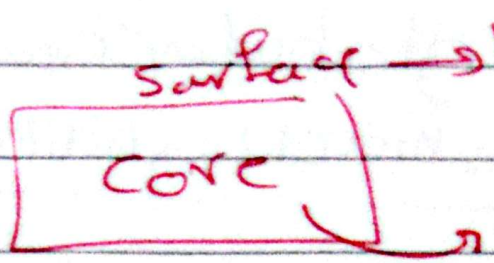
Case harding



gears, shaft application

→ increase surface hardness by 2 ways:

if C → >0.35% → heat treatment → 2 way

① induction harding	② Flame hardening
AC + high frequency induction coil يمر عبر تحتوي القطعة	

(١) حرية او يحتوي القطعة

DATE. NO.

the emf causes heating of part to above A_3

$\frac{1}{d} \propto \sqrt{f}$ heating غرض

depth $\propto \frac{1}{\sqrt{f}}$

السخين لكم ثانية بعدين

الطرق quench بالماء water jet

→ this produce martensite within surface layers making it hard to resist while core unchanged

Flame hardning heat by single oxyacetylene torch or may be part of an advanced apparatus with heat and quench part (controlmobically).

---

if Carbon ≤ 0.35% (0.15 – 0.2)

→ hardning is done by changing the chimistry of the surface

Changing the chemistry

1

Carburizing نجعل فيها

low Carbon steel → upto 0.8-1 كاربون

source of C (carbon) → solid medium
→ liq or gas

C entires steel (diffuses) as function of time and high temp (920-950) °C

in gas carburizing → mixture of methane 5-15 % meton (propane) in a natural carrier gas is used

$CH_4 + Fe \rightarrow FeC + 2H_2$

Surface layer of C

كمان نسخن ما في الفرن بنفس

2 step post Carburizing

① steel → ① heated to A_3 grain Coarse → ② air cooled

② ① heated to above A_3 (fine Austent grain size in surface) refine Martensite

② quenching to get martinsitin surface layers

As carbon in core is low it has low hardenability and core soft and tough

* due to high temp. grain size gets larger

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under Al

DATE NO

2| Nitriding (500-510) range عكس الكاربرايز هون ال

Ferritic range

- one phase change
- → Core قبل العملية لازم يكون في ال
  كل ال preparation الي بدنا ايجي وادا اغير
  prior heat treated should be applied

pure ammonia decomposition

$2NH_3 \rightarrow 2N + 3H_2$

stable إلو زمن عشان nitrogen

→ Solubity of Nitrogen in ferrite very low واغلب إلو بـ خربكون

hard Nitrides (Fe_4N, Fe_3N)

Typical Nitriding steel contains 1% AL 0.2 Mo

1.5 cr ?

ans. as these elemt form very hard and wear resistant Nitrides

4 تابع محاضرة

DATE NO

Effect of alloying element on Fe-C phase digram and transformation rate

2 resum to addition of alloying elemnt to plain C steel?

1. improve or extend existing properties 2. introduce new properties

→ A4 → γ ↔ δ (دلتا فرايت) * A3 → γ ↔ α upper critical temp

* A1 → austenite ↔ perlite lower critical temp

→ Nickel, manganese, cobalt, copper (+C, N) $A_4 \uparrow \downarrow A_3$

austenit become stabe in room temp (austenaite stabilizer)

most have FCC → مثل austenit → so substantially with ease in austenite

→ retard the transformation of Aus back to ferrite (يعيق)

---

chromium, tungeston, vanadium, molybdenum, Al, Si (+Nb)

$\downarrow A_4$ $A_3 \uparrow$ (ferrite stabilizer) BCC like ferrite

→ restrict the filed over which austenite exist → form gamma loop

(γ) كيعمل نطاق الاوستنايت سيوتي بالتالي كيقلص رقعة الفيراريت على الجهة الخارجية

steel يعني كيعمل suppressing لانه بطلت اقدر اذيب مايقدر عندي اكثر holding

---

important effect of alloying element on formation and stability of Carbides within the steel

كيحددو كيثبتو الكاربايد

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تفاعل العوامل الي بتحصل مع
الكربون

DATE NO

Carbides → have significant hardening effect
لما يتواجد في الـ steel خاصة لما يكون اقوى من الـ Iron Carbide
→ Cementite

Copper and lead instead can be used as luprecent

Ni, Si, AL → dissolve in ferrite (solid solution) ما بكونوا كربيد

AL, Ti, VONADIUM → NITRIDES

→ all alloying element will lower eutectoid carbon content
Eoid point → carbide ... يخلي
former → like, Ti, Mo, W صلب
لانو بحتاج كمية اكتر حتى يصير اكرايد
tungsten

Austenite stabilizers → lower Eiod temp
ferrite " → raise " temp
Ti, Mo, W, Si Cr
الاقوى بقص قوة اقل
في الفو بتوصي
بتوصي الـ A3

DATE NO.

Effect on Transformation rate

addition of alloying element
يؤخر تحول الاوستنايت
especially Ni, Cr tend to retard Transformation rate shift the TTT and CCT to the right

→ steel with less carbon <0.35% can be heat treatable with one condition
يجب
alloying element

air او oil مثل ال slower cooling لما نستخدم rates فوائده انو
quenching
martensitic structure احصل على

disadv for alloying element also is the lowering of the Mf temp
Cobalt ال

→ Exception
phase diagram تشوه

→ all elements stren but the carbide former get

stren = uts * tooker

→ another important effect of alloying element is the determination of the final stable structure at room temp

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DATE. NO.

Ch6 | metal alloys → 2 main class 1. Ferrous 2. non Ferrous

"الحديد والصلب"

→ ferrous → steel
→ cast iron C > 2.5 or 2%

→ iron is the primary consitituent

why it's widespread use in engineering? 1. iron containing compondes exist in abundant amount in earth crust

2. produced in economical 1. extraction 2. refining 3. alloying 4. fabrication techniques

3. the are extremly versatile → they can be tailored to have a wide rang of physical and mechanical properties

Steels → iron-carbon alloy

plain carbon steel → carbon only residual amount of impurities other than carbon and little manganese

alloy steel may contain amount of other element added for specific purposes

mechanical properties sensitive to carbon content which is normaly less than 1% for steel ← 1% for steel

Steel contains the carbon concentration low ✓ medium ✓ high ✓ morning glory

Sub classes acording to the concertration of other alloying element low alloy, high alloy carbon steels

تصنيفات داخلية

Cold worked part use & stress relief annealing

DATE NO.

Low carbon steel (plain carbon, high strength low alloy)

1. C < 0.25 wt%
2. can't be heat treated to produce martensite
3. Strengthend by cold working
4. micro structure (consists of) Fe ferrite + pearlite
5. Soft and weak

the good properties → Ductility, toughness, Good machinability and welding + inexpensive

medium - carbon steel (plain carbon, heat treatable)

1. C between 0.25 - 0.6 %
2. may be heat treated by 1. austenizing 2. quenching 3. tempering to improve mechanical properties

~~mostly~~ mostly used in tempered condition tempered martensite

Plain medium carbon steels → low hardenability and can be heat treated only in thin section + high quenching rate or by adding Ni or Cr to shift the CCT and slow cooling

alloy steel can be heat treated to give rise to a variety of strength - ductility combination

→ Heat treated alloys are stronger than low carbon but less ductile

free machining → steels with high machinability sulfur, lead, bismuth

small mns (MnS) balls
rounded / strong ductile
strongly bonded to steel

Fes
sharp edge
weak brittle
weakly bonded to steel

Plain carbon Tool

DATE NO

High carbon steel 1. C 0.6 - 1.4 %. wt

2. always used in the quenched and tempered condition
3. hardest, strongest and least ductile steels
4. high wear resistance

Tool steel are high carbon steel with addition of
Cr, Vanadium, tungesten, Mo (carbide forming element)
to shift the CCT to right
martinsite
A2 → air cooling Cr
W1 → water quenching Cr
D2 → extra low cooling rate Cr
to maintain dimentional accuracy

high alloy → stainless steels highly resistance to corrosion in a number of environment

Cr major alloying element at least 11%. is added for corrosion resistant (chromium)

why?
Cr_oxid → adherent, strong, passive (not porous) (Adherance)
Cr_2O_3
iron_oxid → weak and brittle, flak (porous)
Fe_2O_3

corrosion res can be enhanced by adding Ni or Mo

1. Austentic stainless steel
1 - have stable austenitic FCC crystal structure (austenitic stabilizer) Ni
2. most corrosion resistant
- can be heat treated
- hardened by cold worked
- non-magnetic
- cold work
- austenite

DATE. NO.

like food processing + welding → 316L (2 or 3) تبع S → super low carbon, low carbon

2] Ferritic stailess steel لفايبر ذرة كالية BCC(α) crystal structure due to high level of Cr (ferrite stabilizer)

- strengthened and hardened by cold work & are magnetic

* due to higher Cr they ~~are~~ have ~~higher~~ high resistant to oxidation (chromium content) في بيئة غازية (dry) [4] تبع

3] Martensitic st steel heat treatable + magnetic (يمكن معالجتها BCT نفس الفيريت لكن مكعب)

when good corrosion ~~x~~ or & oxidation with high hardness [4] تبع

من بين الـ 2 ستانليس (فيريتي واوستنايتي)

Cast iron C > 2wt% carbon 3 - 4.35 wt% في الطبيعة

→ from Fe-C phase digram these alloy is in liq state at 1150-1300°C (temp-range) they can be easily melted and cast لسهولة صنعه carbon-steel

→ some iron are brittle and casting يشتغل عليه صار هو الحل العملي الوحيد للشغل عليه (processing)

→ if Si > 1% and slow cooling

Cementite will decompose into ferrite and graphite

$Fe_3C \rightarrow 3Fe(\alpha) + C$ (graphite)

metastable

DATE NO

Gray cast iron

C → 2.5 - 4%
Si → 1 - 3 %

graphite → flakes surrounded by ferrite or pearlite ← (ferrite: slow cooling, pearlite: fast cooling)

graphite → flakes or nodules in a matrix of ferrite form

If loaded in tension → weak + brittle
during tension flakes acts as stress raisers → (sharp)

the structure has much better mechanical properties than gray cast

tension تحت شد ←

application → valves, crankshafts gears and other automotive parts

Ductile or nodular iron

before casting
= gray cast + small amount of magnesium or cerium
mg
ce
will give different micro structure

white iron

(cementite + Perlite)
→ low Si + rapid cooling
Carbon → Cementite

Very hard + brittle
used where extreme hardness and wear resistant with limited ductility ex rollers

→ it's an intermediate step in producing

malleable iron

steps
① (800-900) تسخين لفترة طويلة
in a neutral atmosphere

② cementite decomposes and formation of graphite
graphite → present in the form of cluster or rosettes
in matrix of Ferrite or pearlite

nodular iron it's similar to structure of nodular ε structure
and accounts for high strength high strength
and appreciable ductility

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DATE NO.

applications الاستخدامات Non-Ferrous alloy

disadvantage

limitation of Ferrous alloy ? 1. high density
2. low electrical conductivity
3. Inherent susceptibility to corrosion

alloy are classified according to the base metal

2 type of alloy

Cast alloy
they are brittle so forming or shaping by deformation not possible the normally processed by Casting

Wrought alloy
they are amenable to mechanical deformation (Elastic defor)

Copper and it's alloy

unalloyed

→ unalloyed copper soft, ductile, corrosion resistant and difficult to machine

$\alpha + \beta'$ → hot worked

Corrosion & mechanical properties can be enhanced by alloying

most common copper alloys (brasses) Zinc major alloying element

if Zn 35% α brasses, FCC, soft, ductile, cold worked

if Zn > 35% $\alpha + \beta'$ → BCC, harder stronger

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DATE. NO.

Bronzes another class [↳ Al, tin, Si, Ni]

stronger than brasses but still have good corrosion res

Al and it's alloy

1. low density
   2.7 while iron and steel 7.9 3. corrosion resistance
2. high electrical and thermal conductivity
4. high ductility even at low temp (due to FCC struct)

Limitation → low melting temp 660°C this limit the max temp the material can be used at

Al alloy is versatile offer wide range of propretes

they exist in both cast or wrought forms and contain heat treatable and non heat treatable alloys

↳ precipitation hardening (aging) Al + Cu → Intermetallic Compound

↳ what give Al strength and hardness

cold working

4 digit number

1 2 3 4

1 → alloy group
2 → modification or impurity level
3 4 → same as the two digit right to decimal point for Al percentage

letters → indicating their temper (thermal and/or mechanical treatments)

F → Fabricated
O → annealed, recrystallized
H → strain hardening H1 → SH only
H2 SH then partially annealed H3 then stabilized

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W → solution heat treated

T → thermally treated ≈ XW1 8S

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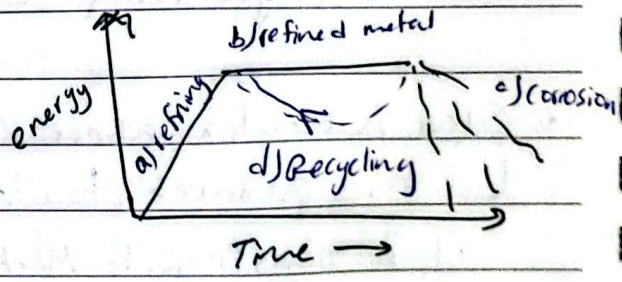
Ch 8 Metallic corrosion & its Prevention

DATE. NO.

Corrosion: The destruction of a material because of it's rxn w the environment.

→ corrosion has great economical & environmental impact
- Corrosion tends to reverse the chemical action of the refining process

→ Metals are found primarily either as oxides or sulfides in the ore



أنواع الـ Corrosion

- Uniform corrosion or attack
- Galvanic (or two metal) corrosion
- Crevice corrosion
- Intergranular corrosion

1 Uniform corrosion or Attack

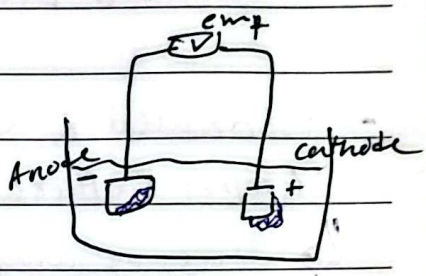
* Most common type of corrosion
* has greatest economical impact
→ " Chemical rxn that takes place uniformly over the entire exposed surface or large area "
* in this case the metal → • becomes thinner • then eventually fails
* This corrosion isn't dangerous
* rust on iron & steel surfaces

DATE. NO.

Prevention of this corrosion:

- Choose the right material
- Coating
- Use of inhibitors
- Cathodic protection

2 Galvanic (or two metal) corrosion



* An electrical potential difference is present b/w 2 dissimilar metal or alloys when they are placed in a corrosive or conductive sol.

* If these metals are brought into contact → the potential diff. produces a net electrical current (I) & corrosion.

* The less resistent metal → corrosion increase (Anodic/Active)
The more resistent metal → corrosion decrease. (cathodic/noble)

Prevention of this corrosion:

- Selection of combination metal or alloys that are close ase possible in the galvanic series.

- Avoid small anodic parts in contact w large cathodic parts

- Insulate dissimilar metal
- Add inhibitors
- If welding is necessary → use welding filler metal same as the base metal

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DATE. NO.

3 Crevice corrosion الشقوق

شقوق

"intensive attach that takes place in crevices & small shielded areas in metal surfaces exposed to corrosives"

- Associated in small volumes of stagnant sol. caused by hole, فتحة gasket surfaces, lap joints, crevices under bolts & rivet heads
  ↳ this is why it's called crevice corrosion / gasket corrosion

Prevention of this corrosion:

- Use welded joints instead of riveted or bolted joints
- Design vessels for complete drainage.
- close crevices in existing lap joints by welding or soldering تسكير الشقوق
- Use solid non-absorbent gaskets such as teflon
- Inspect the equipments & remove deposits.
- Remove wet packing material

4] Intergranular corrosion

DATE. NO.

"localized attack or adjacent to grain boundaries w Little corrosion of the grains themselves".

- Grains for the metal fall out & Strength is lost

- Reason for this corrosion → different in resistance to corrosion blw grain-boundary phases & grains (normally carbides)

- Produces a net potential diff. between grains & grain boundry leading to a attack of the less resistant (anodic) areas.
→ then the Seperation of grains

→ Stainless Steel are Subjected to the attack when exposed to a certain temp range (650 - 950 °C)
- resulting in sensitization (precipitation of chromium carbide at grain boundaries)

- Corrosion resistance of the grains is reduced↓
→ as a result of chrominm depletion → this with inc. the attack of grains & lead to cracking or complete failure.

Minimize intergranular corrosion:
- Use high temp. solution treatment.
- Add Strong carbide-forming element (Stabilizer) Such as titanium, molybdenum.
- lower the carbon content to ≤0.03 %.

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DATE. NO.

(SCC) Stress corrosion cracking

" the cracking of a material under combined action of tensile stresses & corrosion "

- ~~to~~ Part is not attacked on most of it's surface.

- The cracks may be intergranular or transgranular depending on the metal - evironment.

It may be prevented by:
- Change the alloy to more resistant one.
- apply cathodic protection
- Apply coating
- lower the stress level below that of the threshold
- eliminate the critical environment species. ex: distillation
- Introduce compressive residual stresses ex: shot peening.

Corrosion fatigue:

" the reduction of fatigue resistant due to the presense of corrosive medium "

- to prevent it: enhance fatigue strength & corrosion resistance