

# Wear & material pairing

Designing against wear — the wear mechanisms, friction and which material pairs to run together, the PV limit, and the surfaces and coatings that last.

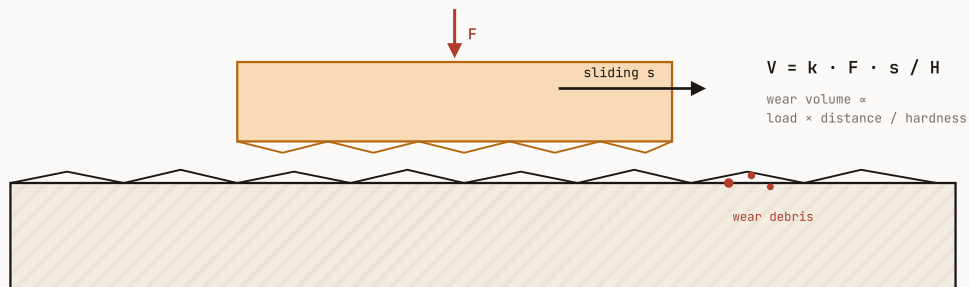
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## ABSTRACT

Wherever surfaces slide, roll or vibrate against each other, material is lost. Wear is not one thing — it has distinct mechanisms (adhesive, abrasive, fatigue, fretting, corrosive, erosive), and the fix depends on which one you have. The recurring levers are material pairing, hardness, surface finish, contact pressure and lubrication.

Section 1 covers the wear mechanisms. Section 2 is friction and material pairing. Section 3 is the PV limit. Section 4 is wear-resistant materials. Section 5 is coatings and surface engineering. Section 6 is selection and a checklist.

### WEAR — SLIDING CONTACT (ARCHARD)



SLIDING WEAR ROUGHLY FOLLOWS ARCHARD'S LAW — VOLUME REMOVED SCALES WITH LOAD AND SLIDING DISTANCE, AND INVERSELY WITH HARDNESS. IDENTIFY THE WEAR MECHANISM FIRST; THE RIGHT PAIR, HARDNESS, COATING OR LUBRICANT FOLLOWS.

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## 1. Wear mechanisms

Identify the mechanism before choosing a fix — Archard's law ( $V = k \cdot F \cdot s / H$  : wear volume  $\propto$  load  $\times$  sliding distance / hardness) sets the scale, but the *type* sets the remedy:

MECHANISM	CAUSE	GUARD AGAINST IT
<b>Adhesive (galling/scuffing)</b>	like surfaces cold-weld at asperities	dissimilar pair, hardness differential, lubrication, coatings
<b>Abrasive</b>	hard particles/asperities plough the surface	harder surface, filtration, exclude debris (seals)
<b>Surface fatigue (pitting)</b>	cyclic Hertzian contact (gears, bearings)	harder/cleaner steel, lower contact stress, EHL film
<b>Fretting</b>	tiny oscillation at "static" joints	raise preload, lubricate, coat, eliminate micro-motion
<b>Corrosive / tribochemical</b>	wear + chemical attack together	compatible materials, inhibitors, coatings
<b>Erosion</b>	impinging particles or fluid	harder/tougher material, redirect flow

<b>Archard coefficient k</b>	Dimensionless wear factor for a material pair and mode (spans orders of magnitude)
<b>PV</b>	Contact pressure $\times$ sliding velocity — the frictional-heat limit for plain bearings
<b>Galling</b>	Severe adhesive wear where surfaces seize and tear — classic for like metals run dry
<b>Self-lubricating</b>	A material that carries its own low-friction phase (PTFE, graphite, oil-impregnated)

## 2. Friction and material pairing

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The single biggest wear lever is **what runs against what**. Never slide **identical metals** dry (especially stainless on stainless or aluminium on aluminium) — they gall. Pair dissimilar materials, or create a hardness differential, or add a low-friction phase.

SLIDING PAIR (DRY)	TYPICAL $\mu$	NOTE
Steel on steel	~0.6	galls — lubricate or change pair
Steel on bronze	~0.3	classic bearing pair
Steel on acetal (POM)	~0.2	quiet, self-lubricating-ish
Steel on nylon	~0.3	absorbs water, dims shift
Steel on PTFE	0.05–0.10	lowest friction; soft, low load
Steel on steel, lubricated	~0.10	a film changes everything

Run a **hard part against a softer, sacrificial one** so wear is concentrated in the cheap, replaceable component.

### 3. The PV limit

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For plain (sliding) bearings and bushings, frictional heat — not pressure alone — sets the limit, captured by **PV** (contact pressure × sliding velocity). Stay under the material's PV limit and check P and V individually:

MATERIAL	MAX P (MPA)	MAX V (M/S)	NOTE
Oil-impregnated sintered bronze	~14	~6	self-lubricating
PTFE-lined metal (DU)	~250 static	~2	dry/marginal lube
Acetal (POM)	~10	~3	quiet, moulded
Nylon (PA)	~10	~3	tough; water-sensitive
UHMWPE	~7	~3	low friction, chemical resistant

(Consistent with the *Bearing selection* reference — use it for rolling-element wear/pitting.)

## 4. Wear-resistant materials

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- **Hardened / nitrided steel**

the default for loaded, lubricated wear surfaces (shafts, gears, cams).

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- **Bronze / oil-impregnated bronze**

bushings, low-speed sliding, conformable.

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- **Engineering plastics**

acetal (gears, low friction), UHMWPE (abrasion, food), PTFE-filled nylon (dry bushings), PEEK (high temp).

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- **Ceramics**

extreme hardness/temperature, low wear, but brittle (pump seals, guides).

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- **Aim for a hardness differential between the pair and the hardest practical surface on the high-wear part.**

## 5. Coatings and surface engineering

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SURFACE	BENEFIT
Nitriding	hard (~700–1000 HV), low distortion, fatigue + wear
Hard chrome	wear + hardness on shafts/cylinders
DLC (diamond-like carbon)	very hard, very low friction, thin
PVD (TiN, CrN, TiAlN)	hard tool/decorative coatings, thin
Thermal spray (WC-Co, etc.)	thick, rebuildable wear layers
Anodize type III (Al hardcoat)	hard, wear-resistant aluminium surface

A **fine surface finish** plus a **maintained lubricant film** beats almost any coating for sliding wear — coat when finish and lube alone can't carry it.

## 6. Selection and checklist

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- **Identify the mechanism (table 1)**  
the remedy depends entirely on it.

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- **Fix the pair**  
dissimilar materials / hardness differential; never like-metals dry.

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- **Stay under PV for plain bearings; under the contact-stress limit for rolling (see Hertz ).**

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- **Finish + lubricate**  
smooth surfaces and the right lubricant (see Lubrication reference); exclude debris with seals/filtration.

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- **Add hardness/coating where finish and lube aren't enough**  
nitride, DLC, hardcoat.

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- **Make the cheap part wear**  
concentrate wear in a replaceable bushing/liner, not the expensive housing.