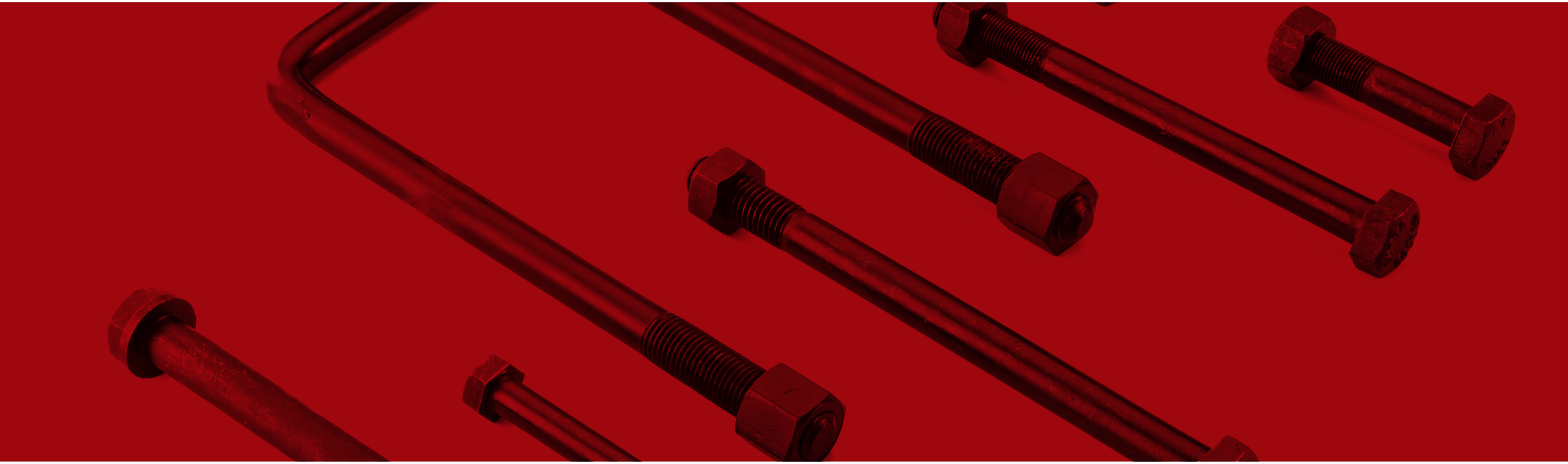
Steels for Cold Formed Parts without Heat Treatment



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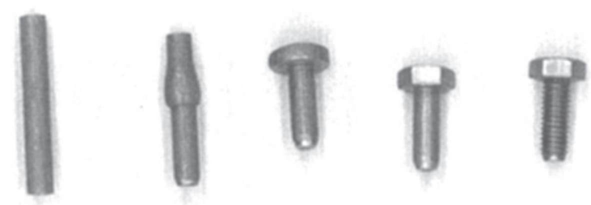
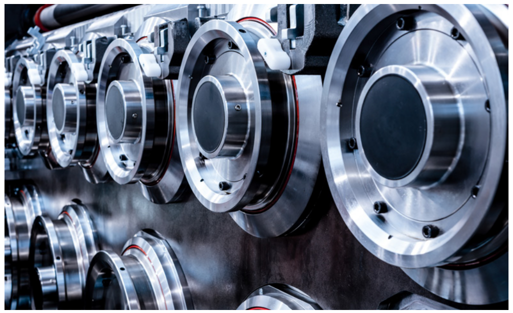
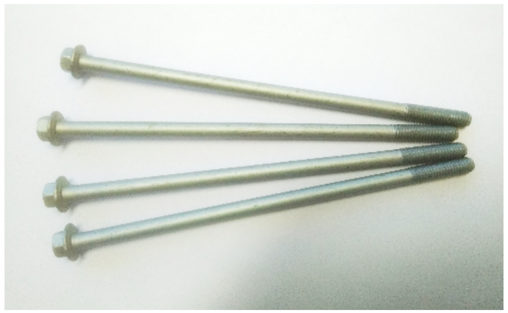
Conventional Process



Hot Rolling → Spheroidizing Annealing → Cold Heading → Quenching & Tempering → Straightening → Fastener





Technical Challenge: Slender Bolts

- Quenching and tempering of **slender long bolts** is particularly challenging, due to distortions. A subsequent straightening is compulsory, what extends the **leadtime**, increases the number of **rejected parts** and the **scattering** of properties between bolts with different straightening deformation
- Fortunately, there are **technological solutions** that skip quench and tempering, but achieve the mechanical properties of grade 8.8

Alternative Processes

- **Deformation hardening** (equivalent reduction 30-60%) of a **microalloyed** steel thermomechanically hot rolled

Thermomechanical Hot Rolling

Spheroidizing Annealing

High Deformation Cold Forging

Quenching & Tempering

Straightening

Fastener

- **Cold forming of a quench and tempered wire rod** of a low carbon steel **(DUCTIL)** with high ductility

Hot Rolling + Direct Quench + Tempering

Spheroidizing Annealing

Cold Forging

Quenching & Tempering

Straightening

Fastener

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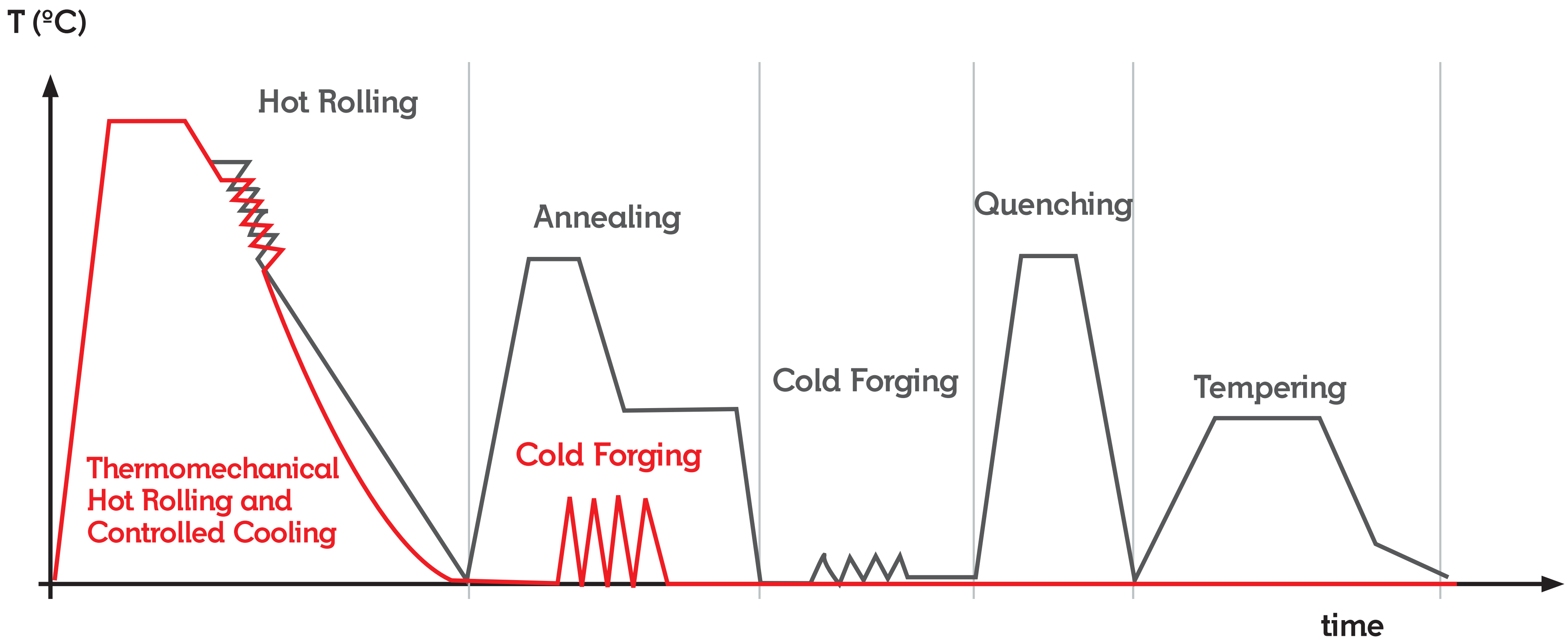
MICROALLOYED Steels

Ferrite-Pearlite Steel with High Ductility

Microalloyed Steels are...

- Low-medium carbon steels that, by microalloying and thermomechanical hot rolling, can be cold forged to achieve the properties required for grade 8.8 fasteners.



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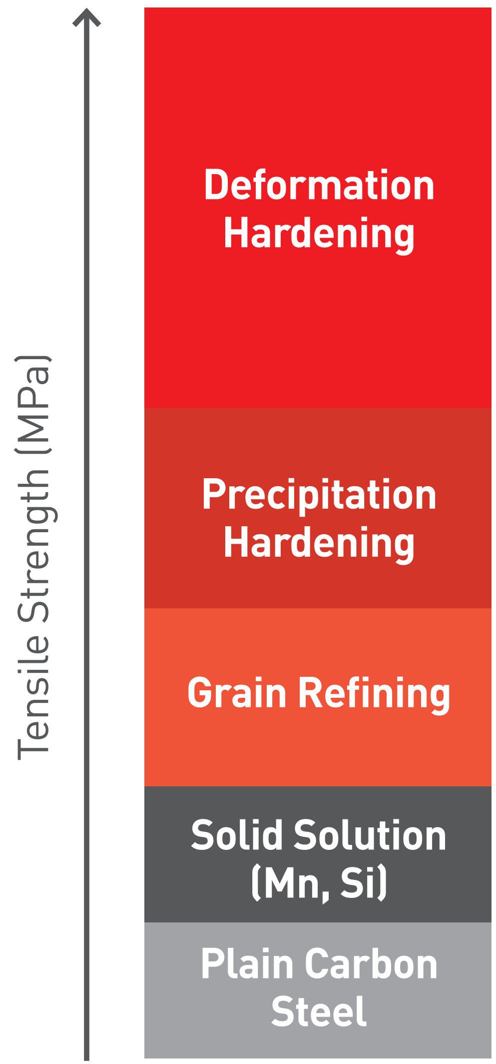
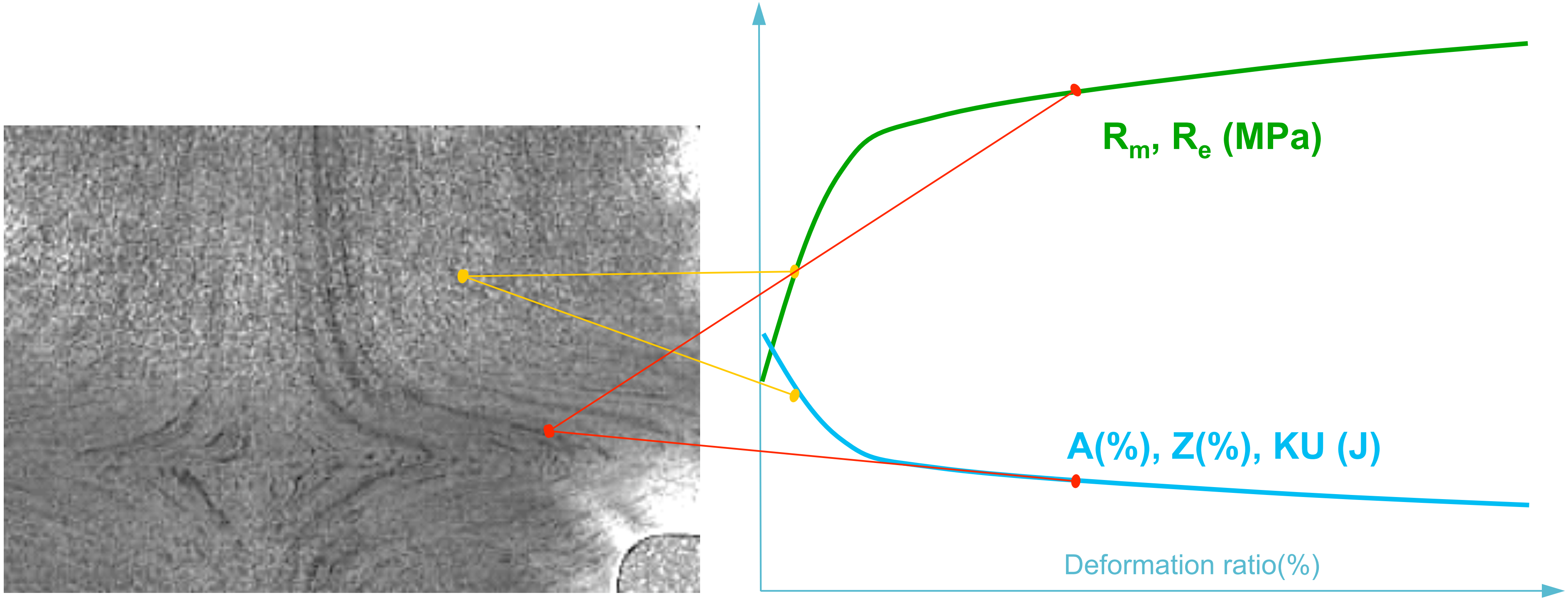
Hardening Mechanisms in Steels

- The tensile strength of an alloyed steel of a certain carbon content can be increased by...
  - Grain size refinement
  - Precipitation of carbonitrides of microalloying elements (B, Ti, V, Nb)
  - Plastic deformation
- A **high deformation** during **cold forging** allows rising noticeably the yield and tensile strength looking out:
  - As much homogeneous deformation as possible between extruded and stamped zones
  - A narrow scatter of metallurgical and mechanical properties in the as-rolled wire rod



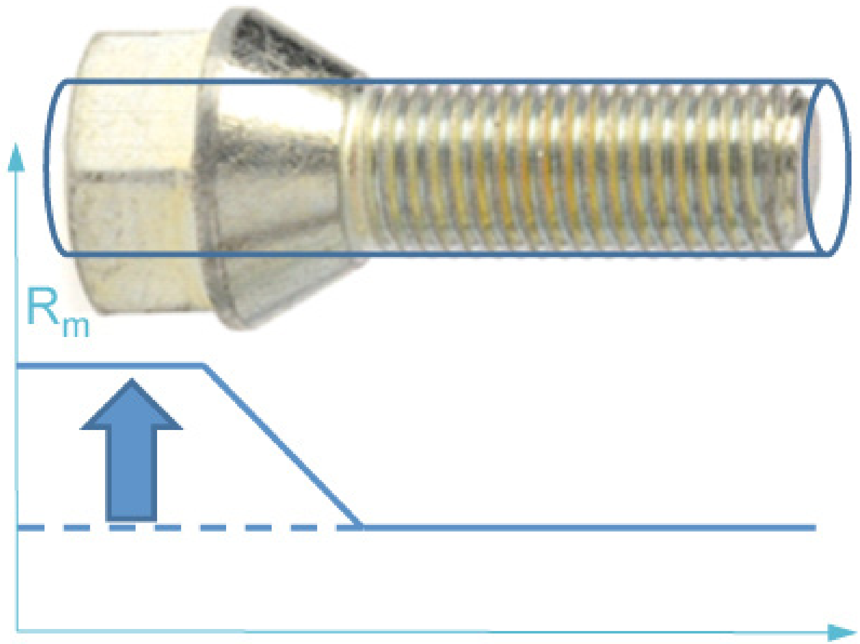
Effect on the Mechanical Properties

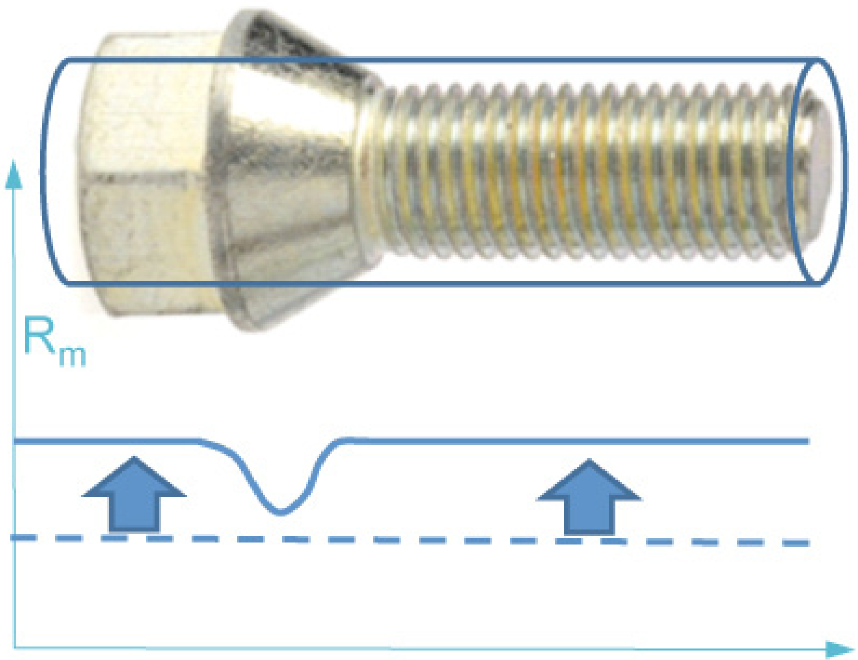
- Deformation Hardening leads to:
  - An equivalent ductility loss
  - Heterogeneity of mechanical properties between areas with very different deformation ratios



Adjustment of Forging Process

- The current forging process generates great hardness divergences in areas with dissimilar deformation ratios
- An adequate balance of deformation, wire rod diameter and equilibrated mechanical features of the raw material allow minimizing the scattering of bolt properties





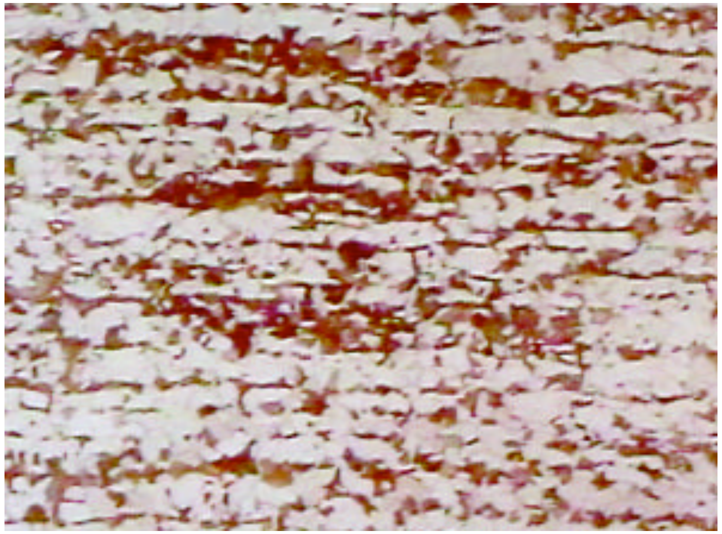
Direct-Use 20MnB5 for Grade 8.8

- Microalloyed steel with high ductility ferrite-pearlite suitable for grade 8.8 after a 30-60% plastic deformation

C	Mn	Si	P	S	Al	B
0,15	0,8	0,15	-	-	-	0,0010
0,25	1,5	0,5	0,03	0,03	0,05	0,0060

Rm (MPa)	Z (%)	A (%)	Hardness (HB)
≤ 700	≥ 65	≥ 25	≤180

Mechanical properties and microstructure in as-supply condition



24MnV6 for Grade 10.9

- Microalloyed steel with high ductility ferrite-pearlite suitable for grade 10.9 when ε>30%

C	Mn	Si	P	S	Al	V	Ti
0,2	1	0,25	-	-	-	0,08	-
0,28	1,6	0,75	0,03	0,03	0,05	0,15	0,005

- Nevertheless, fastening standard introduces some restrictions at the grades 10.9 and upper that limit the use of deformation-hardened steels to special applications (under particular agreements between supplier and end user)

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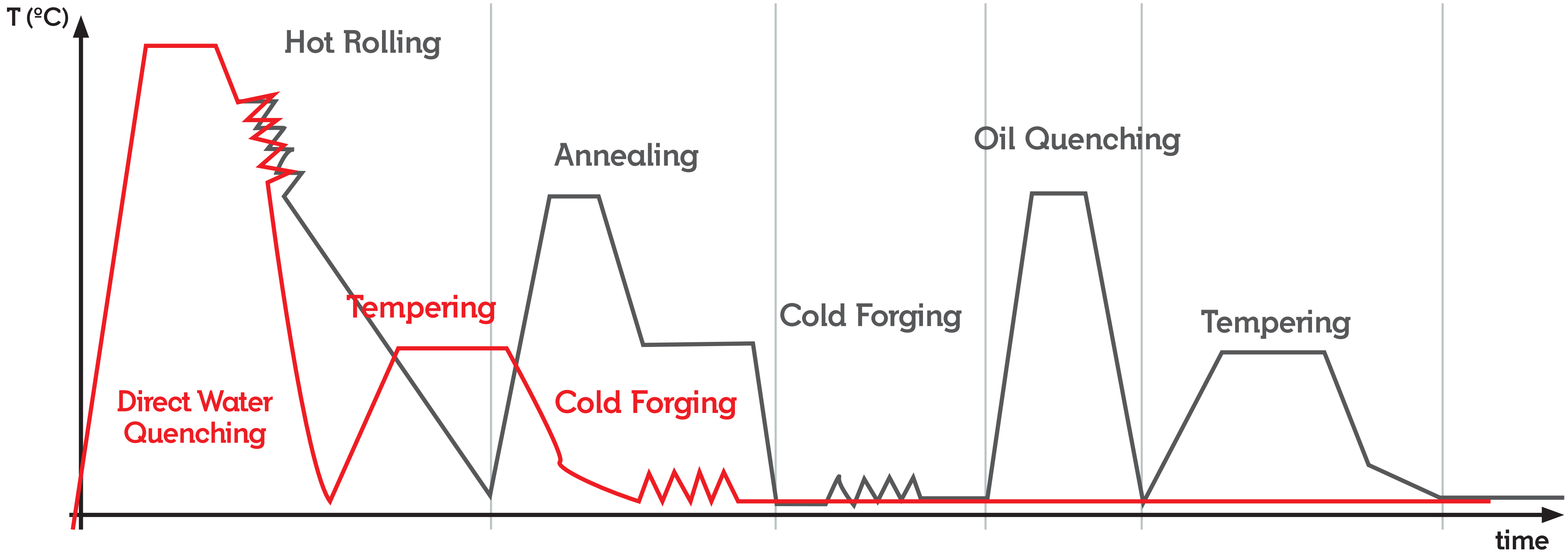
DUCTIL Steels

Cold Formable Quenched & Tempered Low Carbon Steels

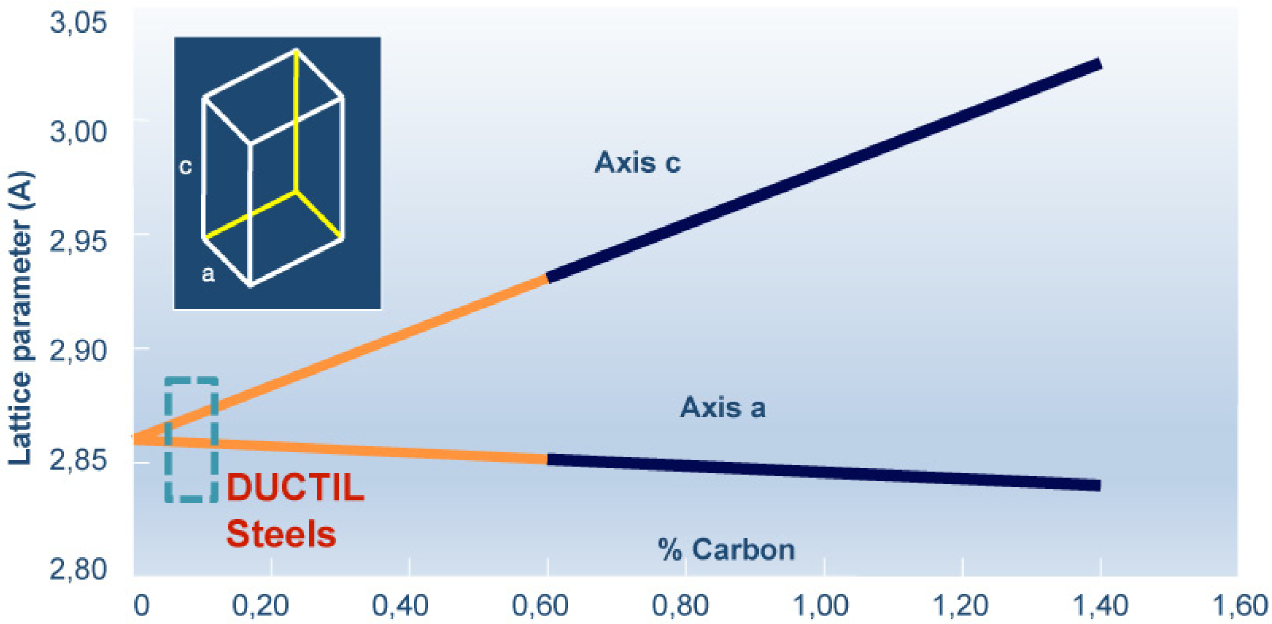
Pre-treated Steels

- Low carbon cold formable tempered-martensitic steels
- Quench and tempering are carried out on the wire rod, therefore final mechanical properties are achieve at the raw material
- Final microstructure is tempered martensite



Ductile Low Carbon Martensite

- Lowering carbon content, the tetragonal lattice of martensite distorts less, leading to a microstructure of a **ductile, deformable cubic martensite**



Chemical Composition

- A balanced alloying makes DUCTIL steels able to be direct quenched and ductile enough for cold forging, achieving grades 8.8 and 10.9 without subsequent heat treatment

DUCTIL80 (grade 8.8)

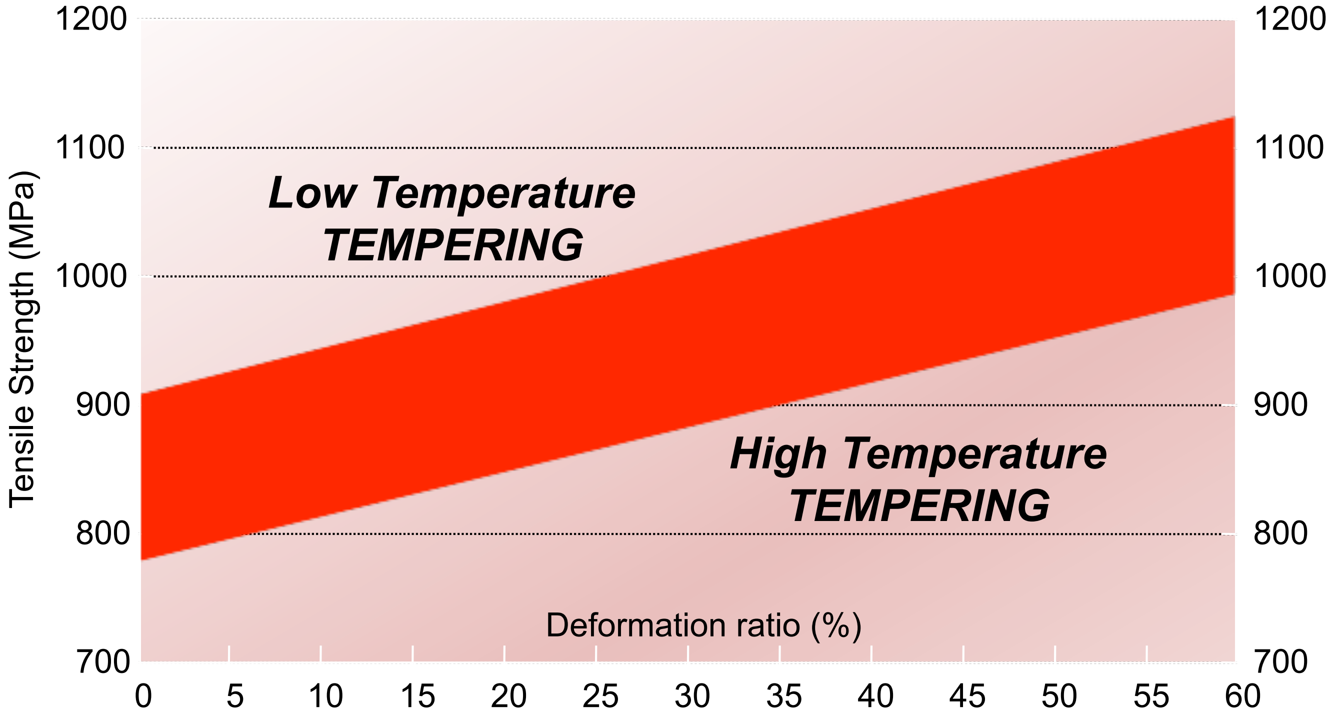
C	Mn	Si	Cr	Mo	Ti	Nb	B
0,04	1,3	0,2	-	-	-	-	-
0,12	1,8	0,4	0,5	-	0,04	0,05	0,003

DUCTIL100 (grade 10.9)

C	Mn	Si	Cr	Mo	Ti	Nb	B
0,05	1	0,1	-	-	-	-	-
0,2	2	1	0,8	0,2	0,05	0,08	0,004

Adjustment of Properties by Wire Rod Tempering

- Depending on the reduction ratio applied during cold forging, it is possible to tune the wire rod strength to attain the required properties for grade 8.8 fasteners



Wire Rod Online Quenching

- Low carbon steel can be quenched directly after hot rolling in a water cooling bed, obtaining a microstructure of cubic martensite, ductile and cold formable
- Subsequent tempering allows to obtain the desired strength and ductility levels
- Pretreated wire rod shows a microstructure of tempered martensite and about 800MPa of UTS

DUCTIL80 – Wire Rod Features

- Microstructure: Tempered Martensite
- Mechanical Properties:

UTS (MPa)	RofA (%)	Upsetting
>800	>65	>1/4

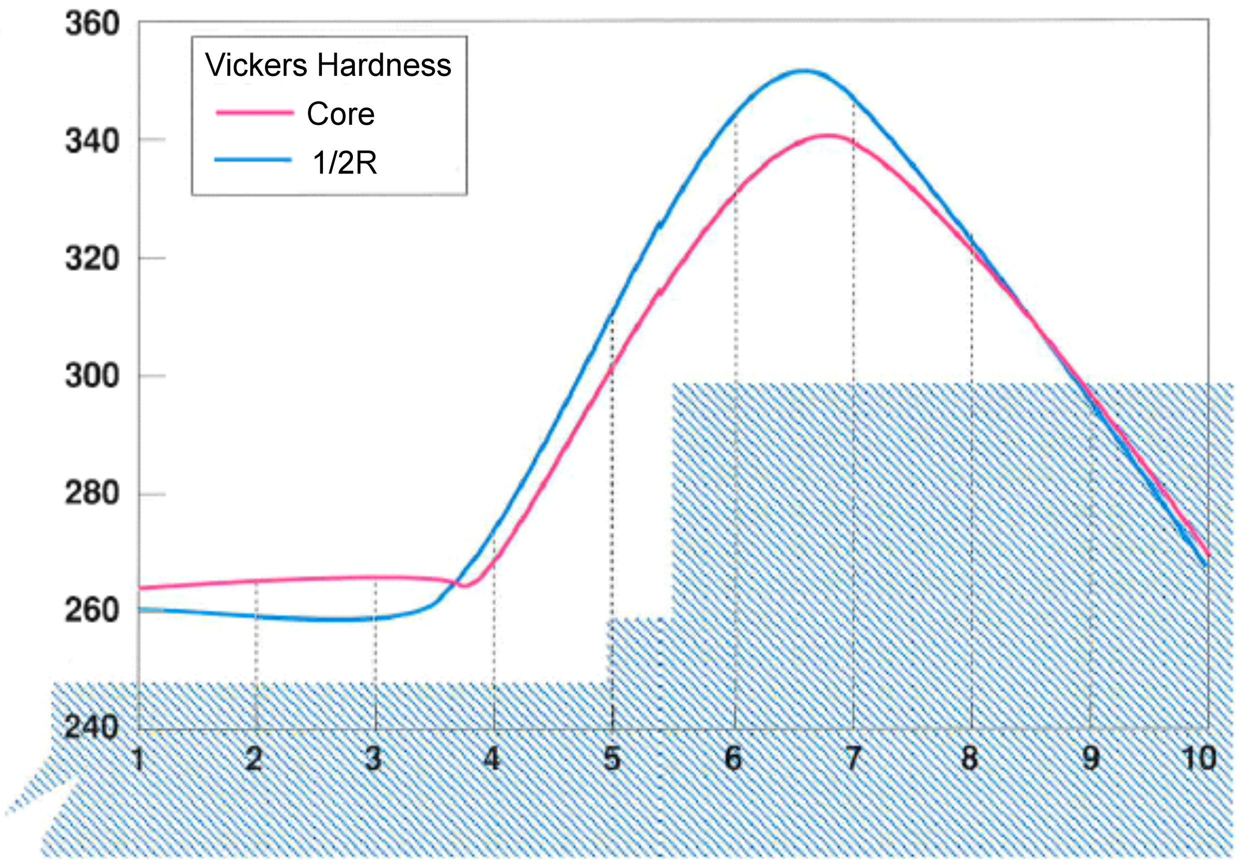
- Cleanliness:

Jerkontoret	Fine	Coarse
A	1,5	1,5
B	1,5	1,5
C	1	1
D	2	1,5

- Tolerances: Ø 5,5-15 (±0,2)
- Surface Quality:
  Defects below 0,03mm (Ø<10)/0,04mm (Ø>10)
- Descarburizing:
  - Total: nil
  - Partial: 0,06mm (Ø<10) and 0,08mm (Ø>10)

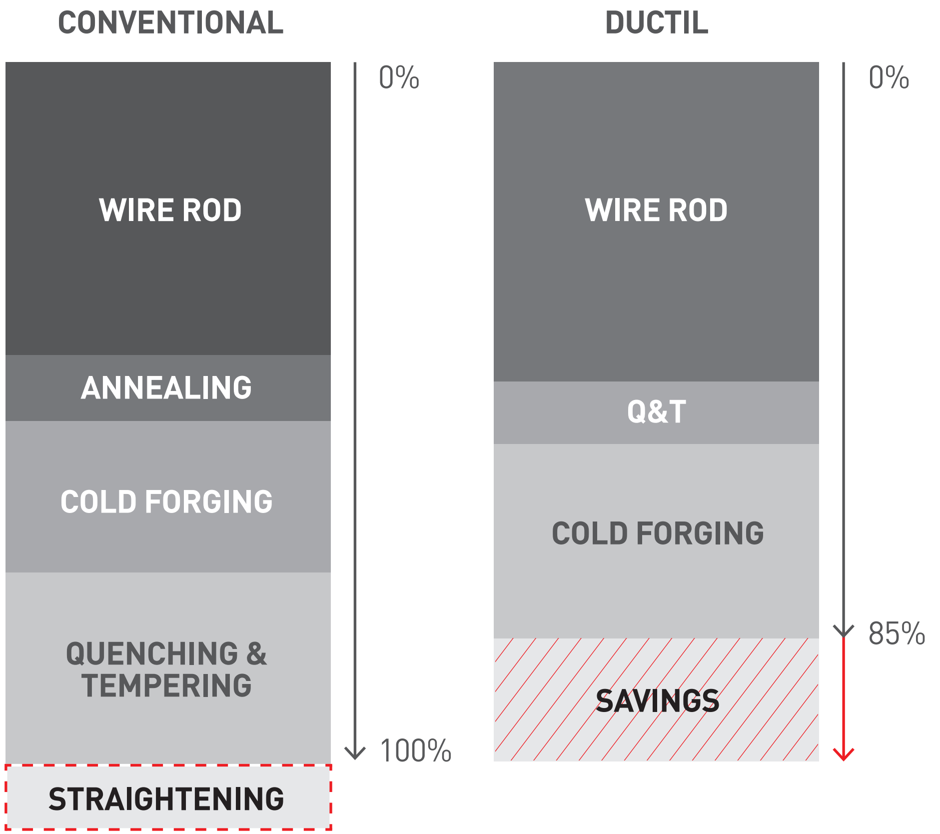
Fastener Forging

- Skin-pass, extrusion and cold heading increase fastener hardness and strength, but fit requirements of standard EN20898



Head hardness (HB)	280-310
Shank hardness(HB)	235-280
Axial Strength (MPa)	800-910
Wedge Strength (MPa)	800-890
Toughness Shank/Head	No cracks

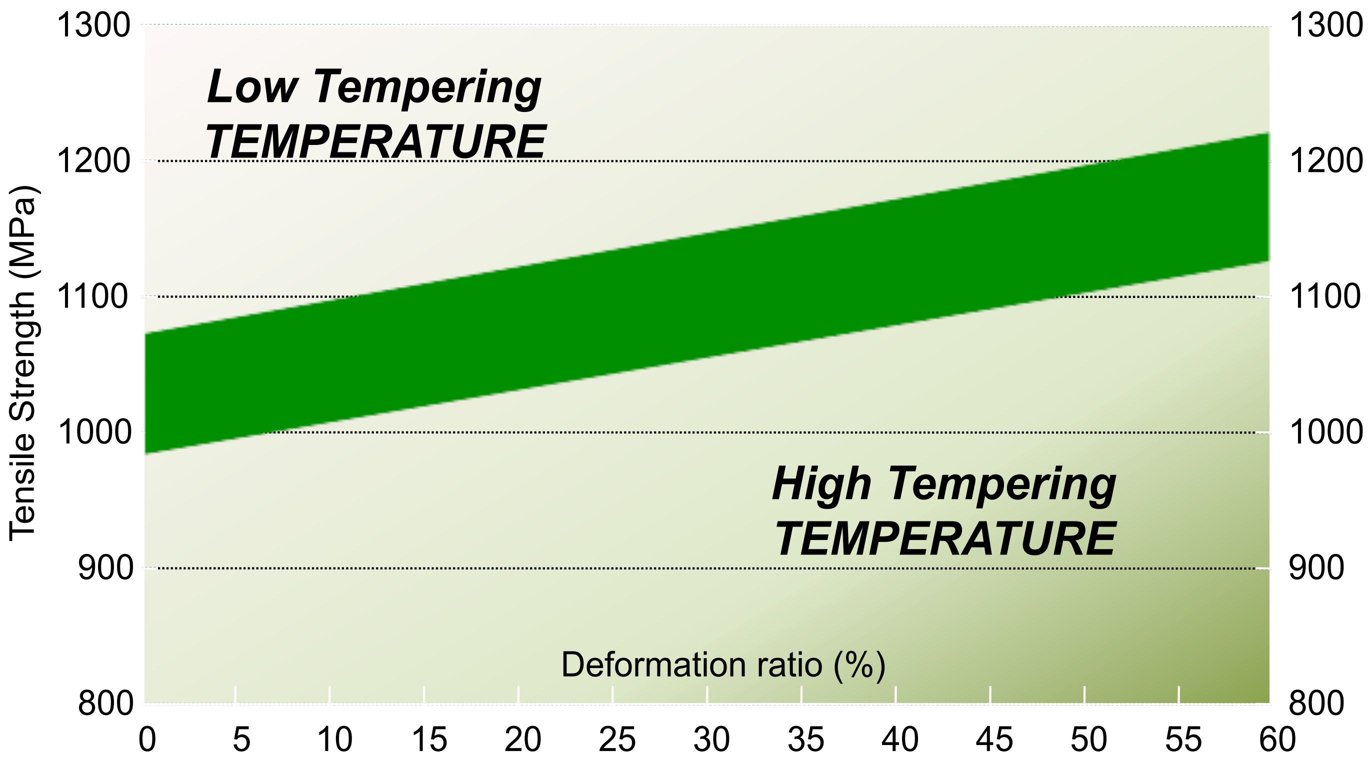
Cost Savings



- Final heat treatment is avoided when DUCTIL steels are used, keepong a microstructure of tempered martensite
- As forged parts are not quenched, distortions are also avoided, particularly in slender bolts
- A **total saving of 15%** is estimated

DUCTIL 100 – Q&T Wire Rod Features

- A higher carbon and alloy content allows DUCTIL100 achieving properties required by grade 10.9 fasteners



Pros and Cons of Direct Use steels

PROS	CONS
• Ability to manufacture **long slender parts** with final straightening • **Cost savings** • **Reduction of operations** and simplification of the manufacturing chain • **Lower process time**	• **Higher heterogeneity** of properties • **Higher tool wear** • **Higher forging stresses** • Lower residual ductility • Higher susceptibility to hydrogen embrittlement

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