FUNDAMENTAL MANUFACTURING PROCESSES

Heat Treating

SCENE 1.
tape 506, 19:07:04-19:07:24
parts pulled from heat, glowing, and transferred to quench for cooling

NARRATION (VO):

HEAT TREATING PROCESSES ARE USED TO ALTER THE METALLURGICAL STRUCTURE AND MECHANICAL PROPERTIES OF METALS OR ALLOYS THROUGH THE USE OF CONTROLLED HEATING...,

AND COOLING CYCLES.

SCENE 2.
tape 488, 00:37:00-00:37:20
mill forms being pulled from heat treating furnaces
tape 502, 14:16:01-14:16:05
tooling being heat treated
tape 493, 01:04:40-01:04:54
parts being loaded for heat treating

NARRATION (VO):

HEAT TREATING PROCESSES ARE SOME OF THE MOST WIDELY-USED AND VERSATILE IN MANUFACTURING. THEY ARE UTILIZED TO TREAT MILL FORMS...,

TOOLING..,

AND PARTS.

SCENE 3.
continue previous shot
tape 483, 11:04:09-11:04:30
aircraft taking off
tape 510, 00:02:24-00:02:29
automobile
tape 232, 04:24:36-04:24:41
mill working
tape 485, 11:12:51-11:12:57
power tool
tape 486, 12:10:22-12:10:28
computer working

NARRATION (VO):

THESE HEAT TREATED PARTS ARE VITAL TO THE SATISFACTORY OPERATION OF PRODUCTS, SUCH AS,

AIRCRAFT,

AUTOMOBILES,

MACHINERY,

POWER TOOLS,

AND COMPUTERS.

SCENE 4.
tape 496, 03:04:00-03:04:08
zoom in, non-ferrous metal being quenched
tape 501, 12:24:27-12:24:55
steel coming out glowing red, and conveyed away
CG, SUPER: Carbon Steels
Alloy Steels

NARRATION (VO):

WHILE MOST METALS AND ALLOYS CAN BE HEAT TREATED IN ONE MANNER OR ANOTHER, THIS PROGRAM FOCUSES PRIMARILY ON THE HEAT TREATMENT OF CARBON AND

ALLOY STEELS.

SCENE 5.
continue previous shot and cg, super, build onto cg
CG, SUPER: Ferrous Materials
Carbon Steels
Alloy Steels
Tool Steels
Cast Irons
Stainless Steels

NARRATION (VO):

THESE CARBON AND ALLOY STEELS ARE FERROUS MATERIALS, WHICH ARE DEFINED AS ALLOYS CONTAINING MORE THAN 50% IRON. OTHER FERROUS MATERIALS INCLUDE:

TOOL STEELS,

CAST IRONS,

AND STAINLESS STEELS.

SCENE 6.
tape 505, 17:03:27-17:03:59
heat treating operation
CG, SUPER: Mechanical Properties
Tensile Strength
Ductility
Impact Strength/ Toughness
Hardness

NARRATION (VO):

THE PURPOSE OF MOST HEAT TREATING PROCESSES IS TO ALTER THE MECHANICAL PROPERTIES OF METALS. THESE MECHANICAL PROPERTIES INCLUDE:

THE METAL'S TENSILE STRENGTH,

THE DUCTILITY OF THE METAL,

THE IMPACT STRENGTH, OR TOUGHNESS OF THE METAL,

AND THE HARDNESS OF THE METAL.

SCENE 7.
tape 295, 03:17:29-03:17:48
bar being bent
CG, SUPER: Tensile Strength
CG, SUPER: Yield Strength
tape 250, 02:05:30-02:05:40
c.u. part being sheared
CG, SUPER: Ultimate Tensile Strength

NARRATION (VO):

THERE ARE TWO IMPORTANT ASPECTS OF TENSILE STRENGTH. THE FIRST IS YIELD STRENGTH, WHICH IS THE MAXIMUM FORCE A MATERIAL CAN TAKE BEFORE STRETCHING PERMANENTLY. THE SECOND IS ULTIMATE TENSILE STRENGTH WHICH IS THE MAXIMUM FORCE THAT CAN BE APPLIED BEFORE A MATERIAL FRACTURES.

SCENE 8.
CG, SUPER: Ductility
tape 1, 00:04:32-00:04:42
slow-motion turning operation
tape 219, 01:01:30-01:01:40
photomicrography of soft steel

NARRATION (VO):

DUCTILITY IS THE ABILITY OF A METAL TO BEND OR STRETCH BEFORE IT FRACTURES. HIGHLY DUCTILE

turning operation
tape 219, 01:01:45-01:01:55
photomicrography of cast iron turning operation

METALS, SUCH AS SOFT STEELS OR ALUMINUM, STRETCH A GREAT DEAL BEFORE FRACTURING. LOW DUCTILITY METALS, SUCH AS CAST IRON, DON'T STRETCH MUCH AND FRACTURE EASILY.

SCENE 9.
CG, SUPER: Impact Strength/Toughness
tape 508, 23:06:12-23:06:23
c.u. hammer hitting concrete

NARRATION (VO):

A MATERIAL'S IMPACT STRENGTH, OR TOUGHNESS IS ITS ABILITY TO ABSORB MECHANICAL SHOCKS WITHOUT FRACTURING.

SCENE 10.
CG, SUPER: Hardness
tape 506, 19:10:43-19:10:55
hardness test being performed
tape 503, 15:22:47-15:23:15
zoom out, c.u. hardness test being performed

NARRATION (VO):

THE HARDNESS OF A MATERIAL IS AN INDICATION OF ITS STRENGTH, BUT ALSO PERTAINS TO WEAR AND SCRATCH RESISTANCE. HARDNESS IS DETERMINED BY PERFORMING A HARDNESS TEST IN WHICH A CALIBRATED FORCE IS USED TO PRESS A SMALL, HARD INDENTER INTO THE SURFACE OF A METAL. THE DEPTH OR SIZE OF THE IMPRESSION IS MEASURED AND CONVERTED INTO A HARDNESS NUMBER. THE LARGER OR DEEPER THE INDENTATION, THE SOFTER THE MATERIAL.

--- TOUCH BLACK ---

SCENE 11.
tape 495, 02:08:24-02:08:32
parts coming out of heat treating
tape 452, 19:18:57-19:19:05
molten metal being poured

NARRATION (VO):

TO UNDERSTAND THE BENEFITS OF HEAT TREATING PROCESSES FIRST REQUIRES AN AWARENESS OF METAL AND ALLOY STRUCTURES.

SCENE 12.
continue previous shot
tape 435, 03:08:13-03:08:25
c.u. metal solidifying

NARRATION (VO):

WHEN A MOLTEN METAL SOLIDIFIES, THE ATOMS ARRANGE THEMSELVES INTO DEFINITE PATTERNS CALLED CRYSTAL STRUCTURES.

SCENE 13.
continue previous shot
tape 514, 00:00:58-00:01:12
GRAPHIC: modeled body-centered cubic
CG, SUPER: Body-Centered Cubic
tape 514, 00:01:18-00:01:32
GRAPHIC: modeled face-centered cubic
CG, SUPER: Face-Centered Cubic

NARRATION (VO):

THE TWO MOST COMMON CRYSTAL STRUCTURES IN METALS ARE:

BODY-CENTERED CUBIC...,

AND FACE-CENTERED CUBIC.

SCENE 14.
tape 514, 00:01:38-00:01:52
GRAPHIC: single, simplified face-centered cubic
tape 514, 00:02:13-00:02:24
GRAPHIC: zoom out, simplified face-centered cubic filling screen
tape 514, 00:04:10-00:04:20
GRAPHIC: developing grains #3
tape 514, 00:04:30-00:04:40
GRAPHIC: developing grains #4
tape 514, 00:04:50-00:05:00
GRAPHIC: developing grains #5
tape 514, 00:05:10-00:05:20
GRAPHIC: developing grains #6
tape 514, 00:05:30-00:05:40
GRAPHIC: developing grains #7
tape 514, 00:05:50-00:06:00
GRAPHIC: developing grains #8
tape 514, 00:06:10-00:06:20
GRAPHIC: developing grains #9
tape 514, 00:06:27-00:06:40
GRAPHIC: grains in boundary

NARRATION (VO):

THESE CRYSTAL STRUCTURES GROW UNIFORMLY IN ALL DIRECTIONS WITHIN EACH DEVELOPING CRYSTAL. AS THE METAL COOLS THESE CRYSTALS ARE CONFINED BY THE ADJACENT DEVELOPING CRYSTALS, FORMING GRAINS. THE LINE OF INTERSECTION BETWEEN GRAINS IS CALLED A GRAIN BOUNDARY.

SCENE 15.
tape 514, 00:06:57-00:06:59
confined crystal highlighted #1
tape 514, 00:07:17-00:07:19
confined crystal highlighted #2
tape 514, 00:07:02-00:07:04
confined crystal highlighted #3
tape 514, 00:07:27-00:07:29
confined crystal highlighted #4
tape 514, 00:06:52-00:06:54
confined crystal highlighted #5
tape 514, 00:07:22-00:07:24
confined crystal highlighted #6
tape 514, 00:07:12-00:07:14
confined crystal highlighted #7
tape 514, 00:07:06-00:07:08
confined crystal highlighted #8

NARRATION (VO):

BECAUSE THE GRAINS FORM INDEPENDENTLY, THEIR CRYSTAL STRUCTURES DEVELOP TILTED IN VARIOUS DIRECTIONS.

SCENE 16.
tape 514, 00:08:20-00:08:30
GRAPHIC: flat sheet of atoms, stick connections
tape 514, 00:07:36-00:07:46
ANI: flat sheet of atoms with electromagnetic connections
tape 514, 00:09:11-00:09:27
ANI: arrows appear on opposing sides of atoms top and bottom, pushing towards center, applying load, atoms stretching a lot, load removed, atoms springing back into shape

NARRATION (VO):

ALL ATOMS IN THESE CRYSTALLINE STRUCTURES ARE HELD IN PLACE BY ELECTROMAGNETIC ATTRACTION TO NEIGHBORING ATOMS. IF A FORCE, OR LOAD IS APPLIED TO A METAL, THESE ELECTROMAGNETIC BONDS STRETCH, ALLOWING THE ATOMS TO MOVE SLIGHTLY. WHEN THE LOAD IS REMOVED, THE BONDS PULL THE ATOMS BACK INTO POSITION.

SCENE 17.
tape 514, 00:10:15-00:10:34
ANI: flat sheet of atoms with electromagnetic connections, arrows appear on opposing sides top and bottom, pushing towards center, applying load to atoms, atoms stretching a lot, then tear apart, continue moving with load being applied

NARRATION (VO):

IF THE APPLIED FORCE EXCEEDS THE METAL'S YIELD STRENGTH, THOSE ELECTROMAGNETIC BONDS WILL BREAK, CAUSING PERMANENT STRETCHING, OR DEFORMATION.

SCENE 18.
continue previous animation
tape 514, 00:11:00-00:11:15
GRAPHIC: flat sheet of atoms, stick connections
tape 514, 00:11:22-00:11:27
GRAPHIC: flat sheet of atoms, alloy atom #1 appears
tape 514, 00:11:32-00:11:37
GRAPHIC: flat sheet of atoms, alloy atom #2 appears
tape 514, 00:11:42-00:11:47
GRAPHIC: flat sheet of atoms, alloy atom #3 appears
tape 514, 00:11:52-00:11:57
GRAPHIC: flat sheet of atoms, alloy atom #4 appears
tape 514, 00:12:02-00:12:07
GRAPHIC: flat sheet of atoms, alloy atom #5 appears
tape 514, 00:12:12-00:12:17
GRAPHIC: flat sheet of atoms, alloy atom #6 appears
tape 514, 00:12:22-00:12:27
GRAPHIC: flat sheet of atoms, alloy atom #7 appears
tape 514, 00:12:32-00:12:37
GRAPHIC: flat sheet of atoms,

NARRATION (VO):

TO MAKE METALS STRONGER AND MORE RESISTANT TO DEFORMATION, IT'S NECESSARY TO STRENGTHEN THEIR CRYSTAL STRUCTURES. THIS IS DONE BY ADDING ALLOYING ELEMENTS, WHICH ARE OTHER METALS OR NON-METALLIC ELEMENTS, LIKE CARBON.

alloy atom #8 appears
tape 514, 00:12:42-00:12:47
GRAPHIC: flat sheet of atoms,
alloy atom #9 appears
tape 514, 00:12:52-00:12:57
GRAPHIC: flat sheet of atoms,
alloy atom #10 appears

SCENE 19.
continue previous sequence

NARRATION (VO):

THE ADDITION OF AN ALLOY INTRODUCES FOREIGN ATOMS WITHIN THE CRYSTAL STRUCTURE OF THE BASE METAL, DISRUPTING THE STRUCTURAL UNIFORMITY.

THIS DISRUPTION RESULTS IN INCREASED STRENGTH.

SCENE 20.
tape 503, 15:15:47-15:15:55
alloying element added to parts
tape 514, 00:00:50:00
freeze frame, blue background
CG: Alloying Elements
Carbon
Manganese
Chromium
Molybdenum
Silicon
Nickel

NARRATION (VO):

IN ADDITION TO CARBON, OTHER ALLOYING ELEMENTS CAN BE ADDED TO BASE METALS, SUCH AS:

MANGANESE,

CHROMIUM,

MOLYBDENUM,

SILICON,

AND NICKEL.

STEELS CONTAINING SUCH ELEMENTS ARE CALLED ALLOY STEELS.

SCENE 21.
tape 514, 00:11:42-00:11:47
GRAPHIC: flat sheet of atoms,
alloy atom #3 appears
tape 514, 00:11:52-00:11:57
GRAPHIC: flat sheet of atoms,
alloy atom #4 appears
tape 514, 00:12:02-00:12:07
GRAPHIC: flat sheet of atoms,
alloy atom #5 appears
tape 514, 00:12:12-00:12:17
GRAPHIC: flat sheet of atoms,
alloy atom #6 appears
tape 514, 00:12:22-00:12:27
GRAPHIC: flat sheet of atoms,
alloy atom #7 appears
tape 514, 00:12:32-00:12:37

NARRATION (VO):

IN MANY CASES, JUST ADDING AN ALLOYING ELEMENT TO A BASE METAL MAKES IT STRONGER AND HARDER, AND IMPROVES IT'S MECHANICAL PROPERTIES. BUT FOR MOST STEELS, EVEN GREATER PROPERTIES IMPROVEMENT CAN BE ACHIEVED THROUGH HEAT TREATMENT.

GRAPHIC: flat sheet of atoms, alloy atom #8 appears
tape 514, 00:12:42-00:12:47
GRAPHIC: flat sheet of atoms, alloy atom #9 appears
tape 514, 00:12:52-00:12:57
GRAPHIC: flat sheet of atoms, alloy atom #10 appears
tape 506, 19:03:21-19:03:36
parts going in for heat treatment

SCENE 22.
continue previous shot
tape 514, 00:00:50:00
freeze frame, blue background
CG: Through Hardening Processes
Increase the strength & hardness throughout an alloy's cross-section
Surface Hardening Processes
Create different properties at the surface than at the center of a metal structure
Softening Processes
Decrease the hardness of metals and alloys

NARRATION (VO):

HEAT TREATING PROCESSES CAN BE CLASSIFIED INTO THREE GROUPINGS:

THROUGH-HARDENING PROCESSES THAT INCREASE THE STRENGTH AND HARDNESS THROUGHOUT AN ALLOY'S CROSS-SECTION,

SURFACE HARDENING PROCESSES THAT CREATE DIFFERENT PROPERTIES AT THE SURFACE THAN AT THE CENTER OF A METAL STRUCTURE,

AND SOFTENING PROCESSES THAT DECREASE THE HARDNESS OF METALS AND ALLOYS.

--- FADE TO BLACK ---