

## **2. Steel Properties**

### **2.1. What Are the Properties of Steel?**

Each grade of steel has a number of typical properties that determine the difference between the various steel grades. The most important properties can be divided into three groups:

- physical properties
- chemical properties
- mechanical properties

The mechanical properties are determined by the chemical composition and the microstructure. The chemical composition and the processing during the various production stages determine the microstructure and the properties of the final product. Together they constitute the intrinsic properties of the steel. These intrinsic properties are laid down according to international standards. However, some customers may impose their own specifications based on their own experience, and these are often more stringent than the standard.

In addition to the intrinsic properties of the material, a customer may also require it to be suitable for certain applications or demand certain performance properties. After all, there is little point in producing a material that meets the standards or the customer's specifications if it still causes problems in practice. These are called the technological properties.

The final choice for a specific steel grade depends upon its price and the possibility to obtain a combination of the properties desired.

### **2.2. Physical Properties**

The most important element in all steel grades is iron. Carbon steel contains at least 98% iron. Steel alloys such as stainless steel usually contain over 70% iron.

Therefore, most physical properties of steel are governed by the presence of iron:

- melting point
- density
- thermal conductivity
- thermal expansion
- electric and magnetic behavior

In many instances, the specifications and standards refer only to the mechanical properties and chemical composition, since the physical properties cannot be changed just like that. For

example, the density of non-alloyed steel and steel alloys is about the same:  $7.85 \text{ g/cm}^3$ . The microstructure hardly affects the density or other physical properties.

The magnetic properties are an exception here. For certain applications such as steel in transformers or permanent magnets, the magnetic properties are very important. Non-alloyed steel grades are usually magnetic at room temperature, but non-magnetic at elevated temperatures. Magnetic properties are strongly influenced by the microstructure and the chemical composition, and some steel alloy grades such as high grade stainless steel, are non-magnetic.

### **2.3. Chemical Properties**

By its very nature, iron reacts very readily with oxygen present in air to form iron oxide. In combination with humidity we call this rusting or corrosion. At elevated temperatures, such as during hot rolling, a thick oxide layer is rapidly formed.

The chemical composition of steel largely determines its resistance to oxidation or the pernicious influence of other elements. Thus the presence of chromium in steel causes a thin, corrosion resistant layer of chromium oxide to be formed on the steel surface. When damaged, this layer regenerates itself. Steel grades alloyed with large amounts of chromium and nickel are corrosion resistant in most environments and are therefore called stainless steel.

The microstructure can affect the chemical properties. Impurities in the steel or a change in its microstructure, for instance as a result of thermal treatment, can change the resistance against corrosion.

### **2.4. Mechanical Properties**

The mechanical properties describe how steel grades behave when subjected to a mechanical load. They are listed in all specifications. The mechanical properties are strongly affected by the chemical composition and the microstructure.

Mechanical properties change with temperature and environmental conditions. Consequently, the conditions during the test must always be mentioned when reporting mechanical properties. The most important mechanical properties are: yield point, tensile strength, elongation, hardness, toughness, fatigue, etc.

In most instances, the mechanical properties are the decisive factor in the choice a steel grade for a given application. The best way to specify a steel grade is to refer to an internationally recognized standard. These standards assist both the customer and the steel producer when describing the required mechanical properties and technological properties in practice.

### **2.5. Chemical Composition**

The chemical composition is also a very important aspect of steel. In addition to iron, steel also contains other elements such as alloying elements that have been added for a purpose or unwanted impurities. The most important elements are: carbon, manganese, silicon, phosphorus, sulphur, aluminum, nitrogen, titanium, niobium, vanadium, copper, chromium, nickel and boron.

The chemical composition has an important effect upon the microstructure, the physical and mechanical properties as well as the technological properties of steel.

## **2.6. Technological Properties**

These properties are explicitly linked to the subsequent use or treatment of the material. They can be seen as a result of a combination of intrinsic properties. We mainly distinguish between:

- formability
- weldability
- resistance to fatigue
- suitability for cutting and punching
- suitability for enameling
- coatability
- suitability for thermal treatment

## **2.7. Measuring of Steel Properties**

### **2.7.1. Chemical Composition**

The chemical composition of the steel is determined by analysis in the steel plant. The chemical composition is determined online while the steel is still liquid. Samples are taken at various stages (the blast furnace, desulphurising, the converter and the ladle treatment). These samples are dispatched immediately to the laboratories adjacent to the steel plant. There, the chemical composition is determined by various analytical techniques according to the element to be measured. Within a few minutes, the composition is known.

The strength and hardness of the steel is determined to a large extent by its chemical composition. The more alloy elements added, the harder the steel. The chemical composition also affects the microstructure of the steel: the grain size, the preferred texture etc.

## **2.7.2. Mechanical Properties**

In order to measure the mechanical properties of a steel grade, a number of standardized physical tests are carried out.

### **2.7.2.1. Tensile Test**

During a tensile test, a standardized sample is clamped in a tensile testing machine, after its initial length and cross section have been measured. By moving one of the jaws, the sample is submitted to a load. As a result, the sample elongates and thins until it eventually breaks. During the test, the force and the elongation of the sample are measured.

### **2.7.2.2. Hardness Test**

Hardness is important because it gives us an idea of the resistance a material offers to abrasion. There are a number of different methods of measuring hardness but they are all based upon the same principle.

Hardness is the resistance offered by the material to permanent indentation caused by a body of a certain shape to which a certain force is applied. The various methods differ from each other according to the indenter (a ball, a pyramid, a cone) and the force applied.

In all cases the depth of the indentation is measured. This is a measure of the hardness, since the harder the material, the shallower the indentation will be.

Because the hardness also expresses the resistance to plastic deformation, there is a good correlation between hardness and ultimate tensile stress.

### **2.7.2.3. Notched Impact Strength Test**

The toughness of a material is not so easy to express as a number as a tensile strength, since the toughness depends not only on the material itself, but also on the conditions under which it is measured. For this reason, the notched impact strength test is carried out under deliberately unfavorable conditions. During the test, a notched test bar is broken in a single blow. The energy needed to break the sample is a measure of its toughness.

The test result is highly temperature dependent. For this reason, the test is usually carried out at various temperatures. The lower the temperature, the less tough the sample is and thus the lower the impact strength.

**Points to remember:**

- The most important properties of steel are physical, chemical and mechanical.
- Physical properties are governed by the presence of iron: melting point, density, thermal expansion, conductivity, electrical and magnetic behavior
- The chemical composition of steel largely determines its resistance to oxidation or the pernicious influence of other elements.
- Mechanical properties describe how steel grades behave when subjected to a mechanical load. They change with temperature and environmental conditions
- Chemical composition of steel is determined online while the steel is still liquid.
- Mechanical properties are measured by standardized tests: tensile test, hardness test and notched impact strength test

**ex1**

**Please select technical terms from the text below and translate them:**

Mechanical Properties

The mechanical properties describe how steel grades behave when subjected to a mechanical load. They are listed in all specifications. The mechanical properties are strongly affected by the chemical composition and the microstructure.

Mechanical properties change with temperature and environmental conditions. Consequently, the conditions during the test must always be mentioned when reporting mechanical properties. The most important mechanical properties are: yield point, tensile strength, elongation, hardness, toughness, fatigue, etc.

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**Suggested answers:**

Mechanical properties – Mechanické vlastnosti

Steel grades – Jakosti oceli

Mechanical load – Mechanické zatížení

Chemical composition – Chemické složení

Microstructure – Mikrostruktura

Yield point – Mez kluzu

Tensile strength – Pevnost v tahu

Elongation – Elongace

Hardness – Tvrlost

Toughness – Houževnatost

Fatigue – Únava materiálu

Technological properties – Technologické vlastnosti

ex2

1. Each grade of steel has a number of typical properties that determine the difference between the various steel grades . The most important properties can be divided into three groups: physical properties , chemical properties and mechanical properties .
2. The chemical composition of the steel is determined by analysis in the steel plant . The chemical composition is determined online while the steel is still liquid . Samples are taken at various stages.
3. The strength and hardness of the steel is determined to a large extent by its chemical composition. The more alloy elements added, the harder the steel.
4. Hardness is the resistance offered by the material to permanent indentation caused by a body of a certain shape to which a certain force is applied.
5. The toughness of a material is not so easy to express as a number as a tensile strength, since the toughness depends not only on the material itself, but also on the conditions under which it is measured. For this reason, the notched impact strength test is carried out under deliberately unfavorable conditions. During the test, a notched test bar is broken in a single blow. The energy needed to break the sample is a measure of its toughness .

ex3

**Translate into Czech:**

What Are the Properties of Steel?

Each grade of steel has a number of typical properties that determine the difference between the various steel grades. The most important properties can be divided into three groups:

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Vlastnosti oceli – co to je?

Každá jakost oceli má množství typických vlastností, které jsou ni charakteristické. Nejdůležitější vlastnosti mohou být rozděleny do tří skupin:

- fyzikální vlastnosti
- chemické vlastnosti
- mechanické vlastnosti

Mechanické vlastnosti jsou určeny chemickým složením a mikrostrukturou. Chemické složení a zpracování během rozličných výrobních fází určuje mikrostrukturu a vlastnosti finálního výrobku a spoluvytváří charakteristické vlastnosti oceli. Tyto individuální vlastnosti jsou stanoveny mezinárodními standardy, ale někteří zákazníci prosazují vlastní specifikace na základě svých zkušeností a tyto jsou často přísnější než standardy.

Kromě individuálních vlastností může zákazník rovněž požadovat, aby byl materiál vhodný pro určité aplikace, případně trvat na určitém chování materiálu. Ostatně, nemá smysl vyrábět materiál podle standardů nebo požadavků zákazníka, pokud způsobuje problémy v praxi. Toto jsou technologické vlastnosti.

Konečný výběr konkrétní jakosti oceli závisí na ceně a možnosti získání kombinace požadovaných vlastností.

**Use external resources for the following answers:**

1. Find a Czech testing laboratory on the internet where you can have any steel properties examined.

2. Find a Czech resource on the internet mentioning a notched impact strength test. What are the translations into Czech? Find at least three different ones.

1. Read more at:

<http://www.mmresearch.eu/> or

<http://www.svum.cz/>

2. Read more at:

<http://ebookbrowse.com/2-4-1-vrubova-zkouska-houzevnatosti-razem-v-doc-d71927067>

(**Vrubová zkouška houževnatosti rázem v ohybu** - Czech translation #1)

<http://www.quido.cz/mereni/vrub.htm>

(**Zkouška vrubové houževnatosti** - Czech translation #2)

<http://jaja.kn.vutbr.cz/~janirek2/dok/materialy/5tRaz.doc>

(**Zkouška rázem v ohybu podle Charpyho** - Czech translation #3)

ex5

**Vyjmenuj tři testy mechanických vlastností (uved' anglický název a český překlad). Co se v každém testu měří (uved' anglický název a český překlad)?**

**Answer:**

1. Tensile test – Tahová zkouška



Měří se: síla a protažení vzorku – Force and the elongation of the sample are measured

Všimněte si že se neříká „pull test“ či jinak podobně. Tensility – tažnost, napínatelnost

## 2. Hardness test – Zkouška tvrdosti

Měří se: hloubka vtisku - The depth of the indentation is measured.

## 3. Notched impact strength test - Zkouška vrubové houževnatosti

Měří se: Energie potřebná ke zlomení vzorku - The energy needed to break the sample is a measured.

Notch – vrub , impact – náraz , strength – síla , pevnost , houževnatost

ex6 transkate into ctech

### Chemical Composition Chemické složení

Carbon Uhlík

Manganese Mangan

Silicon Křemík

Phosphorus Fosfor

Sulphur Síra

Aluminum Hliník

Nitrogen Dusík

Titanium Titan

Niobium Niob

Vanadium Vanad

Copper Měď

Chromium Chrom

Nickel Nikl

Boron Bor

Oxygen Kyslík

Iron Oxide Oxid železitý

Chromium Oxide Oxid chromitý

ex7

**1) Najděte na internetu název mezinárodní organizace řídící chemické názvosloví.**

**2) Kdo zajišťuje český překlad?**

**3) Najděte stránky popisující tvoření anglického názvosloví.**

**Answers:**

1) Chemickou nomenklaturou se zabývá Mezinárodní unie pro čistou a užitou chemii (International Union of Pure and Applied Chemistry – IUPAC, <http://www.iupac.org>). Názvy IUPAC jsou po celém světě přijímány jako oficiální.

2) Českým překladem se zabývá národní centrum IUPAC pro Českou republiku (<http://www.imc.cas.cz/cz/umch/iupaccentre.htm>) ve spolupráci s Českou společností chemickou (<http://www.csch.cz>).

3) Pro podrobnější informace můžete navštívit: <http://www.websters-online-dictionary.org/definitions/IUPAC%20nomenclature%20of%20inorganic%20chemistry?cx=partner-pub-0939450753529744%3Av0qd01-tdlq&cof=FORID%3A9&ie=UTF-8&q=IUPAC%20nomenclature%20of%20inorganic%20chemistry> (28.10.2011)