HEAT TREATMENT · CASE HARDENING · PLATING · COATINGS · REFERENCE DOCUMENT · PUBLIC

Heat & surface treatment

Changing a part after machining — steel heat treatment, surface hardening, and the plating/coating choices for corrosion, wear and appearance, plus the gotchas.

REVISION	ISSUED	OWNER	COMPANION
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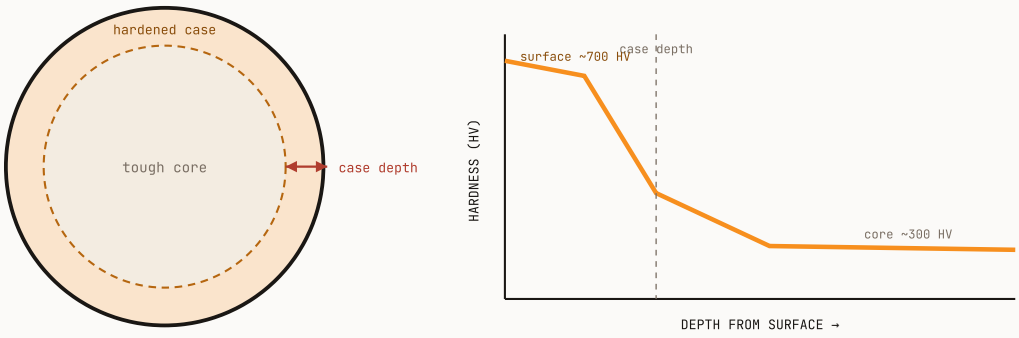
ABSTRACT

After a part is made, treatments tune what the material alone can't: heat treatment changes bulk strength and hardness, surface hardening adds a wear-resistant skin over a tough core, and plating/coating add corrosion resistance, wear resistance or appearance. Each has dimensional and process consequences to design for.

Section 1 frames it. Section 2 is steel heat treatment. Section 3 is surface hardening. Section 4 is plating and coatings. Section 5 covers aluminium and stainless specifics. Section 6 is selection and gotchas.

CASE HARDENING — HARD CASE, TOUGH CORE



CASE HARDENING GIVES A HARD, WEAR-RESISTANT SURFACE OVER A TOUGH CORE — THE HARDNESS FALLS FROM THE SURFACE TO THE CORE OVER THE CASE DEPTH. MOST "TREATMENTS" CHANGE EITHER THE BULK (HEAT) OR JUST THE SURFACE (CASE / PLATING / COATING).

CONTENTS

1. What treatments do

Two questions decide the route: do you need to change the **bulk** (strength/hardness/ductility) or just the **surface** (wear, corrosion, looks)?

`Heat treatment`	Heating/cooling cycles that change bulk microstructure and properties
`Case hardening`	A hard surface "case" over a tough, unhardened core
`Plating`	A metal layer deposited (electro or electroless) for corrosion/wear/appearance
`Conversion coating`	A surface chemically converted (anodize, passivate, phosphate)
`Hydrogen embrittlement`	Delayed cracking of high-strength steel from plating-absorbed hydrogen

2. Steel heat treatment

PROCESS	PURPOSE	RESULT
Annealing	soften, relieve stress, ease machining	soft, ductile, coarse grain
Normalizing	refine grain, uniform structure	moderate strength, consistent
Quench & temper (harden)	high strength/hardness	hard then tempered to set toughness
Stress relief	remove residual stress (post-weld/machining)	little property change, stabilises dimensions

The **temper** after quenching is the design lever: low temper = harder/more brittle, high temper = tougher/softer. Specify the target hardness (e.g. "harden & temper to 40–45 HRC"), not just "harden". See the *Hardness reference* for HRC↔strength.

3. Surface hardening

A hard skin over a tough core resists wear and contact fatigue (gears, shafts, cams) without making the whole part brittle:

METHOD	CASE DEPTH	NOTES
Carburizing	0.5–2 mm	low-carbon steel; deep, hard case; some distortion
Nitriding	0.1–0.5 mm	low distortion (low temp), very hard, corrosion resistant
Induction / flame	selective	medium-carbon steel; harden only where needed

Specify **case depth and surface hardness**; the hard case raises bending and pitting fatigue strength (pairs with the *Hertz* and *Gear* references).

4. Plating and coatings

FINISH	FUNCTION	NOTES
Zinc plate / galvanize	sacrificial corrosion	cheap, common; H-embrittlement risk on high-strength steel
Zinc-nickel	better corrosion	automotive, harsh environments
Electroless nickel (EN)	uniform hard + corrosion	even on complex shapes (no current path)
Hard chrome	wear, hardness	shafts, cylinders; decorative chrome is thin
Anodize (aluminium)	corrosion + wear + colour	type II decorative/dyeable, type III hardcoat (wear)
Passivation (stainless)	restore corrosion resistance	removes free iron; no dimensional change
Phosphate	paint base, mild corrosion, break-in	manganese/zinc phosphate
PVD / DLC	very hard, low friction, thin	tools, decorative, dry-running surfaces
Powder coat / e-coat	durable paint	thick build-up — account for it on fits

5. Aluminium and stainless specifics

- **Aluminium tempers (e.g. 6061-T6) come from solution + age heat treatment**
  don't anneal a structural temper away with welding heat. **Anodizing** grows an oxide that
  adds
  ~half its thickness per side to dimensions; type III hardcoat is thicker — mask threads and account for build-up on fits.
- **Stainless relies on its chromium-oxide film; passivation restores it after machining (which smears free iron and causes rust spots). It doesn't change dimensions or hardness.**
- **Galvanic pairing: plating and dissimilar coatings change the galvanic couple**
  see the
  Galvanic compatibility chart
  .

6. Selection and gotchas

- **Hydrogen embrittlement: electroplating high-strength steel (≥ ~10.9 / 40 HRC) can cause delayed cracking**
  bake within hours of plating, or use mechanical zinc / non-electrolytic finishes.
- **Dimensional change: plating and anodizing add thickness; carburizing/quench can distort. Treat after rough machining and finish-grind critical features after treatment, or allow for growth.**
- **Masking: threads, bearing seats and electrical contacts usually need masking from coating build-up.**
- **Distortion: thin/asymmetric parts warp in quench**
  design symmetric sections, use press-quench or low-distortion nitriding where flatness matters.
- **Checklist: decide bulk vs surface → pick heat-treat (with target hardness) and/or case hardening (depth + hardness) → choose corrosion/wear/appearance finish → check H-embrittlement, dimensional growth, masking and distortion → sequence treatment vs finish-machining on the drawing.**