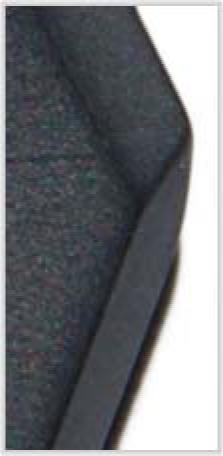
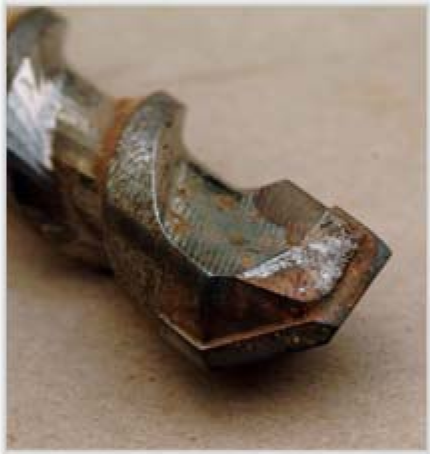
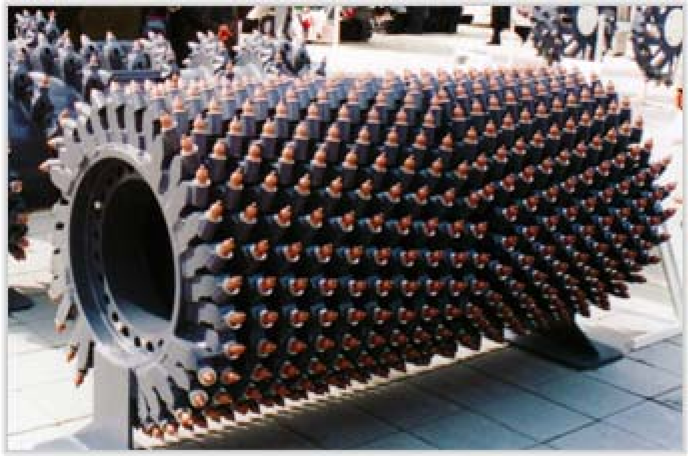
Description

Image

Caption

1. Tungsten carbide tool tip. © images-of-elements.com - (CC BY-SA 3.0) 2. Masonry drill bit tip. A tungsten carbide insert is brazed to the steel drill body. © Emrys2 at en.wikipedia - (CC BY-SA 3.0) 3. Tungsten carbide tipped cutter drum of a road recycler © Dw1975 at en.wikipedia - (CC BY-SA 3.0)

The material

Tungsten carbide (WC) is most commonly used in the form of a 'cemented' carbide, or cermet: particles of WC held by a small amount (5-20%) of metallic binder, usually cobalt. Its exceptional hardness and stability make it an attractive material when wear resistance is essential. Properties depend on grain size and shape and the proportion of carbide to metal. Cermets are expensive but, as cutting tools, they survive cutting speeds 10 times those of the best tool steel. Shaping is usually done by pressing, sintering and then grinding; the tool bit is brazed to a shank or blade made from a cheaper steel. Cermets can be vapor-coated with titanium nitride to improve wear resistance even further.

Compositional summary

WC/ 2 - 10%Co

General properties

Density	1.53e4	-	1.59e4	kg/m^3
Price	* 18.7	-	29	USD/kg
Date first used	1923			

Mechanical properties

Young's modulus	* 625	-	700	GPa
Shear modulus	* 243	-	283	GPa
Bulk modulus	360	-	410	GPa
Poisson's ratio	0.18	-	0.21	
Yield strength (elastic limit)	* 335	-	550	MPa
Tensile strength	370	-	550	MPa
Compressive strength	* 3.35e3	-	6.83e3	MPa
Elongation	0			% strain

Hardness - Vickers		2.2e3	-	3.6e3	HV
Fatigue strength at 10^7 cycles	*	285	-	420	MPa
Fracture toughness		2	-	3.8	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	5e-5	-	1e-4	

Thermal properties

Melting point		2.83e3	-	2.92e3	°C
Maximum service temperature	*	750	-	1e3	°C
Minimum service temperature		-273			°C
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		55	-	88	W/m.°C
Specific heat capacity		184	-	292	J/kg.°C
Thermal expansion coefficient		5.2	-	7.1	µstrain/°C

Electrical properties

Electrical conductor or insulator?		Poor conductor			
Electrical resistivity		20	-	100	µohm.cm

Optical properties

Transparency	Opaque

Processability

Moldability	2	-	3
Machinability	1	-	2

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Limited use
Nitric acid (10%)	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	

	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Excellent
O2 (oxygen gas)	Excellent
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Excellent
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production		82.4	-	91.1	MJ/kg
CO2 footprint, primary production		4.44	-	4.9	kg/kg
Water usage	*	47.8	-	144	l/kg

Material processing: energy

Grinding energy (per unit wt removed)	*	43.1	-	47.6	MJ/kg

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	*	3.23	-	3.57	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✘			
Recycle fraction in current supply	30	-	32	%
Downcycle	✔			
Combust for energy recovery	✘			
Landfill	✔			
Biodegrade	✘			
Toxicity rating	Non-toxic			
A renewable resource?	✘			

Environmental notes

Preparing tungsten carbide products is energy intensive, and cobalt is a comparatively rare element, regarded as strategic because of its unique properties. For this reason, tungsten carbide is, where possible, recycled.

Supporting information

Design guidelines

Tungsten carbide (WC) and cermets - which are 80 to 95% WC - can only be shaped by slitting with diamond tools and by grinding, liming the shapes to which they can economically be formed. They are used only where needed: the tips (but not the shanks) of cutting tools for drilling, sawing, rock cutting. Only diamond-tipped tools are more wear resistant. Technical ceramics are formed by the following steps.(a) Pressing, isostatic pressing, powder extrusion (for bars and tubes) or powder injection molding (for intricate, high-volume parts).(b) Green-machining in the unfired state, using standard tools.(c) Firing or "sintering" typically at 1550 - 1700 C for 12 to 20 hours; the part shrinks by about 20%.(d) Diamond grinding to achieve tighter tolerance and surface finish: +/- 10 microns is achievable. The cost of a ceramic part is greatly increased if it has to be diamond-ground. Thus design for net-shape sintering, eliminating step (d) is highly desirable. The standard tolerance for as-fired dimensions is +/- 1% or 125 microns, whichever is greater.

Technical notes

Tungsten carbide starts as a powder, is pressed with up to 10% of cobalt to the desired shape, then fired at a high temperature under pressure, causing the cobalt to melt and bond the powder particles together.

Typical uses

Cutting tool tips; abrasives; cermets, oil-drilling and stone-cutting equipment, dental

Tradenames

Cermet, Cemented carbide.

Links

Reference

ProcessUniverse

Producers