

Lecture 40: Application of physical metallurgy: Ultra high strength steel

Questions:

1. Compare the crystal structures of two alloy steels having nominal carbon content (a) 18%Cr (b) 18%Cr8%Ni. Can these be hardened by conventional quenching from a high temperature?
2. High speed cutting tools are made of 18W4Cr1V0.6C and it is used in hardened and tempered condition. Unlike normal hardened and tempered plain carbon tool steel it does not lose its cutting ability even when it is red hot. Explain why it is so.
3. How is the mechanism of strengthening in maraging steel different from that in conventional ultra high strength steel?
4. Explain why commercial steels / alloys having lower stacking fault energy exhibit higher creep resistance.
5. Does all steel suitable for ausforming exhibit transformation induced plasticity?

Answers:

1. (a) BCC: ferrite (b) FCC: austenite. 18%Cr steel cannot be transformed to austenite which is the main criterion for conventional hardening process by heating & quenching. This is because amount of ferrite stabilizer present is beyond γ loop. Therefore it cannot be hardened by this method. 18Cr8Ni on the other hand is austenitic at room temperature. Steels that could be hardened by conventional process develop martensitic structure on quenching to room temperature. Therefore this too cannot be hardened as above. However through cold work and subzero quenching some martensite may form in 18Cr8Ni steel.
2. High speed tool steel retains its hardness even when it is red hot because it has significant amount of strong carbide former which precipitates during the 4th stage of tempering (gives secondary hardening) before these are put to use. The precipitate is coherent with the matrix. This gives it excellent micro-structural stability to resist particle coarsening and retain its hardness.
3. Martensite in normal steel is hard primarily due to carbon. Presence of excess carbon is responsible for tetragonal distortion. This is why martensite in normal steel has BCT structure. Maraging steel has very little carbon. Therefore martensite that forms here is BCC. In virtual absence of carbon it is soft. It can be cold worked to give desired shape and increase its strength. On aging at around 500°C inter-metallic compounds precipitate. This results in further increase in strength. Therefore apart from solid solution strengthening unlike conventional steel martensite in maraging steel derives its strength from cold working and precipitation hardening.
4. All creep resisting alloys have precipitates which obstruct movement of dislocation that is responsible for deformation. Usually precipitates are strong. Stress required to shear these is high. Therefore dislocations held up at obstacles can move either by climb (restricted to edge

dislocation) or cross slip (restricted to screw dislocation). There are also restrictions imposed by crystal structure on slip planes and burgers vectors of mobile dislocations. If stacking fault energy is high the partials join to form a perfect dislocation that could either cross slip or climb depending on its character. If SFE is low the distance between the two partial is large. It would require higher stress to join these. Therefore lower SFE gives higher creep resistance.

5. No not all. Only steels whose M_s temperature is little lower than room temperature and temperature is higher than room temperature would respond to transformation induced plasticity if it is heavily deformed above M_d temperature. Such steels are in metastable state during service. If a crack develops in the steel martensite would form at crack tip. Such a transformation is accompanied by volume expansion resulting in local deformation. The region surrounding the crack tip would resist such deformation. Therefore more work has to be done so that the crack would grow. This gives the steel high yield strength and toughness. Such steels are known as TRIP steel.