Metallurgical Features and Applications of Maraging Steels

- Dr. Thoguluva Raghavan Vijayaram
FET Faculty (Engineering and Technology)
MMU Multimedia University, Malaysia

DR. THOGULUVA RAGHAVAN VIJAYARAM

Maraging steels are iron based alloys well known for possessing superior strength without losing malleability. It is free from carbon and hence it differs from other types of steels. Maraging steels are a class of high strength steels which are characterized by very low carbon contents and the use of substitutional elements to produce age hardening in Iron-Nickel Martensites. The name maraging was coined from a combination of martensite and age hardening. It is a special class of low carbon ultra-high strength steels which derive their strength not only from the carbon and also from the precipitation of inter metallic compounds. Original development was carried out on 20 and 25% Ni steels to which small additions of Aluminium, Titanium and Niobium were made.

Original maraging steels introduced in 1960s based on Cobalt as their strengthening agent and the percentage of Cobalt lies between 7 to 12%. It was called as Cobalt strengthened maraging steels. In 1980s, Titanium was used as a strengthening agent and often called as Titanium strengthened 18%Ni Maraging steels. It is generally classified as C Type 18%Ni Maraging steel and T Type 18%Ni Maraging steel.

The term maraging relates to aging reactions in very low carbon martensitic steels for the development of ultra-high strength. Due to an excellent combination of high strength and hardness, ductility and toughness combined with corrosion resistance, the class of stainless maraging steels are used in many technological sectors where weights saving aspects are of great importance such as aerospace and military. Ease of heat treatment and dimensional stability make these steels also attractive for use in machinery and tooling. Maraging steels are characterized by a high Nickel contents and higher levels of ductility and toughness when compared to conventional high carbon martensitic grades of equivalent strength. On quenching from austenitic conditions they form a soft but heavily dislocated martensite. In this condition maraging steels can easily be machined and, if required, cold worked. Maraging steels containing 18% Nickel along with Cobalt, Molybdenum, Titanium, and Aluminium additions have been established as ultra high strength structural steels. The nominal yield strengths of these steels in the fully age

hardened condition range from 200 ksi to 350 ksi and the corresponding designations are 18Ni (200), 18Ni (250), 18Ni (300), and 18Ni (350) respectively. Maraging steels are called as ultra high strength steels. It is available as near net shape castings in the commercial steel market. Maraging steels obtain their hardness through precipitation reactions at relatively low temperatures.

Heat treated maraging steel dies have practically 100% Martensite and it has a prolonged die life. It achieves full properties through martensitic precipitation aging and hence the name "Maraging steels". Carbon free protective atmospheres are not required during annealing or aging. It is aged at 480 to 495 degree centigrade for 3 to 6 hours. They are more expensive than H13 Hot Work Die Steels. Die life is more than 3 to 5 times when compared to H13. Considerable savings are attainable during die manufacturing and maintenance. Uniform dimensional changes can be obtained and EDM may be applied for machining purpose. Less maintenance and reduced heat checking and pitting can be achieved. It is easy to weld and more resistant to soldering of the die cast alloy. Excellent polishability can be obtained and no need to remove the die from the press for stress relieving.

Marlok C1650 Steel is a maraging steel used as a die steel material for die casting processes. It contains C<0.01%, Ni=18%, Mo=5%, Co=11%, and Ti=0.30% respectively. Hardness of this type of maraging steel lies between 48 to 51 HRC. Fracture toughness in K_{1c} mode is equal to 80 $MPam^{1/2}$ and thermal conductivity is equal to 29 W/mK. The numerical values of the three moduli of maraging steels are listed in the Table-1.

Table-1	
Young's Modulus	195 GPa
Shear Modulus	77 GPa
Bulk Modulus	140 Gpa

The density of maraging steel is equivalent to 8 gm/cm3 and the melting point is 1413 degree centigrade. Vasco Max alloys are maraging steels containing 18% Ni. These alloys are produced by vacuum melting and it can be converted into the mill product forms such as like billets, bars, rods, coils, and wires. It is most suitable for die castings. It has superior ductility, toughness, low coefficient of thermal expansion and elasticity, excellent tempering resistance, good corrosion resistance and thermal conductivity. The benefits of maraging steels are its excellent resistance to heat checking and small stresses in thermal cycling, less softening in use, less erosion and oxidation.

Maraging steels are considered as the best tooling materials. It possess excellent mechanical properties like higher yield strength and UTS. Besides, it has higher impact strength, fatigue strength, compressive strength, toughness, ductility, hardness, and wear resistance. It has excellent machinability characteristics and readily cold and hot formed. Maraging steels are highly resistant to crack propagation and possess good wettability and polishability. For heat treating, maraging steels require lower furnace temperature. Uniform and predictable shrinkage occurs during heat treatment. Minimal distortion occurs during thorough hardening and free from the formation of carburized or decarburized layers on its surface. Maraging steels have the unique combination of ultra high yield and tensile strength, ductility, and fracture toughness of any ferrous materials. It can retain its strength up to 350 degree centigrade. Having a very low carbon martensite, the structure is soft and readily machinable. It can be surface hardened by nitriding. Maraging steels are typically applied to produce missile and rocket motor cases, wind tunnel models, recoil springs, flexures, AC Motors, landing gear components, high performance shifting gears and fasteners, extrusion tools, casting dies, and core pins. Engine components such as crankshafts and gears that work at warm temperatures and the firing pins of automatic weapons that cycle from hot to cool repeatedly while under substantial loads and impacts are made from maraging steels. Their uniform expansion and ease machinability characteristics makes it useful in high

wear portions of assembly lines and as well as in die manufacturing.

Maraging Steel is two times harder than stainless steel and 85% harder than pure titanium. Maraging steel alloys are twice as hard as stainless steel and 35% stronger than the hardest titanium alloy. On the Rockwell Scale of Hardness, stainless steel is 23-26, titanium alloys 28-41 and Maraging Steel 52-55.

Maraging Steel alloys have been available to the golf industry for years. The purpose of utilizing thin maraging steel face inserts allow the face to flex to produce a high coefficient of restitution or rebound effect, just like the use of titanium in modern drivers as a way to increase the ball velocity coming off the face. In addition, there is a considerable weight savings that allows the golf club designer to place more weight elsewhere in the head to improve launch angles and reduce spin rates. Maraging steel is used in lieu of titanium because it is easily bonded to a stainless frame in fairway woods, hybrids and irons.

Maraging steel 250 is an 18 percent nickel steel that has been strengthened with cobalt. Maraging 250, like all maraging steels, goes through an aging process that forces the metal to cool from its molten state to its solid state over an artificially long time. This process results in tempered steel that has both high levels of strength and hardness. It will also resist certain stresses and maintain its structure in environments that would cause irreparable changes to many other steels. The properties that make Maraging 250 particularly appealing to many industries is its workability. This allows Maraging 250 to be more versatile than many other alloys in its class. However, it is still the alloy's strength and resistance to extreme temperatures that make it a truly effective material in a wide range of atmospheres. After Maraging 250 has undergone heat treatment, it demonstrates excellent mechanical properties. It will reach yield strength of 240 ksi and a fracture toughness of 75 k1c. These properties have made Maraging 250 effective in the

construction of missile and rocket motor cases, landing and takeoff gear, and high performance shafting.

Maraging steel 300 is an iron-nickel steel alloy that, as with all maraging steels, exhibits high levels of strength and hardness. However, Maraging 300 also possesses an extreme resistance to crack propagation, even in the most extreme environments. Maraging 300 is often used in applications where high fracture toughness is required or where dimensional changes have to remain at a minimal level. The unique properties of Maraging 300 have made it an integral part of the aircraft and aerospace industries. It is often used in rocket motor casings and the landing gear for certain planes. Maraging 300 is also effective in the design of power shafts and low-temperature cooling systems.

Maraging steel 350 refers to crystalline tempered steel. Martensite, which is created through an aging process. When aging is used, steel is forced to cool from its molten state to its solid state over a prolonged period of time. The result is a metal that is harder and stronger than it would be had the steel been allowed to cool at a natural rate. Maraging 350 is an alloy that has become an integral material in the airplane and aerospace industries. Due to its strength and its ability to withstand extreme conditions including frequent and sudden changes in speed and temperature, Maraging 350 is used in the production of rocket motor cases, takeoff and landing gear, and certain munitions created by defense companies. Maraging 350 also has uses in less drastic applications such as die casting and high performance shafting.

Maraging steel 362 is known for their exceptional strength and hardness. Their ability to resist various forms of stress in extreme environments has made maraging steels commonplace in the aerospace and aircraft industries. Each maraging alloy has its own unique qualities, but many of them are used in similar applications. Maraging 362, like other maraging steels, undergoes an artificial aging process. This process leads to the material's added strength and hardness. The results of the aging procedure has recently caught the eye of golf club designers and manufacturers who have begun to use maraging alloys on the faces of their clubs in the hope that players will see increased power and that clubs will not corrode over time. Maraging steel gives you an elevated level of strength, hardness, and ductility. These steels are created through an aging process that results in the development of a hard, brittle crystalline called martensite. The term "maraging" is, in fact, a simple combination of martensite and aging. The construction of maraging steel allows it to withstand atmospheres that would quite simply destroy most standard steel. The aging process instills maraging steel with the ability to withstand sudden changes in speed and temperature, even at extreme levels. This quality has made maraging steel alloys an important component of many of the air and spacecraft used today.

Acknowledgement

The author expresses his thanks and gratitude to the Faculty of Engineering and Technology, FET, MMU, Multimedia University, Melaka Campus, Bukit Beruang, 75450, Melaka, Malaysia.