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A Review on Steel Metallurgy

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Abstract

Steel is mostly manufactured in the manufacturing industries and it is nearly ninety percent due to its extremely higher strength and high toughness. This review paper discusses on the classification of steels, steel as a potential engineering material, mechanical properties and fabrication properties of steels. It also explains on its applications, low alloy steels groups and its properties. This review article also discusses on special steels like micro alloyed steels, maraging steels and Hadfield manganese steel. The paper explores the mechanical and fabrication properties of steel, explaining the variables that affect its behaviour under stress and how it reacts to manufacturing processes. This information is crucial for maximizing productivity in real-world applications. The review also explores the wide range of uses for steel, from crucial parts of infrastructure and transportation to structural elements in building. A sizeable portion of steel alloys known as low alloy steels are examined for their unique characteristics and uses, highlighting their ability to improve mechanical performance at a reasonable cost. We go into great detail about specialized steels, such as Hadfield manganese steel, which is known for its unmatched toughness and wear resistance, maraging steels, which are valued for their extraordinary strength, and microalloyed steels, which are praised for their refined grain.

Keywords: Plain carbon steel, Alloy steel, Maraging steel, stainless steel, micro alloyed steel, Hadfield steel

INTRODUCTION

Unalloyed carbon and iron steel is known as plain carbon steel. Eutectoid steel has a carbon content of 0.8 percent, according to the iron carbon equilibrium diagram. The carbon content of hypoeuctectoid steel is less than 0.8%. Carbon in hypereutectoid steel is more than 0.8% but still within 2%. Structural steels, another name for mild steel, have 0.2% carbon [1]. Low carbon steel is defined as having a carbon content of between 0.15% and 0.25%. Understanding the characteristics and behavior of regular carbon steel is essential to understanding the larger field of steel metallurgy. It serves as a reference point for examining the various alloying elements, heat treatments, and processing techniques that characterize complex steel compositions. In light of this, the review paper undertakes a thorough investigation of plain carbon steel, covering its categorization, mechanical attributes, manufacturing features, and variety of uses. This paper highlights the continued importance of plain carbon steel in the contemporary industrial landscape by shedding light on the complex interactions between composition, structure, and performance. 0.6% carbon content in medium carbon steel. High carbon steel is defined as having a carbon percentage of more than 0.6% and falling between 2% and 4% [2]. Figures 1, 2, and 3 below display photomicrographs of various plain carbon steel types [3].

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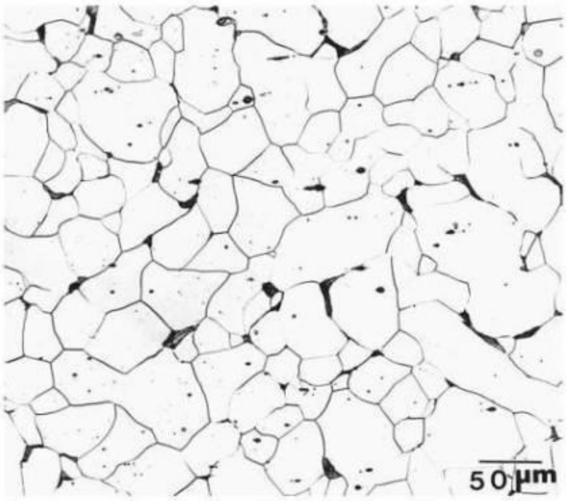
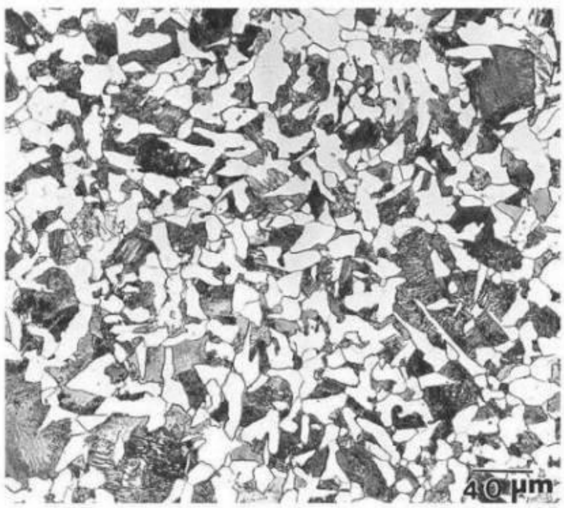


Low-carbon AISI/SAE 1010 Steel

Figure 1. Low carbon steel (ferritic structure of low carbon steel with patches of dark pearlite phase) [2]



Medium-carbon AISI/SAE 1040 Steel

Figure 2. Photomicrograph of Medium carbon steel (0.4%C steel).

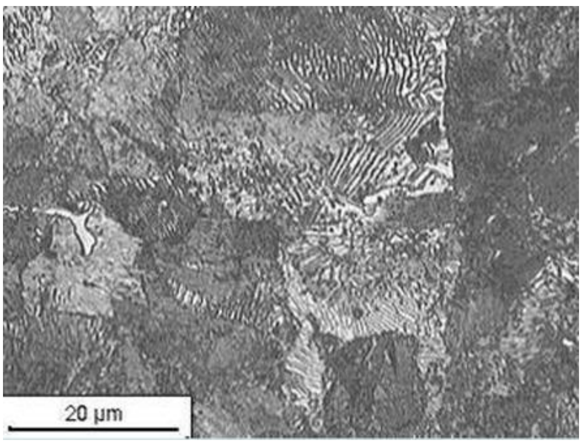


Figure 3. High carbon steel (0.8% Carbon, pearlite is the major constituent, which can be seen as wormy texture) [3].

STEEL AS A POTENTIAL ENGINEERING MATERIAL [2]

- Extremely good mechanical properties like tensile strength and ductility, good machining and welding characteristics, very good corrosion resistance, high fatigue and creep resistance.
- Easy forming and perfect processing which can be developed by controlling carbon and impurities in the steels along with control of microstructure, temper and texture
- Excellent heat treatment characteristics to respond to wide varieties of microstructural requirements for wide ranging engineering applications [3].
- Good weldability and surface engineering possibility, which can be gainfully used for complex fabrication and difficult to form component manufacturing, requiring special surface properties
- Can be made to withstand extreme corrosive and hot environment by special alloying, coating, and surface treatment [4].
- Very high familiarity, availability to exact quality and recyclability of steels.

PROPERTIES OF STEELS AND THEIR CONTROLLING FACTORS [2]

Although a steel's mechanical qualities are crucial for its engineering applications, a steel can also have other kinds of properties, each with unique controlling factors [2]. The properties of steels are listed in Table 1 below along with the factors that control them.

FABRICATION PROPERTIES OF STEELS [2]

Applications for steels include load-bearing members, chemical environment protection, and temperature-sensitive operation [5]. Steels are formed into parts and components and used under specific conditions. Because steel is used in end applications, it must be carefully chosen based on the necessary mechanical, chemical, or physical qualities. However, steel must first be fabricated, shaped, or formed into parts and components in accordance with design. This requires the following fabrication properties.

- Formability for forming under dies and presses
- Bendability for bending and shaping to some contour
- Forgability for forging and shaping the parts
- Machinability for machining the component to design

GROUPS OF PLAIN CARBON STEELS: PROPERTIES AND INDUSTRIAL APPLICATIONS

The AISI-SAE code, a four-digit code, designates plain carbon steels. The first two digits of this code, which stand for "10," indicate that the steel in question is plain carbon steel. The percentage of carbon is expressed in hundredths of a percent in the final two digits [6]. In plain carbon steel, manganese content varies from 0.30% to 0.95%. Plain carbon steel also has phosphorus sulphur, silicon and other elements [1]. These type of steels are used as sheets for forming applications to produce automobile body panels and fenders [3]. According to AISI 1020 to AISI 1040, steels under this designation codes are called as medium carbon steels which is used to produce shafts and gears. It is designated as AISI 1060 to AISI 1095 are used for die blocks, springs, and cutters and shear blades [1, 7]. The below mentioned Table-2 shows the mechanical properties according to AISI-SAE Number [1]. Table-3 depicts the applications according to AISI-SAE Number [1].

Table 1. Properties of steels and their controlling factors [2].

Property name	Properties	Controlling factors
Physical	Modulus of elasticity, Modulus of rigidity	Structure of crystal and crystallography
Chemical	Corrosion resistance, Oxidation resistance and Pitting resistance	Residual stresses
Mechanical	Hardness, Ductility, Toughness and Impact strength	Microstructure influenced by Grain size

Table 2. Mechanical properties according to AISI-SAE Number [1].

AISI-SAE Number	Plain carbon steel tensile strength in MPa	Yield strength of plain carbon steel in MPa	Ductility %
AISI 1010	400	262	47
AISI 1020	448	331	36
AISI 1040	621	414	30
AISI 1060	814	780	22
AISI 1080	1304	980	25
AISI 1095	1263	814	13

Table 3. Applications according to AISI-SAE Number [1].

AISI-SAE Number	Applications
AISI 1010	Sheets and strips for wire drawing
AISI 1020	Sheet plates and structural sections, shafts and gears
AISI 1040	Shafts, gears and studs
AISI 1060	Spring wire, forging dies and rail road wheels
AISI 1080	Die blocks used for forging operations
AISI 1095	Wires, Milling cutters used in milling operations

MECHANICAL PROPERTIES AND ENGINEERING APPLICATIONS OF LOW ALLOY STEELS

Alloy steels are created by adding elements to plain carbon steels, such as manganese, nickel, chromium, molybdenum, tungsten, vanadium, cobalt, boron, copper, aluminum, lead, titanium, columbium, and niobium [1, 4]. Alloy steels are composed of fifty percent alloying elements. Low alloy steels are those that have between 1% and 4% of alloying elements [8]. The low alloy steels' properties and engineering uses are displayed in Table 4 [1] below.

Low-alloy steels that are commonly used include SAE 5140, SAE 4140, 817 M40 (EN-24), and 534 A99 (EN-31). Ferritic martensite steel and austenitic stainless steel with 18Cr/8Ni content are two types of high alloy steels. Alloy steels can also be categorized based on their predominant chemical constituents or properties. For instance, alloy steels can be categorized as follows: (a) Heat-resistant steel; (b) Hardening grade steel; (c) Free-machining steel; (d) Stainless steel; and (e) Chromium steels, Manganese steel, Nickel steel, and Tungsten steel to indicate the dominant chemical constituent [2, 9].

MICRO ALLOYED STEELS

Specialized steels are made for particular uses in the engineering sector. Micro alloyed steels are becoming more significant among them. The idea of micro alloying is used to create micro alloyed steels. Strong nitrides and carbides are created in steel by adding very small amounts of elements like titanium, niobium, and vanadium—0.15% by weight.

Table 4. Properties and Engineering applications of low alloy steels [1].

AISI-SAE designation	Tensile strength of low alloy steels in MPa	Low alloy steels yield strength values in MPa	Ductility %	Respective engineering applications of low alloy steels
AISI 1340	1587	1421	20	Bolts
AISI 5140	1580	1449	29	Automotive Transmission gears
AISI 4140	1550	1339	30	Airplane gas turbine engine gears
AISI 4620	573	373	31	Transmission gears, chain pins, roller bearings
AISI 8620	635	407	31	Transmission gears

Microalloyed steels are a special class of high-strength, low-alloy (HSLA) steels that get their strength from the finely dispersed precipitates of carbides and nitrides. These precipitates improve the mechanical properties of steel and strengthen its matrix without the need for costly heat treatments. Better mechanical properties have been attained as a result of this [5].

MARAGING STEELS

Superior strength and malleability are well-known attributes of maraging steels. In comparison to other kinds of steel, it contains a very low carbon content [6]. In these kinds of steels, the precipitated intermetallic compounds provide strength in addition to the carbon content [9]. In order to create maraging steels, 20% and 25% Ni are added to steels along with trace amounts of titanium, aluminum, and niobium [10].

MARLOK C1650 STEEL

One particular variety of maraging steel is Marlok C1650. This particular maraging steel is used to make the die used in the die casting process. [8]. The following is the chemical makeup of Marlok C1650 steel. 0.01% carbon, 11% cobalt, 5% molybdenum, 18% nickel, and 0.30% titanium are all present. The range of hardness is 46–50 HRC. In the KIc mode, this steel has a fracture toughness of 80 MPa m1/2 and a thermal conductivity of 28 W/Mk [9].

HADFIELD MANGANESE STEEL [3, 10]

In 1882, a specific type of high alloy steel is developed. It is called as Hadfield's manganese steel. It is the first high alloy steel. Low alloy steels containing chromium are produced to enhance its strength and wear resistance. Hadfield steel is used to produce bearings [9]. Steels containing molybdenum are widely applied to manufacture axle gears and transmission parts. Hadfield steel is a type of high carbon steel containing 14% manganese [7]. This particular steel is produced for high wear resistance application. It is also used to produce armours [10].

STAINLESS STEELS

Stainless steels are created to address corrosion resistance. Steel's high chromium content makes it a valuable engineering material [9]. Ferritic, martensitic, austenitic, and age-hardening stainless steels are the different types of wrought stainless steels. Stress corrosion is less likely to occur in duplex stainless steels. Compared to ferritic steels, ferritic stainless steels are more durable [8, 10].

CONCLUSION

Different designated systems are used to categorize plain carbon steels. The specific steel type and its engineering use will determine this. A wonderful illustration of maraging steel is Marlok C1650. Soldiers' armor is made from Hadfield steel. Stainless steels are great steels that resist corrosion. It has many household uses and is used to make utensils.

REFERENCES

1. William Smith, Principles of Materials science and engineering, McGraw Hill, Third edition, ISBN 0-07-114717-9 (International), pp: 481-567, 1996
2. S K Mandal, Steel metallurgy Properties, specifications and applications, McGraw Hill, pp: 123-218, ISBN: 978-0-07-184462-8, 2015
3. Total Materia, The world's most comprehensive materials database, Switzerland, April 2012.
4. Rollason, E.C. Metallurgy for Engineers. London: The English Language Book Society and Edward Arnold Ltd., 1973.
5. Reed-Hill, Robert E. Physical Metallurgy Principles. New York: Van Nostrand Reinhold Co., 1973.
6. Higgins, R.A. Engineering Metallurgy (Applied Physical Metallurgy). New Delhi: Viva Books, 2004.
7. Bhadeshia, H. and Honeycombe, R. Steels: Microstructures and Properties. Oxford: Butterworth-Heinemann, New York, 2006.

8. Smallman, R.E. Physical Metallurgy and Advance Materials. Oxford: Butterworth-Heinemann, 2007.
9. Raghavan, V. Physical Metallurgy: Principles and Practice. New Delhi: PHI Learning, 2006.
10. M K Banerjee, Comprehensive materials finishing, Science direct, Elsevier, https://doi.org/10.1016/B978-0-12-803581-8.09185-2, Volume 2, pp: 1-49, 2017

