# 3.2 Heat Treatments

Refer to Table 4 for features of heat treatments.

**Table 4. Features of Heat treatments**

| Contents | Induction hardening | Flame hardening | Case hardening | Nitrocarburizing | | Nitriding |
|---|---|---|---|---|---|---|
| Materials | Carbon steel with 0.4-0.6% Carbon<br>SCM435, SCM440<br>SMn443, SNC836<br>SNCM439, etc. | Carbon steel with 0.4-0.6% Carbon<br>SK5-7, Ductile Cast Iron<br>SCr435, SCr440<br>SCM435, SCM440, etc. | Carbon steel with below 0.23% Carbon<br>SNC415, SNC815<br>SCM415, SCM420<br>SNCM420, etc. | ① Low and mean content of Carbon steel | ② Carbon, Alloy, Stainless and Cast steels | SACM645 and others<br>For Nitriding process, material should consist of Aluminium and Chromium. |
| Heat treatment | Put gear into the coil of quenching machine then turn on high power of eddy current to the coil. Overheat the surface of gear and immediately apply jet cooling water to gear for instant cooling.. Long items can be fabricated with quenching by process of heated coil line continued by instant cooling in longitundinal direction. | Economical method of heat treatment compared with others if the Induction hardening was expensive (for small volume and extra large item).<br>Heating only the part you wish to harden by burner to overheat. When surface becomes austenite composition, jet-spray the water for instant cooling. As a result, only this part hardens.<br>Method of tempering is process of using low temperature tempering of 150°-200°C. | Gear together with charcoal and Carbonic barium are seald in a melting pot and heated for 4-8 hours at temperature 900°-950°C. Carbon permeates to gear surface. Use for producing a variety of items in small quantities.<br>Gas carburizing is performed with easy adjustment for amount of Carbon carburizing, Depth of Carburizing has minute scales on the surface of gear. Environmentally friendly and has consistent quality. Process time is shorter than Solid carburizing and suitable for mass production. | ① Soak gear with low and medium carbon content into the Salt bath (main constituent is NaCN), to produce film of 0.2mm or below on the gear surface. Processing temperature will be 750° to 900°C and it is suitable for small amount of production. This is an economical method but the salt bath is toxic and hazardous to health.<br>② Isonite<br>Using method of Salt bath Nitriding NaCNO or Potassium bath to Nitride by nascent Nitrogen. Treatment temperature is 500° to 600°C and last for 24 hours. Effective hardness depth will be 0.015 to 0.020. | | Material is modified to the Sorbite composition by quenching. After which the gear is put into the Nitriding furnace. When ammonia gas is injected into furnace with temperature 500° to 900°C, decomposed Nitrogen is absorbed to form a hard layer on the surface of the gear.<br>Treatment hours will span from tens of hours to a few hundred hours depending on the depth of hardness required. |
| Hardening depth | It is difficult to have the bore, core and section to harden. Generally, steel material suitable for hardening is used to perform quick quenching on the surface. Core area keeps original composition. Harden surface with little oxidation using instant overheat and instant cooling. Perform thermal refining with quenching temperature of 30° to 50°C and provide water cooling to allow the Austenite to diffuse into the gear easily. There is high heat efficiency for direct overheating which causes the hardness of Tooth tip to be higher than Dedendum area of the gear. | | Tolerance of case depth less than 0.2mm is difficult for Solid carburizing. Carburizing depth below 0.7mm is not suitable. Regardless of the shape of goods, same layer of hardness can be obtained. Mask the area that does not require hardening to prevent carburizing. | Isonite is an economical surface hardening method that saves time for hardening, self-lubricating and has low coefficient of friction. | | There is less strain from heat influence during heat treatment by low temperature. Hardening layer provides surface with better wear resistance, heat resistance and anti-corrosion. Layer of hardening expands gear by 0.02mm to 0.03mm as Nitrogen is absorbed. |
| Productivity | Hardening to limited parts is possible.<br>Heat treatment duration only takes a few seconds.<br>Automated system is possible.<br>Suitable for mass production. | Hardening to limited parts is possible.<br>Heat treatment duration only takes a few seconds.<br>Simple equipment has inconsistent hardness. | Heat treatment hardens whole body.<br>Long heat treatment duration. | Economical cost and short treatment duration | | Heat treatment hardens whole body.<br>Very long heat treatment duration. |
| Hardness | $H_S$55 ~ 75<br>$H_RC$41 ~ 56 | $H_S$55 ~ 75<br>$H_RC$41 ~ 56 | $H_S$70-85<br>$H_RC$52 ~ 62 | $H_S$88-92<br>$H_RC$64 ~ 66 | | $H_S$100 以上<br>$H_RC$68 以上 |
| Strain | Smaller strain than quenching and tempering. | Larger strain than quenching and tempering. | Larger strain than induction hardening | Minute strain | | Minute strain |
| Cost | Economical cost for mass production | Economical cost | More costly than induction hardening | Economical cost for mass production | | Costly |
| Depth of hardness | 0.8 ~ 7mm (Alloyed steel is over 4.0mm) | 1 ~ 12mm (Alloyed steel is over 4.0mm) | Solid Carbunizing 0.7 ~ 5mm<br>Gas Carbunizing 0.2 ~ 5mm | 0.015 ~ 0.02mm (Specialized steel is 0.1 to 0.2) | | 0.1 ~ 0.6mm (Uneconomical to use above 0.4) |
| Feature | Suitable for mass production in simple form<br>Electrically controlled automation system is possible<br>Stable quenching<br>Quenching to limited parts is possible<br>Quenching equipment is expensive | No limitation for size and form<br>Quenching to limited parts is possible<br>Quenching equipment is economical cost<br>Overheating temperature is difficult to control. | Easy to adjust carbon density<br>Uniform depth of Carbunizing<br>Easy to adjust depth of Carbunizing | Beware of polluting, as treated salt is deadly poisonous<br>Vulnerable to impulse load | | Excellent wear resistant, heat resistant and anti-corrosion<br>Heat treatment after Nitriding is unnecessary<br>Minute deformation<br>No occurrence of hardening crack |
| Other applications | Chain wheel<br>Pin | Crankshaft<br>Camshaft | Shaft, Pin, Cam, Bush for Roller chain | Camshaft | | Diesel injection nozzle<br>Gauge |

There is also Plasma nitriding, which is not mentioned here that causes minute strain compared to other methods by thermal influence while hardening tooth. It has been omitted from this report. Refer to Table 4 for features of Nitration.