Some Major Steels

Advanced

General remarks

- All commercial steels have some code number that identifies what is. Unfortunately, there is no universal system. Much in use is the system of the "British Standard Intitute" (**BSI**). But then we have "old" and "new" "**BS**" identifieres; and the Americans have of course there own systems. The most commonly used system of designation in the United States is that of the Society of Automotive Engineers (**SAE**), or of the (American Iron and Steel Institute) **AISI**, or the combined **SAE-AISI**system.
  - Then we have the German **DIN** norm, the Japanese .... and so on and so forth. Not to mention, the names the steel producing companies give their products.
  - It also goes without saying that people stick to the norms only loosely.
  - In short, it is a mess.
- Just for a taste treat, here are the (greatly abbreviated) systems behind two versions.
  - **BSI** There are always **6** digits; the meaning is
    - The first three digits denote the general family: **000 - 199** for plain carbon steels, **300 - 499** for stainless steel, and so forth.
    - The fourth character denotes the major property (**A =** chemical composition, **M =** mechanical properties, **H =** hardebability, **S =** stainless, etc.
    - The last two digits give the carbon content times **100**.
  - **AISI** There are four to five digits:
    - The first two digits refer to the major alloying elements in code.
    - The last two or three digits givethe carbon content times **100** (**xx40 = 0,4 % C**; **xx120 = 1,2% C**

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  - In short, steel names are a science in itself, the Internet, however, offers complex translation tables.

Plain Carbon Steels

- To keep with tradition, we allow a little bit of **Mn** and **Si** into the mix, and still count it as plain carbon steel.
- Plain carbon steels (including the sub-specification of "mild" steels), are still the most popular kinds of steel; they are the "workhorse" of the "metalbending industry" (which includes car making and large parts of building constructions) and account for about **90 %** of the steels produced.
  - Their most imortant property is their (low) price and their often good workability and weldability. This compensates for the not-so-good properties in comparison to more sophisticated alloy steels.
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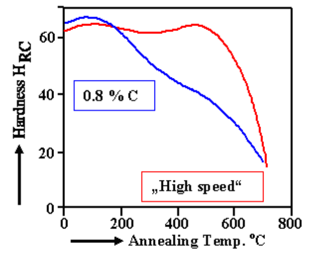
Tool Steels

- Tool steels must be very hard - after all you want them to cut regular steel on a lathe or with your power drill.
  - Essentially you use high-carbon steel; the most common mixture is **1 % C** and **0.3 % Si**, **0.3 % Mn**. Properly quenched and tempered, at least the outer cutting part will be hard.
  - However, if the tool becomes hot - and that happens whever you try to cut metal - you may loose the hardness because you "run the temper", i.e. anneal the martensite. This restricts you to low cutting speeds and plenty of cutting fluid use for cooling.
- Economically, this is not so good, so you turn to **high-speed steels**.

- Use a high alloy steel, e.g. **1 % C** and **0.4 % Si**, **0.4 % Mn**, **4 % Cr**, **6 % Mo**, **6 % W**, **2 % V**, and **5 % Co**
- Quench and temper as usual, but now the **Mo**, **Mn**, and **Cr** will give you good hardenability, the cementite, finely dispersed together with the solution hardening if the other elemtns gives you basic strength.
- If the tool now gets hot, say **500 ^{o}C - 600 C** (more than enough to give you a good burn if you touch it), interesting things happen: The **Fe_3C** cementite particles dissolve, but the carbon they release now forms a fine dispersion of carbides - **Mo_2C**; **W_2C**, and **VC**
- At room temperature, these carbides, formed during what is called **secondary hardening**, make the steel even stronger than the original cementite particles.
- Of course, you now have a rich field for optimizing - which elements and how much of each; and there are many kinds of high speed steel. The picture shows a sample with a composition quite different from the composition given above.



Hardness of **0.8 % C, 18 % W, 4 % Cr, 2 % V** high-speed steel in comparsion to **0.8 %** C steel as a function of temperature

- In total, getting your tool hot makes it stronger, not weaker - a big advantage for fast processing.

Medium Alloy Steels

- We did not discuss this subgroup in the backbone text; but it contains interesting members of the steel family.
  - If you own good tools, e.g. wrenches ("Schraubenschlüssel"), they may haev been advertised as "Chrome Vanadium steel".
  - They ususally contain more alloying elements than just the two mentioned, a typical composition might be **0.3 % C**, **0. 75 % Mn**, **0.3 % Si**, **1.8 % Ni**, **0.87 % Cr**, **0.4 % Mo**, **0.1 % V**.
  - It appears that **Cr** and **V** have nore "sex appeal" when it comes to selling than **Mo** or **Ni**; but there might also be historical reasons.
- "Chrome Vanadium steel" is also a steel of choice for springs - from small ones to truck suspension springs. Here ie a txpcial composition:
  - For stress springs – i.e. suspension springs, truck brake system or similar utilization with high working regimes and good relaxation properties; Diameters: **(3.00 - 12.50) mm** **(0.50 - 0.65) % C**, **(35 - 1.65) % Si**, **(0.35 - 0.70) % Mn**, **(0.15 - 0.25) %V**, **(0.40 - 0.70) % Cr**, **<0.025 % P; S**, **<0.12 % Cu**.

Stainless Steels

- A typical ferritic stainless steel consists of **0.04 % C**, **0,45 % Mn** and **14 % Cr** .
  - It is not particularaly hard, but then its mainly used for forks and spoons, where hardness is not required. It is stainless, but rather ductile, and easily shaped from thins sheet by stamping.
- If hardness is of concernm e.g. for knives, or pairs of scissors, a martensitic grade is called for.
  - **0.3 % C**, **13 % Cr**, **0,4 % Mn** will do the job. After hardening by martensite formation, the structure is tempered to a hardness range of **500 - 700 H_V**. In addtition, some carbide formers like **Ti**, **Nb**, **V**, or in particular **Mo** might be added, to improve corrsion resistance in "salty" environments.

Austenitic Steels

- The most common austenitic steel is "**18/8**" with about **18 % Cr** and **8 % Ni**, **1 % Mn** and **(0.05 -0.1) % C**.
  - **Ni** and **Mn** stabilize the austenite at room temperature; the stell is non-magnetic and rather ductile. It can be shaped by cold-working, which will also lead to considerable work-hardening (a direct consequence of the **fcc** structure with its dislocation geometry).
  - Great for cold-drawing or pressing kitchen sinks and bowls; not so good for machining.
- A famous austenitic steel is "Hadfield's steel" from around **1890**, containing **13 % Mn** and **1.2 % C**.
  - It combines maximum hardness with maximum strength. In its prime state, all the **Mn** and **C** is held in solid solution, but as soon as it is deformed, it will undergo a martensitic transformation ncleated by the deformation which leads to a hardening to abut **500 - 550 H_V**.
  - This is particularily important wherever wear resistance is the ultimate reqirement - the heavily impacted surface areas harden while the bulk keeps its resilience. In a way, that may have been the first "smart material".