Level 2 Industrial Case Study

Stainless Steels

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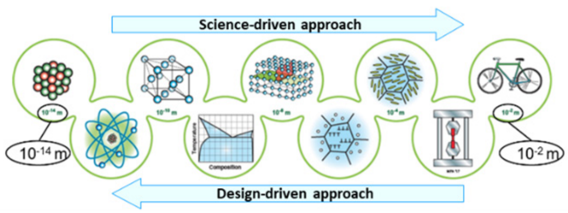
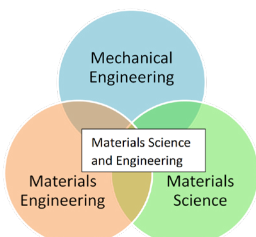
1. Beyond Materials Selection

Granta EduPack has always been excellent for teaching a design-driven approach to materials for engineers and designers. In addition, there are some embedded binary phase diagrams and textbook-style support for materials science in the Science Notes. In the new Materials Science and Engineering (MS&E) database 2019, however, these parts have been made more visible and are supplemented with features to boost introductory MS&E teaching and learning.



We have found that materials educators around the world have a wide mixture of backgrounds and that materials courses in mechanical engineering programs, for instance, are taught in a variety of ways. It therefore makes sense to treat this diverse subject area jointly as Materials Science and Engineering, without excluding either theoretical or applied aspects.

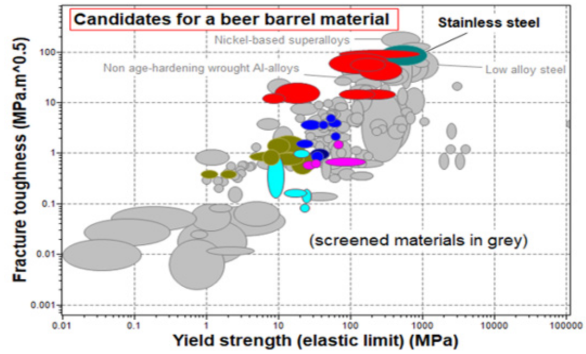


In this simplified industrial case study, we look at how to bridge science and engineering by exploring the novel Phase Diagram Tools and MS&E data-tables to facilitate the understanding of stainless steels and Ni-Cr alloys. Both of which are crucial in many everyday products.

2. Exploring Stainless Steels

Stainless steel is one fascinating material that can be investigated using Granta EduPack and the MS&E database. Steel is by far the most common engineering metal, however, many ferrous alloys are prone to corrosion by rust. Therefore, if you want a robust material which will be in contact with liquids, say a beer barrel, this is a problem.

Beer barrels need to have high yield strength and fracture toughness as well as excellent durability to water and alcohol but low price, here < $10/kg. A bubble chart shows that stainless steels are among the best candidates.

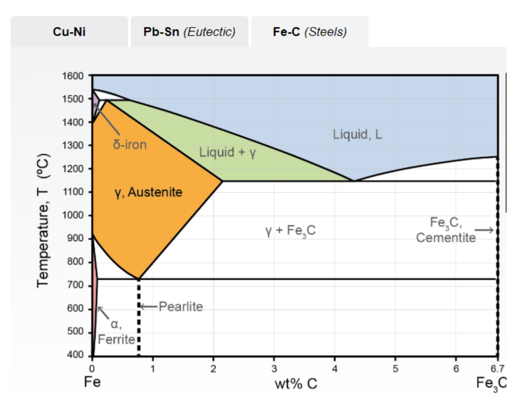


Carbon steels are made highly resistant to corrosion primarily by adding 11-12% (or more) of chromium as an alloying element. Nickel and molybdenum are other elements that also enhance properties and corrosion resistance. The corrosion resistance of iron-chromium alloys has been known for around 200 years, recognized by, for example, French metallurgist Pierre Berthier, who suggested their use in cutlery. The first patent of what we now call Stainless steel, a "Water Resistant Alloy", was filed in Britain 1872 by John T. Woods and John Clark.

Stainless steel is interesting from a materials science and engineering perspective, since alloying elements, phase diagrams and microstructures play important roles in understanding its properties. Indeed, three of the main types of stainless steels are named after their microstructures; *Ferritic, Austenitic*, and *Martensitic.*

3. What can EduPack do?

Starting with the phase diagram of carbon steel, we can use the *Phase Diagram Tool* to locate two of the main phases mentioned above. Ferrite, or α-iron, has a BCC microstructure while Austenite, or γ-iron, has FCC.



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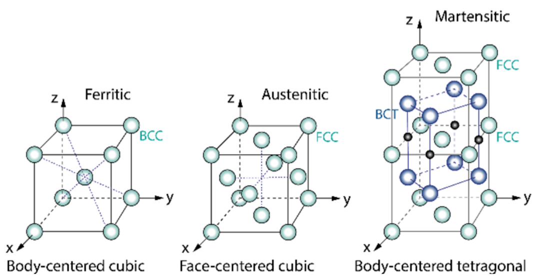
Crystal structure images of α-iron and γ-iron can be found in their respective datasheets located in the Elements data-table within the MS&E database. Below, we have added the structure of Martensite, for comparison.

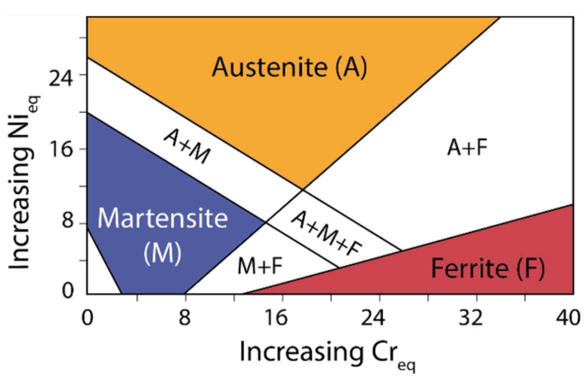


Ferritic stainless steels rely on ***added Cr*** and contain small amounts of C, usually less than 0.10%. These are the cheapest and are popular in, e.g., cutlery. Mo can be added for aggressive conditions such as sea water. Ferritic steels are ductile but not as formable as Austenitic stainless steels.

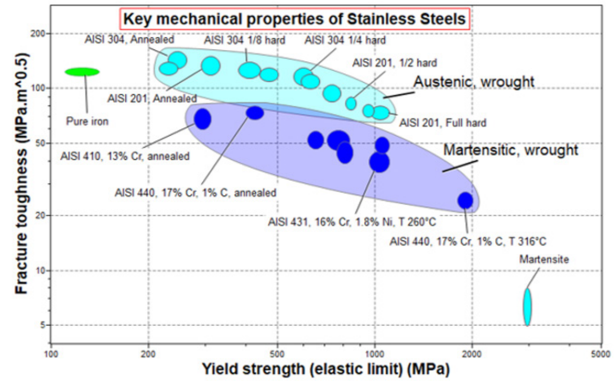
Austenitic stainless steels are the most common ones, used everywhere from kitchen sinks to aerospace. The FCC microstructure at room temperature is achieved by the ***addition of Ni and/or Mn***. Corrosion resistance can still be enhanced by adding Cr. These steels cannot be hardened by heat treatment, but work hardened to high strength while still retaining some ductility and toughness.

Martensitic stainless steels have ***higher C content***, up to 1%, and can be strengthened by heat treatment. They are used, e.g., in bolts, nuts and screws.

At room temperature, pure ***Cr has a BCC structure*** and promotes excellent durability to water and aqueous solutions by enabling a protective Cr2O3 surface layer that prevents corrosion, while pure ***Ni has an FCC structure*** and can stabilize the austenitic phase of solid stainless steel at all temperatures. For this reason, Ni, together with e.g. Mn and C are called ***Austenite stabilizers***. Cr, on the other hand, together with e.g. Mo and Si are called ***Ferrite stabilizers***, seen in the Schaeffler diagram below.

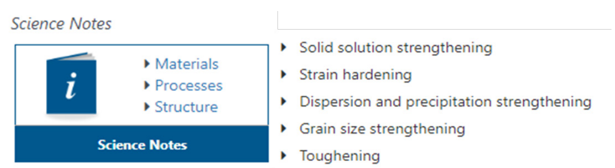


The above-mentioned mechanical properties can be visualized using the Property-process profile data-table.



Precipitation hardening (PH) stainless steel is another important category of stainless steels not mentioned in the discussions above. These are Cr and Ni containing steels that provide an optimum combination of the properties of martensitic and austenitic grades, obtained by heat treatment/ageing. Precipitation hardening is achieved by the addition of, e.g., Al, Ti,+ Cu, or Nb, either singly or in combination.

Further insights into the modification of material properties can be found under the new heading of *Structure*, in the Science Notes icon at the home page.



4. Conclusions

In this simplified industrial case study, we have explored the novel Phase Diagram Tools and MS&E data-tables to facilitate the understanding of stainless steels.

Alloying elements and microstructures play important roles in defining Stainless Steels, demonstrated by three of the main types of stainless steels investigated; *Ferritic* (BCC), *Austenitic* (FCC), and *Martensitic* (BCT).

Mechanical properties can be followed using the *Property-Process Profile* data-table that contain data on the effect of some alloying and heat treatments to metals.

A new *Structure* section of modification mechanisms have been included in the Science Notes. These can clarify the strengthening process of Precipitation Hardening (PH) Stainless Steels, for example.

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