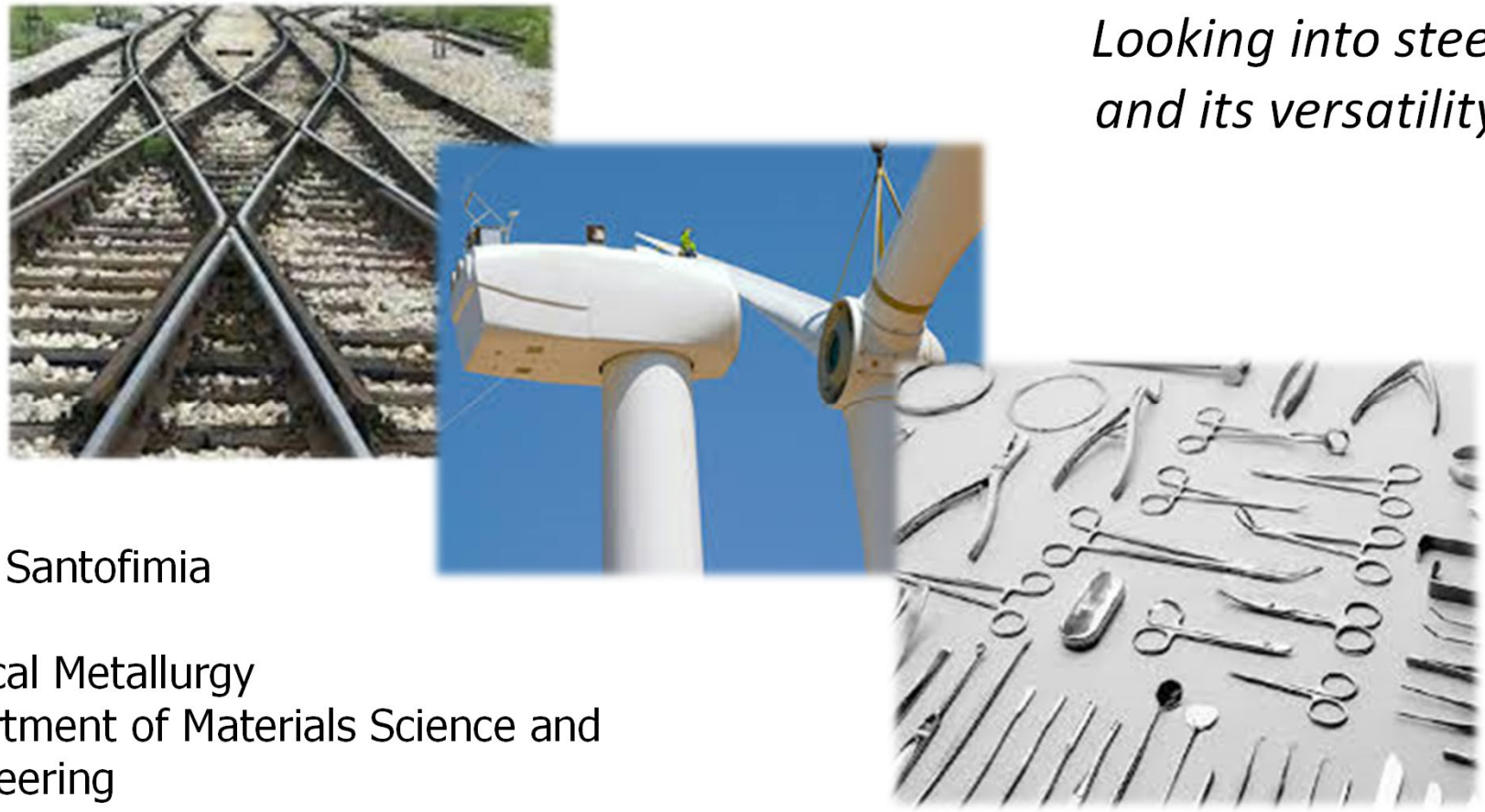


Looking into steel and its versatility

Maria Santofimia

Physical Metallurgy
Department of Materials Science and Engineering

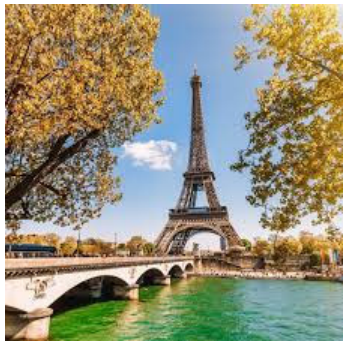
Overview of steels and applications

How many commercial grades of steel?

- 35
- 350
- → 3500

Approximately 75% of currently applied steels have been developed in the past …

- …200 years
- …50 years
- → …20 years



If the Eiffel Tower were to be rebuilt today, the engineers would only need 1/3 of the steel that was originally used in 1889.

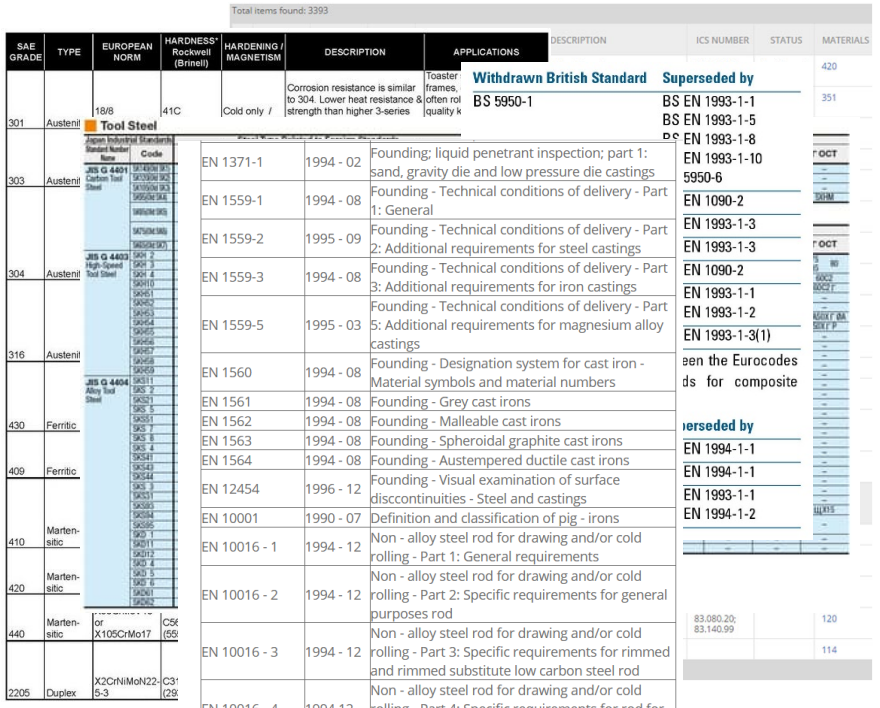
https://worldsteel.org/about-steel/about-steel/

Overview of steels and applications

With so many steel grades and applications, how to provide an overview?

Grading systems

DIN ASTM GOST AISI/SAE JIS AFFNOR UNI EN BS



SAE GRADE	TYPE	EUROPEAN NORM	HARDNESS Rockwell (Brinell)	HARDENING / MAGNETISM	DESCRIPTION	APPLICATIONS
301	Austenit	18/8	41C	Cold only /	Corrosion resistance is similar to 304. Lower heat resistance & strength than higher 3-series	Toaster frames, often rol quality k
		Tool Steel				
303	Austenit					
304	Austenit					
316	Austenit					
430	Ferritic					
409	Ferritic					
410	Marten-sitic					
420	Marten-sitic					
440	Marten-sitic	or X105CrMo17				
2205	Duplex	X2CrNiMoN22-5-3				

EN 1371-1	1994 - 02	Founding; liquid penetrant inspection; part 1: sand, gravity die and low pressure die castings
EN 1559-1	1994 - 08	Founding - Technical conditions of delivery - Part 1: General
EN 1559-2	1995 - 09	Founding - Technical conditions of delivery - Part 2: Additional requirements for steel castings
EN 1559-3	1994 - 08	Founding - Technical conditions of delivery - Part 3: Additional requirements for iron castings
EN 1559-5	1995 - 03	Founding - Technical conditions of delivery - Part 5: Additional requirements for magnesium alloy castings
EN 1560	1994 - 08	Founding - Designation system for cast iron - Material symbols and material numbers
EN 1561	1994 - 08	Founding - Grey cast irons
EN 1562	1994 - 08	Founding - Malleable cast irons
EN 1563	1994 - 08	Founding - Spheroidal graphite cast irons
EN 1564	1994 - 08	Founding - Austempered ductile cast irons
EN 12454	1996 - 12	Founding - Visual examination of surface disccontinuities - Steel and castings
EN 10001	1990 - 07	Definition and classification of pig - irons
EN 10016 - 1	1994 - 12	Non - alloy steel rod for drawing and/or cold rolling - Part 1: General requirements
EN 10016 - 2	1994 - 12	Non - alloy steel rod for drawing and/or cold rolling - Part 2: Specific requirements for general purposes rod
EN 10016 - 3	1994 - 12	Non - alloy steel rod for drawing and/or cold rolling - Part 3: Specific requirements for rimmed and rimmed substitute low carbon steel rod
EN 10016 - 4	1994 12	Non - alloy steel rod for drawing and/or cold rolling - Part 4: Specific requirements for rod for special applications
EN 10020	1995 - 12	Definition and classification of grades of steel

DESCRIPTION	ICS NUMBER	STATUS	MATERIALS
Withdrawn British Standard	Superseded by		
BS 5950-1	BS EN 1993-1-1 BS EN 1993-1-5 BS EN 1993-1-8 EN 1993-1-10 5950-6 EN 1090-2 EN 1993-1-3 EN 1993-1-3 EN 1090-2 EN 1993-1-1 EN 1993-1-2 EN 1993-1-3(1) een the Eurocodes ds for composite erseded by EN 1994-1-1 EN 1994-1-1 EN 1993-1-1 EN 1994-1-2		

https://en.wikipedia.org/wiki/Steel_grades

Steel wires

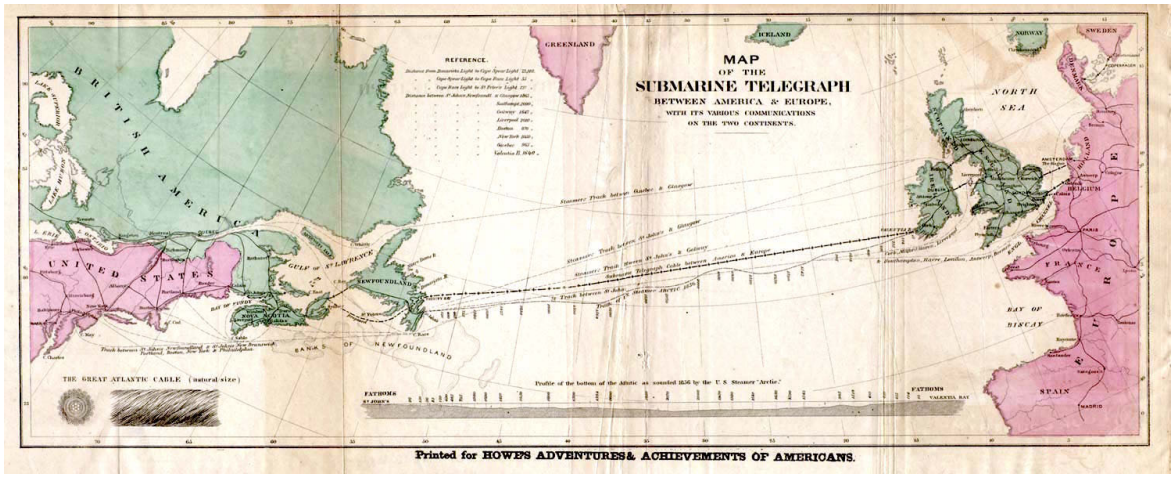
Rods / wire

Rope

Steel wires

1854, James Horsfall patented the heat treatment for wires.

"An improvement in the manufacture of wire for pianofortes and other musical instruments".



1858, heat treatment used for the first transatlantic telegraph cable.

Steel wires

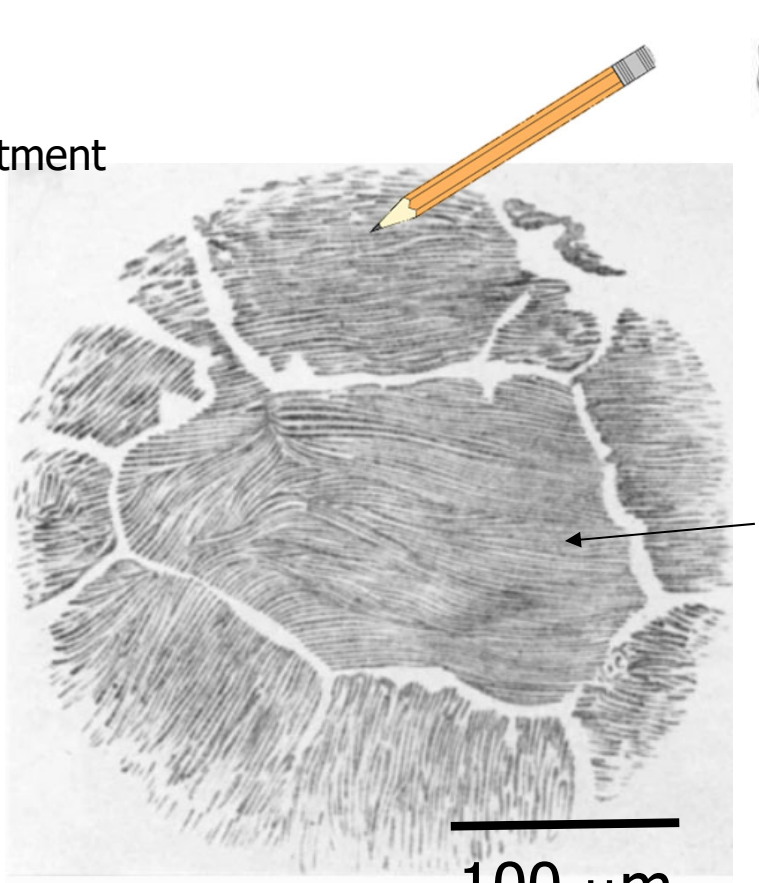
1854, James Horsfall patented the treatment for starting microstructure for wires.

Wires with 0.8 wt.% C, furnace 970 °C, then slow cooling.

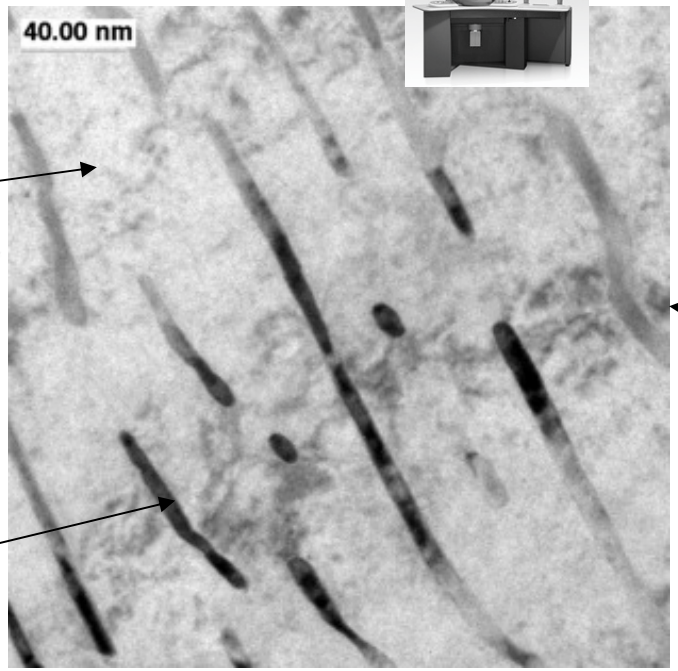
1863, Henry Clifton Sorby etches with acid a microstructure of steel for the first time to investigate it.

1886, Sorby observes and sketches **pearlite.**

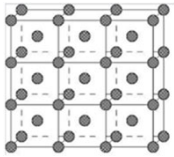
For 32 years, wires were used, but their microstructure was a mystery.



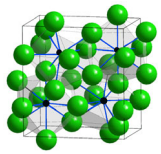
Steel wires

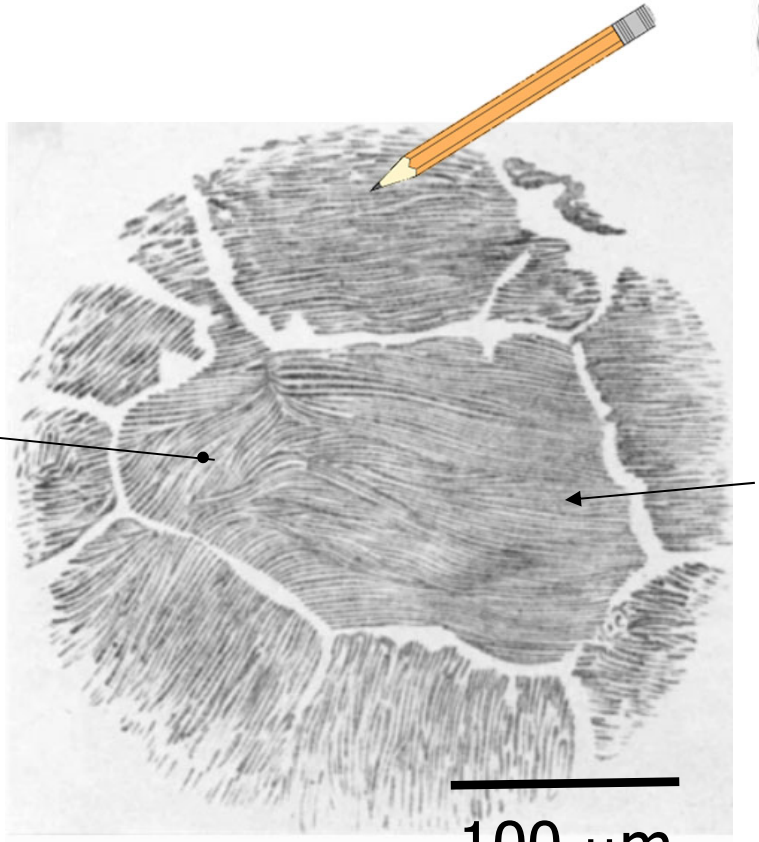


BCC



Fe_3C

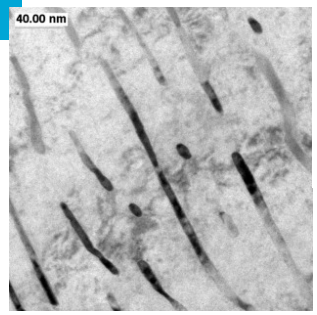




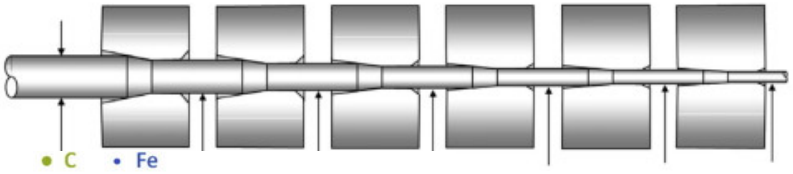
Pearlite

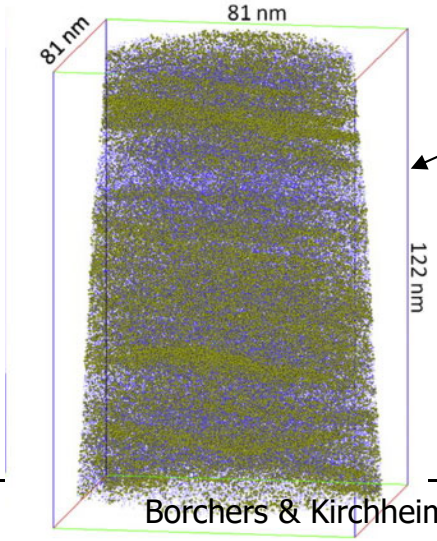
Steel wires

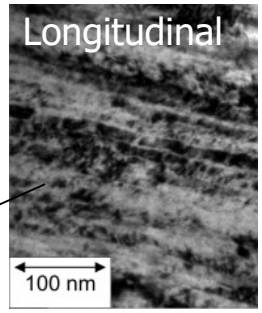
Wires are cold-drawn, leading to the strongest metallic bulk material.



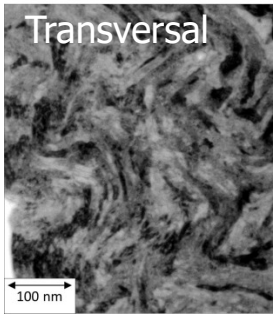
Starting pearlite microstructure







Reduction of interlamellar spacing
Changes in orientation



Bending of microstructure.
Fragmentation

Partial dissolution of Fe_3C ,
C enrichment of BCC.
Discussion continues...

Borchers & Kirchheim. Progress in Materials Science. 2016

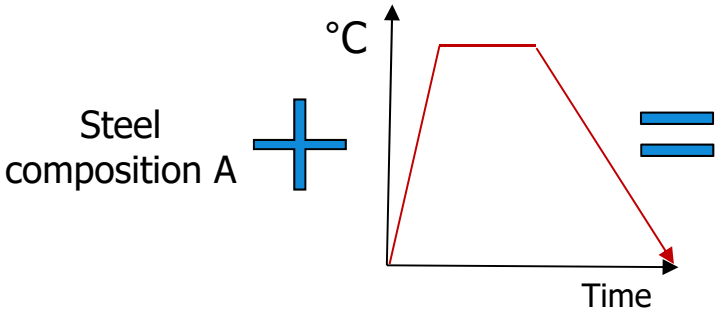
Steel wires

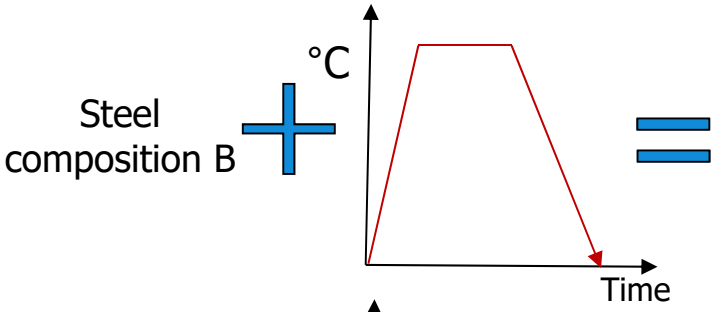
Not only engineering applications…

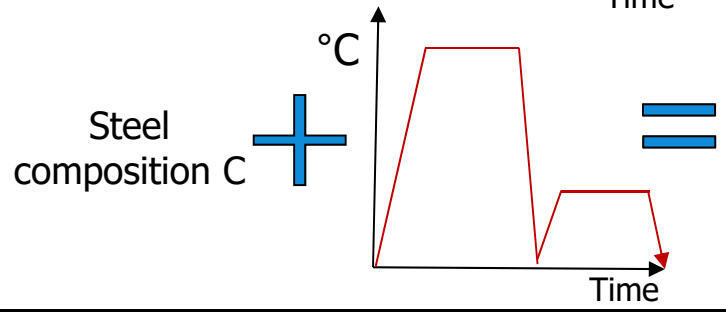
Steel bars

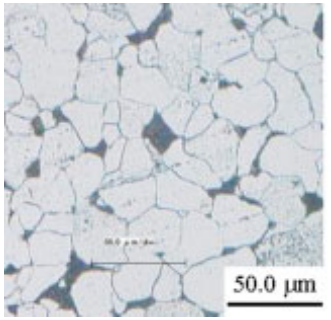
Bars do not have the right microstructure (nor shape)

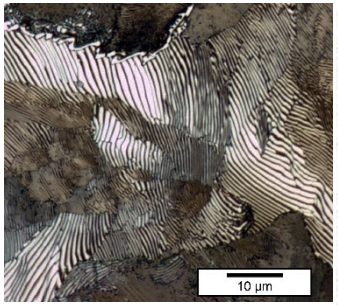
They must be thermo-mechanicallly treated.

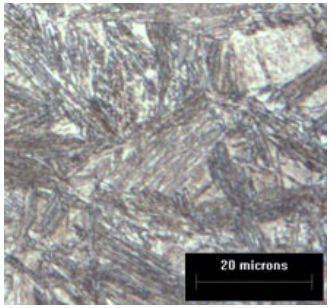




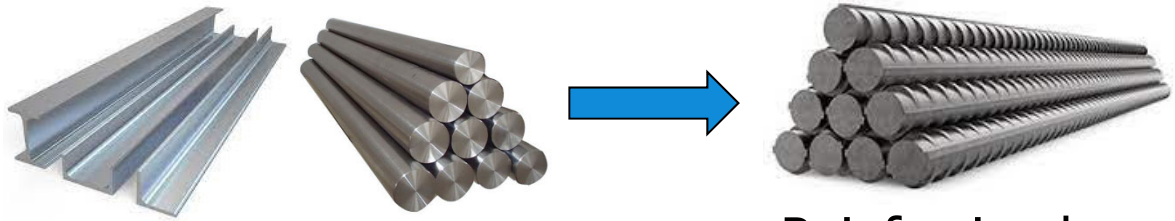




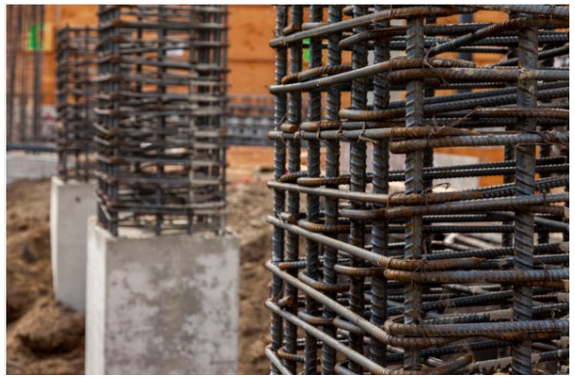




Steel bars in reinforced concrete

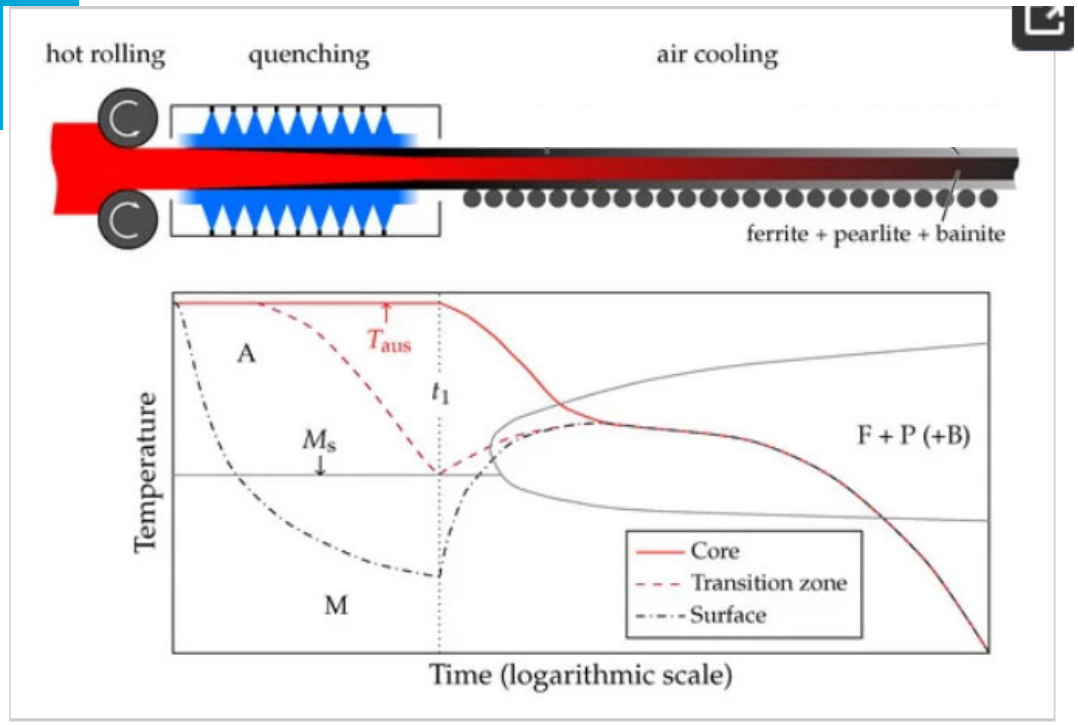


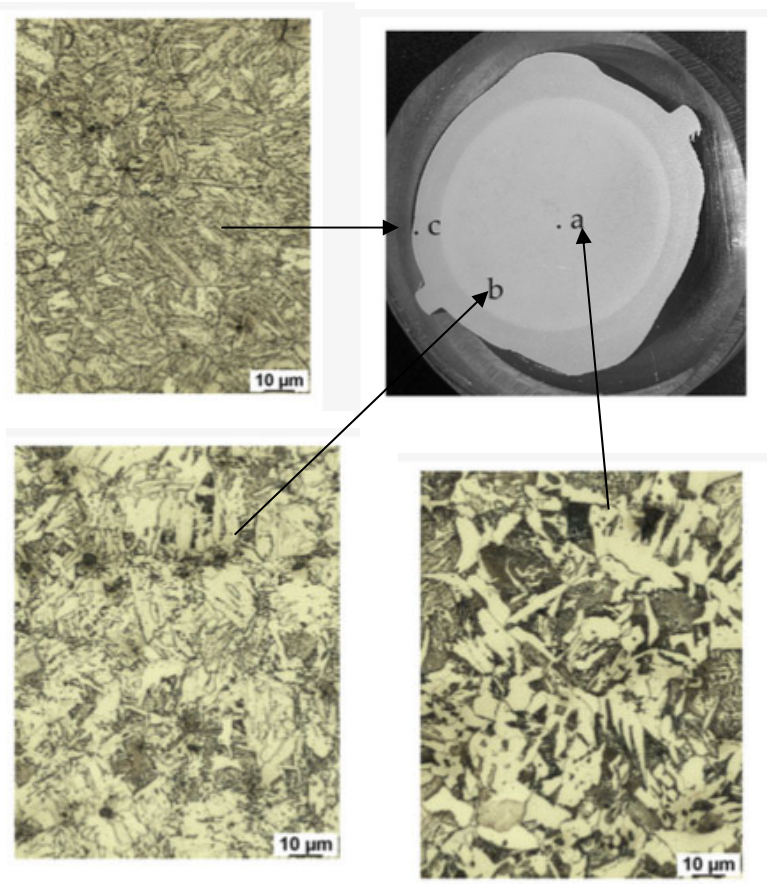
Reinforcing bars



- Strong in tension, compensating concrete compression.
- Indentations for better bond with concrete
- Similar coefficients of thermal expansion.
- Almost 100% recycled.
- Susceptible to rusting.

Steel bars in reinforced concrete

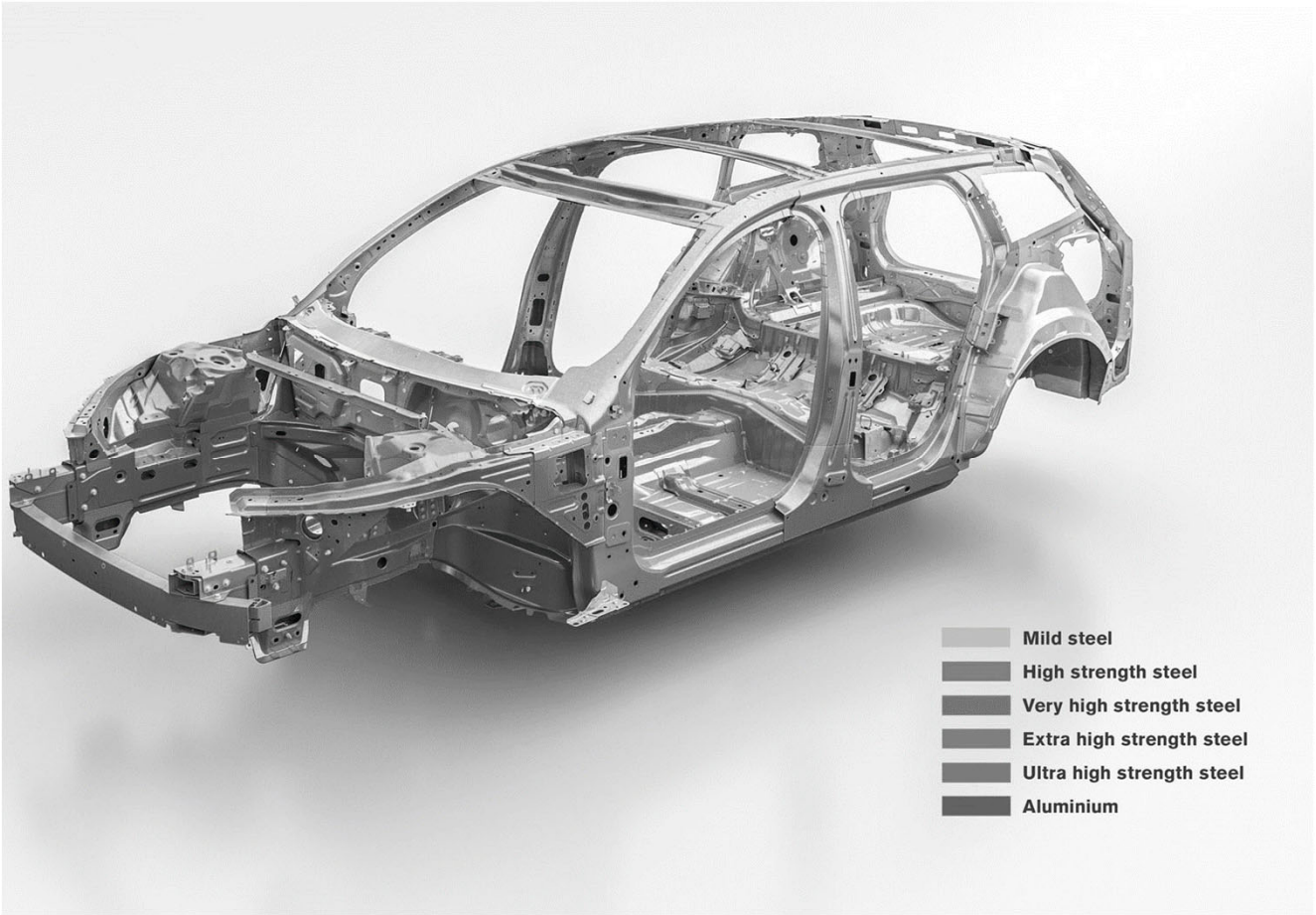




Hameed et al. Appl. Sci. 2021, 11, 550. B500B steel rebar 28 mm.

Flat steel

Flat steel

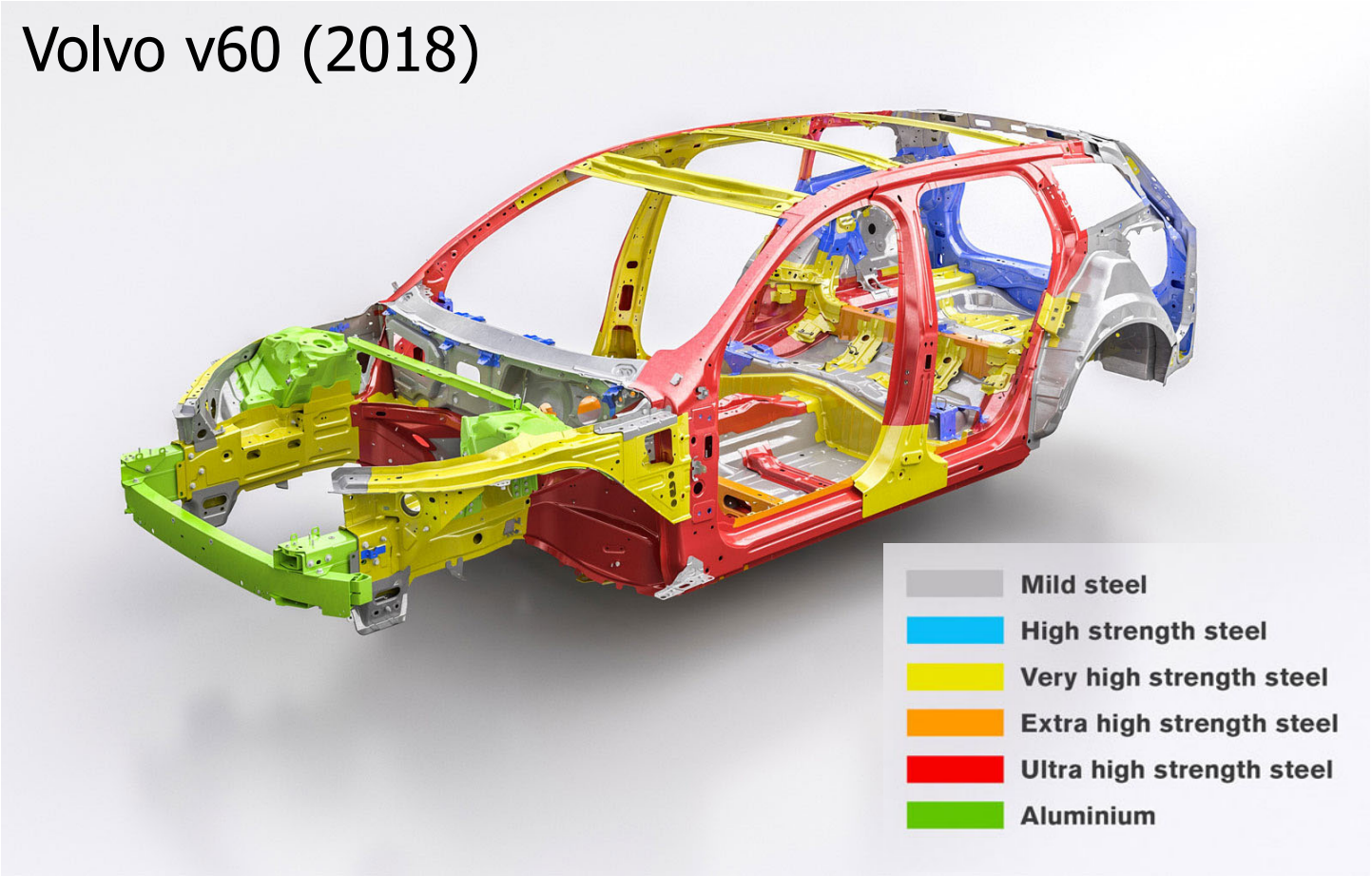

Mild steel
High strength steel
Very high strength steel
Extra high strength steel
Ultra high strength steel
Aluminium

Flat steel

Safety

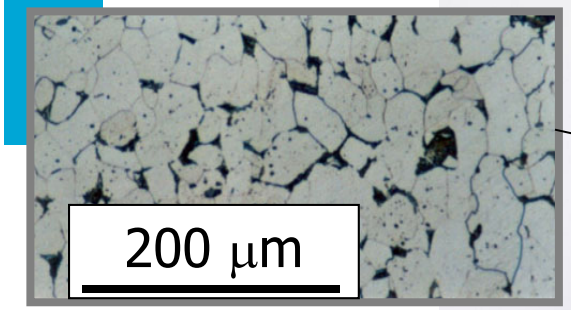
Light weight

Cost

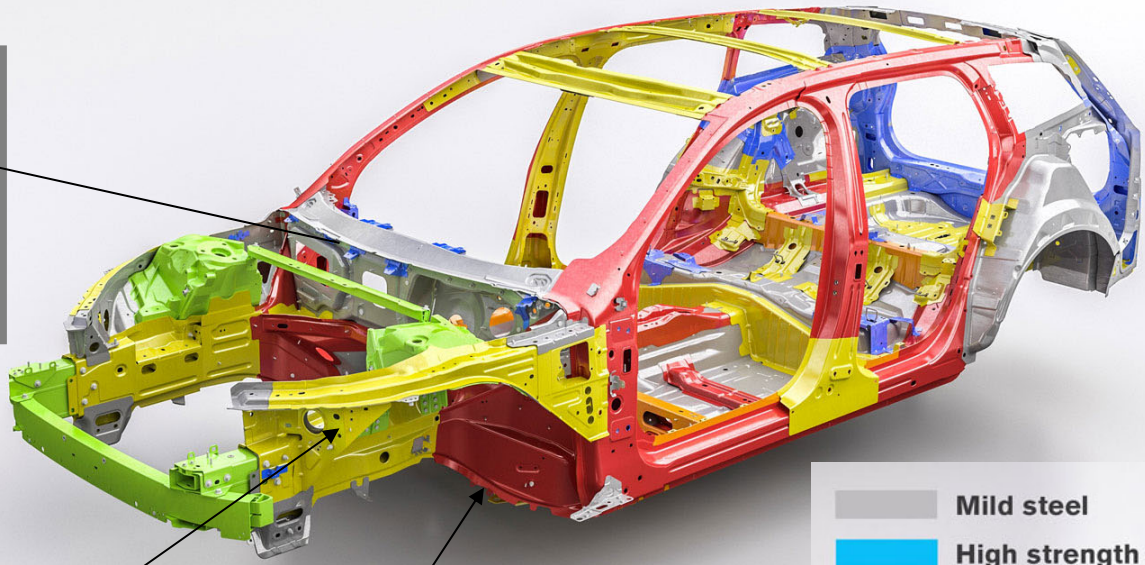


Flat steel

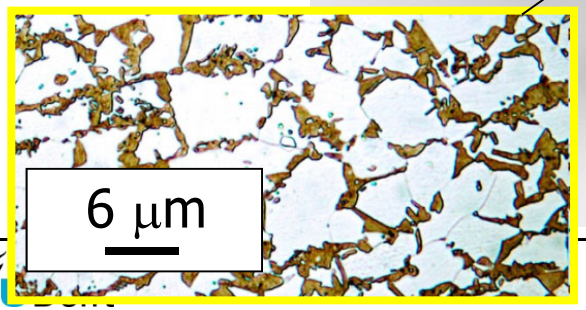
Volvo v60 (2018)



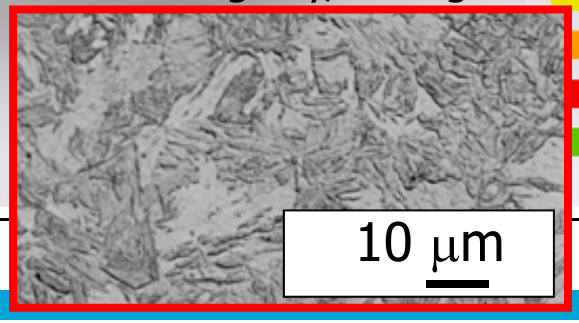
Surface quality, dent resistance



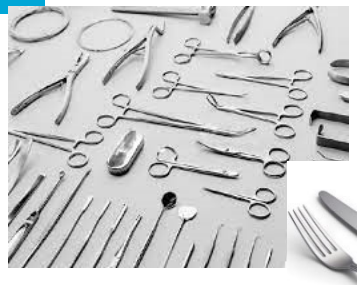
Impact resistance



Rigidity, strength



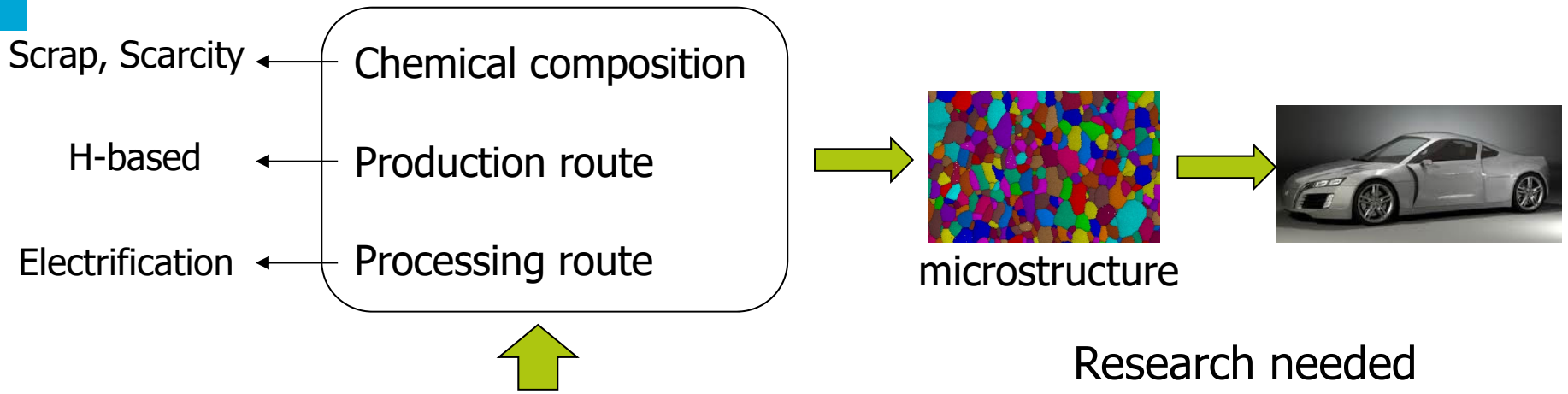
Other special steels



Stainless steels
vs
Weathering steels

Future challenges

1. Need of continuous development of microstructures for challenging applications.
2. Radical changes in steel production and processing.



Energy & materials transition
will affect these three

Research needed
Excellent expertise available

Thank you!!