

Wear Coefficients and Design Rules for Tool Steel

Wear is a system property, so the grade cannot be chosen from a hardness table alone. What can be quantified is how severe the wear situation is, which mechanism each motion and environment produces, where each material class is used, and the limits that keep a contact in mild wear.

Reference only. This is a reference summary of published practice and it is not a specification of ours. The values are reproduced from the source tables, and what a particular tool reaches depends on the grade, the section, the equipment and the cycle that follows. Final selection is confirmed on the job.

One wear number that compares across mechanisms

Wear mechanism	Sliding wear coefficient, $(V \times H) / (P \times S)$
Adhesive wear	10 ⁻⁷ to 10 ⁻¹
Abrasive wear	10 ⁻⁶ to 10 ⁻¹
Corrosive wear	10 ⁻⁷ to 10 ⁻²
Fatigue wear	≤ 10 ⁻⁶

The observed range of the dimensionless sliding wear coefficient for each mechanism, from the source table, where V is the volume of wear, H the hardness of the wearing surface, P the applied load and S the sliding distance. The values are taken from tribosystems in which that mechanism is the predominant one.

Which mechanism each motion and environment produces

Motion and environment	Mechanisms involved	What the source says
Rolling, two body, no slip	Fatigue	The mildest wear situation. Smooth surfaces are preferred and, with pure rolling, fatigue is the predominant mode.
Rolling with slip, and rolling with particles	Fatigue, adhesive, abrasive	Wear increases with increasing slip and with the presence of particles. Adhesive and abrasive modes can predominate once slip or particles are present.
Impact against a stationary body	Fatigue (elastic or plastic), adhesive	Induced vibration and misalignment can cause fretting, which raises wear. Plastic deformation is generally unacceptable except in short life applications, and for lives above 10 ⁶ cycles the contact stresses need to stay in the elastic range.
Impact against a moving body	Fatigue (elastic or plastic), adhesive, abrasive	Wear increases with the amount of sliding and sliding effects can predominate. Fluid lubrication effects can be very significant, and the presence of particles raises wear.
Sliding, unidirectional, dry, fluid or with particles	Fatigue, adhesive, abrasive	More than one mechanism is involved. Fatigue is the mildest and the conditions that minimise adhesion and abrasion are preferred, with low contact stresses. With particles present, abrasion tends to become the predominant mode.
Sliding, cyclic, small amplitude	Fatigue, adhesive, abrasive	Mild to severe wear transitions are often associated with the transition from elastic to plastic deformation, and the predominant mechanism can change as wear proceeds. In mild wear situations the terminal mode is often fatigue.
Impingement, low angle, with particles	Abrasive (cutting)	The particle cuts the surface rather than deforming it, which is why low angle impingement is the abrasive form of erosion.
Impingement, high angle, with particles	Fatigue and abrasive (deformation)	At high angle the particle deforms the surface, and the damage is a mixture of deformation and fatigue rather than clean cutting.
Flow, streamline, with particles	Abrasive (cutting)	Without particles the mechanism in a flowing fluid is cavitation, and impinging fluid droplets act like particles. Corrosion effects are often present as well.
Flow, turbulent	Fatigue, abrasive	Turbulence raises the damage over a streamline flow, and with particles the abrasive component appears alongside the fatigue one.

Operational classification of wear situations, condensed from the source table. The source adds a general note that with fluids other than lubricants, synergistic effects between corrosion and wear often occur, that oxidative wear is probable with metals and ceramics in all situations, and that the operational characterisation may differ at different locations on the same part.

Which material class is used against each wear situation

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Material class	Sliding, unlubricat ed	Sliding, lubricated	Sliding, abrasion	Rolling, unlubricat ed	Rolling, lubricated	Rolling, abrasion	Impact	Three- body abrasion	Fluid erosion	Cavitation	Drop erosion	Particle erosion
Structural alloys												
Surface treatments	X	X	X			X		X				
Hard surfacing	X	X	X			X	X	X			X	X
Soft coatings	X	X										X
Alloy steels		X	X	X	X	X	X	X				X
Tool steels	X	X	X	X	X	X	X	X		X		
Stainless steels												
Precipitation hardened stainless												
Martensitic stainless												
Cast irons												
Graphitic cast iron												
White cast iron												
High-temperature alloys												
Refractory materials	X	X					X	X				
Superalloys		X		X						X	X	X
Copper-base alloys												
Bronze		X									X	
Beryllium copper		X					X					
Soft bearing alloys (babbitts)		X										
Carbides	X	X	X	X				X			X	X
Ceramics	X		X					X	X		X	X
Polymers												
Thermosets	X											
Thermoplastics	X	X									X	
Elastomers				X	X		X	X		X	X	X
Carbons	X											
Lubricating composites	X	X										

Typical wear applications for selected engineering materials, reproduced from the source table, in which a cross marks the wear situations each material class is used in. Surface treatments, hard surfacing and soft coatings are grouped under structural alloys in the source, and the stainless steels, cast irons, high temperature alloys, copper base alloys and polymers are each split into the families listed here.

The limits that keep a contact in mild wear

Design rules for wear applications

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Design rule for wear applications	Design rule for wear applications
1. Reliance on analytical design procedures increases the degree of conservatism that should be used.	14. The thickness of conventional coatings should generally be greater than 100 µm.
2. Wear is a system property, so utilise all the parameters that influence wear.	15. Use moderate surface roughness.
3. Design with the limits and the characteristics of the materials in mind.	16. Avoid the use of stainless steel shafts with impregnated sintered bronze.
4. Design so that a mild wear condition exists.	17. When moulded, filled plastics tend to show a significant difference between initial and long term wear behaviour.
5. Minimise exposure to abrasive particles.	18. When glass or other hard fillers are used, the hardness of the counterface should be equal to or greater than that of the filler. For glass this hardness should be above 60 HRC.
6. Optimise the contact to minimise stresses, ensure good alignment, and round corners and edges.	19. The tendency for galling can be reduced by using dissimilar and hard materials of low ductility, lubricating, and reducing contact stresses. Stress levels above the threshold for galling should be avoided.
7. Use a lubricant whenever possible.	20. Avoid designs in which fretting motions can occur.
8. Use dissimilar materials.	21. When fretting motions are present, design for optimum sliding wear life and to minimise abrasive wear.
9. To increase system life it is sometimes necessary to increase the hardness of both members.	22. Sacrificial wear design should be considered when satisfactory life cannot be achieved by other means.
10. Rolling is preferred over sliding.	23. Conform to vendor recommendations for optimum wear performance.
11. Sliding or fretting motions should be eliminated in impact wear situations.	24. Changes associated with design modifications or new applications should be reviewed carefully for their effect on potential wear behaviour.
12. Impacts should be avoided in sliding contacts.	25. Wear is a system property, so a material that wins on one bench test may not win on the job.
13. Elastomers frequently outperform harder materials in impact situations.	

Design rules for wear applications, reproduced from the source list. The final entry restates the system property point that the source makes before the list: a material that wins on one bench test may not win on the job.

Where these rules meet a specific grade

Aobo Steel, tool steel supplier

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Source, ASM Handbook, Volume 20, Materials Selection and Design, ASM International, 1997.

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