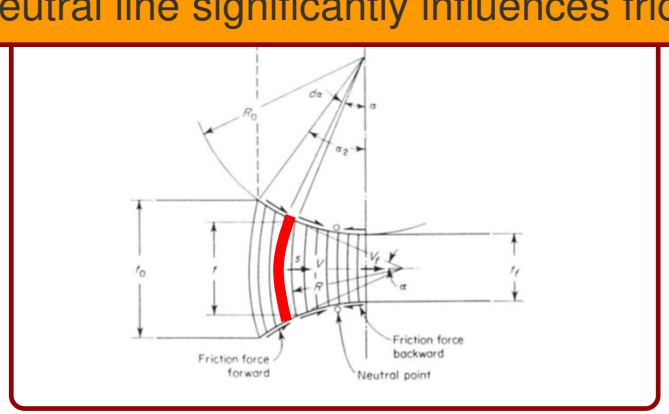


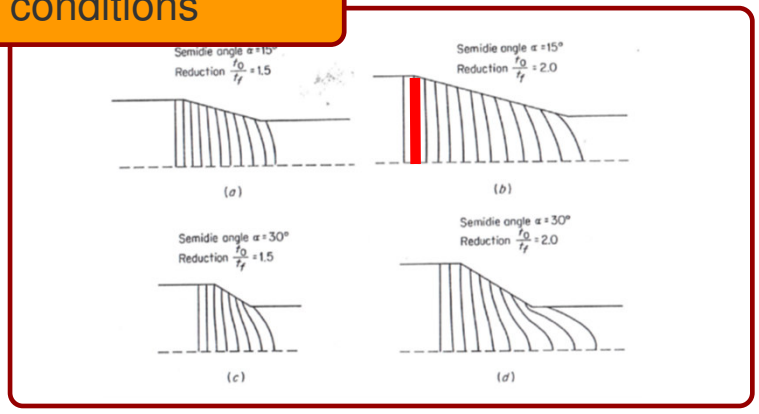
Drawing



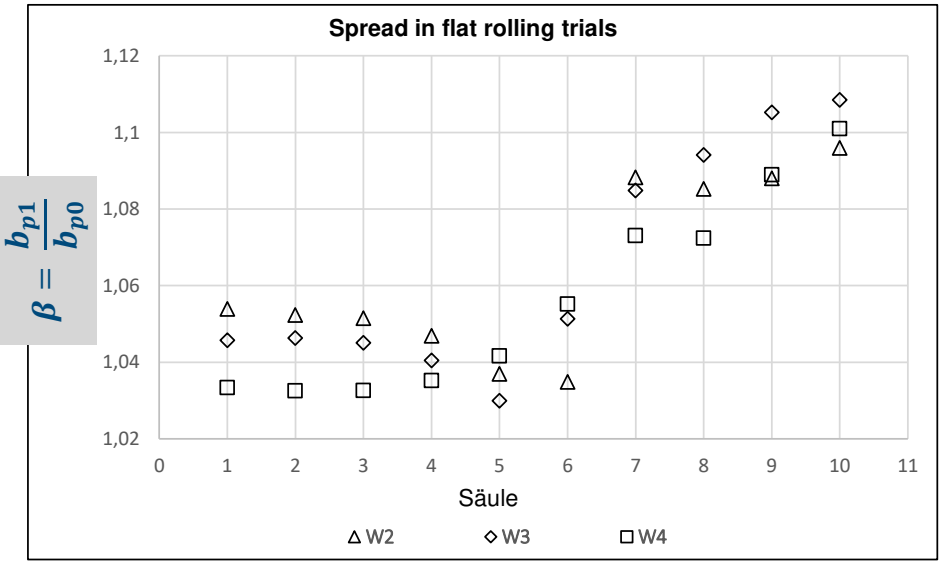
➢ Shifting of neutral line significantly influences friction conditions



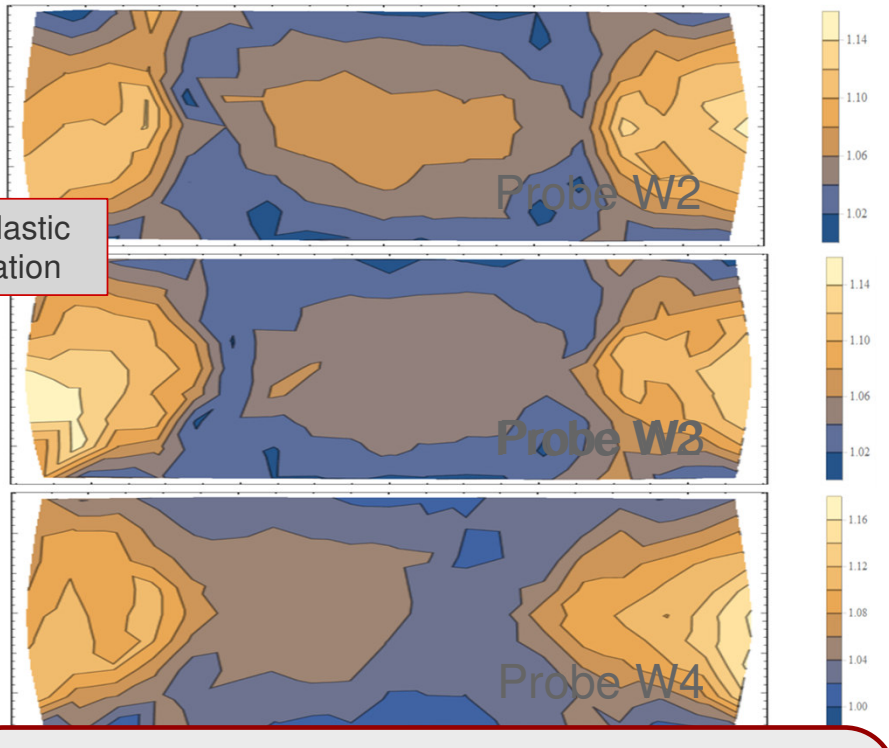




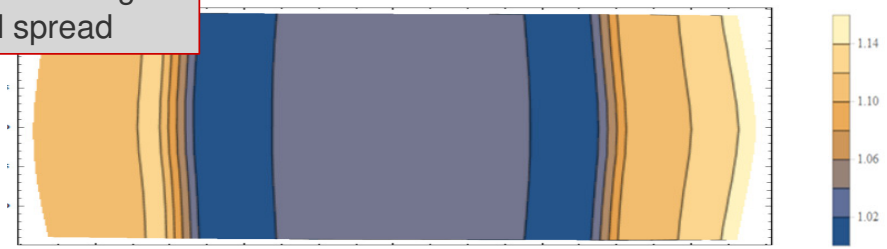
Example for local spread in flat rolling



Visio - plastic investgation



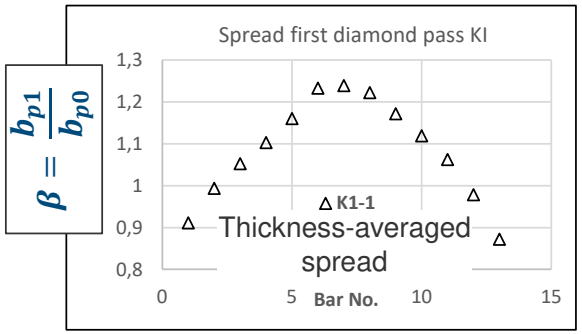
Thickness-averaged local spread



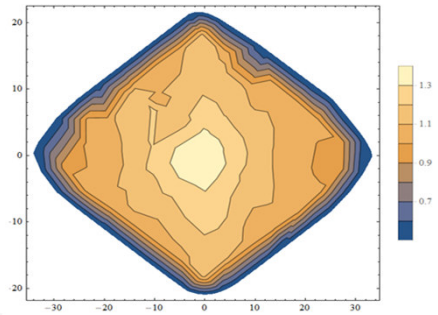
At the edges material flows more easily to the sides than in rolling direction.

- Enfored upsetting at the strip center
- Spread (bulging) at the edges
- Description in pillar models valid

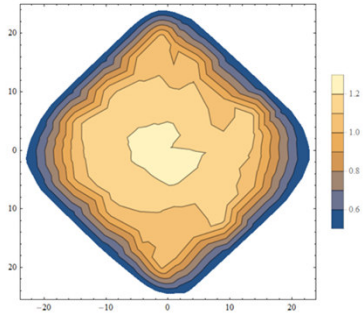
Groove rolling in comparison between experiment and Finite Element simulation



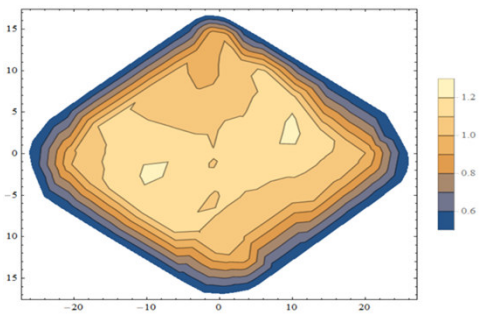
First diamond pass

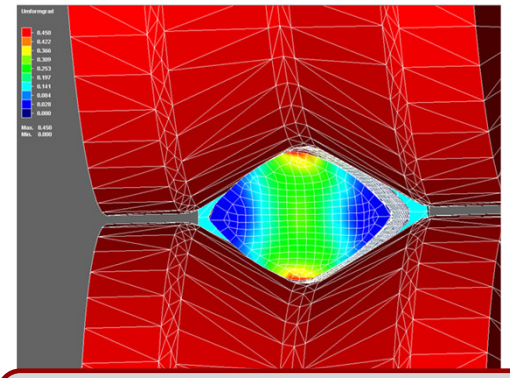


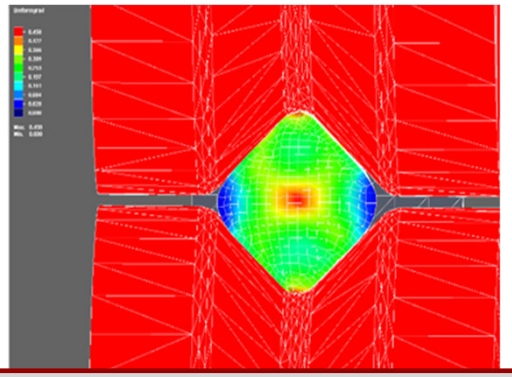
Square pass

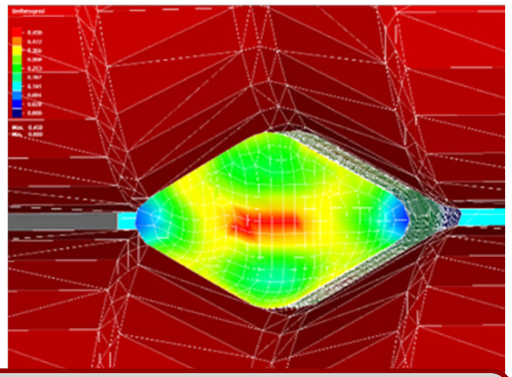


Second diamond pass







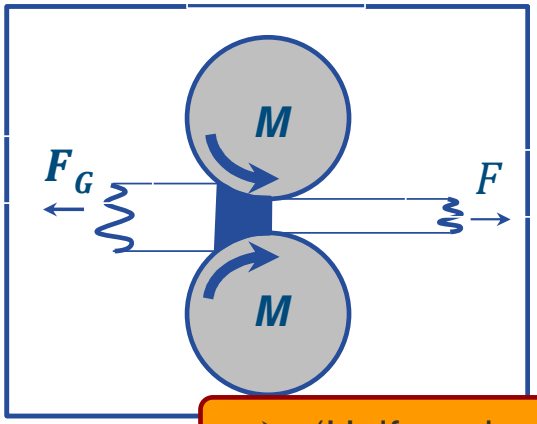


Comparison of local spread predicted from experiment and FE - Simulation
- Maximum spread and strain within regions of maximum thickness reduction

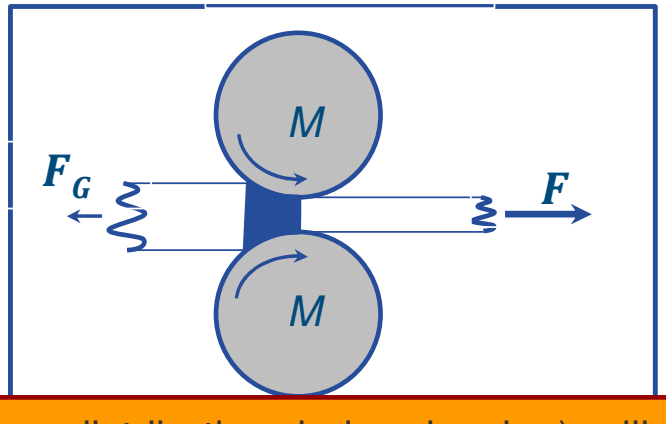
Possible tool configurations – Strain state and hardness distribution

NF Wire Forum

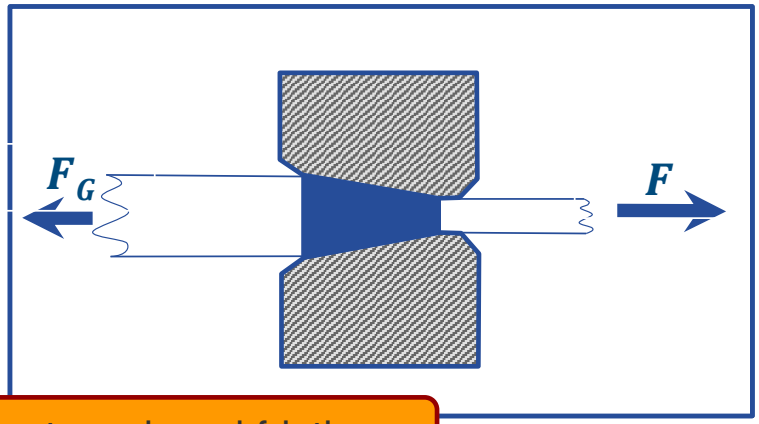
Rolling



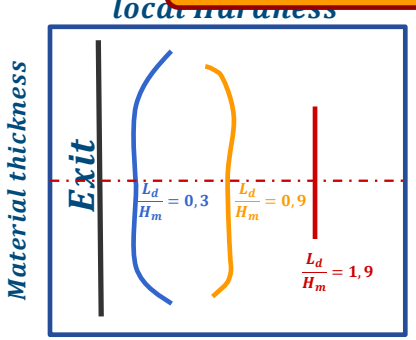
Roll drawing

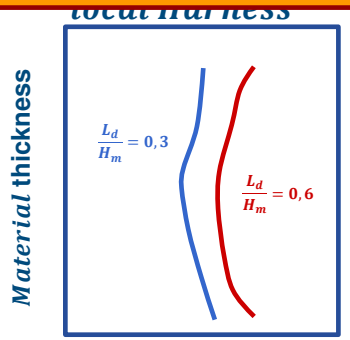


Drawing

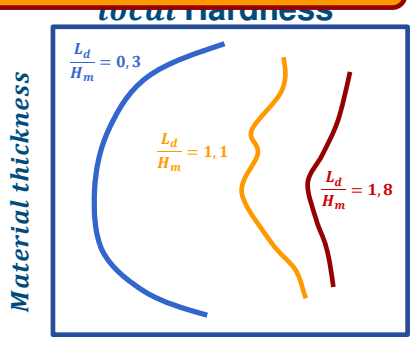


➢ (Uniform hardness distribution during drawing) rolling due to reduced friction





Hundy und Singer,
J. of the Institute of
Metals 1954-55 Vol. 83
S. 401-407

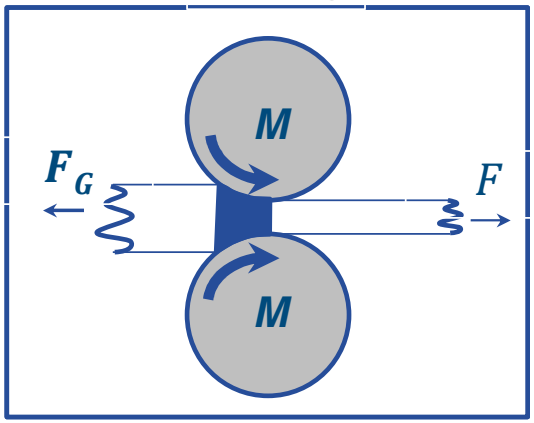


Cu
Drawing angle 30°

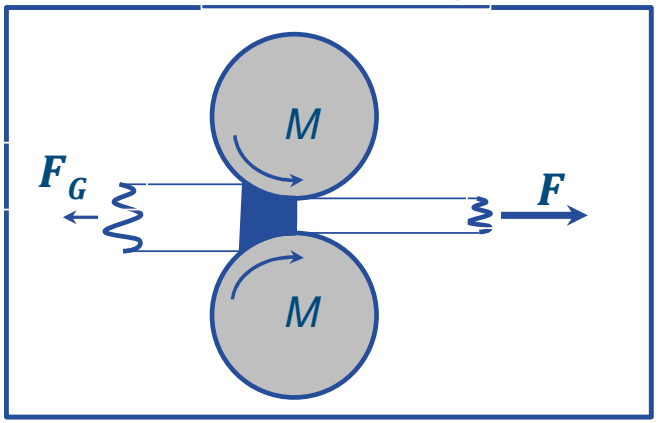
Possible tool configurations – maximum strain

NF Wire Forum

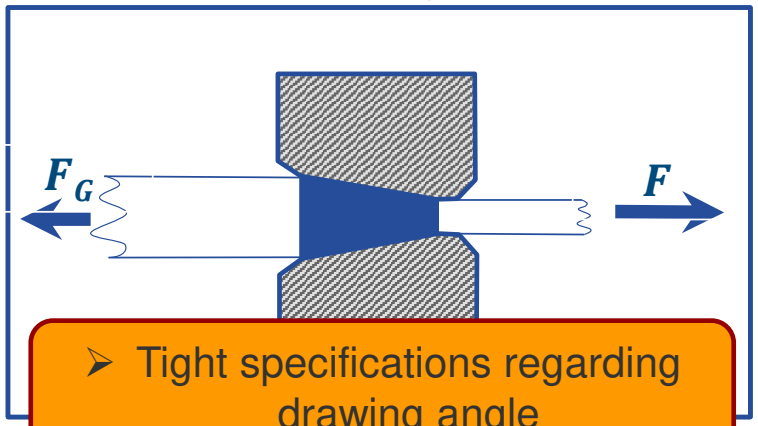
Rolling



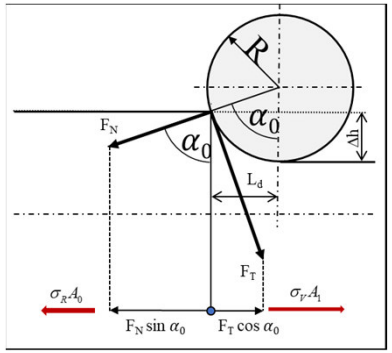
Roll drawing



Drawing



➢ Tight specifications regarding drawing angle

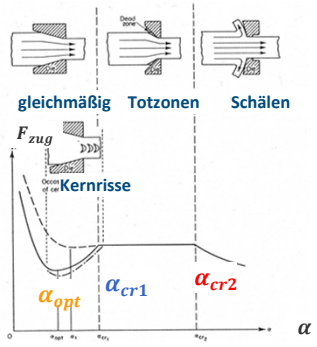


➡ **Max. Ziehkraft** $F_Z < R_{m_1} \cdot A_1$

➡ **Greifbedingung** ➡ $\Delta h_{max} \approx \mu^2 R$

➡ **Durchzugsbedingung ohne Längszug**

➡ $\Delta h_{max} \approx 2..3\ \mu^2 R$



Max. drawing force

$F_Z < R_{m_1} \cdot A_1$

Dead zones

α_{cr1}

Peeling angle

α_{cr2}

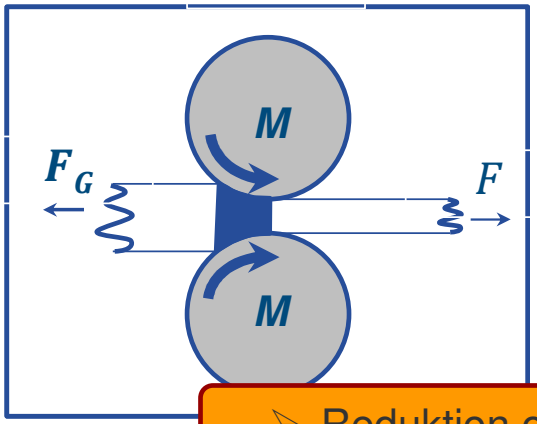
Opt. Drawing angle

α_{opt}

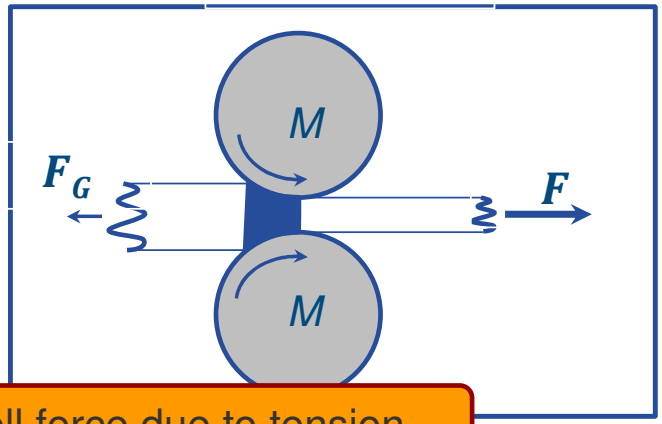
Comparison of manufacturing processes – Stress state

NF Wire Forum

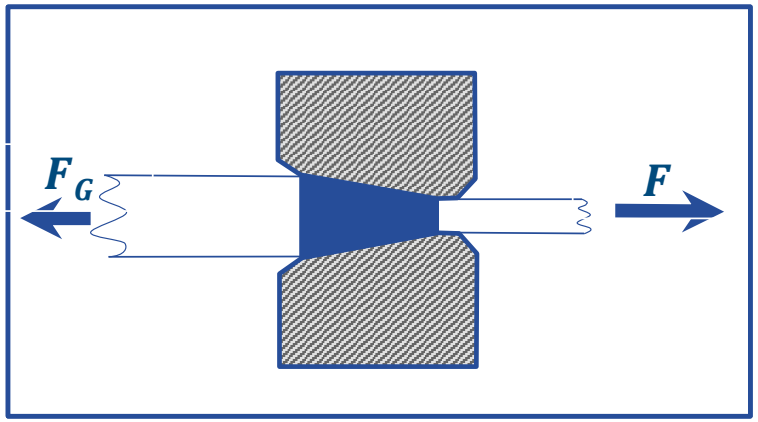
Rolling



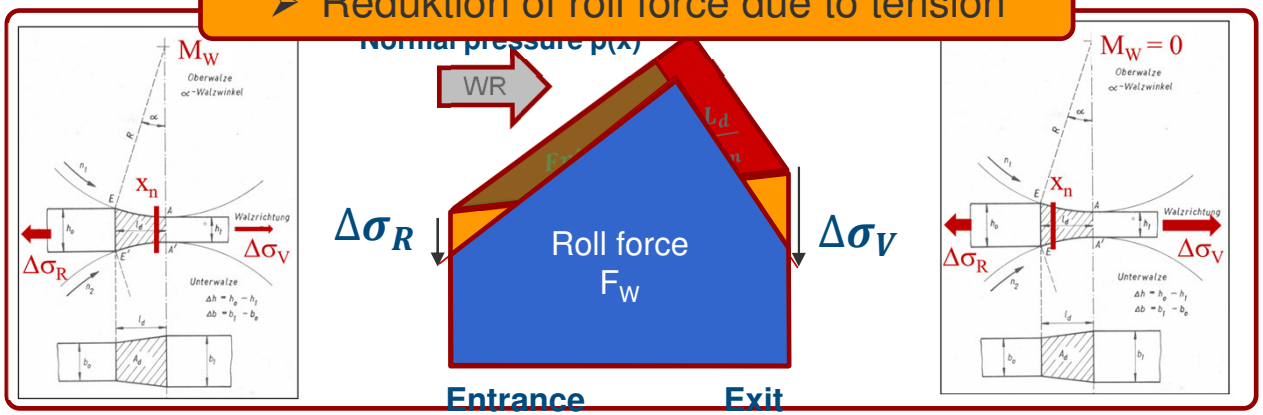
Roll drawing

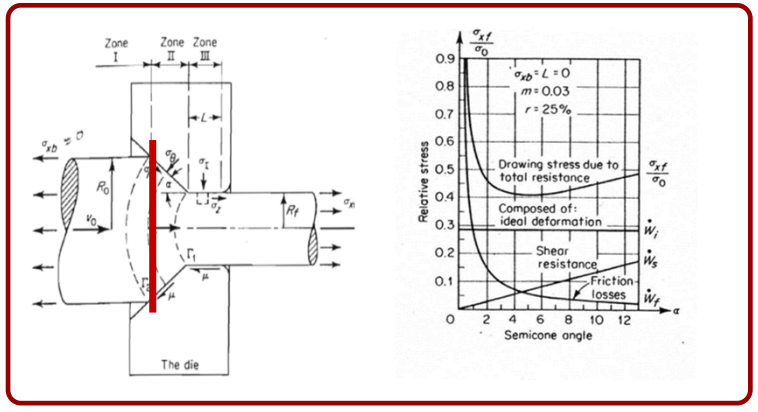


Drawing

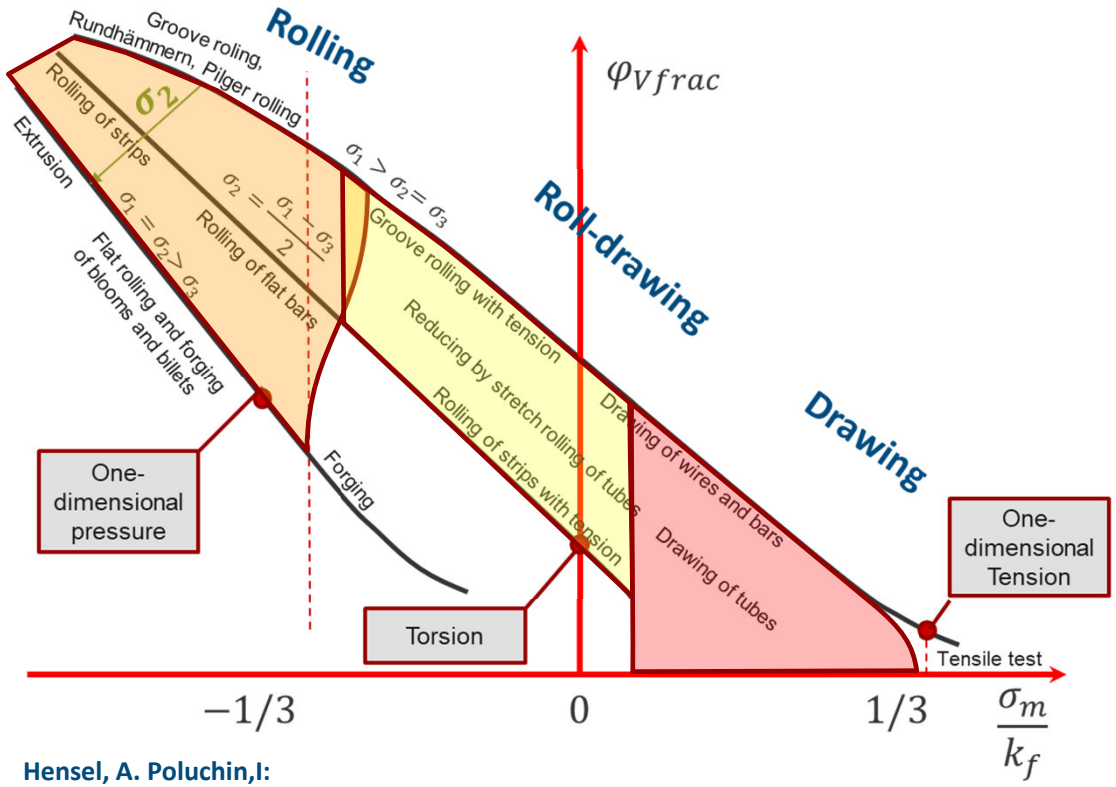


➢ Reduktion of roll force due to tension





Dependence of formability on the average stress state



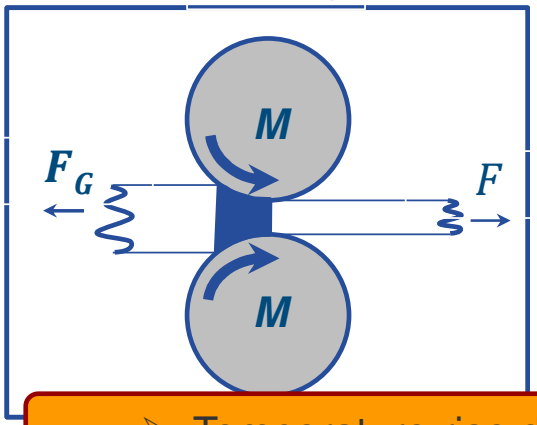
Hensel, A. Poluchin,I:
Technologie der Metallformung, VEB Verlag für die Grundstoffindustrie 1990

- As tensile stresses become more dominant, the formability decreases.
- A high hydrostatic pressure component significantly improves formability.
- Significantly higher degrees of deformation can be achieved with caliber rolling of wires than with wire drawing.

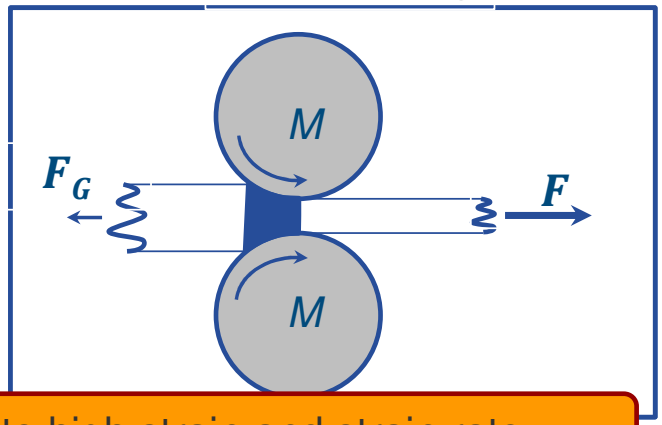
Comparison of manufacturing processes – Temperature distribution

NF Wire Forum

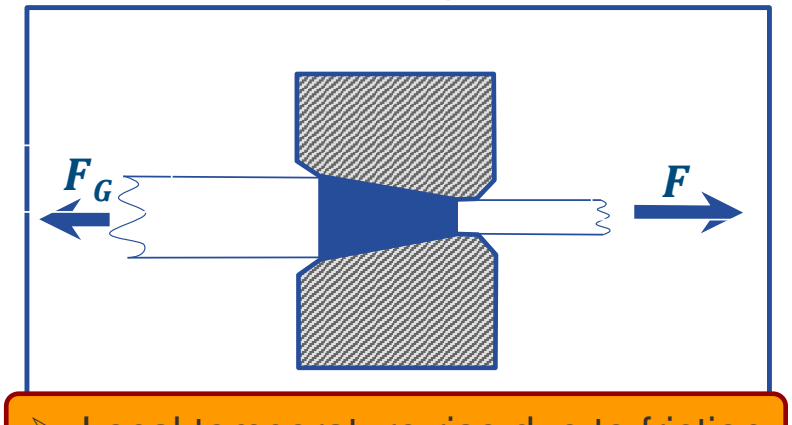
Rolling



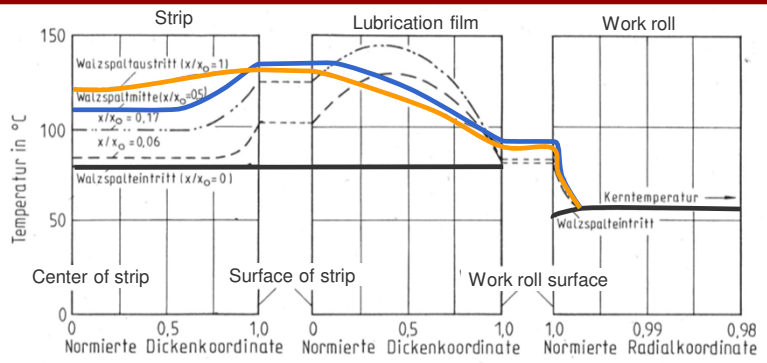
Roll drawing

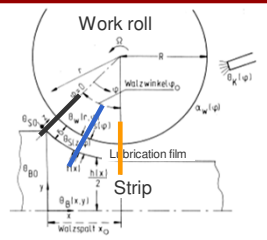


Drawing



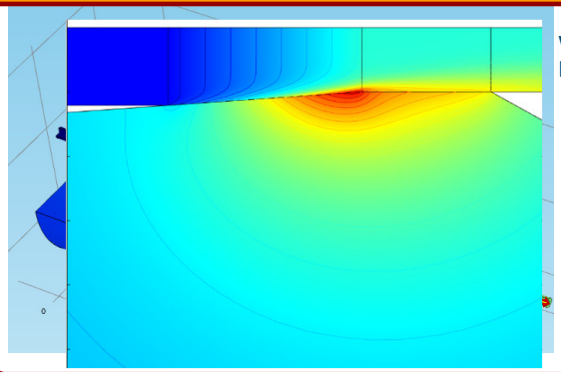
➢ Temperature rise due to high strain and strain rate





Braun-Angott; Berger 1978
Arch. Eisenhüttenwesen
Vol. 49 / Nr.9 S. 443-448

➢ Local temperature rise due to friction

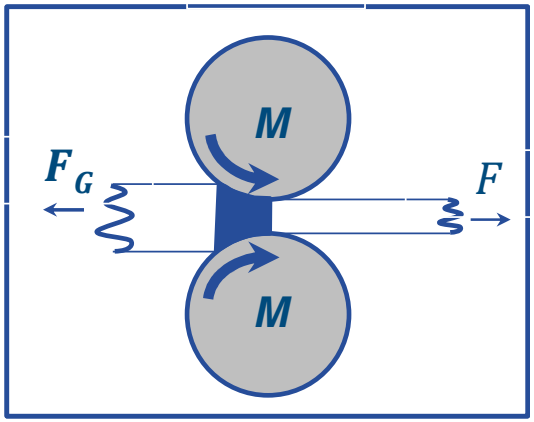


W. Müller:
Diss IMFTUBAF

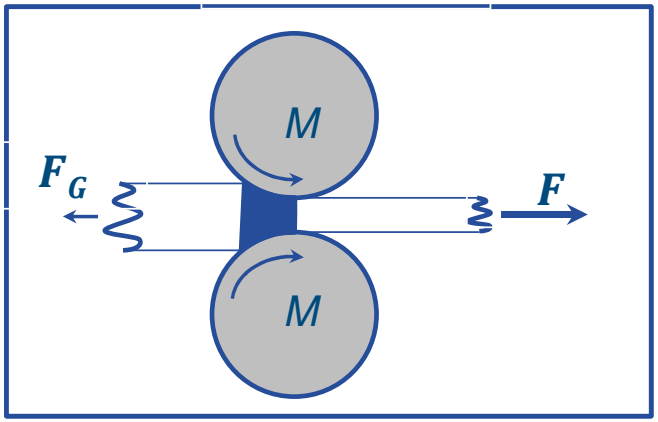
Possible tool configurations

NF Wire Forum

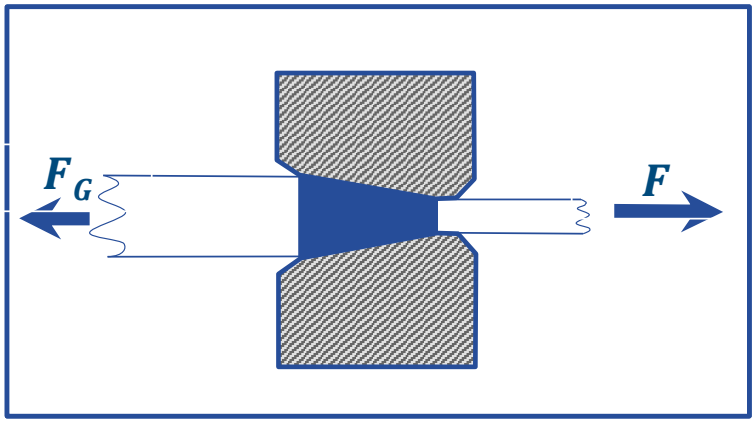
Rolling

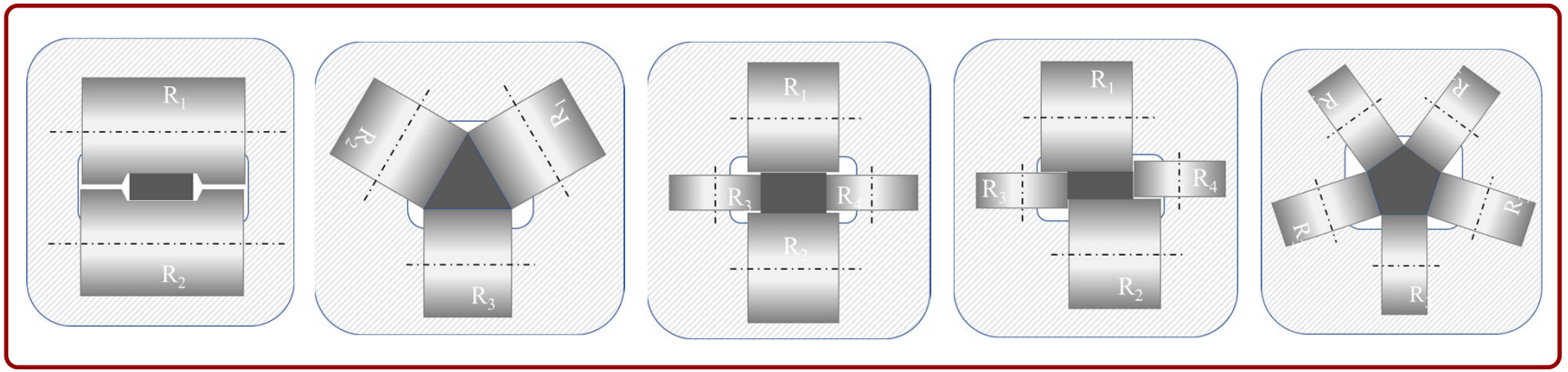


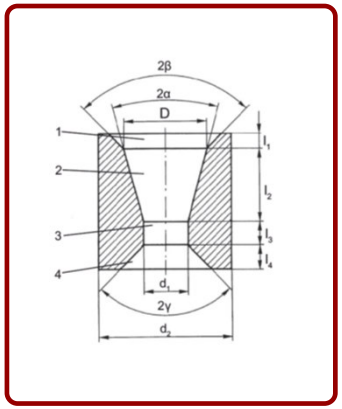
Roll drawing



Drawing







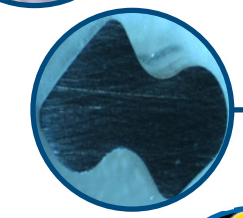
Agenda



1. Institute of Metal Forming (IMF) at the TUBAF
Who we are and what we offer



2. Rolling – Roll-Drawing – Drawing
Strain and stress state, temperature distribution,
Gripping condition, maximum strain, process limitations



3. Example Z-profile in different forming processes
Tensile stress, hardness, surface roughness

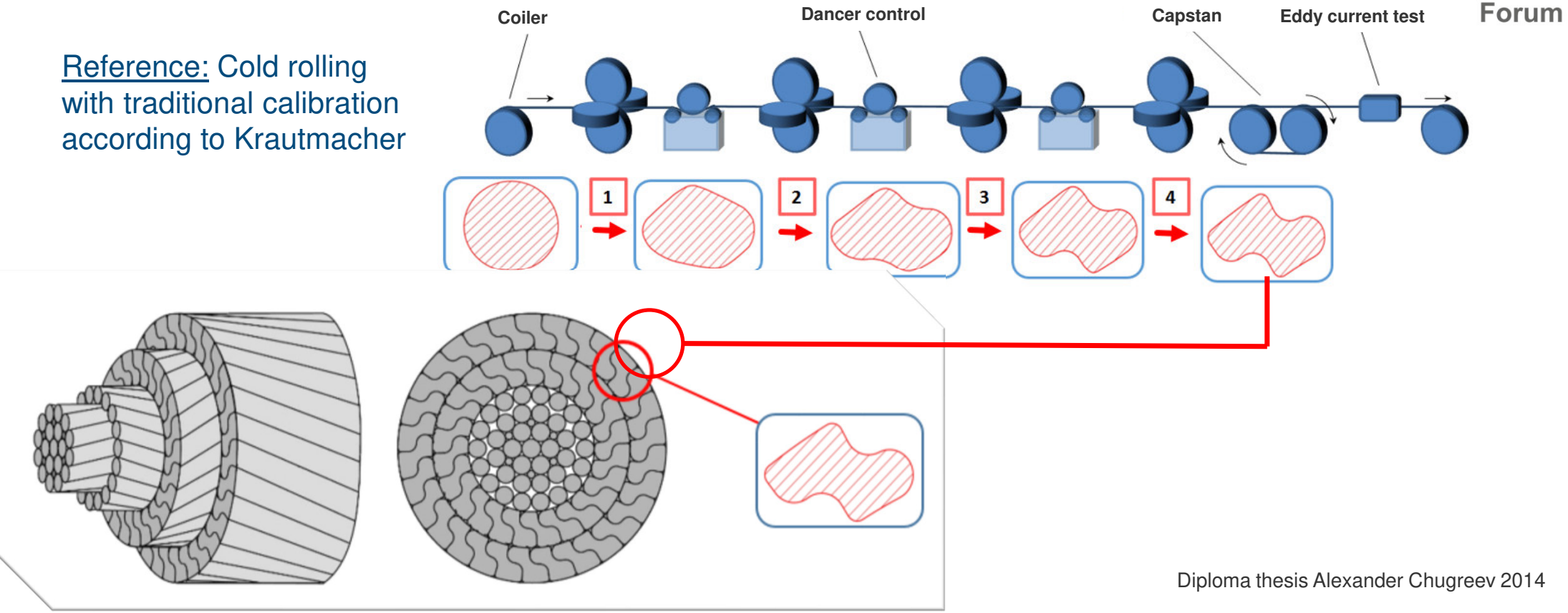


4. Open source simulation software PyRolL
IMF.PyRolL @ Github Python – groove pass simulation in a nut shell

Production of Z-profiles by cold profile rolling

Forum

Reference: Cold rolling with traditional calibration according to Krautmacher

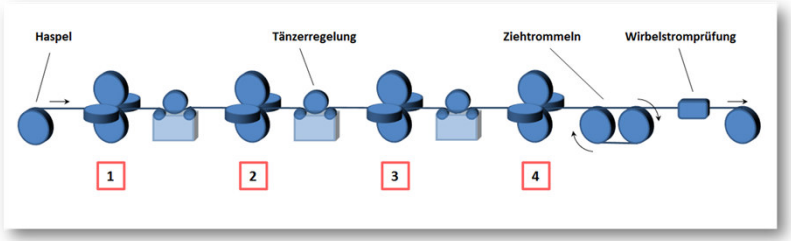


Diploma thesis Alexander Chugreev 2014

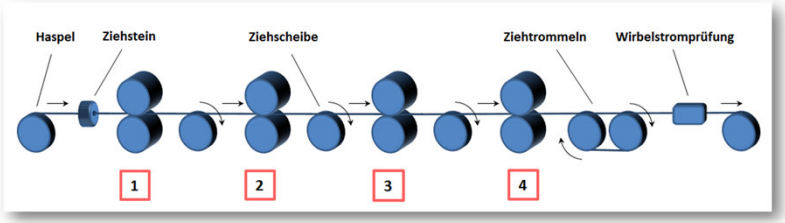
Production of Z-profiles - a comparison of technologies

NF Wire Forum

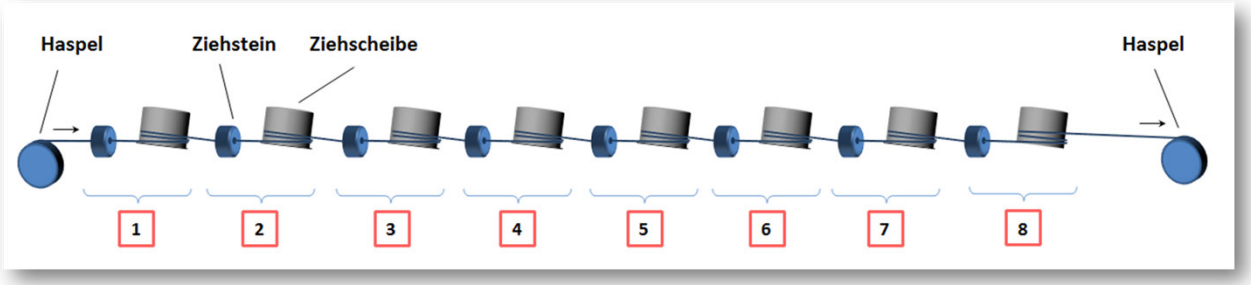
Rolling



Roll – Drawing



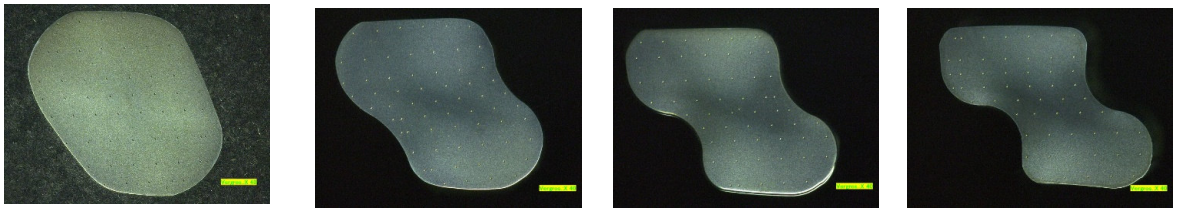
Drawing



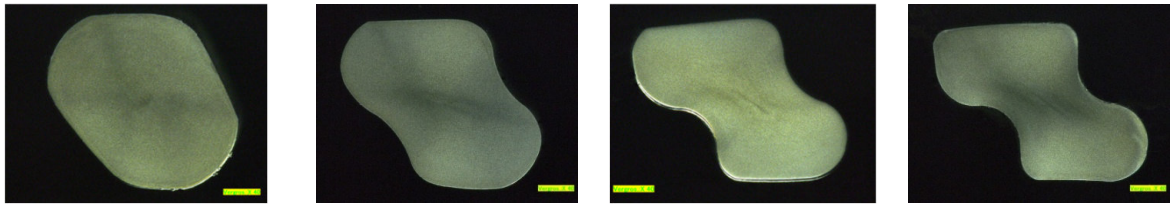
Production of Z-profiles – Technologies in comparison – Forming sequence

NF Wire Forum

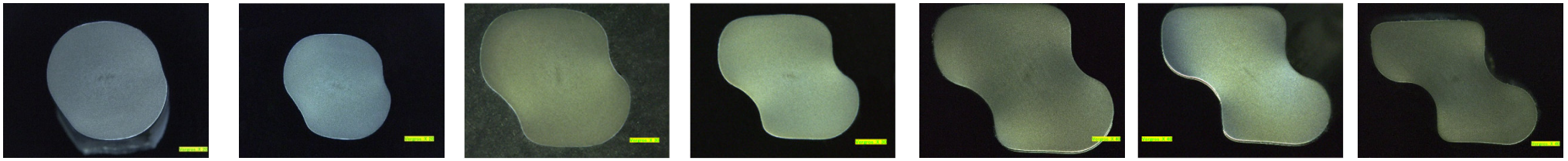
Rolling



Roll – Drawing



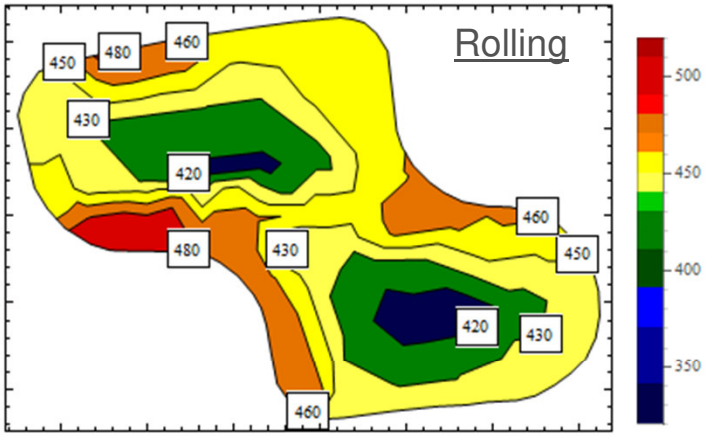
Drawing

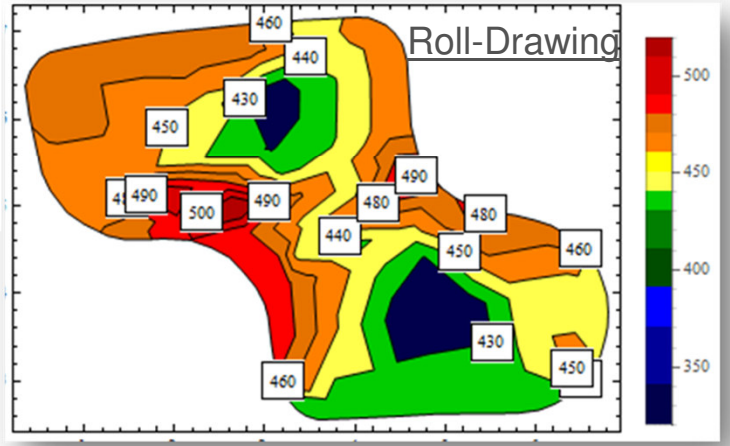


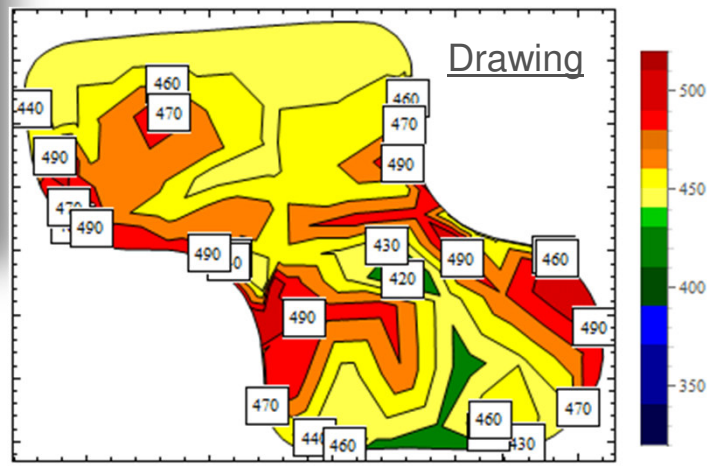
Comparison of the influence of the manufacturing process for Z-profiles

NF Wire Forum

Hardness mapping HV1

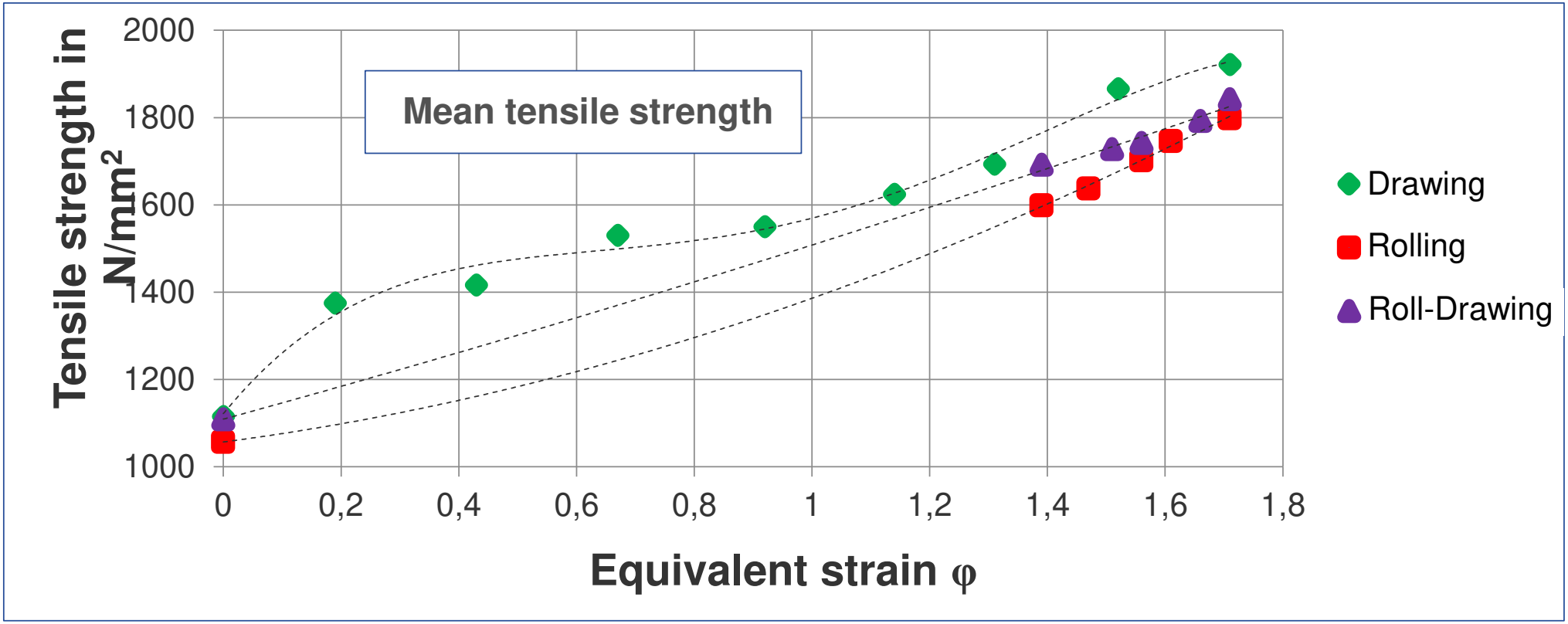




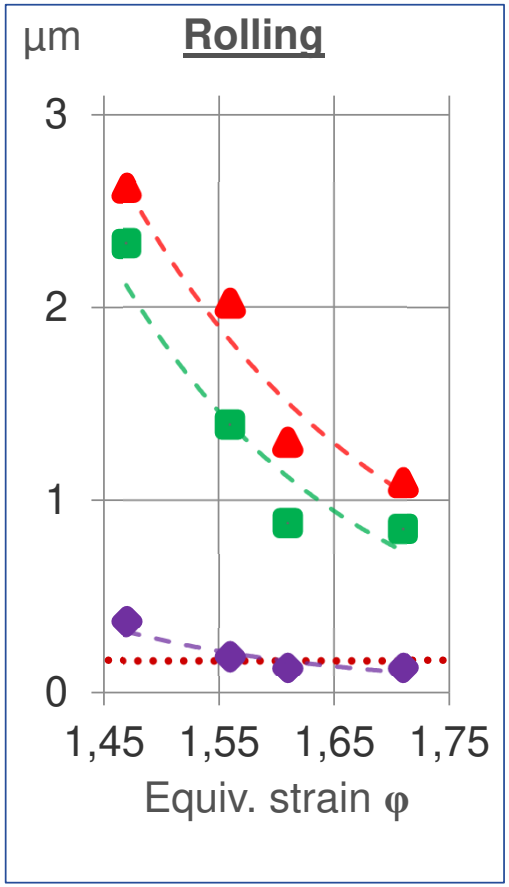


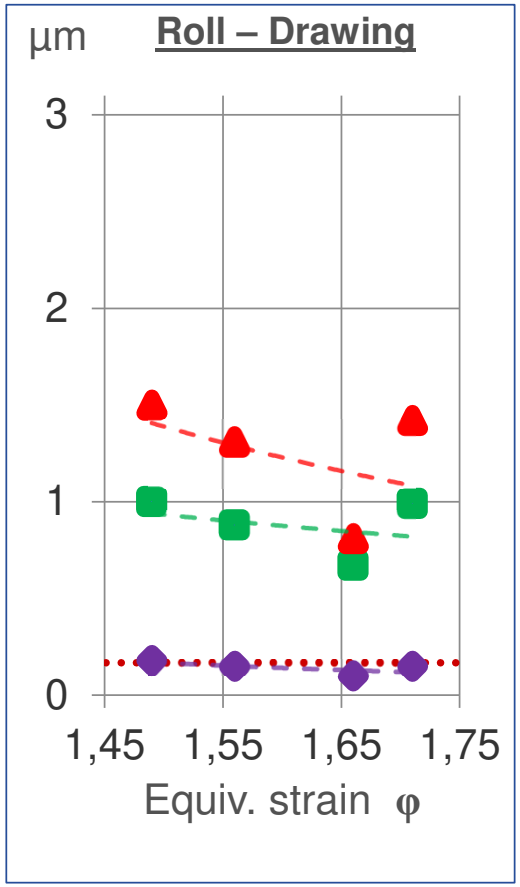
- Inhomogeneous hardness distribution
- Hardness distributionduring rolling and roll – drawing can always be optimized through groove pass design

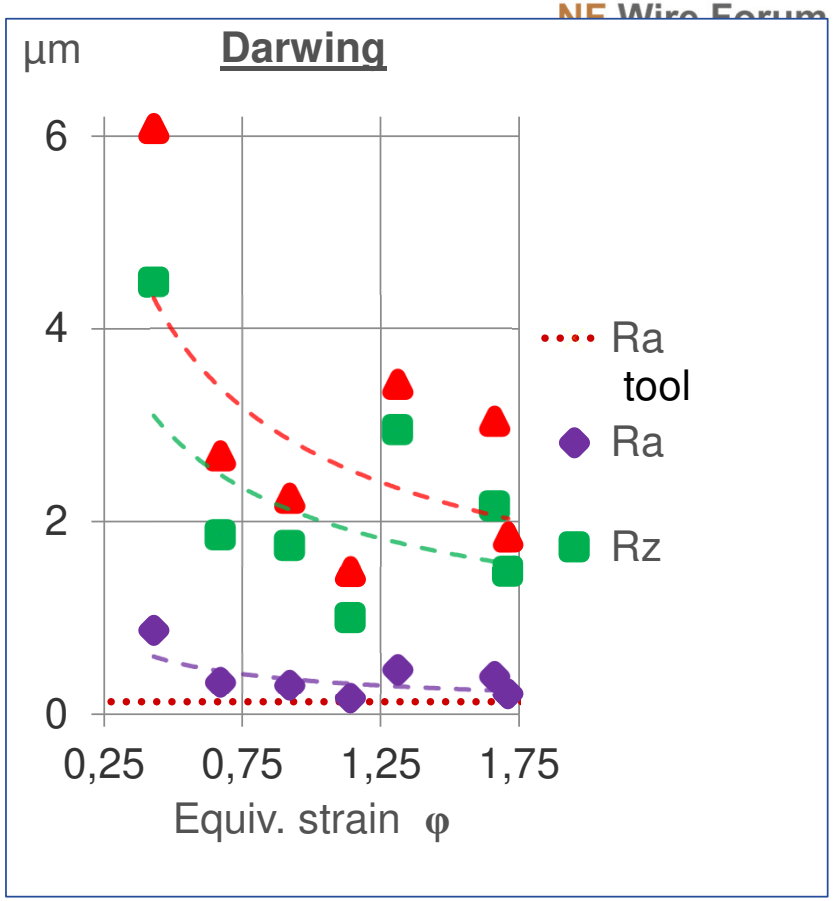
Comparison of the influence of the manufacturing process for Z-profiles



Comparison of surface roughness

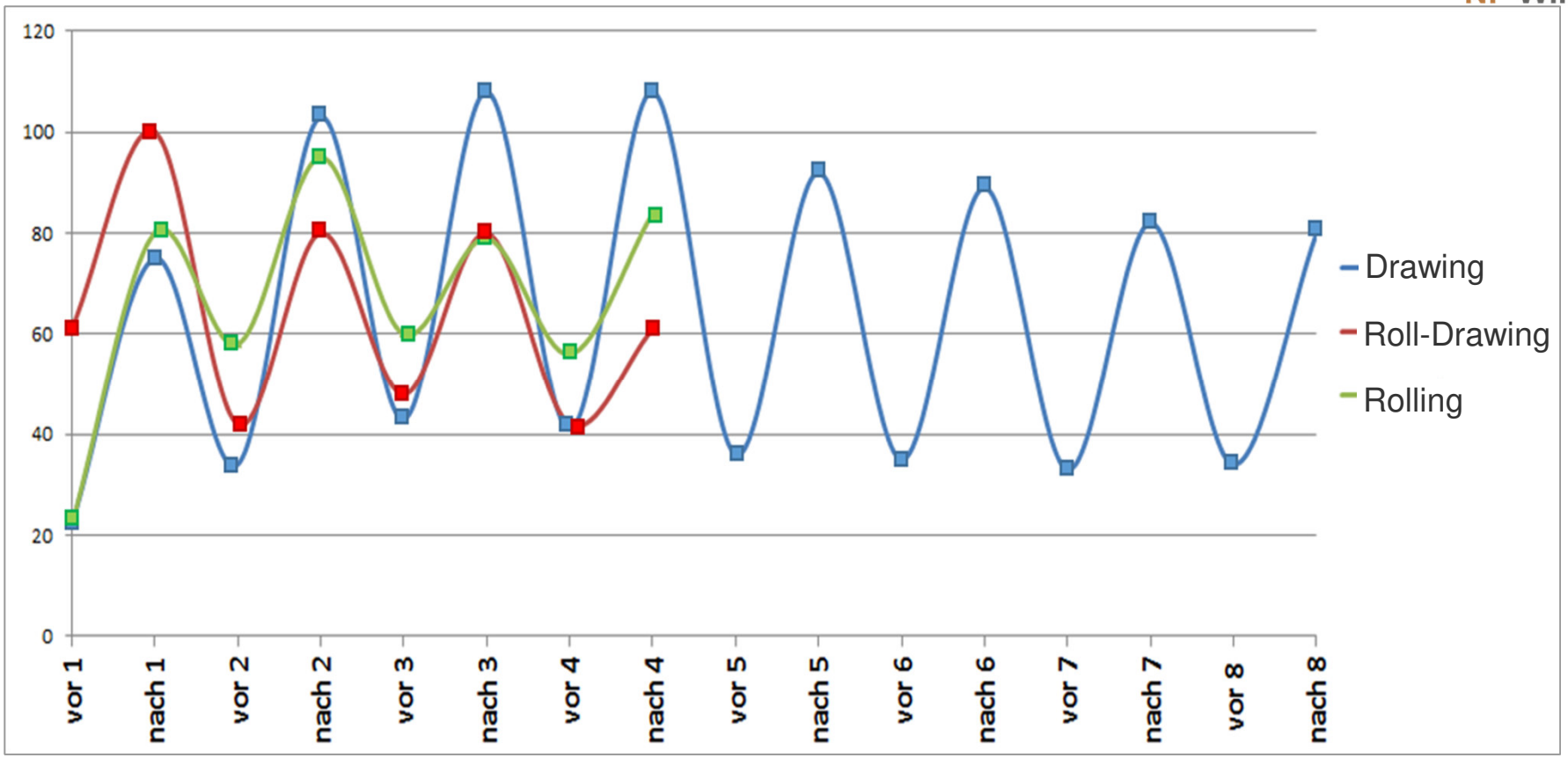






Comparison of the temperature curve

NF Wire Forum



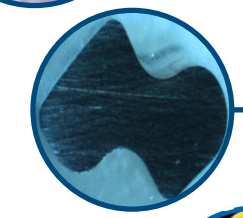
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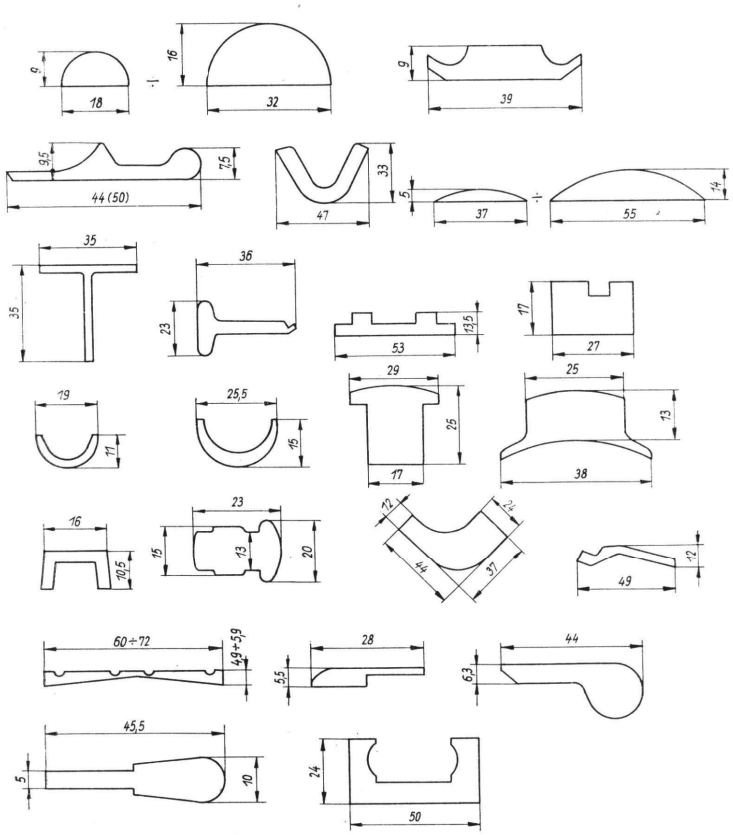


3. Example Z-profile in different forming processes
Tensile stress, hardness, surface roughness



4. Open source simulation software PyRolL
IMF.PyRolL @ Github Python – groove pass simulation in a nut shell

Objectives and tasks in groove pass design



Neumann, H: Kalibrieren von Walzen,
2. Auf., VEB Verlag für Grundstoffindustrie 1976

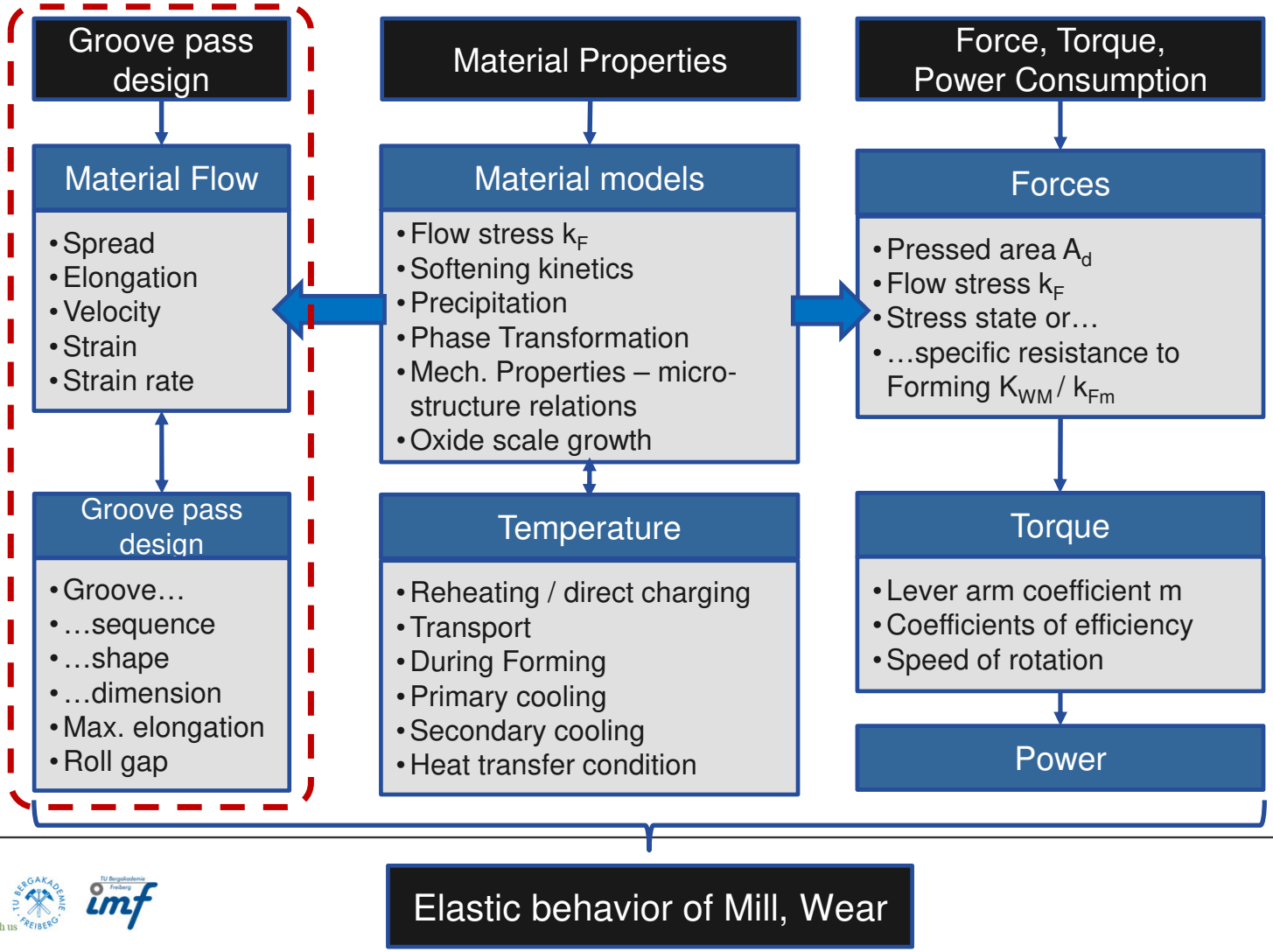
General asymmetric profiles are designed for caliber rolling geometrically based on following known basic calibrations. :

- General edging caliber
- Cutting pass
- Angle passes
- Flange passes
- Cup iron / Rail passes
- Universal passes

Typical shape features are:

- Irregular grooves (unequal pressure)
- Small flanges and Web
- Asymmetric mass distribution
- Overlaps that cannot be rolled directly
- Precise indentations or elevations with high tolerance requirements

Aspects of process modeling



Industrial Application

PyRolL

PyRolL – Fast and extendable simulation tool for long products



Motivation

- Hybrid approach using semi-analytic column model
- Magnitudes faster than FEM
- Extendable for local specialities and models needed
- Autonomous optimization of given groove pass design strategies

Methodical Approaches

- Multiscale simulation by in-house implemented simulation models
- Extendable platform for efficient algorithm plug-in
- Validation by industrial and research trials
- Partially open source code for transparent scientific interaction

More information and download

PyRoIL – Open-Source and object oriented framework for rolling applications

PyRoIL – Basic

- Based on Python
- Licensed under BSD-3-Clause license
- Source code published on GitHub
- Flexible and extensible architecture:
  - Large library of model approaches (plugins) and applications (extensions)
  - Possibility to implement your own code
- Further extensions available from **Kalibrierzentrum@imf.tu-Freiberg.de**

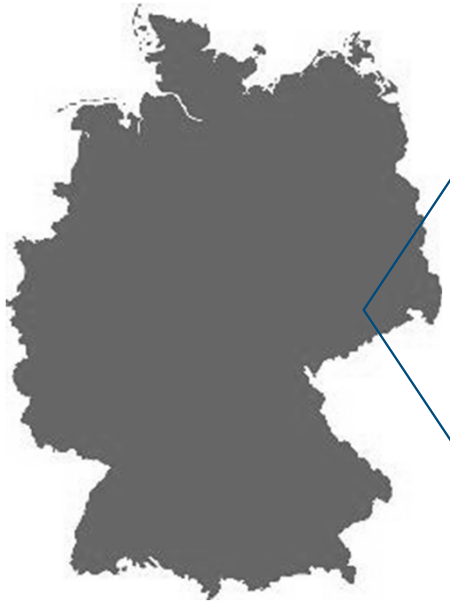


Downloads:
https://github.com/pyroll-project

https://pypi.org/search/?q=PyRoll

More information on:
https://pyroll-project.github.io/

Thank you!



Institute of Metal Forming
office@imf.tu-freiberg.de
Tel. +49 3731 39-4180



Upcoming events:

19. – 20. 3. 2026
MEFORM
Current Contributions in Metal Forming

7th Freiberger Kalibreurstag 2026 (26./27.08.2026)
"Material-related rolling schedule design for flange passes"

PyRolL user meeting 28.08.2026