PDC drill bits

Polycrystalline diamond materials, for use in polycrystalline diamond compact (PDC) bits, are one of the most important material advances for oil drilling tools in recent years. Fixed-head bits rotate as one piece and contain no separately moving parts. When fixed-head bits use PDC cutters, they are commonly called PDC bits. Since their first production in 1976, the popularity of bits using PDC cutters has grown steadily, and they are nearly as common as roller-cone bits in many drilling applications.

Polycrystalline diamond compact (PDC) styles

- Matrix-body bit
- Steel-body bits

The two provide significantly different capabilities, and, because both types have certain advantages, a choice between them would be decided by the needs of the application.

Matrix-body

“Matrix” is a very hard, rather brittle composite material comprising tungsten carbide grains metallurgically bonded with a softer, tougher, metallic binder. Matrix is desirable as a bit material, because its hardness is resistant to abrasion and erosion. It is capable of withstanding relatively high compressive loads, but, compared with steel, has low resistance to impact loading.

Matrix is relatively heterogeneous, because it is a composite material. Because the size and placement of the particles of tungsten carbide it contains vary (by both design and circumstances), its physical properties are slightly less predictable than steel.

Steel-body

Steel is metallurgically opposite of matrix. It is capable of withstanding high impact loads, but is relatively soft and, without protective features, would quickly fail by abrasion and erosion. Quality steels are essentially homogeneous with structural limits that rarely surprise their users.
**Design of matrix and steel-body bits**

Design characteristics and manufacturing processes for the two bit types are, in respect to body construction, different, because of the nature of the materials from which they are made. The lower impact toughness of matrix limits some matrix-bit features, such as blade height. Conversely, steel is ductile, tough, and capable of withstanding greater impact loads. This makes it possible for steel-body PDC bits to be relatively larger than matrix bits and to incorporate greater height into features such as blades.

**Advantage of matrix-body PDC bits**

Matrix-body PDC bits are commonly preferred over steel-body bits for environments in which body erosion is likely to cause a bit to fail. For diamond-impregnated bits, only matrix-body construction can be used.

**Advantage of steel-body PDC bits**

The strength and ductility of steel give steel-bit bodies high resistance to impact loading. Steel bodies are considerably stronger than matrix bodies. Because of steel material capabilities, complex bit profiles and hydraulic designs are possible and relatively easy to construct on a multi-axis, computer-numerically-controlled milling machine. A beneficial feature of steel bits is that they can easily be rebuilt a number of times because worn or damaged cutters can be replaced rather easily. This is a particular advantage for operators in low-cost drilling environments.

**Development of PDC bits**

Fortunately, both steels and matrix are rapidly evolving, and their limitations are diminishing. As hard-facing materials improve, steel bits are becoming extremely well protected with materials that are highly resistant to abrasion and erosion. At the same time, the structural and wear-resisting properties of matrix materials are also rapidly improving, and the range of economic applications suitable for both types is growing.

Today’s matrix has little resemblance to that of even a few years ago. Tensile strengths and impact resistance have increased by at least 33%, and cutter braze strength has increased by ≈80%. At the same time, geometries and the technology of supporting structures have improved, resulting in strong, productive matrix products.
Polycrystalline diamond compact (PDC) cutters

Diamond is the hardest material known. This hardness gives it superior properties for cutting any other material. PDC is extremely important to drilling, because it aggregates tiny, inexpensive, manmade diamonds into relatively large, intergrown masses of randomly oriented crystals that can be formed into useful shapes called diamond tables. Diamond tables are the part of a cutter that contacts a formation. Besides their hardness, PDC diamond tables have an essential characteristic for drill-bit cutters: They efficiently bond with tungsten carbide materials that can be brazed (attached) to bit bodies. Diamonds, by themselves, will not bond together, nor can they be attached by brazing.

Synthetic diamond

Diamond grit is commonly used to describe tiny grains (≈0.00004 in.) of synthetic diamond used as the key raw material for PDC cutters. In terms of chemicals and properties, manmade diamond is identical to natural diamond. Making diamond grit involves a chemically simple process: ordinary carbon is heated under extremely high pressure and temperature. In practice, however, making diamond is far from easy.

Individual diamond crystals contained in diamond grit are diversely oriented. This makes the material strong, sharp, and, because of the hardness of the contained diamond, extremely wear resistant. In fact, the random structure found in bonded synthetic diamond performs better in shear than natural diamonds, because natural diamonds are cubic crystals that fracture easily along their orderly, crystalline boundaries.

Diamond grit is less stable at high temperatures than natural diamond, however. Because metallic catalyst trapped in the grit structure has a higher rate of thermal expansion than diamond, differential expansion places diamond-to-diamond bonds under shear and, if loads are high enough, causes failure. If bonds fail, diamonds are quickly lost, so PDC loses its hardness and sharpness and becomes ineffective. To prevent such failure, PDC cutters must be adequately cooled during drilling.

Diamond tables

To manufacture a diamond table, diamond grit is sintered with tungsten carbide and metallic binder to form a diamond-rich layer. They are wafer-like in shape, and they should be made as thick as structurally possible, because diamond volume
increases wear life. Highest-quality diamond tables are ≈2 to 4 mm, and technology advances will increase diamond table thickness. Tungsten carbide substrates are normally ≈0.5 in. high and have the same cross-sectional shape and dimensions as the diamond table. The two parts, diamond table and substrate, make up a cutter.

Forming PDC into useful shapes for cutters involves placing diamond grit, together with its substrate, in a pressure vessel and then sintering at high heat and pressure.

PDC cutters cannot be allowed to exceed temperatures of 1,382°F [750°C]. Excessive heat produces rapid wear, because differential thermal expansion between binder and diamond tends to break the intergrown diamond grit crystals in the diamond table. Bond strengths between the diamond table and tungsten carbide substrate are also jeopardized by differential thermal expansion.