AHLEFEDERN

Progressive Suspension Springs with Non-Constant Wire Diameter

Target: Design of Physical Best Light Weight Springs

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Dipl. Ing. Bernd Rhönisch
AHLE-Federn GmbH & Co
51789 Lindlar

Overview

1) Overview Gebrueder Ahle GmbH
- **Position in market**
- **Product range**

2) Chassis springs
- **Requirements: Deflection curve, installation space, weight, noises**
- **Progression**
- **Comparison of progressive chassis springs**

3) Miniblock-springs
- **The principle of non-constancy**

4) The Ahle-Process
Development, manufacturing

5) Advantages of Miniblock-springs
- **Design of every required progressive deflecton curve**
- **Optimization of required installation space**
- **Weight reduction by efficient material use**
- **Noise-elimination, no contact corrosion!**
- **Comparison of different spring systems**

6) Comparison: Steel springs – Pneumatic suspension systems

7) Summary

1. Company Overview

- **Position in Market Space**
- **Customers, Product Range**

Products:

Helical Compression Springs

- **Rebounds springs by round- and flat wire**
- **Chassis springs as cylindrical or Miniblock-springs with linear or non-linear deflection curve**

Applications:

- **Chassis springs for automotive applications**
- **Brake springs for trucks und rail-vehicles**
- **Technical springs**

Design and Prototype Manufacturing

Design and calculation methods:

Ahle spring calculation algorithms

FEM (Nastran)

CAD (ProEngineer)

Integrated tool- and prototype-manufacturing

BMW

MAGNA STEYR FAHRZEUGTECHNIK

PORSCHE

DAIMLER

TENNECO Automotive

DELPHI Driving Tomorrow's Technology

Eibach FEDERN

Nutzfahrzeuge

GM

OPEL

WABCO

KNORR-BREMSE

ZF SACHS

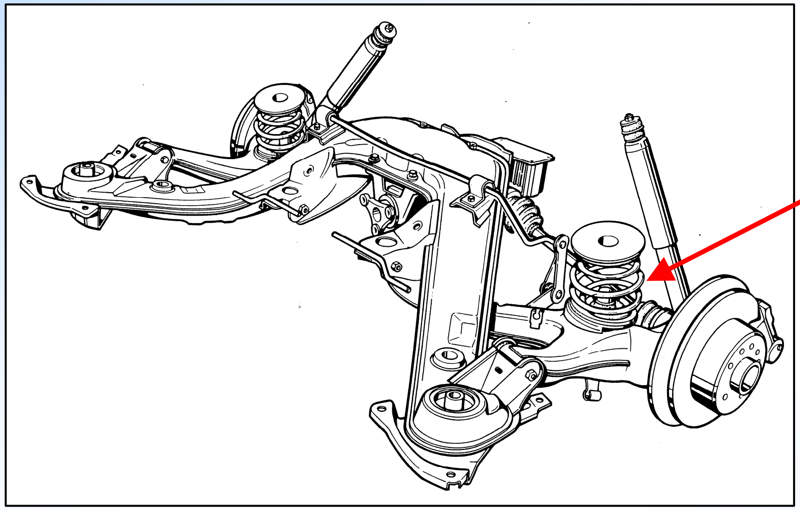
Antriebs- und Fahrwerk-komponenten

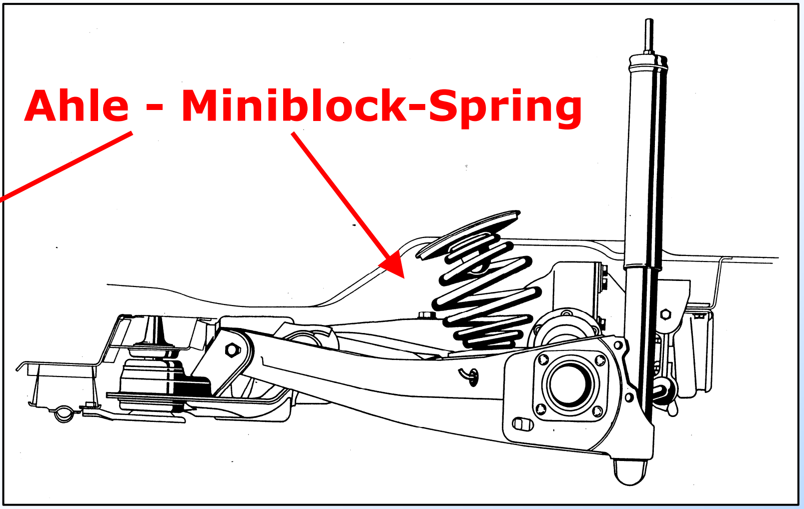
2. Chassis Springs

- **Requirements: Deflection Curve, Installation Space, Weight, Noises**
- **Progression**
- **Comparison of Progressive Chassis Springs**

Requirements for Spring Design:

(Progressive-) Deflection Curve,
Installation Space, Weight, Noises





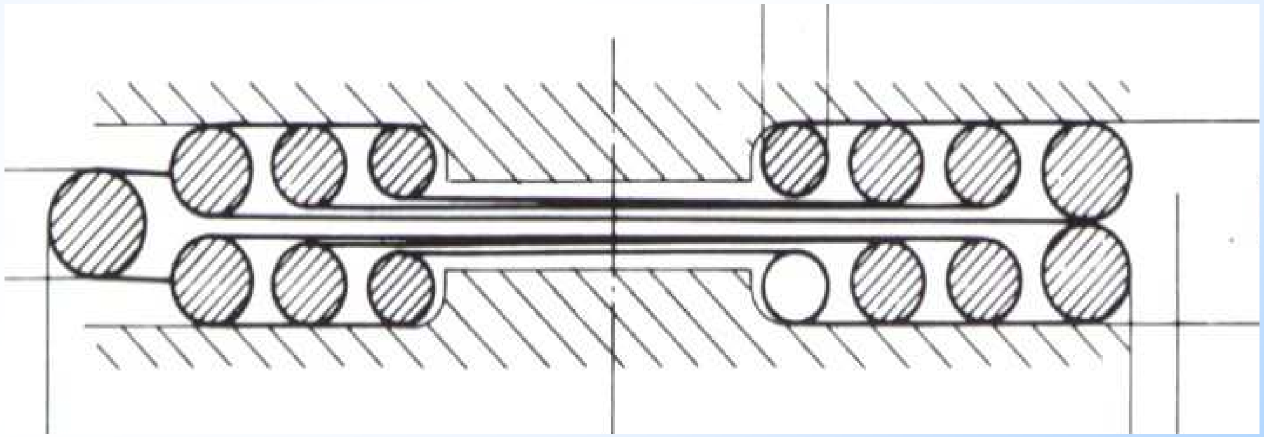
Built-In Situation: Ahle Miniblock-Spring in car rear axle, OPEL

Built-In-Situation : Ahle Miniblock-Spring in car rear axle, OPEL

Requirements: Less Weight, no Rattling Noises

Less weight caused by non-constant wire diameter

No coil contact – leads to no contact noise (no coil-rattling!)



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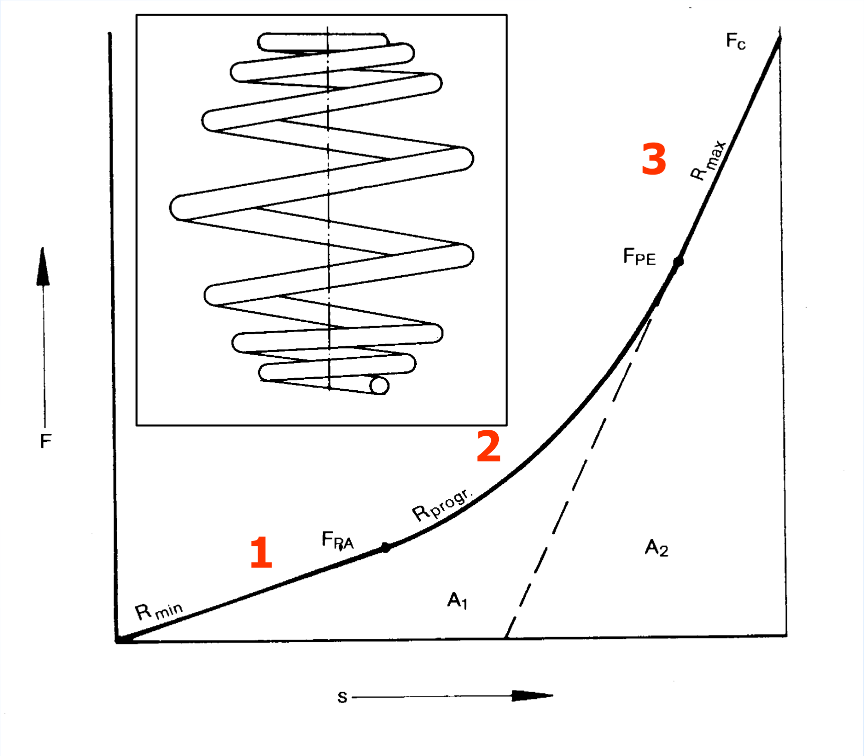
Progression

Exposition of a progressive characteristic line

The deflection curve consits of three sections:

Section 1: linear rate (initial rate)
Section 2: progressive rate
Section 3: linear rate (end rate)

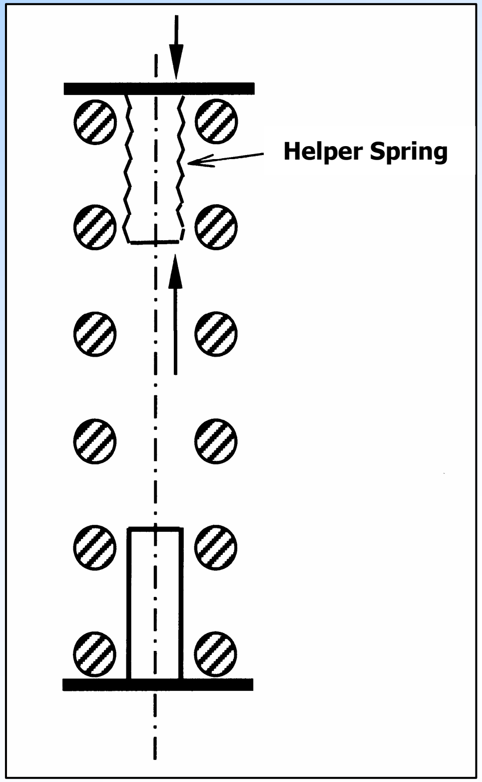


Comparison of progressive Chassis Springs

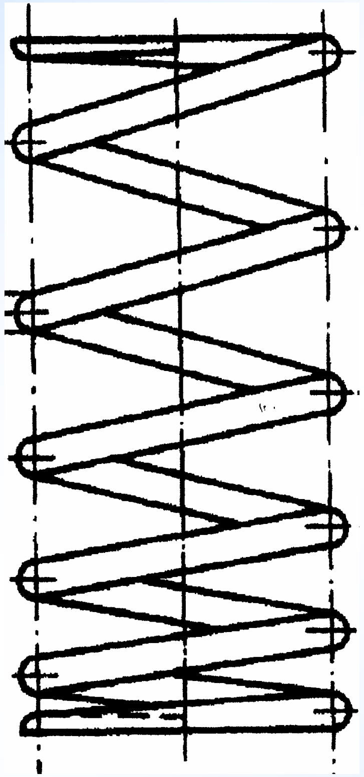
Fundamantal Solutions:

- Cylindrical compression spring + helper spring
- Springs with non-constant pitch
- Springs with non-constant coil diameter (conical spring)
- Springs with non-constant pitch, non-constant coil diameter
- Springs with non-constant pitch, non-constant coil diameter, plus non-constant wire diameter

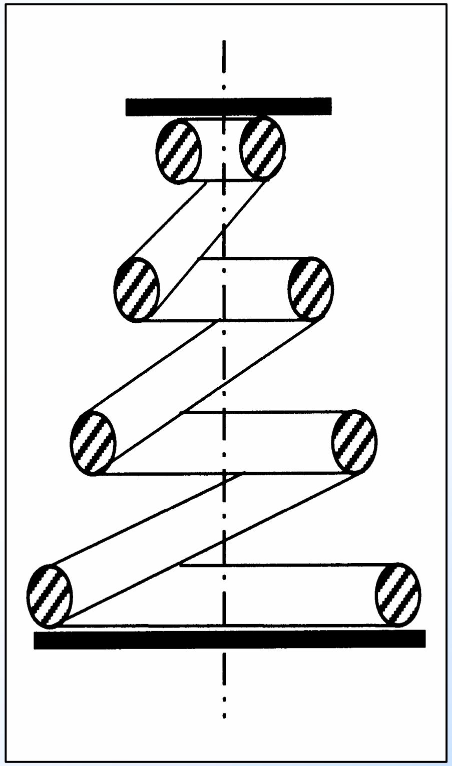
Fundamental Solutions for Progressive Helical Compression Springs



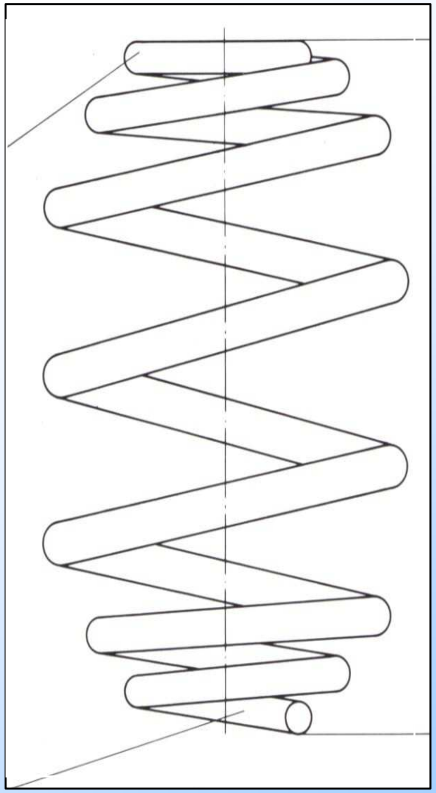
Helical compression spring plus + helper spring



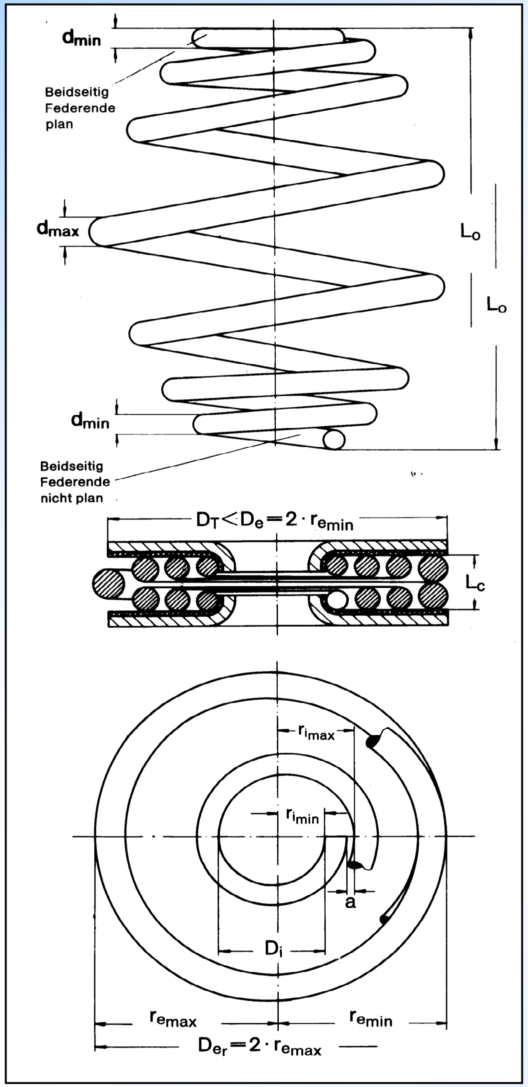
Helical compression spring with non-constant pitch



Conical spring with <u>non-constant coil diameter</u>



Barrel spring with non-constant wire diameter



Combination of:

- **non-constant pitch**
- **non-constant coil diameter**
- **non-constant wire diameter**

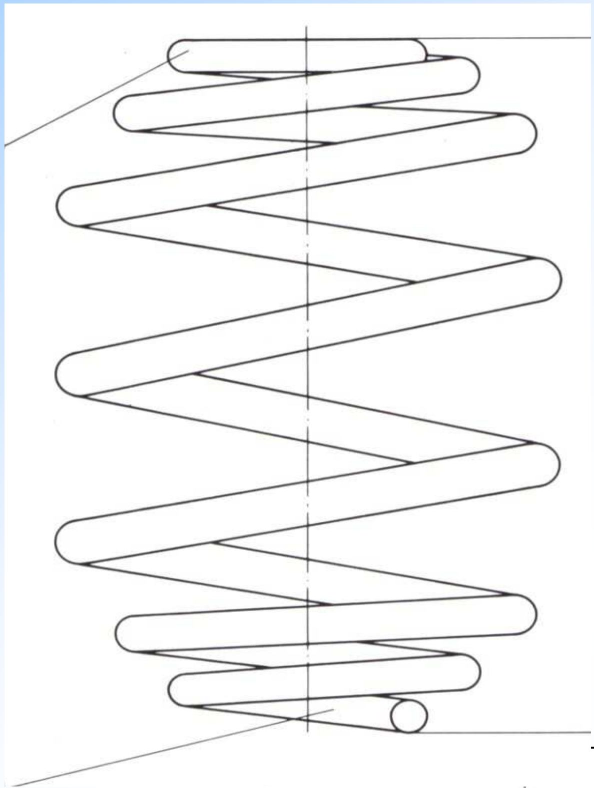
leads to

Miniblock-Spring

3. Miniblock-Spring

The principle of ´*non-constancy*´

The principle of *´Non-Constancy´*



Non-constant pitch

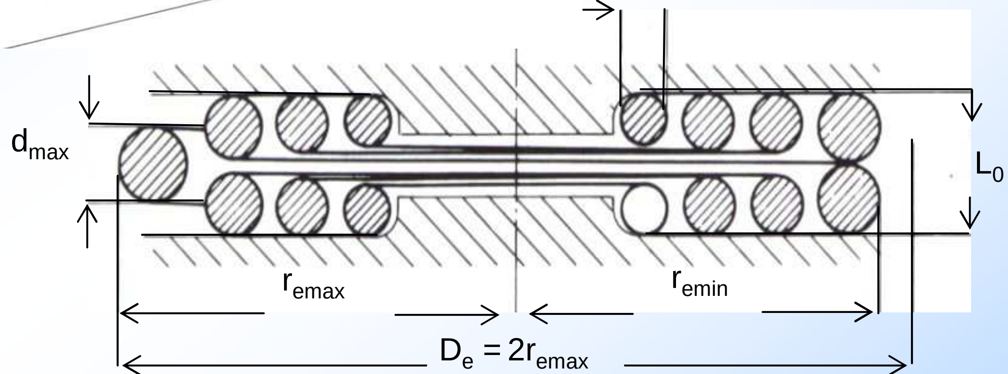
Progression

Non-constant wire diameter:

1.) Progression
2.) Weight reduction: „Light weight"

Non-constant coil diameter:

1.) small block (Miniblock)
2.) No coil contact (noise elimination)



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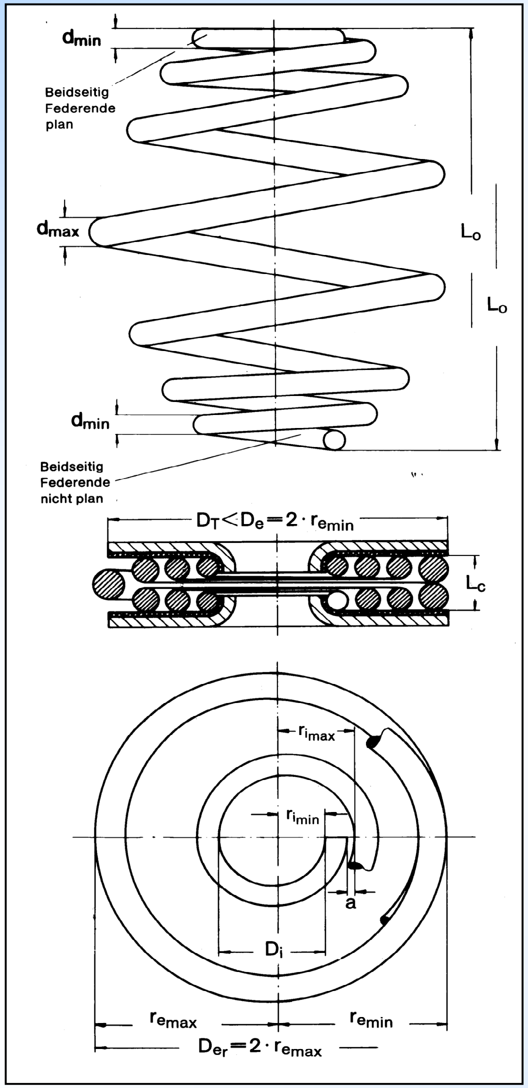
Physical Best Light-Weight Spring



Non-constant wire diameter:

Weight reduction caused by optimized material usage

Progressive spring:

Initial rate is lower than end rate

The effect is: → Coil sections with smallest wire diameter lay down within deflection and are „shut down" . In this position, the coils are inactive!

The effect is: → There is much less stress within the inactive coils

The effect is: → The material use of whole spring can be reduced caused by weight optimized starting coils and end coils!

The effect is: → **The complete spring becomes lighter!**

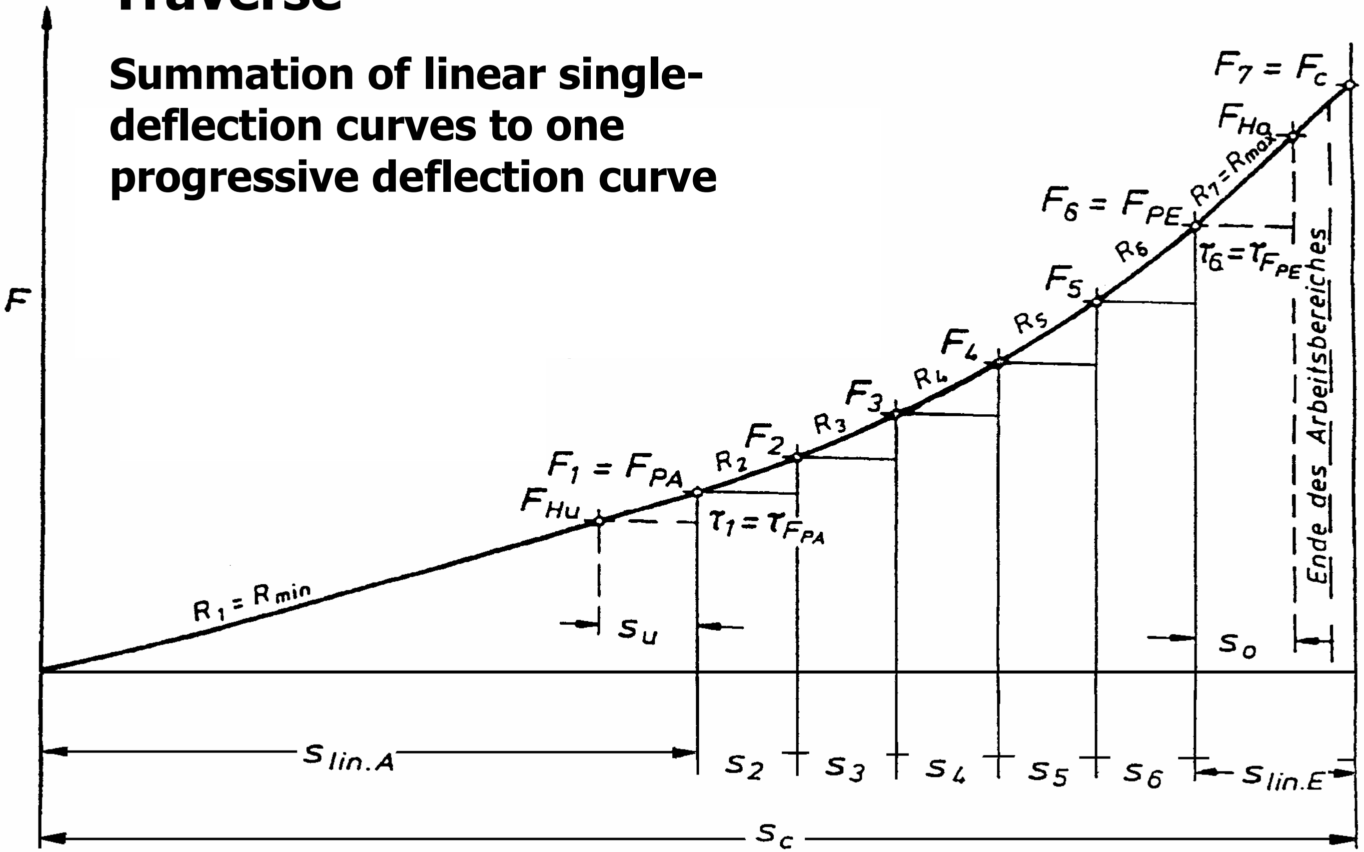
4. The Ahle-Process

Development and manufacturing of compression springs with non-constant wire diameter

Ahle-Process: 1. Development of Springs (Evaluation, Design, Simulation, Prototyping)

Traverse

Summation of linear single-deflection curves to one progressive deflection curve



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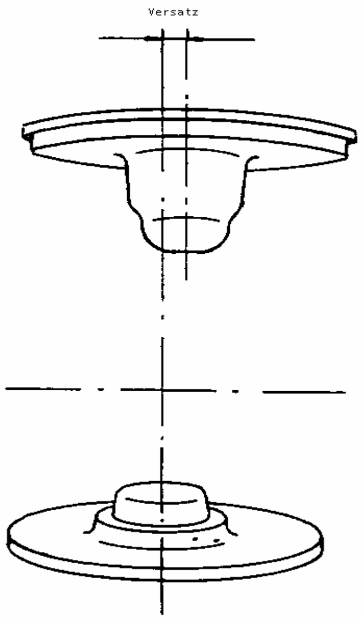
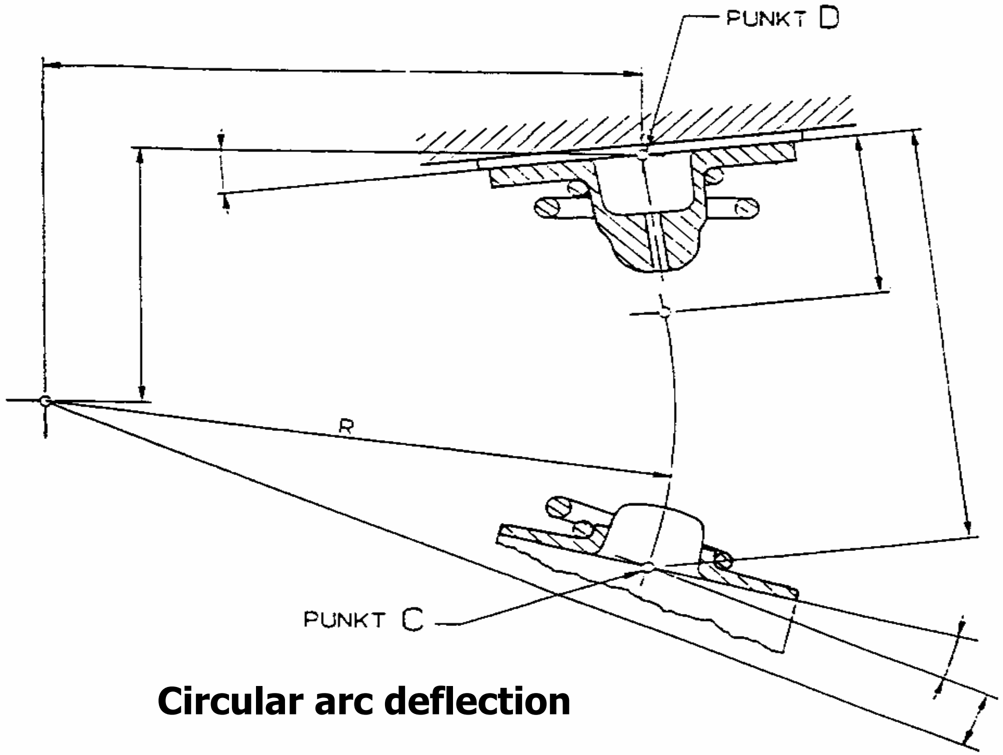
Complex Stress Conditions in Real Transversal Systems

(bending + torsion = equvalent stress + non-constant wire diameter)

Termination by Finite Elemente Method (FEM)

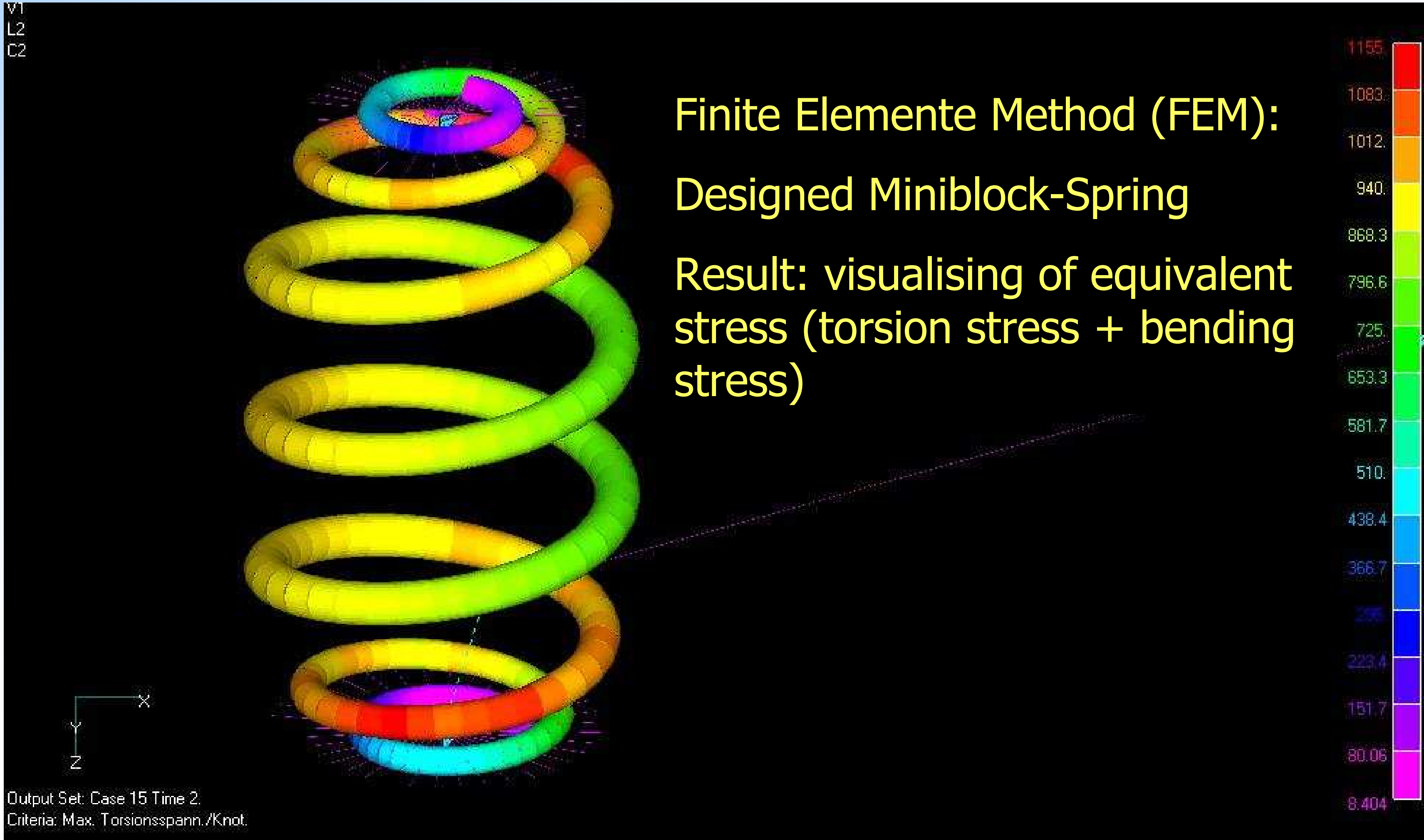


Axle offset



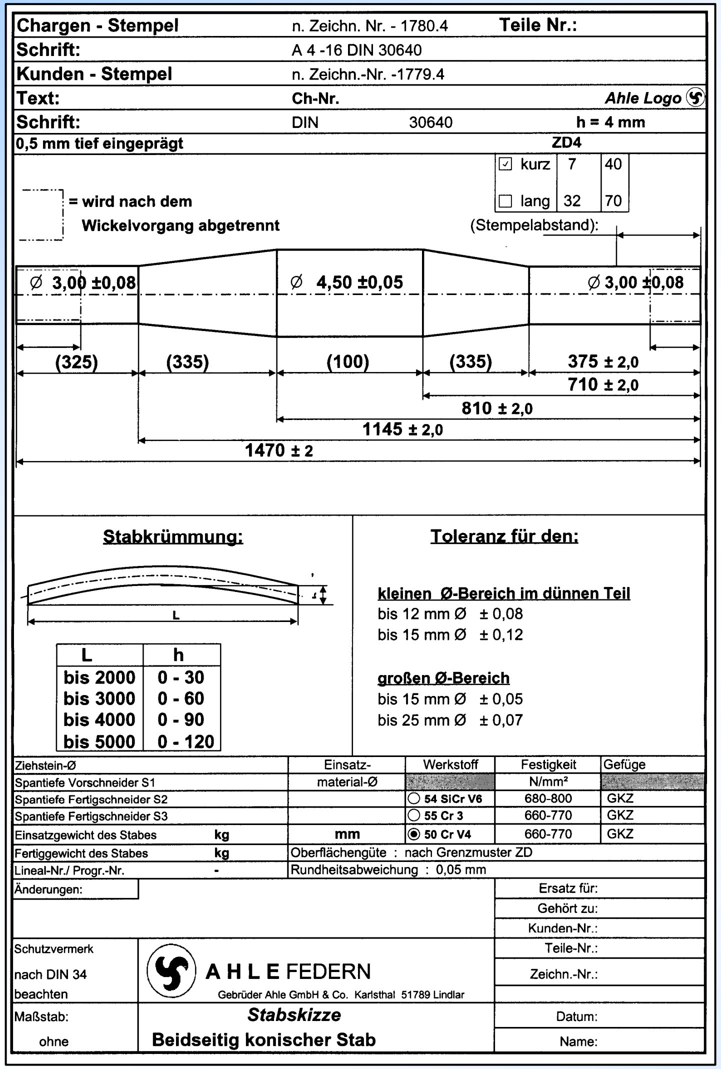
Circular arc deflection

Finite Elemente Simulation

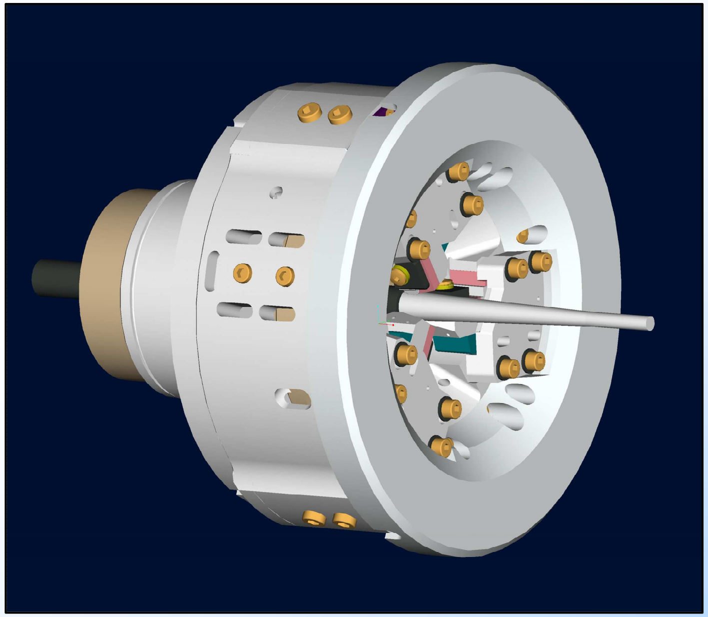


Ahle-Process:

2. Manufacturing of wires with non-constant diameter



Typical bar-drawing with non-constant wire diameter



Reduction of material use by drawing and turning (peeling)

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Ahle-Process (Overview)

Process-steps

1. Design
2. Simulation (FEM)
3. Test spring manufacturing
4. Quality tests

1. Devlopment

1. Bar manufacturing (Peeling)
2. Coiling (rough spring)
3. Hardening
4. Tempering
5. Warm setting
6. Shot peening
7. Zinc phosphating
8. Powder coating
9. Final testing
10. Signing

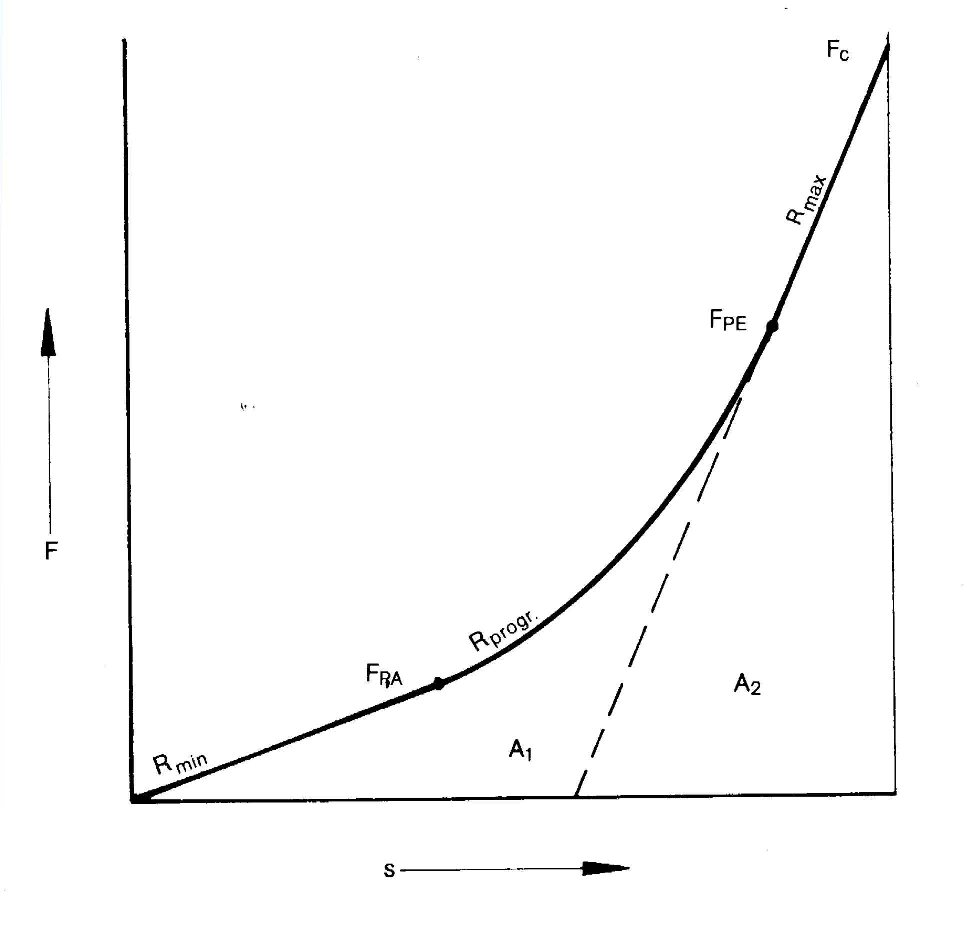
2. Manufacturing

Quality Control (ISO / TS 16949)

4. Advantages of Miniblock-Spring

- **Implementation of every required deflection curve**
- **Low installation space**
- **Weight reduction (optimized material usage, light weight)**
- **Noise-elimination**
- **Comparison of different spring systems**

Implementation of every required deflection curve



R_{min} : start rate
R_{max}: end rate
R_{progr}: progressive rate
F_{PA}: force, start of progression
F_{PE}: force, end of progression
F_C: force close to solid length

The Ahle-Process allows to design springs with deflection curves with a range of rates up to 1:3!

Small Installation Space

315,00 mm

Small Installation Space

270,38 mm

Small Installation Space

248,08 mm

Small Installation Space

225,77 mm

Small Installation Space

203,46 mm

Small Installation Space

181,15 mm

Small Installation Space

158,84 mm

Small Installation Space

136,53 mm

Small Installation Space

114,23 mm

Small Installation Space

Please...

91,92 mm

Small Installation Space

give...

69,61 mm

Attention to:

58,45 mm

here:

Solid length: 47,30 mm

=15% of free length L_0

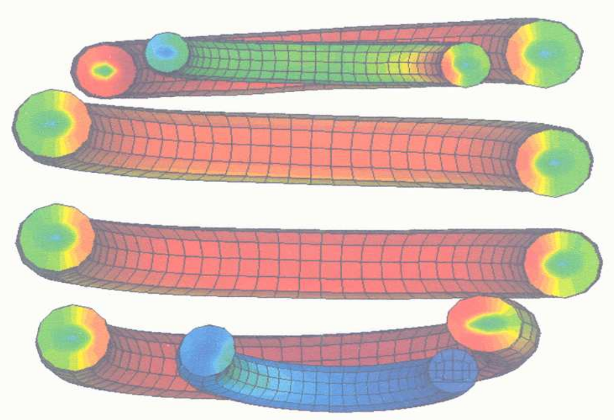
47,30 mm

315,00 mm

Light Weight:

Target: in every coil section exists a similar equivalent stress

Solution: The wire diameter has to be adapted to stress load within coil sections (different wire diameter)



FEM-Simulation

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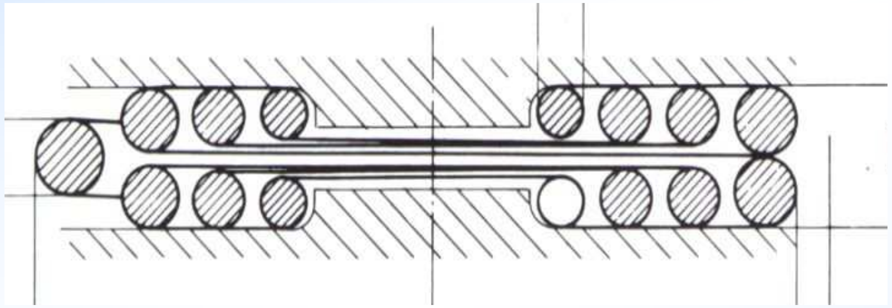
Noises / Corrosion



No coil-contact – no noise, no surface defects!

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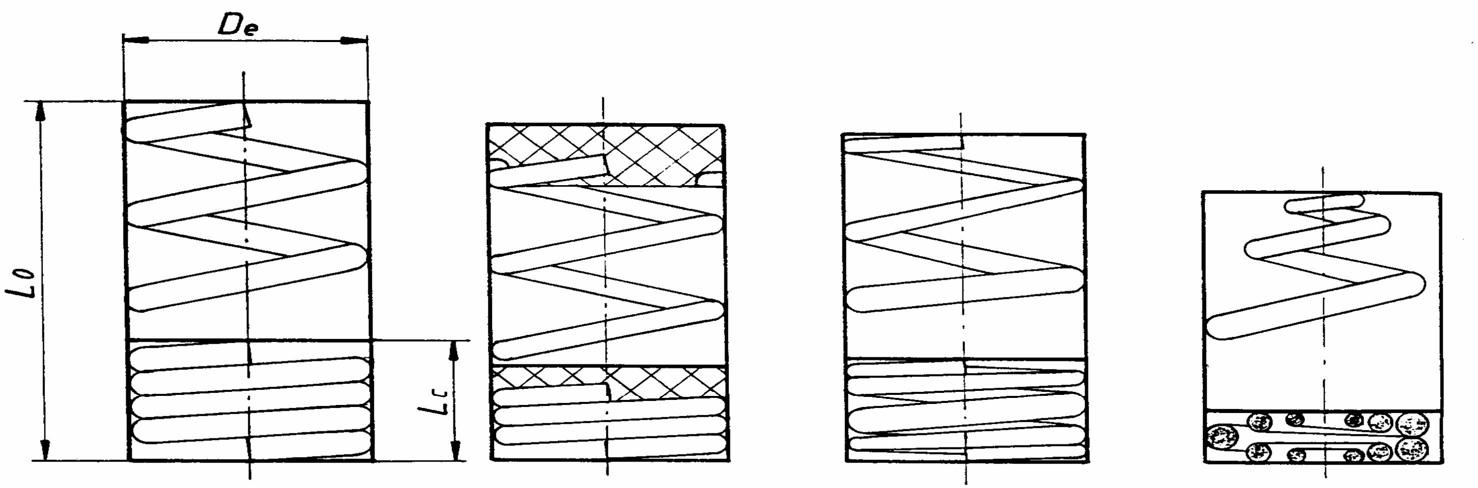
Comparison of Spring Types Concerning to One Reference



Cylindrical spring	Cylindrical spring + helper spring	Cylindrical spring non-constant wire diameter	Miniblock-spring
Spring weight: 100%	**Spring weight:64 %** (without helper spring!)	**Spring weight: 74 %**	**Spring weight: 57 %**

The Miniblock-spring is designed as the physical best light weight spring and has in addition a very small solid lenght

5. Comparison:

Steel spring – Pneumatic Suspension System

Complexity of Pneumatic Suspension Systems

- Spring-Damper-Systems (Pneumatic Suspension)
- Electrical driven compressor
- Pressure tank
- Electronical control unit
- Level sensors (axles)
- Acceleration sensors at wheel suspensions

but:

progressive steel spring solution consits of only one component!

Fundamental Comparison of Spring-Systems

Properties	Steel Spring with progressive deflection line	Pneumatic Suspension System
Time Response Characteristic	**ooo**	**oo**
Reliabiliy Durability	**ooo**	**??**
Practicable Progression Rate	**ooo**	**oo**
Length of Deflection	ooo	ooo
Resonance Frequency	oo	oo
Variation of distance of car-body and ground	**----**	**ooo**
Manufacturing costs	**ooo**	**----**
Design of characteristic line	ooo	ooo
Weight of System	**ooo**	**----**
Energy Requirement	**ooo**	**----**
Maintenance	**ooo**	**??**
Stabilizing Control	**----**	**ooo**
Recycling	**ooo**	**o**

Legend:

ooo
Excellent

oo
good

o
satisfactory

Less good

??
No results availlable

6. Summary

Summary

A Progressive Helical Compression Spring with Non-Constant Wire Diameter Leads to Following Conditions:

- an optimized material use
- very low weight
- a low required installation space
- noise elimination
- high progression with only one component
- an economical und low-maintenance solution

Thank you very much for your attention!

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