Niobium

Niobium for advanced steel springs

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Contents

- Key properties of spring steels
- Benefits of Niobium
- Technical case studies

Spring steels

- Used in manufacture of springs for automotive and industrial suspension applications
- Often low-alloy manganese, medium-carbon steel or high-carbon steels used with a very high yield strength
  - Return to original shape despite significant deflection or twisting
- Development of Niobium microalloying techniques enable production of steels with
  - Better mechanical and fatigue resistance behaviour
  - Improved resistance to corrosion and hydrogen embrittlement

OEMs have competing requirements

- Modern automotive spring steels used in suspension need to balance a number of potentially conflicting properties

Large Elastic Area

High Fatigue Resistance

High Yield and Tensile Strength

High Toughness

Resistance to Impact and Overload

Good Formability

Relaxation (Sag) Resistance

Superior Surface quality

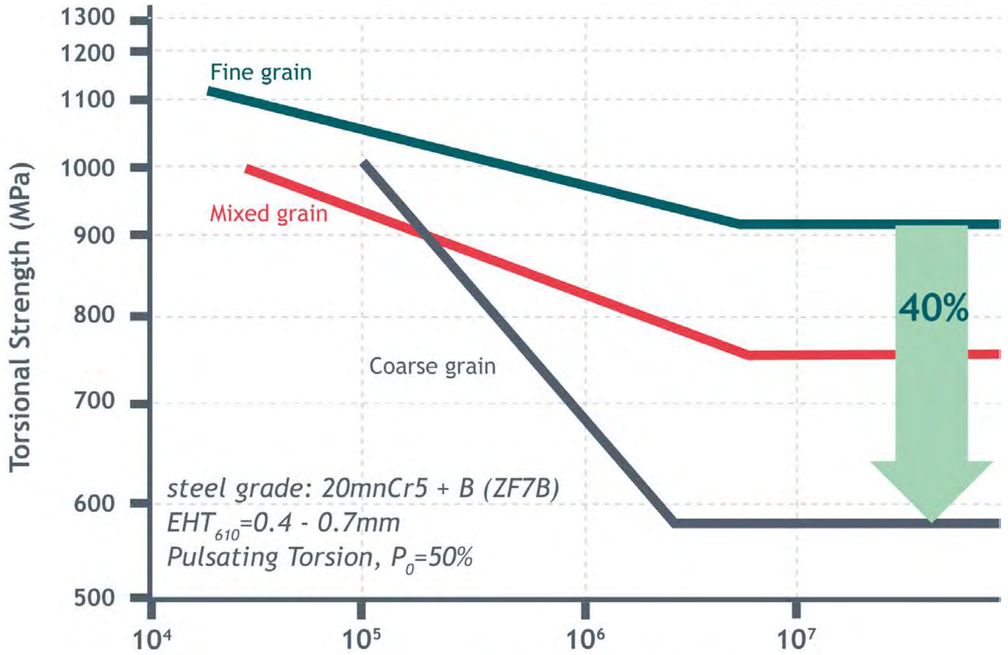
Trends in development of spring steels

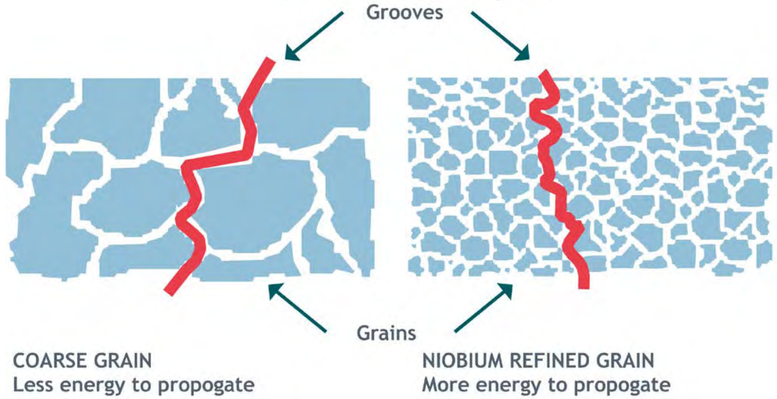
- Increase tensile strength to allow lightweighting in spring design
- Improve in-service performance by reducing sagging, fatigue, hydrogen embrittlement and corrosion fatigue
- Optimize heat and/or thermomechanical treatments in production to achieve:
  - Greater productivity
  - Better energy efficiency
  - Improved product performance
  - Reduced environmental impact

Conventional spring steels unable to meet these requirements without Niobium microalloying

Improving spring steels

- Steels with large grains are more likely to fail under stress
  - Cracks more likely to form
  - Once formed, cracks propagate more easily
- Niobium is a strong grain refining alloy
  - Prevents formation of large grains even at very high process temperatures
  - Ensures homogeneous microstructural phase distribution
  - Improves strength, toughness and fatigue resistance
  - Reduces tendency for hydrogen embrittlement to occur in extra high strength spring steels (see following slides)

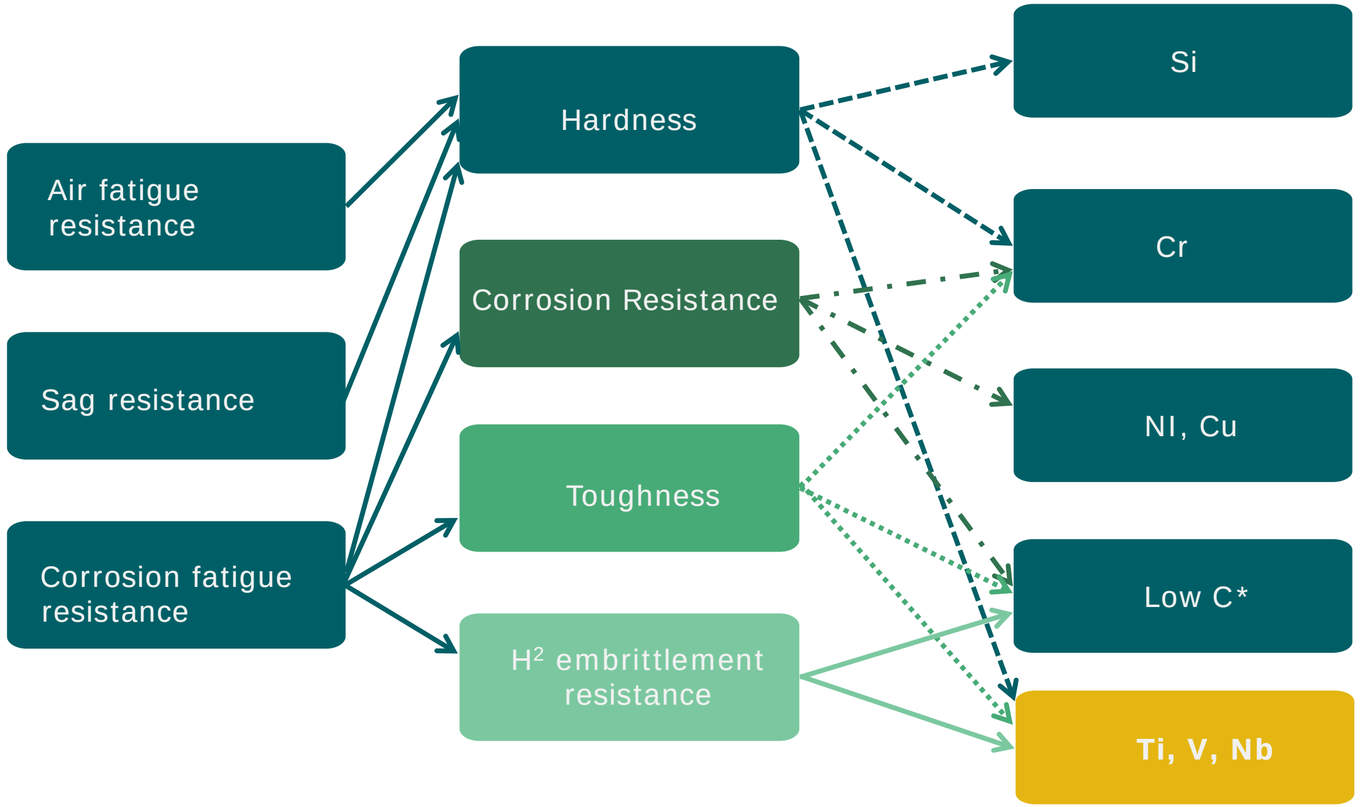




Hardy Mohrbacher, Reverse metallurgical engineering towards sustainable manufacturing of vehicles using Nb and Mo alloyed high performance steels, Advances in Manufacturing, Vol 1, N.1, p. 28-41, 2013.

Designing high strength spring steels with improved fatigue and corrosion resistance

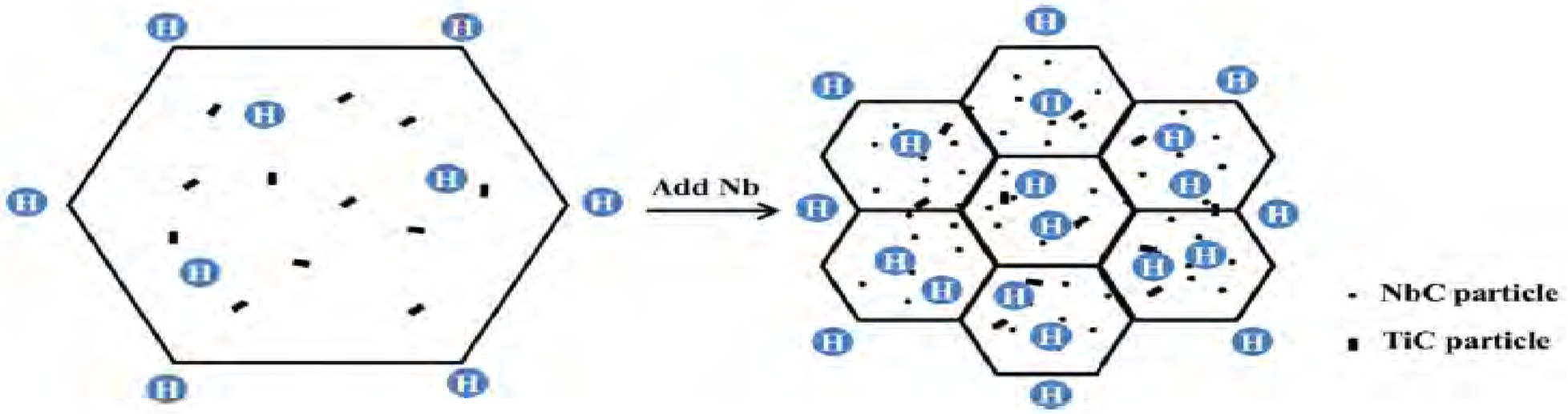
- Microalloying with Niobium provides the best combination of desired properties – hardness, toughness and resistance to hydrogen embrittlement
- Lower carbon levels in the microalloyed steel improves corrosion resistance
- Niobium addition compensates for the undesirable reduction in strength due to lower carbon



Source: Perrard, F.; Yoshihara N.; Mendibibe,C.; Ibaraki, N. "High Strength Spring steels with Improved Ductility and Corrosion Resistance" 2008, International Conference on Steels in Cars and Trucks (SCT) (Stahleisen GmbH) 106-113

Niobium's role in resisting hydrogen embrittlement

- The mechanism by which Niobium improves delayed fracture resistance of steels is unknown at present
- The two main proposals relate to
  - Niobium/Carbon acting as a hydrogen trap – main mechanism
  - The grain refinement effect of Niobium (C,N) – secondary mechanism



Zhang, S.; Huang,Y.; Sun,B.:Liao Q.;Lu, H.;Jian,B.;Mohrbacher,H.;Zhang,W.;Guo,A.;Zhang,Y. "Effect of Nb on hydrogen-induced delayed fracture in high strength hot stamping steels " 2015, Materials Science & Engineering A 626 136-143

Conclusion

- Trend towards the use of lower Carbon (to increase corrosion fatigue life) and Niobium for grain refinement in order to keep the desired strength
- Niobium reduces hydrogen embrittlement tendency found in extra high strength spring steels
- Vanadium and Niobium microalloying improves performance over traditional spring steels
- Thermomechanical process in spring manufacturing ensures the optimization of microalloying strategies