Engineering steels for Automotive Applications

- By B.V.R.Raja, N.Pal, P.L.Talwar, N.P.Jayaswal
Alloy Steel Plant, SAIL, Durgapur

Introduction

Engineering steels are basically defined as wrought steels for mechanical and allied engineering purposes. They encompass several carbon, micro-alloyed and alloy steels based on the type of heat treatment (through hardening, case carburizing, induction hardening, nitriding), end use application (bearing steel, spring steel), forming practice (hot rolled, cold forming), specific properties (free cutting machinable steels, corrosion resistant stainless steels, creep resistant steels) and the conversion process from semi-finished to finished products (forging from bloom/billet, black or bright bar, rod , wire, tube, flats).

These steels are used for components requiring critical and stringent levels of elasticity, strength, toughness, high temperature creep and fracture resistance, corrosion resistance, wear resistance, machinability and formability. Engineering steels thus, find extensive usage in automotive, railways, defence, oil, power, coal & gas extraction, chemical, agriculture, construction and general engineering manufacturing sectors. Here, automotive sector accounts for 50% of the engineering steels market.

Choice of steel for automotive applications

Generally, the bulk of the steel requirements for the chassis and body work of an automobile are met with cheaper plain carbon steels, while, alloy steels are recommended mainly for engine, gear box, propeller shaft, front axle, rear axle and suspension parts. The engineering steels used in an automobile are broadly classified on the type of heat treatment applied, end use application and forming practice adopted. Ultimately, the choice of a steel is not only dependant on the properties but also on the cost and it's availability.

Heat treated steels

Normalized Steels

Steels containing up to 0.45% C and 1.5% Mn are used extensively in the rolled or normalized condition for general engineering applications requiring tensile strength levels up to 700 Mpa exhibiting ferrite-pearlite micro-structures with application in low stressed parts such as shafts, pulleys, brackets, levers, tubular and suspension parts.

Case carburized steels

Case Carburizing is one of the most common surface treatment processes accounting for 50% of all the surface treatment methods and is based on the diffusion of carbon into the outer surface of the steel at temperatures 850°C to 900°C followed by quenching to transform the case into a hard martensitic structure. The core possess low carbon content and the component so made is then tempered to increase the toughness of the case.

These steels have low carbon contents coupled with presence of alloying elements. The selection of carburizing steels is generally based on core properties and hardenability data to exhibit excellent resistance to wear and fatigue.

Among the steels, low carbon steels are used for fans & pulleys in engine parts, flex plate and cover, turbine & impeller shell of torque converter and sun gear driving shell for transmission parts in an automobile. Alloy Steels in case hardened condition find greater use for various parts in the automobile and is illustrated in Table 1.

Cr and Cr-Mn steels like SAE 5120, DIN 16MnCr5, 20MnCr5 are sensitive to over carburization in strong carburizing media coupled with cracking of the case during slow cooling in box and susceptibility to grinding cracks which necessitates refining treatment after carburizing. Case hardenability is very much influenced by the hardening temperature and the sluggishness of the complex carbide network in the over carburized case going into solution is responsible for the tendency towards excessive brittleness and cracking during grinding. Also, formation of chromium carbide causing depletion of chromium from solid solution of the case result in poor hardenability of the case coupled with danger of austenite retention making the heat unsuitable for direct quenching without any intermediate refining treatment.

High Ni-Cr-Mo steels like En 354, SAE 4320, 4027 used for heavy duty applications with higher core strengths and moderate resistance to shock possess high hardenability and poor machinability in as forged condition necessitating normalizing followed by soft annealing for machinability improvement. Due to the presence of retained austenite in these steels, high hardness is obtained not on the surface but slightly below it and the control of carburizing atmosphere is important to avoid distortion and cracking.

Low alloy steels like SAE 4620, 8620, 8720 are of medium hardenability and find extensive application due to their low cost, better machinability and availability.

Table -1

Case Hardened alloy steel grade	Core Strength on 30 MM dia test bar (MPa)	Applications
SAE 5120	600 - 850	Camshafts, rollers, gudgeon pins, spindles
SAE 4620	750 - 1050	Camshafts, cams, gear box, steering arm sector shafts, transmission components
DIN 16MnCr5	800 - 1100	Small gear wheels, shafts, bevel gear, transmission
SAE 8620, 8720	900 - 1150	Gears, steering mechanism, gear box & transmission components for cars
DIN 20MnCr5, BS 815M17	1000 - 1300	Medium gear wheels, shafts, steering rear axle shaft gears, steering nuts, worm, transmission gear, crown wheels, pinion, differential spider
SAE 94B17	1000 - 1300	Heavy duty gears, heavy vehicle & car transmission components
EN 354, SAE 4320, SAE 4027	1200 - 1350	Heavy duty gears, differential gear and pinion, rear axle drive pinions, heavy vehicle & car automatic transmission components

The optimum case depth for various steel components is based on the design and the service environment. In case of pinions, ball or roller races where locally high unit stress application is involved, the case needs to be sufficiently deep such that the stresses developed at any point below the surface are lesser than the fatigue limit of the material at that point. For applications involving low surface stressing where the resistance to frictional wear is the main consideration, a much shallower case depth is permissible.

Hardened Steels

Direct hardening carbon and low alloy steels exhibit excellent combination of strength and toughness in the quenched and tempered condition. Based on the amount of alloy content, section size and heat treatment variables, tensile strengths up to 2000 Mpa are achieved. It is a well known fact that steels when fully quenched and tempered to the same hardness level have identical tensile properties irrespective of the alloy content. The selection of steel is determined from a set of steels considering capability through hardening to the depth required by the particular component's critical cross sectional thickness and the range of mechanical properties attained by hardening and quenching coupled with availability, cheapness and suitability for the machining and heat treatment facilities available in the plant concerned.

Medium carbon and medium carbon with high Mn steels like IS 37Mn2, En 15, SAE 1340, 1335, 1548, 1041 &1036 possess moderate hardenability combined with good ductility and shock resistance. With tensile strengths 600 MPa – 750 Mpa in hardened and tempered condition, these steels are used in axle, crankshafts & connecting rods in smaller engines.

Steel grades like IS 40Cr1, En 18D & SAE 5140 with tensile strengths of 700 MPa – 1050 Mpa have higher hardenability with good resistance to abrasive wear and suitable for flame and induction hardening. The steels are applied as gears, connecting rods and stub axle steering arms.

DIN 42Cr4Mo2, SAE 4140 & 8640 steels with tensile strengths of 700 MPa to 1150 Mpa are found to possess fairly good hardenability coupled with ductility and toughness in large sections. These steels are suitable for flame, induction hardening and nitriding with applications involving axle shafts, crankshafts, connecting rods, gears, high tensile bolts, studs, propeller shafts etc.

Medium carbon nitriding steels like En 29, En 40B & AFNOR 30CD12 have wide range of tensile properties of 700 MPa – 1550 Mpa with excellent ductility and toughness. Also, the mechanical properties are not sensitive to sectional variations and the steel possesses good low temperature impact values and resistance to embrittlement at high temperatures finding usage in sliding components, cylinder liners, fuel injection systems, inlet valves, gears etc.

SAE 43430, En 24 & DIN 34NiCrMo6 steels with tensile strengths between 700 MPa – 1550 Mpa are of high hardenabilty with good resistance to wear and low temperature brittleness and find use for high tensile bolts, U bolts, studs, gears, pinions, axle shafts, tappets etc.

End use named steels

Spring Steels

These steels exhibit a high elastic limit and a high yield stress to tensile strength ratio. The tensile properties of spring steels vary with the diameter where, smaller the diameter, higher the tensile strength and a vice-versa. Fatigue is the most common cause for spring failures. Hence, it is important to increase fatigue durability of springs. The choice of steel for springs depend upon the cost, manufacturing process and the application.

Carbon steels of 0.5% - 1.2% carbon find major application for helical springs. These steels provide satisfactory results up to 1500 Mpa tensile strength. Due to the lower hardenability, its usage is limited to 25 mm diameter. Alloy steels are preferred for high hardenability, higher elastic limit, better fatigue life for sizes exceeding 25 mm diameter coupled with usage at temperatures exceeding 150°C. Cr-V spring steels like IS 60Cr4 V2, 50Cr4V2 are suitable for high stress applications requiring increased tensile, yield strength and fatigue limits at elevated temperatures finding use for most highly stressed springs such as leaf, helical & torsion bar springs, stabilizers for road vehicles, cup springs and spring washers of up to 30 mm thickness and 40 mm diameter rounds. Here, the presence of chromium in this steel increases hardenability, tensile strength, hardness and toughness with improved corrosion and heat resistance, while, the vanadium present improves tensile strength, elastic limit, & toughness and refines the grain size enabling to resist high impact, shock and alternating stresses keeps the grain size .

Si-Mn spring steels like IS 65Si7 possess good heat resistance than Cr-V spring steels and can be used at temperatures up to 205°C in sizes up to 16 mm. Silicon present in amounts of 2% helps in hardenability improvement, retarding decomposition of e carbide in tempering and strengthens the ferrite. These steels raise the elastic limit without sacrificing ductility and toughness but are prone to de-carburization. The applications include torsion bar springs and spring washers for road vehicles, leaf springs for automobiles and valve springs & springs subjected to high impact stresses in sizes up to 25 mm thickness for flat products and 35 mm diameter for rounds.

Valve steels

Inlet valves in automobiles are made from palin carbon steels or low alloy steels while the exhaust valves are from highly alloyed stainless steels depending upon the operating temperature of the exhaust valves. Automobile exhaust valves operate at around 615°C while that in bus and truck exhaust valves operate between 730°C to 850°C and these high temperatures lead to failures like pitting, scaling , warping, fatigue, breakage and elongation. Inlet valves operate usually at temperatures below 320°C and hence, the carbon steels serve the purpose.

For light duty inlet valves and stem for exhaust valves, steel grades applied are carbon steels like SAE 1041, 1050 and alloy steels like SAE 3140, 5150, 6415 & 8645. For heavy duty inlet and light duty exhaust valves, medium carbon with high Si(up to 4%) & Cr (2.25% - 7.5%) are applied . However, the high silicon content though provides resistance to oxidation, but, the silicon reacts with lead oxide and hence not suitable for leaded, high octane gasoline engines. Heavy duty exhaust valves of steels containing C (up to 0.4%), Mn(7%-9%), Cr(21%), Ni (4% -5%) & N (0.10%-0.25%) are being used.

Bearing steels

Ball, roller and needle bearings are produced from direct hardening high carbon alloy steels or lower carbon alloy carburising steels to meet requirements of high hardness, wear resistance and resistance to contact fatigue.

High carbon hypereutectoid chromium steel SAE 52100 is generally used for making balls of diameter exceeding 15 mm, rollers of diameter 10mm – 30 mm and rings with wall thickness up to 12x mm in hardened and tempered condition with hardness of 61 Rc – 66 Rc to provide excellent wear resistance and contact fatigue resistance. High carbon Cr-Mn-Si steel is applied for rollers with diameter exceeding 30 mm and thicker rings in hardened and tempered condition.

Case carburising steels like DIN 20MCr5 is used for making inner and outer races of tapered roller bearings. Large size rings and rollers are produced from carburising Cr-Ni steel (0.2% C - 4%Ni - 2%Cr). Bearings operated in aggressive media are made from AISI 440C stainless steel.

Free cutting steels

Free cutting machinable low carbon and low alloy steels with deliberate additions of sulphur (up to 0.2%) with inclusion modifying agents for retaining transverse ductility are successfully applied for gears, gudgeon pins and other internal combustion engine components.

Medium carbon steels with sulphur (up to 0.4%), lead (up to 0.3%)or Se (0.1%) are applied for complex shaped components providing high and consistent level of machinability in terms of tool life, chip formation and surface finish for use in wheel studs and power steering shafts.

Alloy carburising and thorough hardening steels with increased amounts of sulphur (up to 0.08%) or lead (0.3%) are found to exhibit excellent machinability.

(to be contd. in the next issue...)

❑❑❑