New advantages for use of taper wire in suspension springs for lightweight design and side load control

Automotive Applications

Vehicle Dynamics Expo
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Karsten Landwehr, Key Account

Agenda

1) Spring design requirements
2) Realization of Miniblock-Springs
3) The Ahle manufacturing process
4) Summary Miniblock-Springs
5) New developments / potential of springs with non-constant wire diameter
6) Summary

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1. Spring Design Requirements

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Customer Requirements to Spring Design

1. (Progressive) Deflection Curve
2. Light Weight Design
3. Packaging Minimisation
4. No Coil Contact
5. Super Progression
6. Low Side Load
7. Characteristic of the Load Deflection Curve

Spring Design Requirements

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Requirement:

1. **(Progressive) deflection curve**
2. **Light weight design**
3. **Small nstallation space**
4. **No coil contact**

Solution:

Non-constant pitch:

- Progression

Non-constant wire diameter:

- Weight reduction: light weight design

Non-constant coil diameter:

- Small block length (Miniblock spring)
- No coil contact (contact elimination)

5. **Super progression**
6. **Low side load**
7. **Characteristic of the load-deflection curve**

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The Non-Constant Principle

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Combination of:

- •Non-constant pitch
- •Non-constant coil diameter
- •Non-constant wire diameter

resulted in the design of the

Miniblock spring

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Miniblock Spring Types

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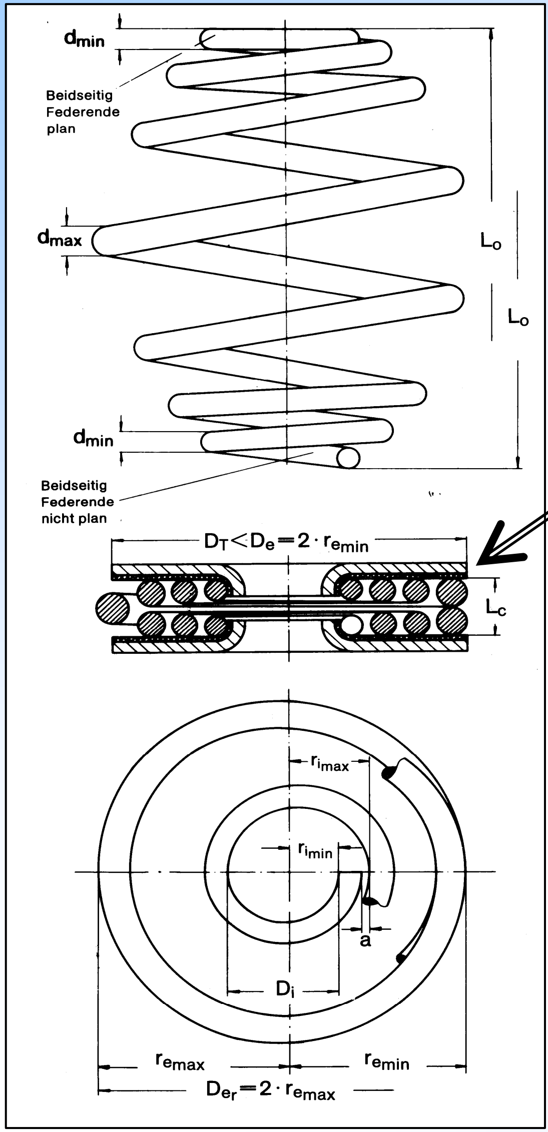
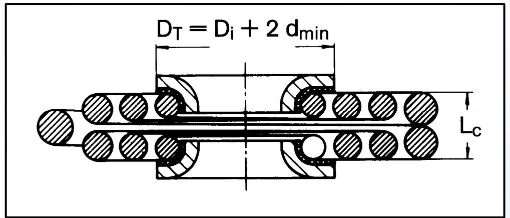


Progressive Miniblock Spring

The spring is symmetrical.
The coils are supported on both sides of the spring disks.



And one-sided progressive spring!

Linear Miniblock Spring

The spring is symmetrical.
The coils are <u>not</u> spported on the spring disks.

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2. Miniblock Spring Design

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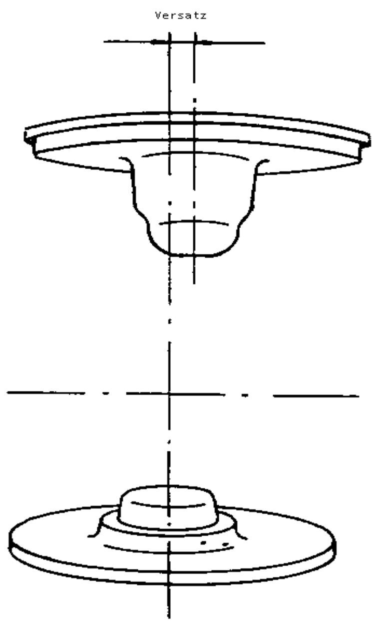
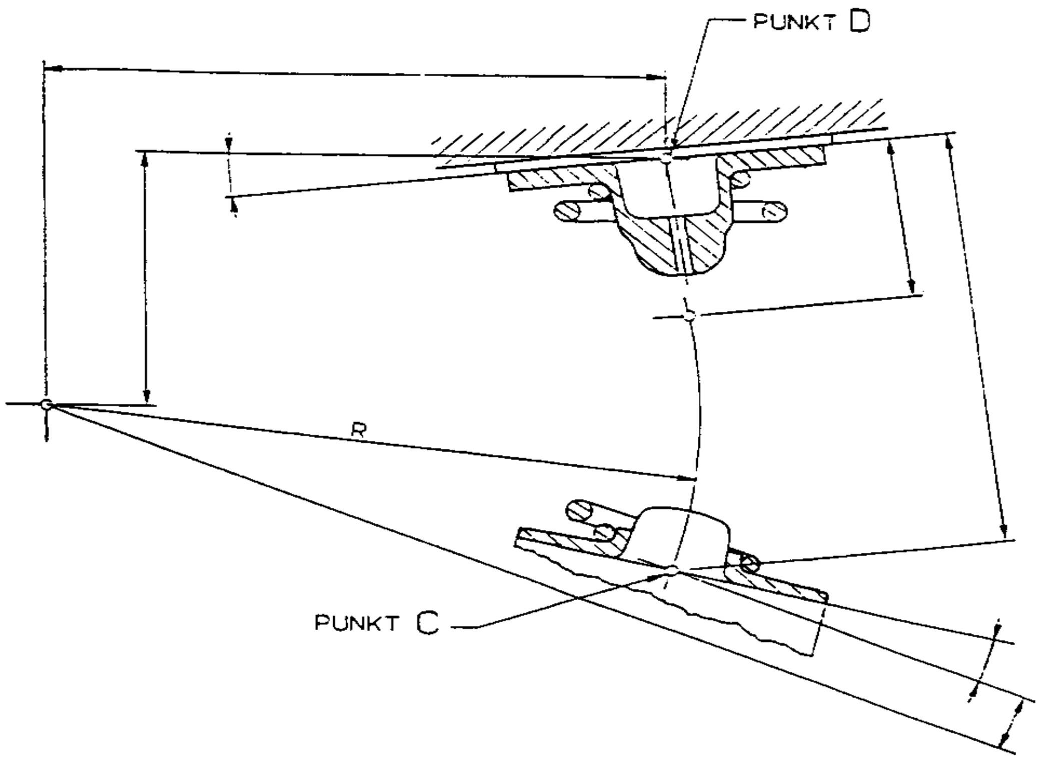
Complex Customer Requirements

Example: realistic packaging and circular arc deflection





Offset Axles

Circular arc deflection

Design and Calculation Methods

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- Ahle Spring Design Algorithm
- Ahle Tool Design Algorithm
- FEM (Femap/Nastran)
- CAD (ProEngineer)
- 3-D Measurement (DEA/Hexagon)
- Integrated Tooling and Prototype Manufacturing

Spring Design Algorithm

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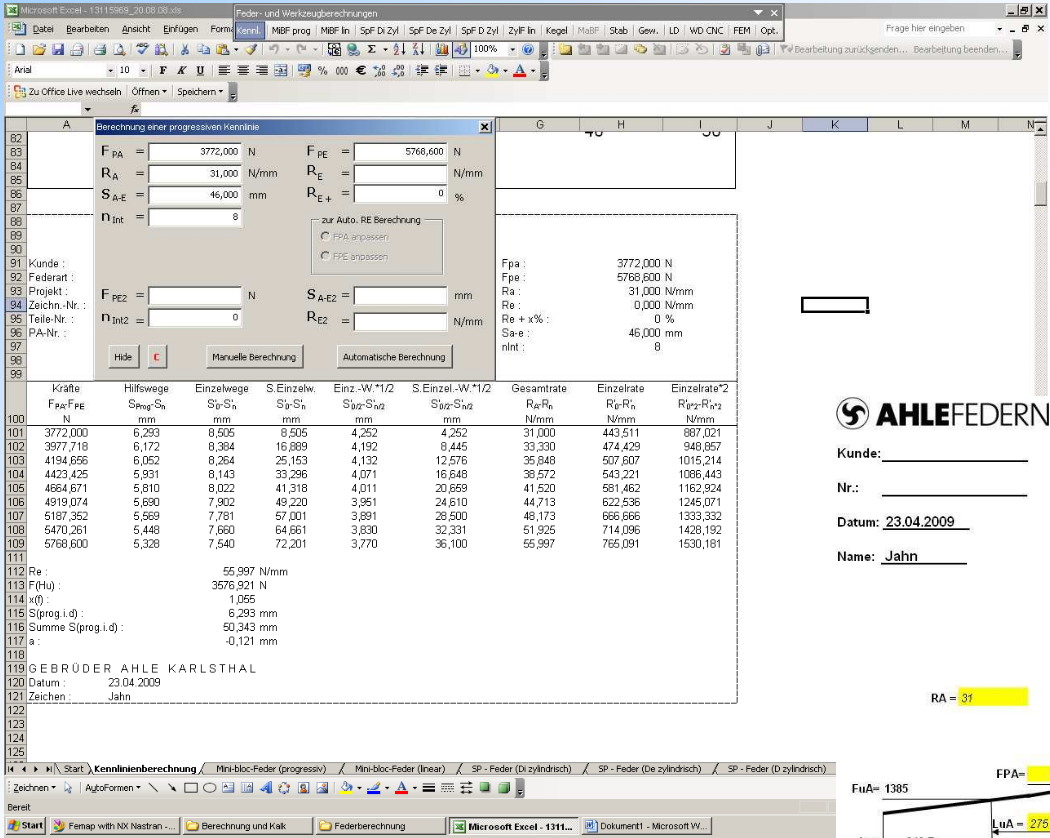

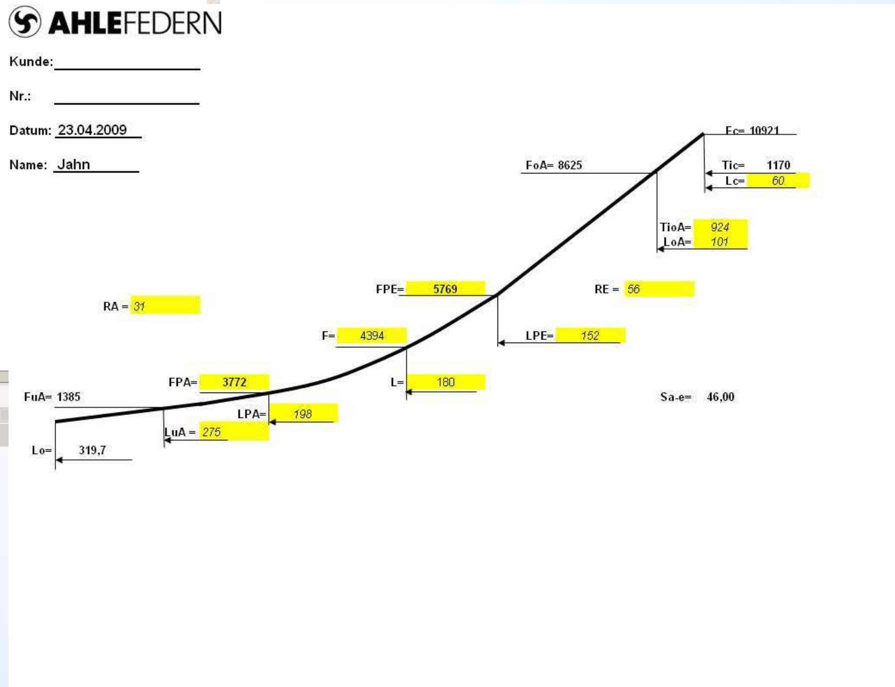

Evaluation of geometry data and characteristic curve

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Tooling Algorithm

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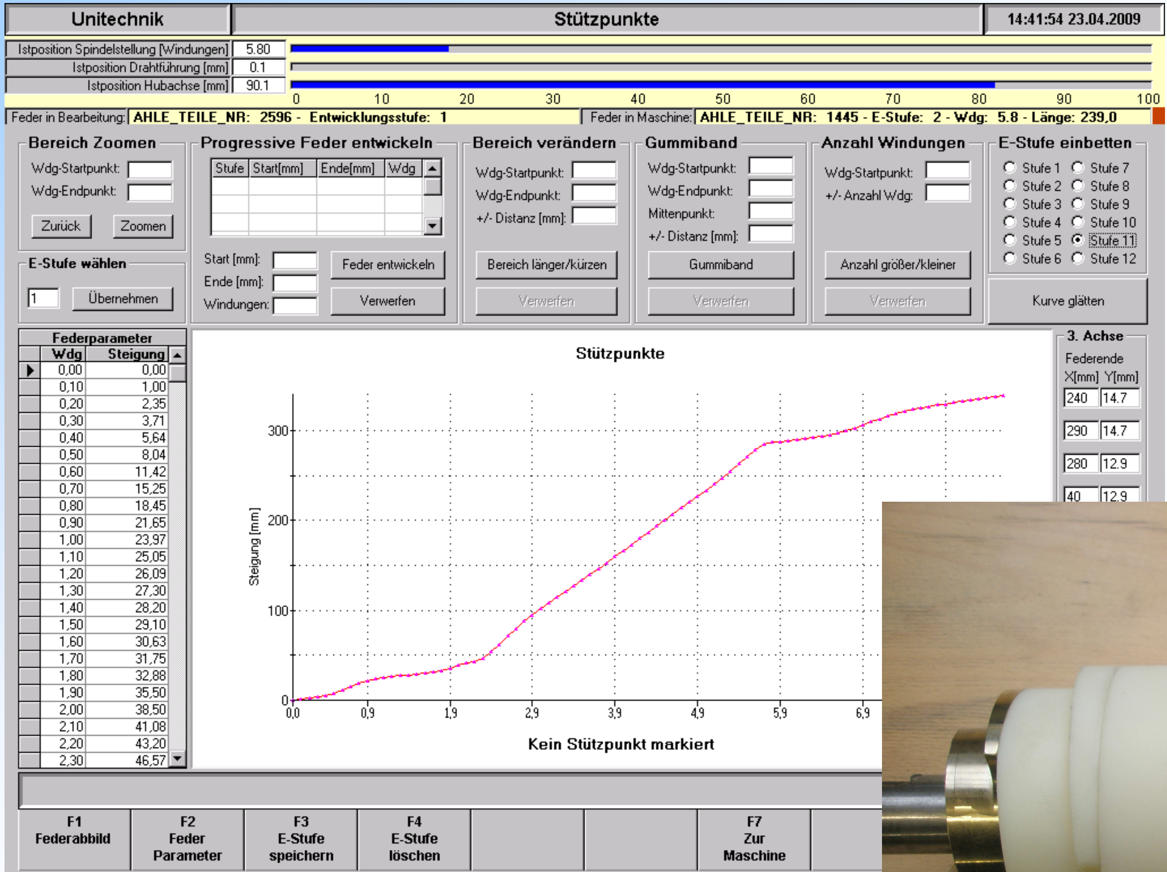
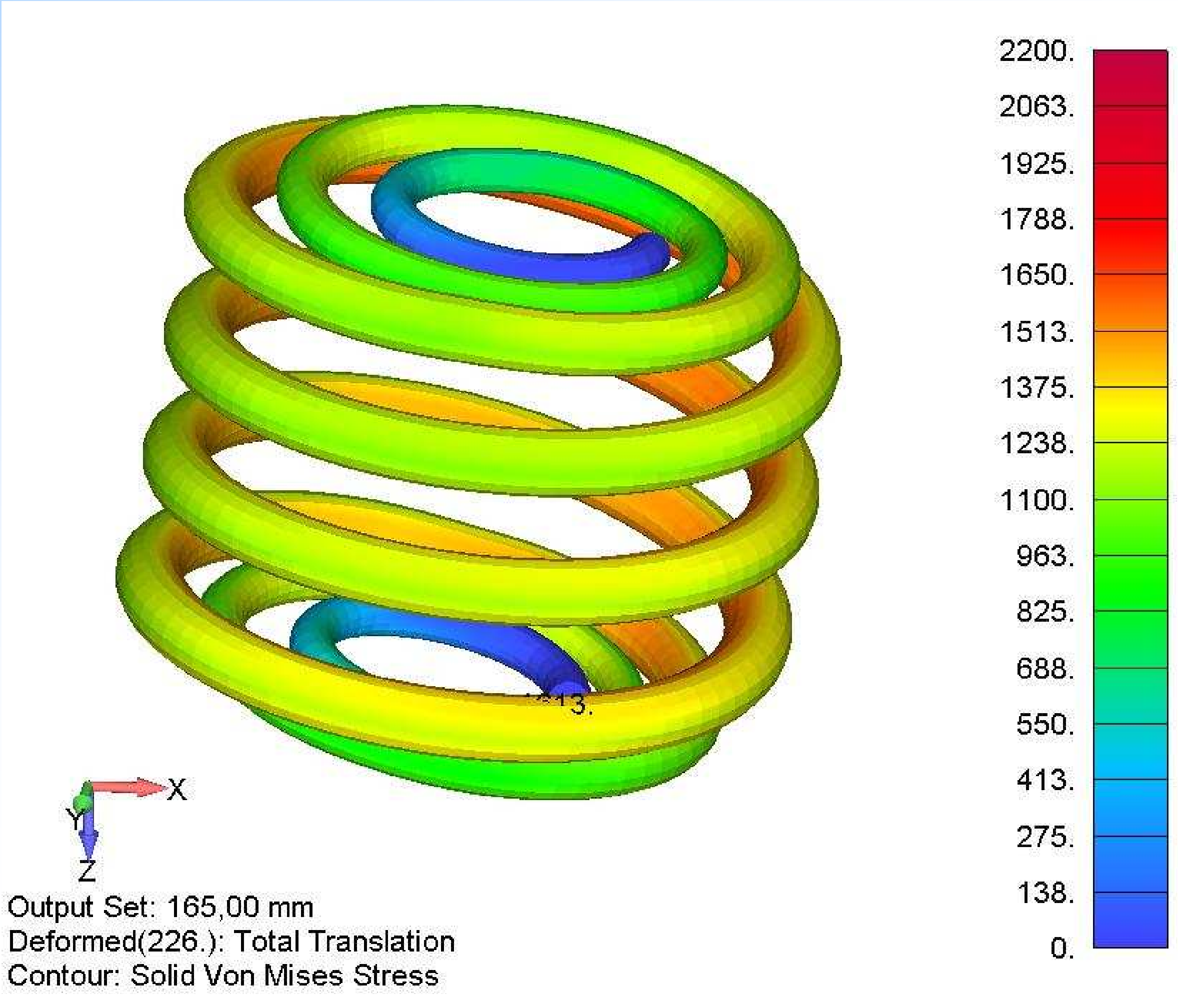


CAM link to tool design

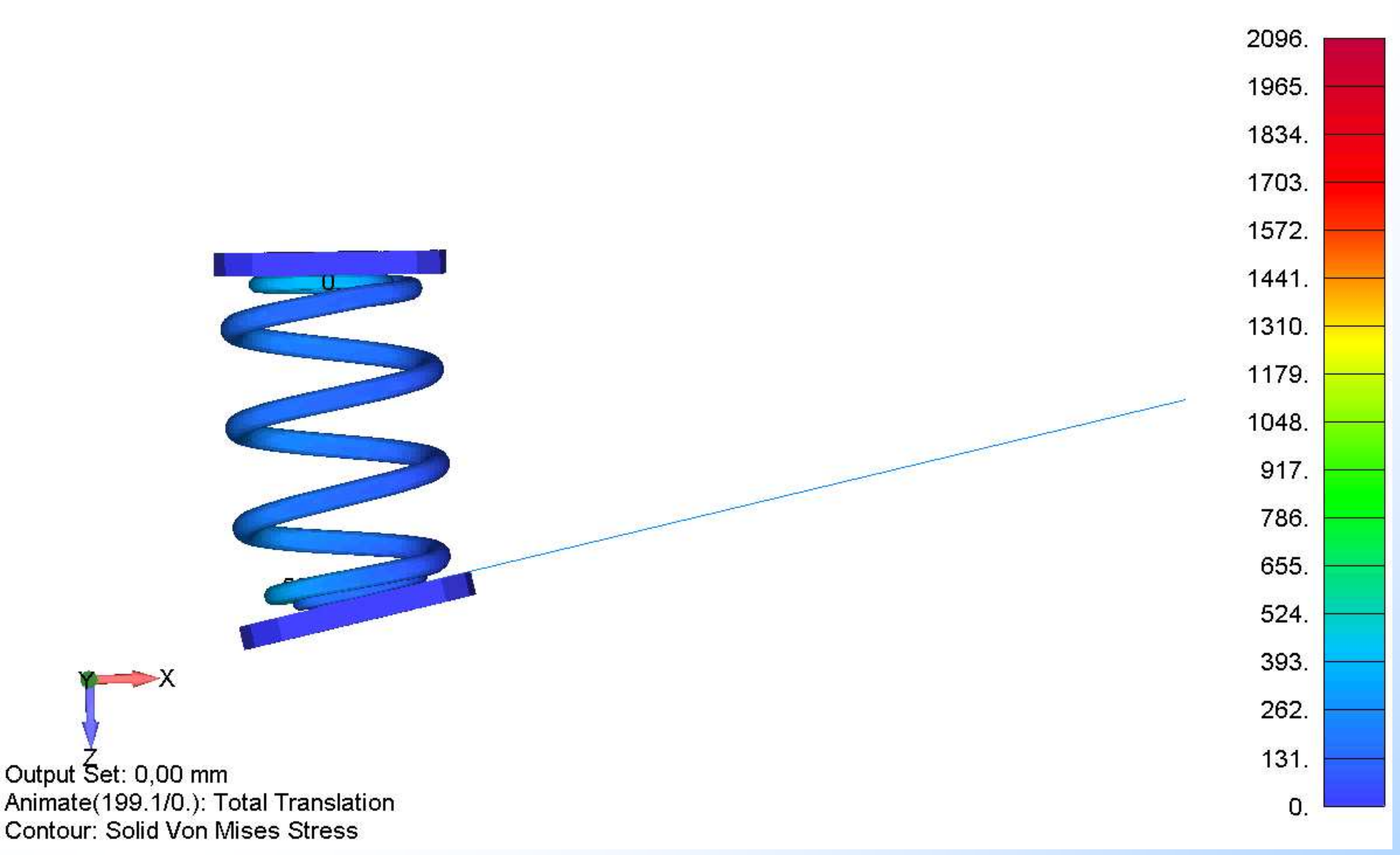
Finite Element Simulation



Model of a Miniblock-Spring

FEM Simulation

FEM simulation helps to analyse stresses (bending and torsion stresses) within spring wire during designing



FEM Simulation

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CAD (Pro-Engineer)

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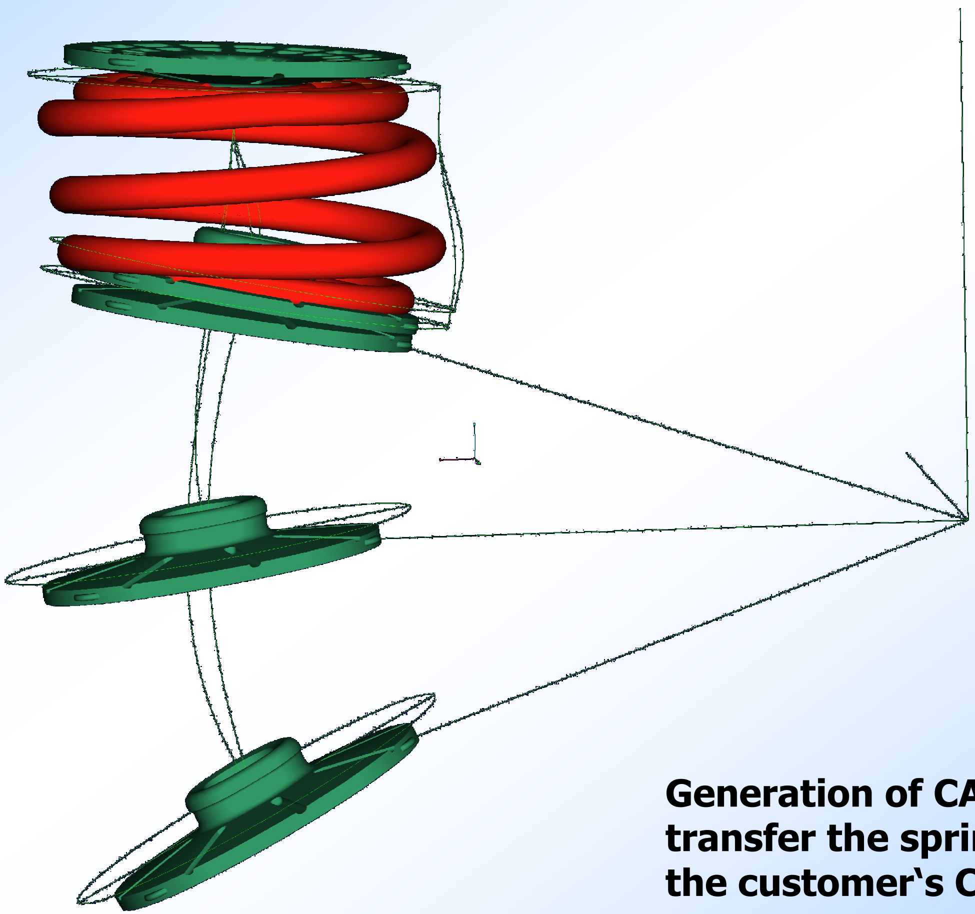
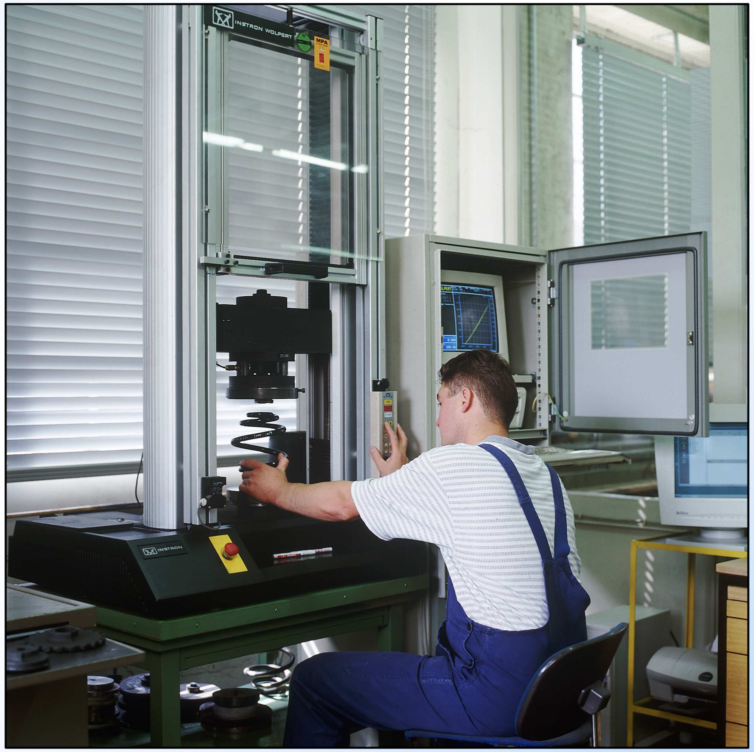


Generation of CAD drawings to transfer the spring design into the customer's CAD system

Tooling / Prototype Development

Product development is close to series production



Checking deflection curve and load during prototype development

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3-D Measurement; DEA/Hexagon

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Capturing geometry data of the real spring, feedback into FEM

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3. The Ahle Manufacturing Process

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Producing Springs from Steel Bars

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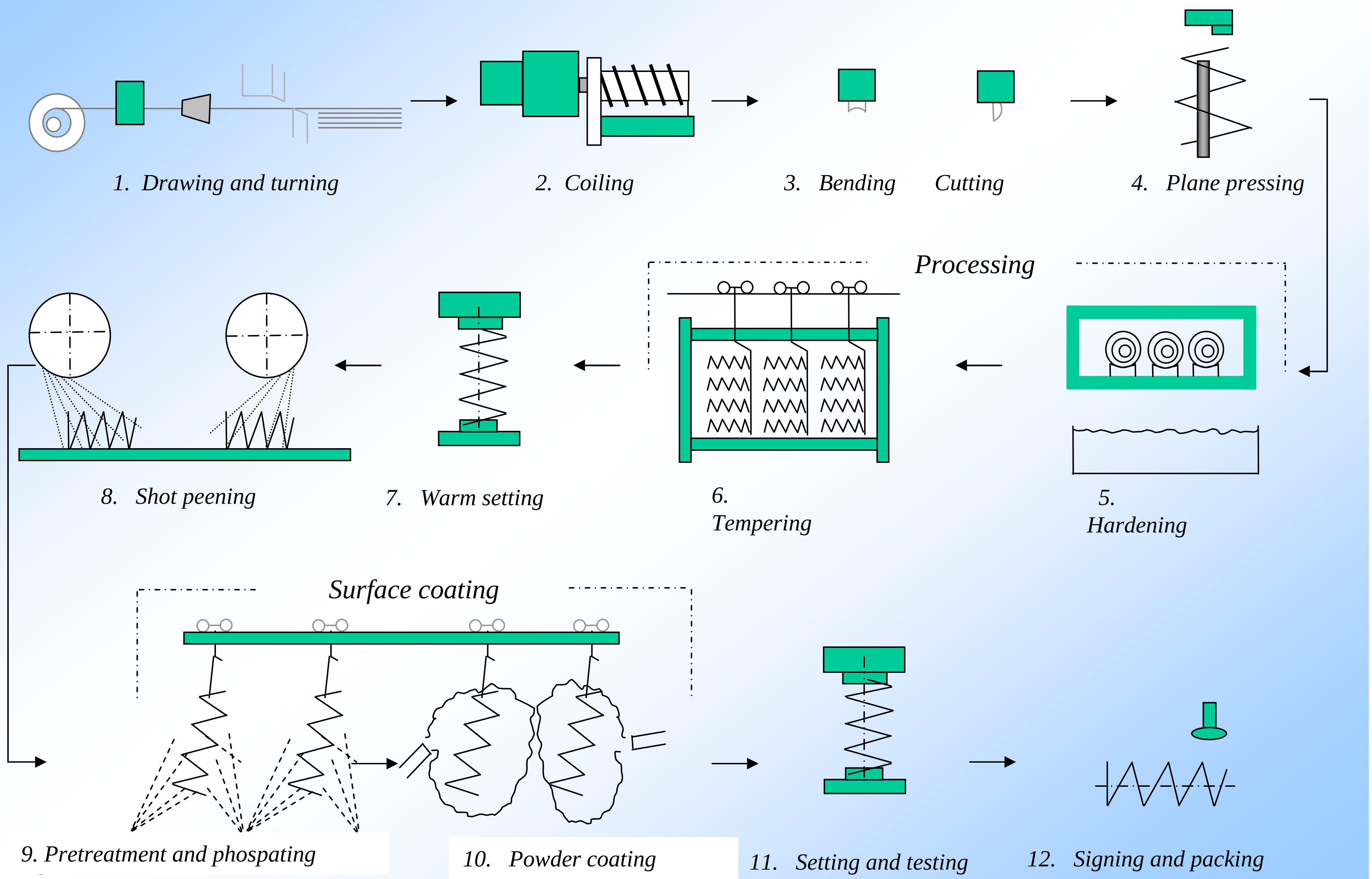

Taper Wire

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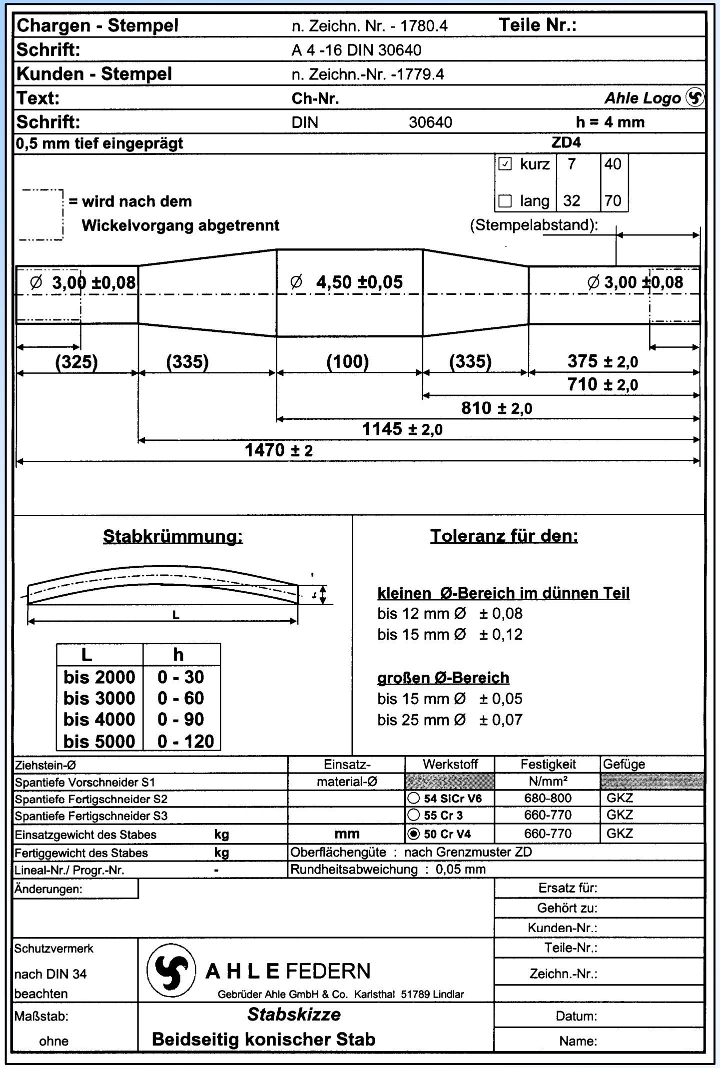
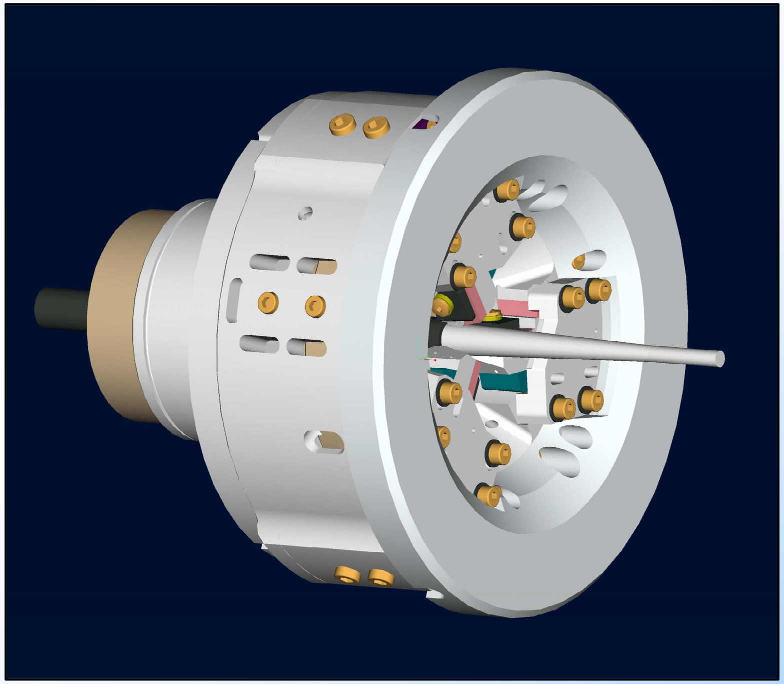


Typical bar drawing (taper wire)

Production of taper wire



Reducing the material in a combination of drawing and peeling processes

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Coiling Process

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Coiling of springs

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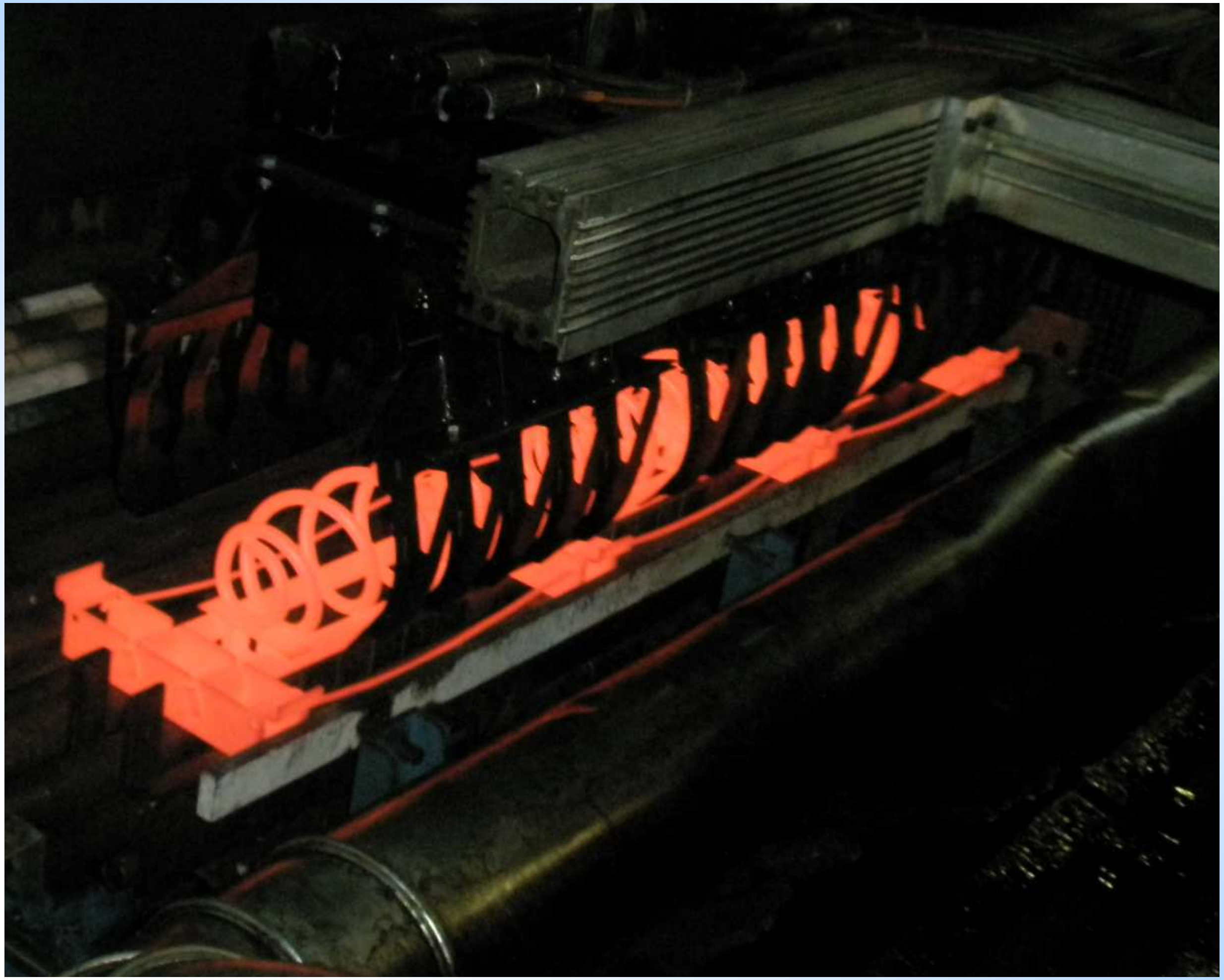
Heat Treatment

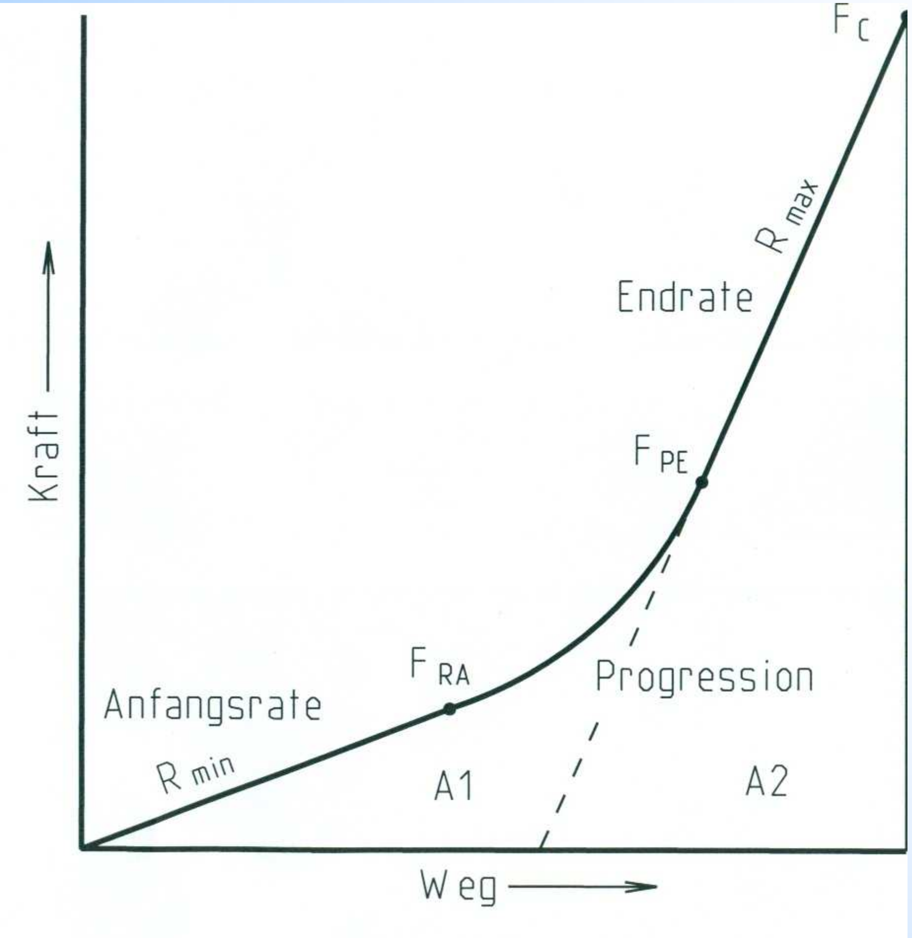


Heat treatment furnace with controlled atmosphere

4. Miniblock Springs, Summary

Requirement: Deflection Line

Execution of every required deflection curve



The Ahle process enables the development and production of chassis springs with a rate ratio of 1:3!

$$Rate = \frac{F}{S} = \frac{G \cdot d^4}{8 \cdot D^3 \cdot n}$$

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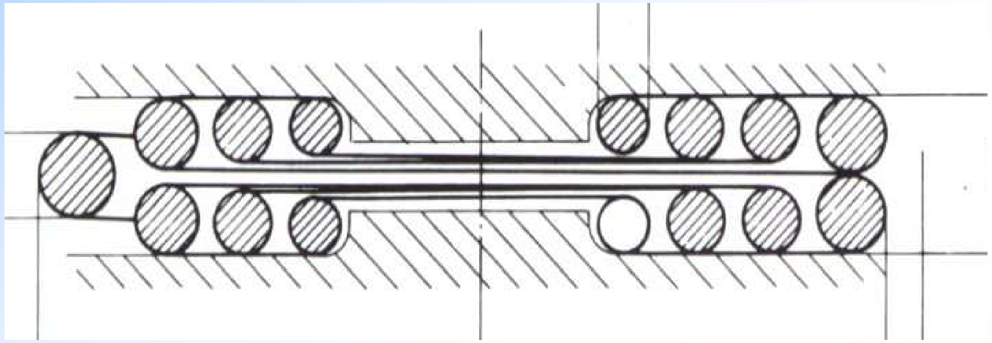
Requirement: Light-Weight Design

Solution: The wire diameter can be adjusted to the stress in this area. As soon as smaller coils have settled, the stress in these coils is reduced. The wire diameter of these coils is thus designed with a smaller diameter.

Result: light-weight design

The Miniblock-Spring is the lightest spring from a physical point of view and offers the lowest block length.

Requirement: No Coil Contact



No coil contact – no noise, no surface damage!

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Requirement: Small Installation Space

315.00mm

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here:

Block length: 47.30mm

=15% of the free length L_0

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47.30mm

315.00mm

Requirements

1. (Progressive) Characteristic Curve ✓
2. Light Weight Design ✓
3. Packaging Minimisation ✓
4. No coil contact ✓
5. **Super Progression**
6. Defined Force Line Piercing Points ✓

- Side load minimisation (piercing points in the spring axis)
- Offset (piercing points are outside of the spring axis)

5. New Developments/ Potential of Springs with Non-Constant Wire Diameter

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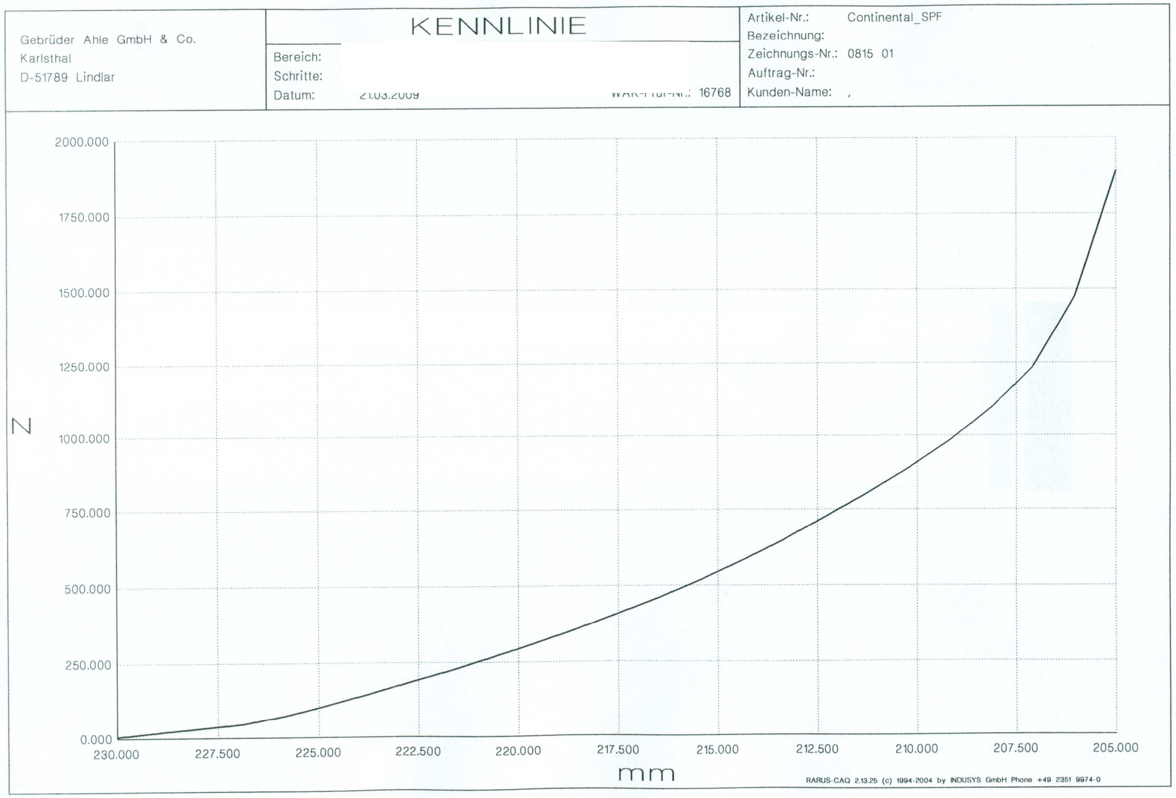
New Development: Mini SPF (Super-Progressive-Springs)



Characteristic curve of a Mini –Super-Progressive Spring (Mini-SPF)

Applications (e.g.):

Rebound spring
Simulator spring

The Ahle process makes it possible to develop and produce super-progressive-springs with a rate ratio of up to zu 1:10!

Comparison: Mini SPF vs. Helical Compression Spring

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	Mini SPF (Super progressive spring)	Helical compression spring
Weight	71 %	100 %
Free length	66 %	100 %
Solid length	58 %	100 %

Different springs with identical properties:

Material, force, initial rate, end rate, outer diameter = constant

Benefit of non-constant wire diameter!

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Requirements

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1. (Progressive) Characteristic Curve ✓
2. Light Weight Design ✓
3. Packaging Minimisation ✓
4. No coil contact (noise elimination) ✓
5. Super Progression ✓

6. Defined Force Line Piercing Points

- Side load minimisation (piercing points near spring axis)

- Offset (piercing points outside of spring axis)

Objectives / Benefits of AHLE Solution

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- Reduction of friction within the spring system
- Reduction of height / length of the spring (improved pedestrian protection!)
- Optimised positioning of the shock absorber system
- Reduced weight of spring
- Easier assembly of the shock absorber system

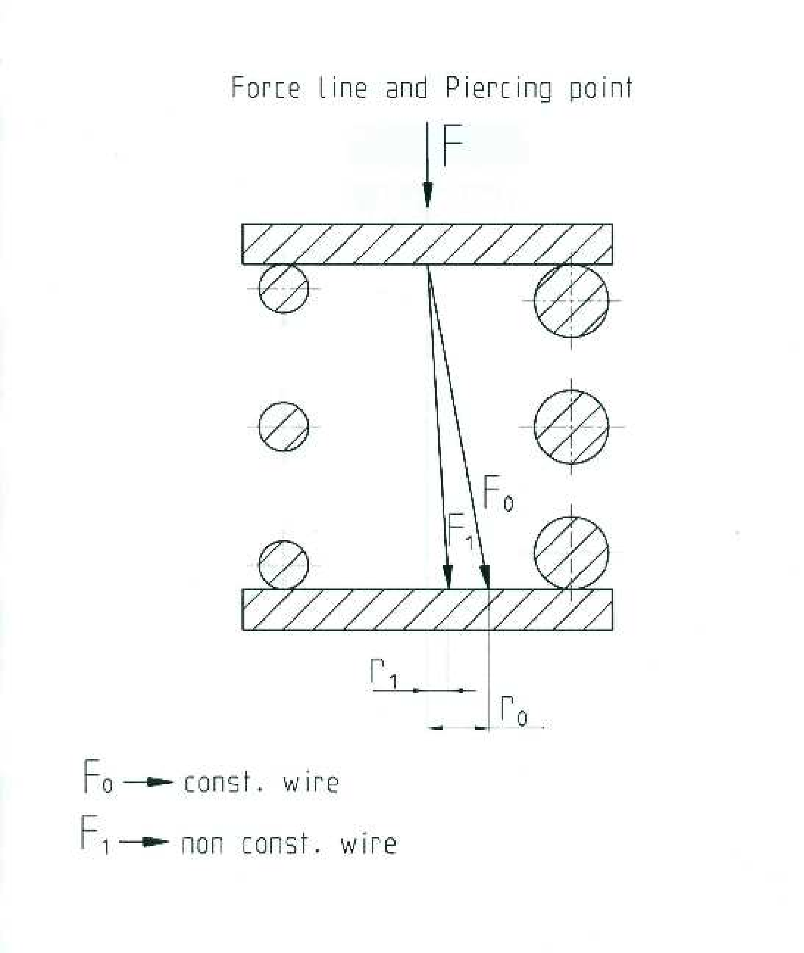
Side Load Correction

Current situation

The side load of a spring depends on its geometric framework conditions

Solution:

Selected wire sections are "thickened" to influence the direction of the force line!

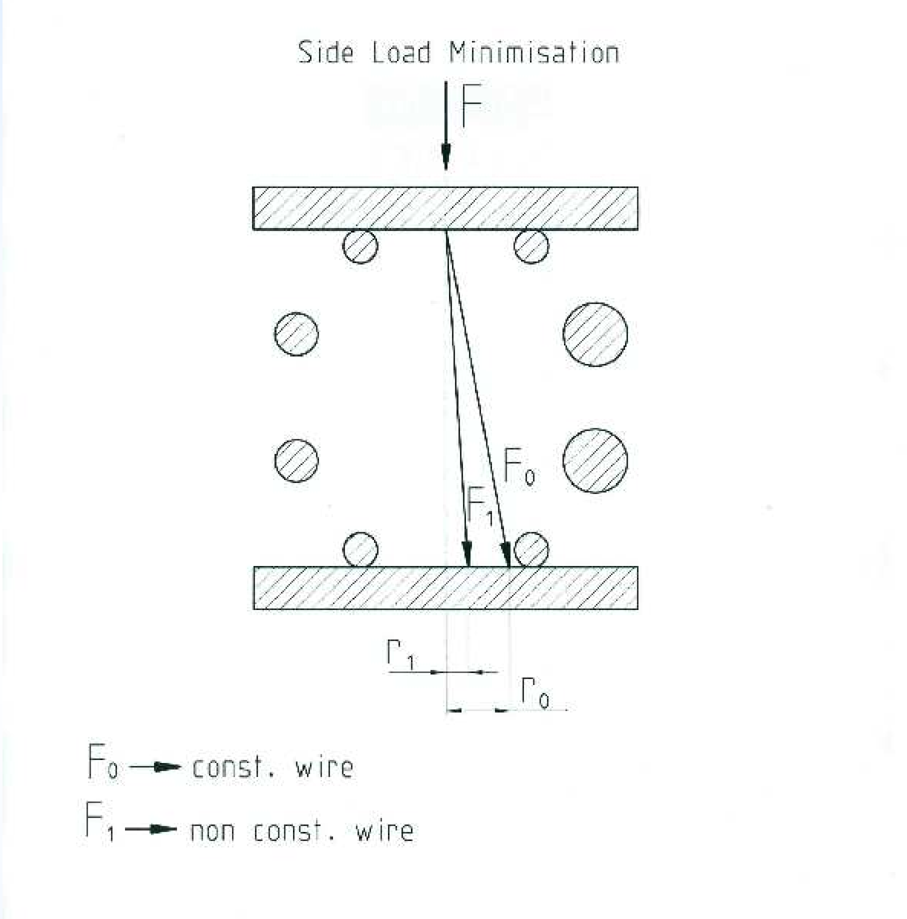


Sketch: modified helical compression spring

Side Load Correction

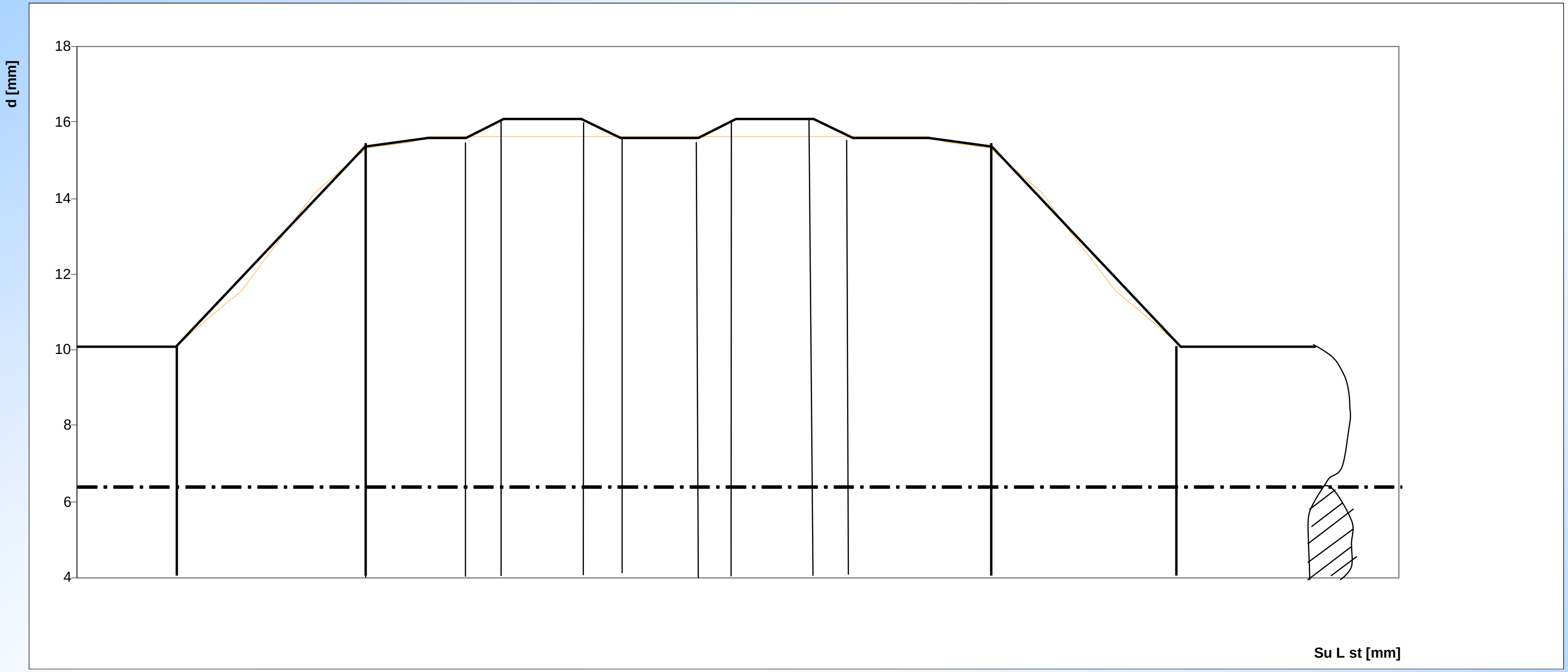
Objective achieved by:

Non-constant wire diameter



Sketch: modified Miniblock-Spring

Side Load Correction



Schematic drawing of a bar with partially thickened wire sections

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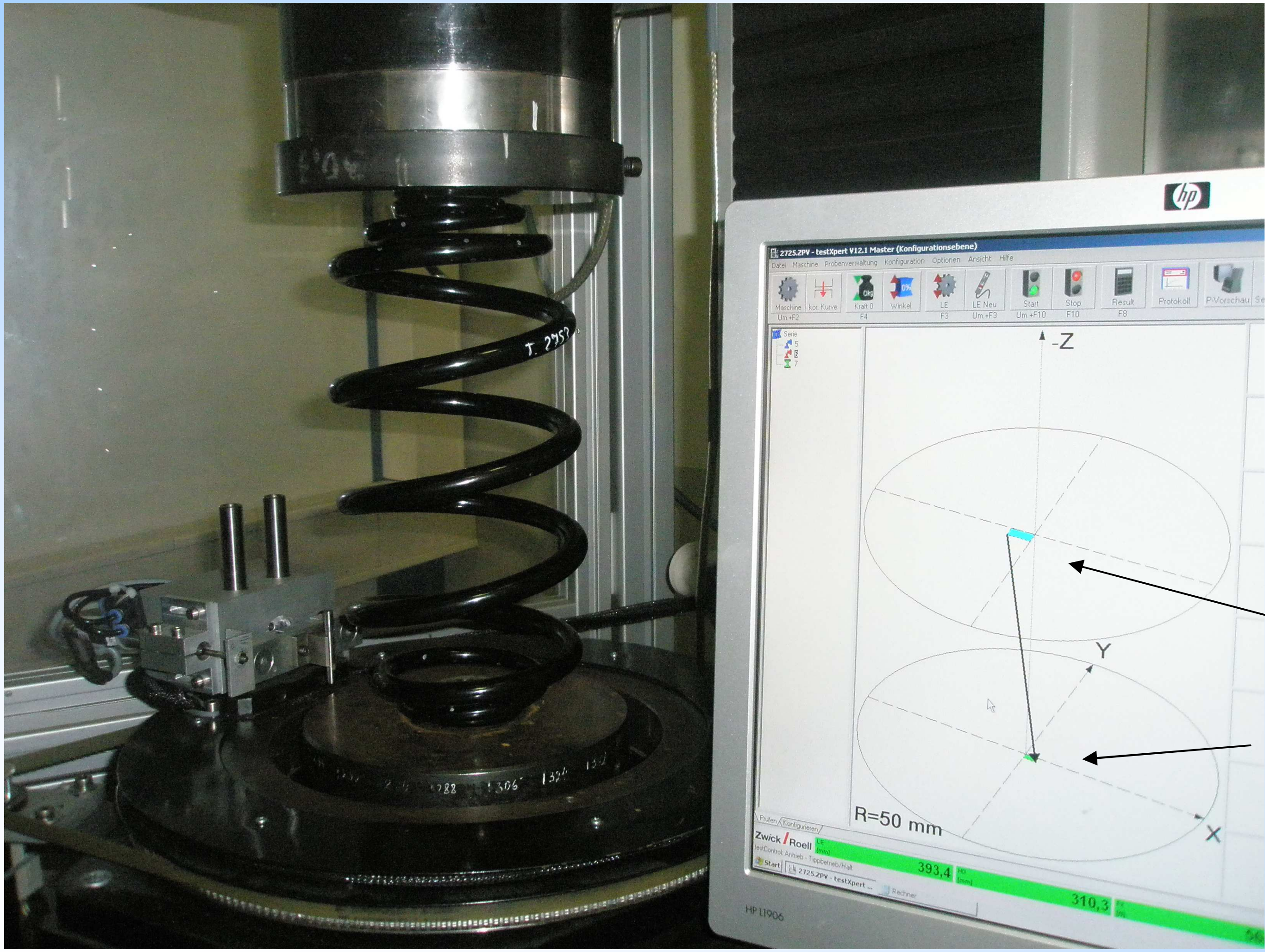
Side Load Determination



Position of piercing points based on the direction of the force line of action

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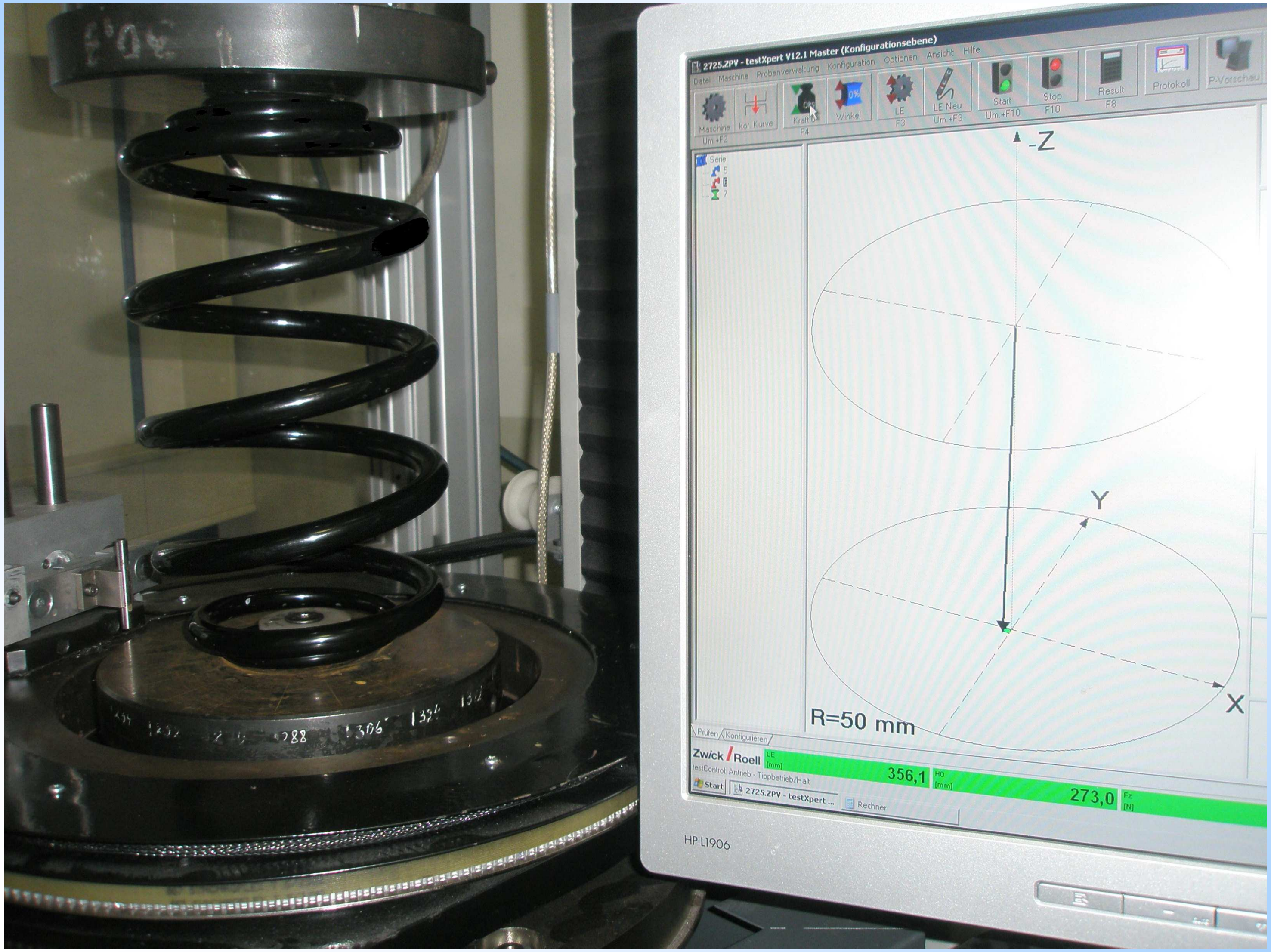
Side Load Minimization



Optimized force line of action of a modified Miniblock-Spring)

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Influencing the Force Line of Action

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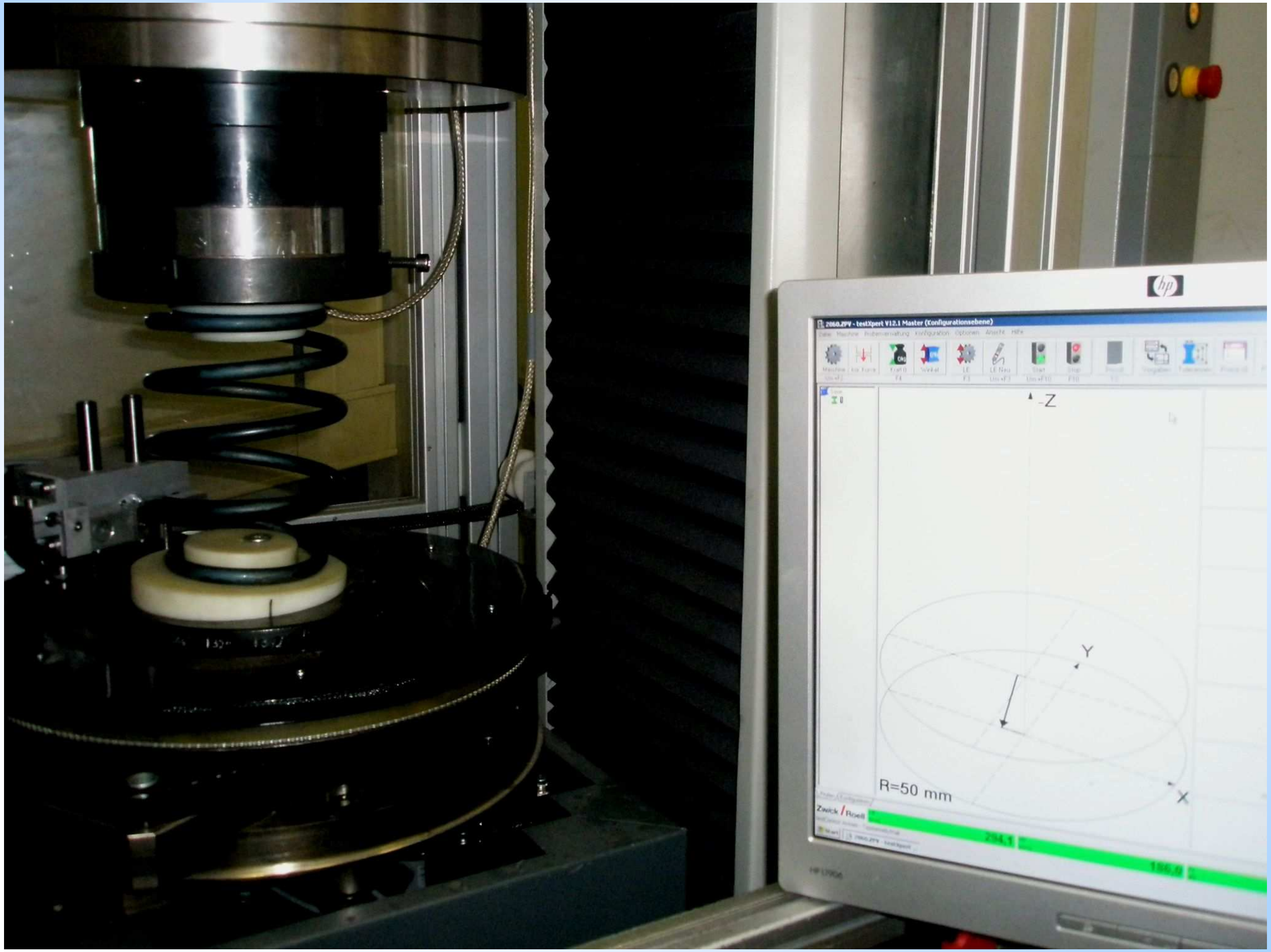

Ahle – Side-Load Spring without bar modification

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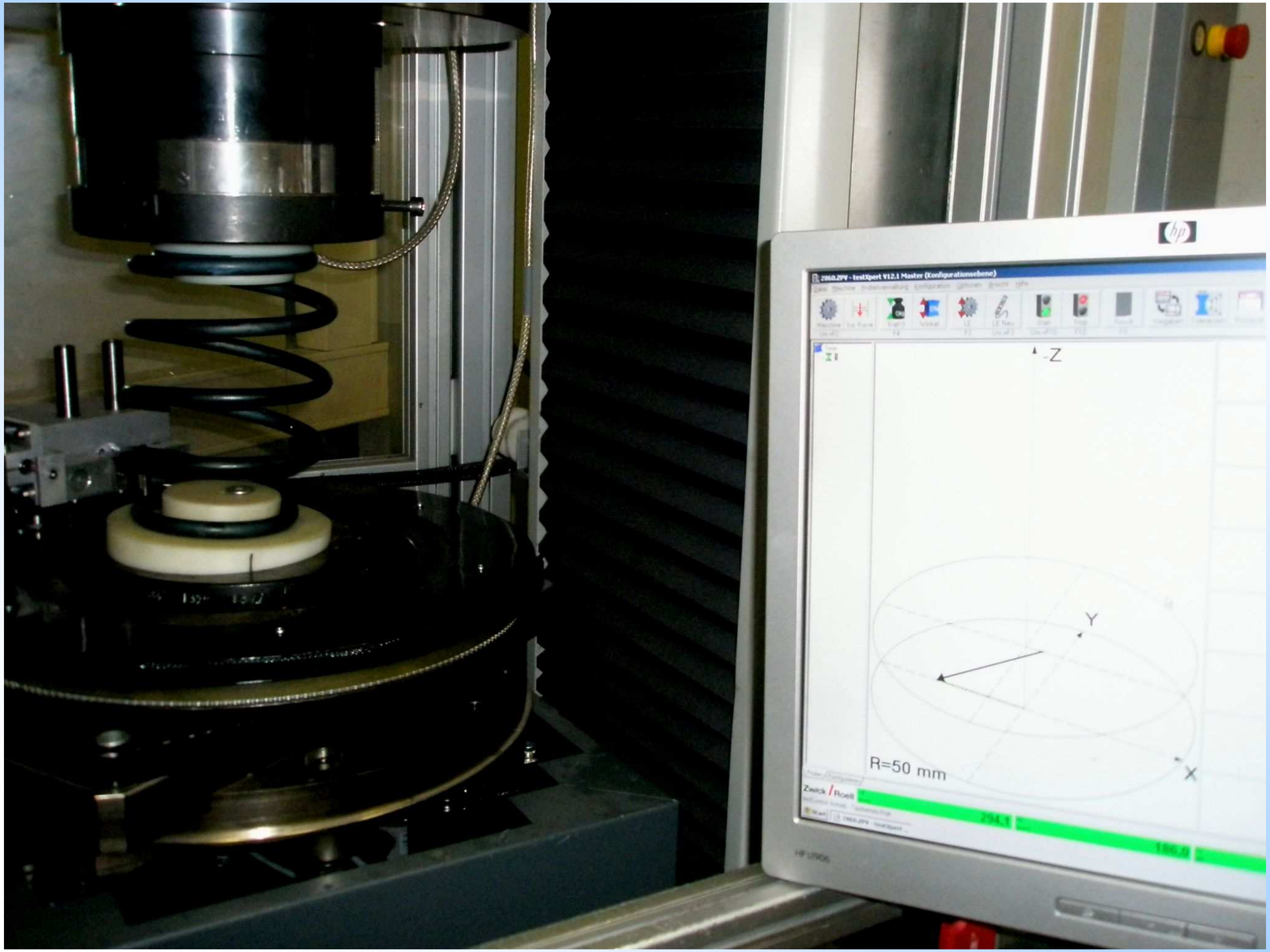
Influencing the Force Line of Action



Ahle – Side-Load Spring with bar modification

Current Status of Developments

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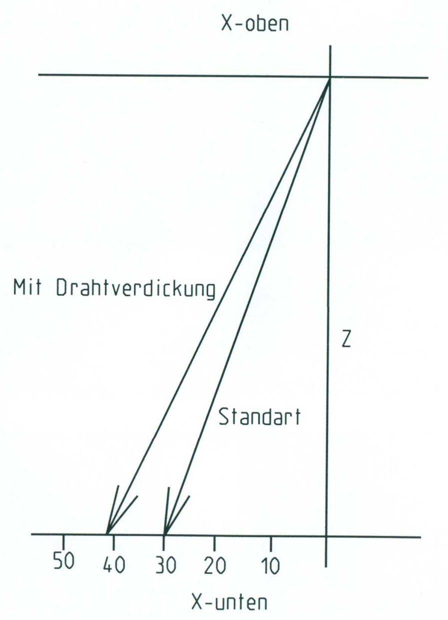
- **Series production of partially thickened bars is possible**
- **Confirmed functionality of the Ahle – Side-Load Spring**



Lower piercing point		Upper piercing point		Side load	Wire
Xunt [mm]	Yunt [mm]	Yob [mm]	Xob [mm]	Fq [N]	
-32.73	-2.86	-6.37	-3.61	577.53	No thickened sections
-32.02	-2.01	-8.98	-3.89	541.61	
-33.05	-1.51	-5.71	-2.93	508.58	
-44.81	0.49	-1.57	2.12	859.93	With thickened sections
-47.59	0.63	-2.32	1.02	825.46	
-48.02	0.79	-2.79	0.78	808.82	

Further development of a competitor‘s side load spring

- **Compared with series side-load springs the Ahle-Solution shows up to 50% larger shifts of the piercing points**

6. Summary

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Summary

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(Progressive) helical compression springs with taper wire show the following properties:

- **Optimum use of material**
- **Low weight**
- **Small packaging**
- **No coil contact**
- **High progression in only one component possibility to influence the force line**

Thank you for your attention

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