UNIT 5
HEAT TREATMENT OF STEEL

Vocabulary

- **Steel processing**
- **Heat treatment: annealing, hardening and tempering**

Grammar and functions

- **Cause and effect expressions**
- **Verbs introducing cause, effect, permission, prevention**

CAUSE AND EFFECT

A common connection between ideas is that of cause and effect. If we ask WHY something happens, we have the **CAUSE (C)**: if we ask what the RESULT of something is, then the answer is the **EFFECT (E).** There are many signals of this link between ideas:

E *BECAUSE* **C**
SINCE **C**, **E**
AS **C**, **E** **- FOR**

(E) | *OWING TO* **C (Noun) , (E)**
debido a
OWING TO THE FACT THAT **C (Sentence) , (E)**
debido a QUE

Owing to/Due to its lightness, Aluminium is used in window structures
Owing to the fact that it is light, Aluminium…
Owing to ***being*** *light, Al…*
BECAUSE OF THE FACT THAT

(E) | *DUE TO* **C (Noun) , (E)**
debido a QUE
DUE TO THE FACT THAT **C (Sentence) , (E)**

(E) | *BECAUSE OF* **C (Noun) , (E)**
a causa de
BECAUSE OF THE FACT THAT **C (Sentence) , (E)**
a causa de QUE

- in spite of /Despite +NOUN/ -ING = ***a pesar de***

In spite of/Despite its lightness, Al. is a strong metal
In spite of/Despite being light, Al. is a strong metal
Al. is a strong metal, despite (it) being light

- Despite the fact that/ in spite of the fact that +SENTENCE ***a pesar de que***

In spite of the fact that it is light, Al. is a strong metal
[Although it is light, Al. is a strong metal]

ONE EFFECT / RESULT / CONSEQUENCE OF **C** *IS* **E**

C *RESULTS IN* **(/from)=dar como resultado E** **(≠*resultar* = become, be…)**

BRINGS ABOUT -

Electromagnetism brought about important advances in electronics
Resulted in
Gave rise to
Led to
Important advances in electronics resulted from the discovery of electromagnetism

I find it/It is interesting to observe how a plant grows= resulta interesante
Steel with a higher percentage of carbon becomes/is/gets harder

GIVES RISE TO = make something happen

LEADS TO (líder)
The economic crisis has led to an important unemployment rate
given rise to

BECOMES Ø (+ adj) = only active, no Direct Object ~~I can become steel a harder metal~~
Becomes a harder metal
TURNS INTO a harder metal/CONVERTS INTO a harder metal

C.	*THEREFORE* *CONSEQUENTLY,* *AS A CONSEQUENCE (,)* *AS A RESULT (,)* *DUE TO THIS,* *THUS=así pues* *HENCE= de ahí que* *THEREBY*	**E**

C, *SO (THAT)* **E**

EXERCISE

1- We use copper in wires ..... its ductility
a) since b)because **c)due to**
2- We mix pure metals with other materials ..... we obtain the required properties
a) so that b) therefore c)because of
3- Aluminium is used in structures ..... it is corrosion resistant
a) as b)due to c)because of
4- Aluminium is used in structures ..... its corrosion resistance
a)because of b)as c)thus
5- Tempering …… a decrease in hardness and an increase in ductility
a) gives rise b) becomes into **c) results in**
6- Plastics are insulators, ... they are used to cover wires
a)since b)due to **c)thus**

7- Annealed steel is more machineable ..... this process releases internal stresses

a)since b)owing to c)hence

8- With hardening, the metal ……. stronger

a)results **b)becomes** c)makes

9- Iron is brittle. . ……. , it is mixed with other materials

a)As result b)Owing to **c)As a consequence**

10- Alloying is a way of changing the properties of metals. ……. we can obtain materials with specific characteristics

a)In this way b)For this c) Because this

READING: HEAT TREATMENT OF STEEL

We can **alter** the characteristics of steel **in various ways**. In the first place, steel **which contains**/CONTAINING very little carbon will be softer than steel that/which contains**/containing** a higher percentage of carbon, **(up) to** the limit of about 1½ %. Secondly, we can heat steel **above** a certain temperature, and then **allow it to cool at different rates**. At this critical temperature, **changes begin to take place** in the molecular structure of the metal. In the process **known as ANNEALING**, we heat the steel above the critical temperature and **permit it to cool** very slowly. This **causes the metal to become** softer than before and **much easier to machine**
/much more easily machineable
/much more easily machined

Annealing has a second advantage. It helps to **relieve** any internal stresses which exist in the metal. These stresses are **liable/likely/possible to** occur through hammering or working the metal, or through rapid cooling. A metal which cools more rapidly on the outside than on the inside produces unequal contractions, which **may give rise to** distortion or cracking. Metal which cools slowly is less **prone/liable** to have internal stresses than metal which cools quickly.

On the other hand, we can **make steel harder/HARDEN (THE) STEEL** by rapid cooling. This is known as **HARDENING**. We heat it up **beyond** the critical temperature, and then **quench** it in water or some other liquid. The rapid temperature **drop/fall** fixes the structural change in the steel which occurred at the critical temperature, and **makes it very hard**. But a bar of this hardened steel is more liable to fracture than normal steel. We therefore heat it again to a temperature below the critical temperature and cool it slowly. This treatment is called **TEMPERING**. It helps (to) relieve the internal stresses which occurred by rapid cooling and **makes the steel less brittle** than before. The properties of tempered steel **enable us to use** it in the manufacture of tools which need a fairly hard steel. High carbon steel is harder than tempered steel but much more difficult to work.

B. Say whether the following statements are TRUE OR FALSE as based on the text.

1. Carbon makes steel harder. **T**
2. When we want to make steel softer and easier to machine we use annealing. **T soften**
3. Annealing increases the internal stresses in the metal. **F It helps to relieve any internal stresses**
4. Steel can be hardened by cooling it slowly. **F Rapid cooling hardens the metal (but makes it more brittle)**
5. High carbon steel can be easily worked because it is soft. **F It is harder and much more difficult to work**

C. Find in the text NOUNS for the following words:

PercentAGE annealiNG hammerING treatMENT

(averAGE) crackING temperING pressURE
hardENING cooliNG
uniformITY
availabilITY, reliabilITY

Operation-OR (2)
DistortION
contractION
(Divert- diversion)

MAKE IT HAPPEN
MELT
the metal MELT
the metal that has previously been heated up to its critical temperature
MELT
CAUSEs IT TO HAPPEN
MELT

A. Answer the questions with information from the text.

1- Which two methods are used to change the properties of steel?
Changing carbon content, heat treatments
2- How does the carbon content affect the properties of steel?
The less carbon steel contains, the softer it becomes
The higher the carbon content, the less soft steel becomes
3- What does heat treatment consist of?
Heating steel up to a certain temperature and allowing it to cool at different rates
4- What happens when we heat steel at a certain temperature?
Changes begin to take place in the molecular structure of steel
5- Which are the three heat treatments?
Annealing, tempering and hardening
6- What two steps are involved in the process of annealing?
Heating steel above the critical point and let it cool slowly
7- Which are the results?
This causes the metal to become softer and much easier to machine. Besides it relieves internal stresses
8- What happens when we cool the metal quickly?
Unequal contractions outside and inside which may cause cracking and distortion
9- What two steps are involved in the process of hardening?
Heating steel beyond the critical temperature and quenching it in water
10-What problem results from hardening and how can we solve this?
This steel can fracture easily. We heat it again and let it cool slowly (tempering)
11-Explain the process of tempering.
We re-heat hardened steel beyond the critical temperature and let it cool slowly. It relieves internal stresses and makes steel harder.
12-What is the difference between tempered steel and high carbon steel?
The former is easier to work (the latter is less easily workable)

CAUSE AND EFFECT

Note the use of the structures following these verbs:

- **CAUSE**: TO CAUSE + OBJECT + TO INFINITIVE
  Ex: High temperatures will *cause* the metal *to melt*.

  TO MAKE + OBJECT + Ø BASE FORM OF THE VERB
  Ex: High temperatures will *make* the metal *melt*.

  TO MAKE + OBJECT + Ø ADJECTIVE
  Ex: The new processing methods *make* stronger steels *possible*.

- **PERMIT**: TO PERMIT + OBJECT + TO INFINITIVE
  Ex: After heating, we *permit* the metal *to cool* slowly.

  TO ALLOW + OBJECT + TO INFINITIVE
  Ex: After heating, we *allow* the metal *to cool* slowly.

  TO ENABLE + OBJECT + TO INFINITIVE
  Ex: Technology *enables* scientists *to discover* new uses for alloys.

  TO LET + OBJECT + Ø BASE FORM OF THE VERB
  Ex: After heating, we *let* the metal *cool* slowly (active voice)
  the metal is *let TO* cool slowly (passive)

- **PREVENT**: TO PREVENT + OBJECT + FROM + -ING
  Ex: The firemen managed *to prevent* the flames *from spreading* further

  TO AVOID + OBJECT + FROM + -ING
  Ex: Relays *avoid* high voltages *from damaging* the circuit.

  TO STOP + OBJECT + FROM + -ING
  Ex: The addition of chromium *stops* steel *from corroding.*

  TO KEEP + OBJECT + FROM + -ING
  Ex: Chromium *keeps* metals *from corroding*.

Chromium prevents/avoids/stops corrosion in the metal

EXERCISES

A. Multiple choice. Choose the best answer and/or complete the sentence.

1. The recommendation of various alternatives can **B** _____ the company to determine which one is best for the particular situation.
A. Make B. Permit C. Let

2. Chemical degradation is a process in which additives **C** _____ plastic to crumble away.
A. Let B. Prevent C. Cause

3. The composite fibers _____ **B** some kinds of brittle materials from cracking.
A. Let B. Prevent C. Make

4. Known as rapid solidification, the process **A** _____ the atoms to freeze in place before they can align in a crystalline lattice.
A. Causes B. Avoids C. Lets

5. Lighter and more heat tolerant than metals, ceramics **A** _____ the engine to run hotter, and therefore more efficiently.
A. Permit B. Prevent C. Make

6. When ceramic is unable to bend, a strong impact will **C** _____ it to crack.
A. Make B. Prevent C. Cause

7. Stress ceramics **C** _____ the crystalline planes from deforming.
A. Permit B. Do not allow C. Prevent

8. Superconductor **B** _____ electrons to flow indefinitely.
A. Prevent B. Permit C. Let

9. Carbon dioxide**ALLOWS/PERMITS**_____ the infrared rays to pass through the atmosphere but **PREVENTS/STOPS** _____ them from leaving again.

10. Insulators **STOP/PREVENT/AVOID** _____ electrons from flowing through them.

The presence of oxygen (MAKE) The mixture burns easily
The presence of oxygen MAKES the mixture burn easily
New technology (ENABLE) Manufacturers increase production
New technology ENABLES manufacturers TO increase production
Safety valves (LET) The steam can escape from the boiler
Safety valves LET (the) steam/vapour escape from the boiler
The depolarizer (PREVENT) Gas does not form on the anode
The depolarizer PREVENTS gas FROM formING on the anode
Non-metallic constituents in iron (CAUSE) The iron behaves in various ways
Non-metallic constituents in iron CAUSE the iron TO behave in various ways
We use goggles (KEEP) Chemicals damage our eyes
We use goggles for KEEPING chemicals FROM damagING our eyes
To KEEP
When the switch is open (STOP) Electricity does not flow in the circuit
When the switch is open, electricity is STOPPED FROM flowing in the circuit
Opening the switch STOPS electricity FROM flowing in the circuit
Rapid cooling (AVOID) Unequal contractions occur in the metal
Rapid cooling AVOIDS unequel contractions in the metal FROM occurring
Good production methods (ALLOW) Manufacturers produce more cars
Good production methods ALLOW manufacturers TO produce more cars
Metals are good conductors (PERMIT) Electricity flows through them
Metals are good conductors that PERMIT electricity TO flow through them

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Exercise A

1. B; 2- C; 3- B; 4- A; 5- A; 6- C; 7- C; 8- B;

9- ALLOWS/PERMITS; PREVENTS/STOPS

10- STOP/PREVENT/AVOID

Exercise B

The presence of oxygen MAKES the mixture burn easily

New technology ENABLEs manufacturers TO increase production
Safety valves LET the steam escape from the boiler
The depolarizer PREVENTS gas FROM formING on the anode
Non-metallic constituents in iron CAUSE the iron TO behave in various ways
When the switch is open, electricity is STOPPED FROM flowING in the circuit
Rapid cooling AVOIDS Unequal contractions (FROM OCCURRING) in the metal
Good production methods ALLOW manufacturers TO produce more cars
Metals are good conductors, which PERMIT electricity TO flow through them
We use goggles TO KEEP chemicals FROM damaging our eyes

B. Write correct sentences with these two columns. Be careful with the changes you will have to make.

The presence of oxygen	(MAKE)	The mixture burns easily
New technology	(ENABLE)	Manufacturers increase production
Safety valves	(LET)	The steam can escape from the boiler
The depolarizer	(PREVENT)	Gas does not form on the anode
Non-metallic constituents in iron	(CAUSE)	The iron behaves in various ways
When the switch is open	(STOP)	Electricity does not flow in the circuit
Rapid cooling	(AVOID)	Unequal contractions occur in the metal
Good production methods	(ALLOW)	Manufacturers produce more cars
Metals are good conductors	(PERMIT)	Electricity flows through them
We use goggles	(KEEP)	Chemicals damage our eyes

LISTENING: STEEL

Listen to the text and fill in the blanks with the word(s) you hear.

1- Which are the characteristics of Carbon steels? _____
_____
2- And what are Alloy steels? _____
3- What is the difference between LOW and HIGH alloy steels? _____
_____
4- Which are the characteristics of Carbon steels? _____
_____
5- Which type of steel is included in the group of alloy steels? _____
6- When was steel first mass-produced? _____
7- The United States, the former Soviet Union, and Japan are what? _____
_____
8- What do all steelmaking processes do? _____
_____ (PIG IRON, SCRAP metal) and **REDUCED IRON ORE, BY OXIDIZING THEM WITH AN AIR OR OXYGEN** blast.
9- Thus what happens? _____
_____
Together with added flux and other waste matter present, form slag.-

(1) pig iron- iron in the chemical state in which it exists when tapped from the blast furnace, without alloying or refinement (FUNDICIÓN BRUTA)
(2) scrap steel-.fragments used for reworking (RECORTES)
(3) flux – a substance used to refine metals by combining with impurities to form a molten mixture that can be readily removed. (FUNDENTE)
(4) slag- The more or less completely fused and vitrified matter separated during the reduction of a metal from its ore. Also called cinder. (ESCORIA)
(5) ingots- oblong mass of metal that has been run while still molten into a mold of sand or the like, esp. such a mass of iron from a blast furnace (the mold or metal formed from the mold). (LINGOTES)
(6) casehardening- In metallurgy, to make the outside surface of (an alloy having an iron base) hard by carburizing and heat treatment, leaving the interior tough and ductile (CEMENTADO)
The main processes are the Bessemer process; the Linz-Donawitz, or basic oxygen, process, and the similar electric-arc process, used for highest-quality steel; and the openhearth process.
10- When the impurities have been removed, then what? _____
_____
11- What happens then to the molten steel? _____
_____
12- How can the properties of carbon steels be improved? _____
_____

1. Which are the elements that can be present in Carbon steels **STEEL is an alloy of IRON and up to 1.7% CARBON, with (small amounts of) manganese, phosphorous, sulfur/sulphur, and silicon.**
2. And what are Alloy steels? **those with other metals are termed ALLOY STEELS -**

3. What is the difference between LOW and HIGH alloy steels? **low-alloy steels if they have LESS THAN 5% of the alloying metal, high-alloy steels if MORE THAN 5%. *… [the amount of the alloying metal, (above-below 5%)]***

4. Which are the characteristics of Carbon steels? **Carbon steels are FAR STRONGER than iron, (and their properties can be tailored to their uses by adjusting COMPOSITION AND TREATMENT)**

5. Which type of steel is included in the group of alloy steels? **including STAINLESS steels -**

6. When was steel first mass-produced? **mid-19th century**

7. The United States, the former Soviet Union, and Japan are what? **the MAJOR PRODUCERS**

8. What do all steelmaking processes do? **remove the impurities in the raw MATERIALS** (PIG IRON, SCRAP METAL) (**and REDUCED iron ore – by oxidizing them with an air or oxygen blast).**

9. Thus what happens? **Thus most of the carbon, silicon, manganese, phosphorous and sulfur/sulphur ARE CONVERTED TO their oxides and,** together with added flux and other waste matter present, form slag.

The main processes are the Bessemer process; the Linz-Donawitz, or basic oxygen, process, and the similar electric-arc process, used for highest-quality steel; and the open-hearth process.

10. When the impurities have been removed, then what? **DESIRED ELEMENTS are added in calculated proportions**

11. What happens then to the molten steel? It **is cast as INGOTS (that are shaped while still red-hot in rolling mills, or it may be cast as a continuous bar) (strand casting).**

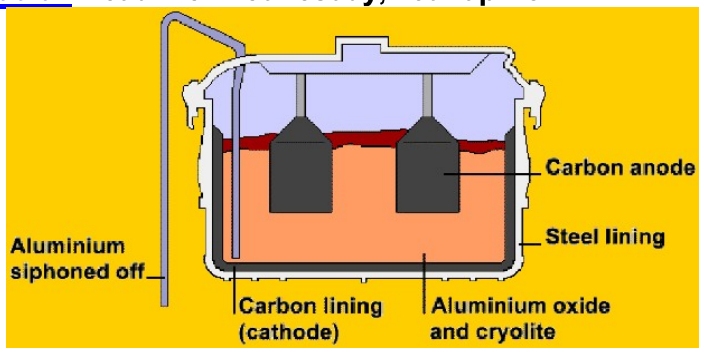
12. How can the properties of carbon steels be improved? **The properties of CARBON STEELS may be greatly improved by heat treatment: ANNEALING, CASE-HARDENING and TEMPERING**

Adapted from *Webster's International Encyclopedia*, 1994:1037.

https://personales.upv.es/adiaz/TEpractice/home.htm Start-unit 4 listening ALLOYS

WRITING

Describe the process shown in the picture. Follow the instructions on http://ttt.upv.es/adiaz Deadline: wednesday, 20th april0



Extraction of aluminium from Bauxite

METHOD In the Hall-Heroult process, aluminium metal is obtained by electrolytic reduction of alumina. Pure alumina melts at over 2000ºC.

In order to (9) produce an electrolyte at lower temperature, alumina is dissolved in molten (10) cryolite at 1000ºC.

The electrolyte is placed in a container coated (11) with graphite, which (12) is used as the cathode.

Carbon anodes are inserted into the electrolyte from the top.

The oxygen produced (13) at the anodes reacts with them, forming carbon dioxide and carbon monoxide. Molten aluminium metal is produced at the cathode and sinks (14) to the bottom (15).

EXTRA READING

STEEL

Heat Treatment of Steel

The basic process of hardening steel by heat treatment consists of heating the metal to a temperature at which austenite is formed, usually about 760° to 870° C (about 1,400° to 1,600° F) and then cooling, or quenching, it rapidly in water or oil. Such hardening treatments, which form martensite, set up large internal strains in the metal, and these are relieved by tempering, or annealing, which consists of reheating the steel to a lower temperature. Tempering results in a decrease in hardness and strength and an increase in ductility and toughness.

The primary purpose of the heat-treating process is to control the amount, size, shape, and distribution of the cementite particles in the ferrite, which in turn determines the physical properties of the steel.

Many variations of the basic process are practiced. Metallurgists have discovered that the change from austenite to martensite occurs during the latter part of the cooling period and that this change is accompanied by a change in volume that may crack the metal if the cooling is too swift. Three comparatively new processes have been developed to avoid cracking. In time-quenching the steel is withdrawn from the quenching bath when it has

reached the temperature at which the martensite begins to form, and is then cooled slowly in air. In martempering the steel is withdrawn from the quench at the same point, and is then placed in a constant-temperature bath until it attains a uniform temperature throughout its cross section. The steel is then allowed to cool in air through the temperature range of martensite formation, which for most steels is the range from about 288° C (about 550° F) to room temperature. In austempering the steel is quenched in a bath of metal or salt maintained at the constant temperature at which the desired structural change occurs and is held in this bath until the change is complete before being subjected to the final cooling.

Other methods of heat treating steel to harden it are used. In case hardening, a finished piece of steel is given an extremely hard surface by heating it with carbon or nitrogen compounds. These compounds react with the steel, either raising the carbon content or forming nitrides in its surface layer. In carburizing, the piece is heated in charcoal or coke, or in carbonaceous gases such as methane or carbon monoxide. Cyaniding consists of hardening in a bath of molten cyanide salt to form both carbides and nitrides. In nitriding, steels of special composition are hardened by heating them in ammonia gas to form alloy nitrides.