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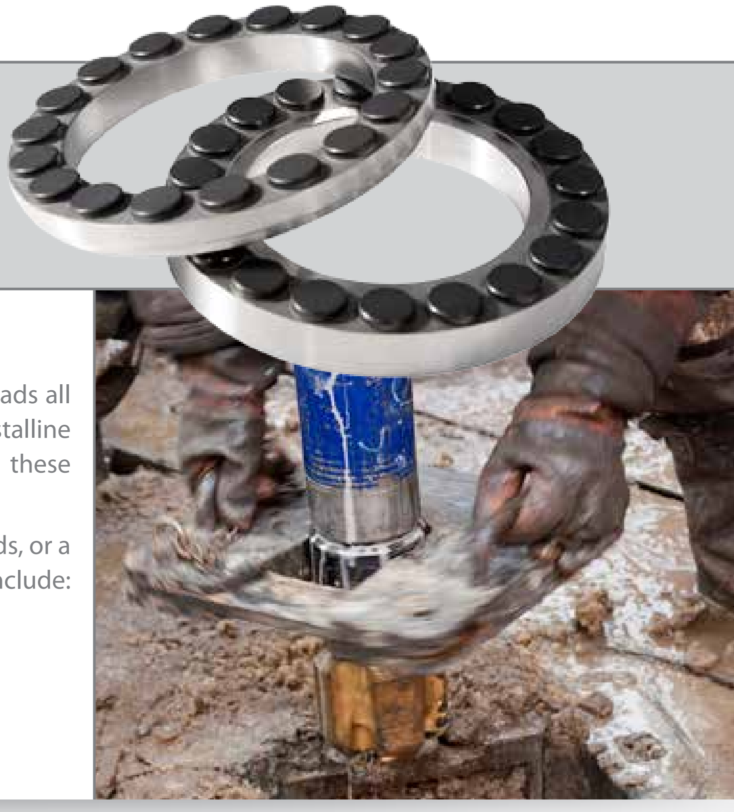
Diamond Bearings for Drilling Tools



Why Diamond Bearings?

Abrasive particles, high temperatures, corrosive chemicals, and high loads all contribute to failure in bearings used in down-hole drilling tools. Polycrystalline Diamond (PCD) bearings outperform other bearing technologies in these harsh conditions due to the unmatched properties of diamond.

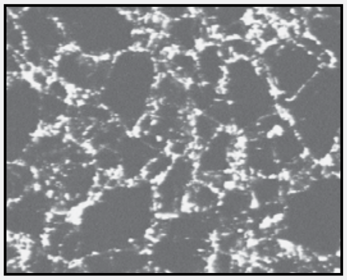
Our bearings are specifically designed to sustain thrust loads, radial loads, or a combination of both thrust and radial loads. Drilling tool applications include:

- Thrust and radial bearings in **drilling motors**
- Thrust bearings in **turbo drills**
- Thrust and radial bearings in **rotary steerable systems**
- Thrust and radial bearings in **power generation turbines**

Advantages of Diamond

PCD bearings are ideally suited for operation in:

Abrasive fluids | Corrosive fluids | High temperatures



- Operate effectively with PCD surfaces in direct contact and when surfaces are partially or fully separated by a fluid-film (mixed-mode and hydrodynamic lubrication).
- Can sustain extreme loads when operating in direct diamond-to-diamond contact when compared to other types of bearings.
- Deliver longer bearing life due to hard, wear-resistance diamond surfaces.
- Operate effectively at a wide range of speeds and loads. For example: in some oil and gas applications, diamond bearings can run between 100 and 6,000 RPM at loads up to 50,000 lbs.
- Simplify equipment and assemblies by eliminating the need for seals and separate lubrication systems.
- In direct contact, PCD bearing friction is low (COF between 0.05 and 0.08). When operating hydrodynamically, friction in PDC bearings is below 0.002.

Key Elements of PCD

- Extreme hardness (wear resistance)
- High thermal conductivity (heat removal)
- High strength
- High toughness
- Low friction

Properties	Polycrystalline Diamond(PCD)	Tungsten Carbide	Steel (4140)	Silicon Nitride	Silicon Carbide
Coefficient of Friction	0.05-0.08**	0.2-0.25†	0.42‡	--	--
Thermal Conductivity (W/m*K)	543	70	42.6	30	85
Fracture Toughness (MPa√m)	13-15	10-25	50	4	3.5-4
Hardness (GPa, Knoop)	49.8	1.8	0.2	1.8	2.4
Compressive Strength (GPa)	6.9-7.6	2.68	--	--	2.5
Young's Modulus (GPa)	841	669-696	205	296	434
Tensile Strength (MPa)	1,300-1,600	334	415	520	500

*ASI 4140 Steel, annealed at 815°C (1500°F) furnace cooled 11°C (20°F)/hour to 665°C (1230°F), air cooled, 25 mm (1 in.) roun(1100°F) temper)
** PCD on PCD in H2O, dynamic
†Tungsten Carbide on Tungsten Carbide, static
‡Steel (Hard) on Steel (Hard), dynamic
YAt 100˚C
Sources: Bertagnolli, US Synthetic; Roberts et al., De Beers; Cooley, US Synthetic; Jiang Qian, US Synthetic; Glowka, SNL; Sexton, US Synthetic; Lin, UC Berkeley, MatWeb.com, Cerco

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How we do things

Our application engineers work closely with each customer to design customized solutions for each application. Factors like expected loads, speeds, drilling environment, and dimensional envelopes are important considerations in the design process.

Test data gathered in our laboratory bearing test stand allows our engineers to estimate the performance of each bearing in specific downhole environments. Customized tests can also be designed and carried out to replicate expected conditions in many applications.

Diamond as a Bearing Material

Polycrystalline diamond is known for its high thermal conductivity, low coefficient of friction, high toughness and other preferred physical and mechanical properties. Having a bearing material with high thermal conductivity reduces localized temperature extremes that lead to bearing degradation. During starting and stopping, high thermal conductivity will reduce the likelihood of localized welding between bearing surfaces, which in turn leads to scoring and galling of the bearing surface. In sliding bearings, low coefficients of friction are desired in order to decrease heat generation and reduce power loss. A bearing material exhibiting large fracture toughness will decrease the likelihood of race damage during extreme operating conditions. Because of its extreme hardness, polycrystalline diamond is ideally suited to resist wear from abrasive particles in lubricants and process fluids.