4. MARAGING STEELS

Classification of chapter:

4.1. Basic chemical composition of Maraging steels
4.2. Principles of manufacturing and influence of chemical composition
   4.2.1. Variants of chemical composition and heat treatment
   4.2.2. Welding conditions
4.3. Applications of Maraging steels

Summarization of chapter terms and questions

Literature

Time necessary for study: 90 minutes

Aim: After studying of this chapter

- you will be informed about basic types of Maraging steels;
- you will understand basic principles of Maraging steels manufacturing;
- you will be able to suggest their chemical composition as well as heat treatment resulting in high level of strength properties;
- you gain knowledge about possible application;

Lecture

4. Maraging steels

4.1. Basic chemical composition of Maraging steels

Maraging steels show high strength properties in combination with very good toughness level. Basic chemical composition follows, resp. different variants and/or combinations of chemical composition are seen (in wt. %) from Fig. 4.1.
Fig. 4.1 Different variants of chemical compositions of Maraging steels

Final properties are as it follows:

- \( R_e = 2000 \) (1800) MPa
- \( R_m = 2300 \) MPa
- \( A = 12\text{-}14\% \)
- \( Z = 40\text{-}50\% \) (without fractures before \( R_m \) reaching)
- High level if fracture toughness

4.2. Principles of manufacturing and influence of chemical composition

Thanks given Ni content (makes \( A_1 \) and \( A_3 \) temperature lower) lower heating temperature is chosen. That corresponds to 900 °C, resp. 820 °C /shorter dwell/air and/or \( H_2O \) (according thickness). Shorter dwell is applied because of restriction of primary austenitic grain growth, because in matrix is nothing what could keep grain boundary and thanks high temperatures these are very moveable. Matrix does not concern not only higher carbon content, which could diffuse on the grain boundaries and in this way defend their
growth. After cooling, austenite is transformed into low carbon martensite (thanks low carbon content in basic matrix), which is not a source of importanter strengthening. Advantage of low carbon is none high strengthening formation during transformation of austenite to martensite. Dislocation density is also very low. Dislocations are not mutually blocked in movement and are able to move quite well. It is also reason of relatively high level of ductility. Thanks low carbon content the paths among carbon atoms are longer. In case of low carbon content in matrix, material is unsignificantly deformed after quenchin. Consequently, none followed tempering is necessary. Material strengthening je realized by further treatment:

1) **Annealing** – tempering/aging at temperature approximately of 480 – 550 °C, when Laves’ phases of added element as Mo, W, Nb are formed, which shows great atomic diameters in comparison with Fe or Ni (e.g. Fe₂Mo).

2) **Annealing** – tempering/aging at temperature about 600 - 700°C, when in matrix intermetallic phases of Ni₃X, or Ni₃(TiAl) and/or Ni₃Mo type precipitate, showing arranged structure (often marked as γ-phase). Intermetallic phases (e.g. of Ni₃Ti type) are marked as η-phase.

3) **Arranged structure**
   Phases of FCC type have a tendency to be split into partial dislocations. The first partial dislocation disturbs the arranged structure and the second one (following the first partial dislocation) restores the arrangement.

3) **Co addition** generally supports formation of face fault of stacking fault type. This hexagonal face defends dislocation passage in matrix and in this way other contribution of matrix strengthening is reached.

**4.2.1. Variants of chemical composition and heat treatment**

In given steel type additions of Ni, C and Mn are presented every (see above). According chemical composition maraging steel could be divided into three groups as follows:
1) Co + Mo (W, Nb)
2) Ti + Al
3) Co + Mo (W, Nb) + Ti + Al

All three groups of martensitic steel can their high-strength properties reach by two ways of heat treatment:

**A)** 900 °C (820 °C)/ air or H$_2$O for $\gamma \rightarrow \alpha'$ + $\gamma$ residual transformation + 600-700 °C/8-10 h, when from matrix intermetallic phases Ni$_3$(TiAl), marked as $\gamma$-phase precipitate. It results to depletion of autenitic matrix in Ni and Ti and consequently to M$_s$-temperature increase and in this way the $\gamma$ residual can be quite transformed to $\alpha'$-martensite. During other aging process (at temperature of 480 °C – 550 °C) Laves' phases can be formed, resp. Addition of Co can be positively shown, which importantly decreases stacking fault energy and supports stacking faults formation in austenitic matrix, which blocks dislocation movement.

**B)** Increase of strength properties is also possible to realize by use of high temperature mechanical treatment (HTMT) during deformation approximately at 60 % at about 870 °C in austenite. By this way it is possible to reach $R_m$ level ca 1950 MPa. Afterwards, treatment like in the A case follows. When deformation of austenitic matrix is carried out in area of 550 °C, it is under low temperature mechanical treatment (LTMT), than $R_m$ can be increased up to ca 2050 MPa. However, decrease of ductility must be awaited on the level approximately of 6-8 %.

**4.2.2. Welding conditions**

Conditions for welding are very good. Carbon content is low and the elements as Mn, Mo etc. are in carbon equivalent (Ceq.) equation every divided by some integer, so in the end the Ceq. is low. After welding none properties are changed, welds show toughness and heat stresses can be eliminated by annealing at 450 °C. For welding tungsten electrode is mostly used and therefore it is demanded to weld under protective atmosphere of Ar, so that tungsten would not be oxidised.
4.3. Applications of Maraging steels

There, where high strength, together with good toughness is demanded. For example bearings for brick constructions on which steel girders (steel sections) etc. are put. Further in ship industry, special cars and special technique.

∑ Summarization of chapter terms

In the end of this chapter main terms that you should master are repeated.
Maraging steel, annealing/aging, low carbon martensite, high temperature termomechanical treatment, low temperature termomechanical treatment, stacking fault, Laves´ phase, intermetallic phases.

Questions

1. What variants of basic chemical composition exist in maraging steels?
2. Explain basic possibilities principle of treatment of maraging steels, so that high level of strength properties would be reached?
3. Explain the main influence (function) of intermetallic phases in maraging steels.
4. Precipitation of Maraging steel is realized under which conditions?
5. Explain the influence of Laves´ phases in maraging steels?
6. Under which conditions Laves´ phases are formed in martensitite steels?
7. What the function has Co addition in maraging steels?
8. Explain influence of arranged structure in intermetallic phases.

Literature:


