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DEEP WELL CORING OF OIL AND NATURAL GAS WELLS

1. INTRODUCTION

A core from the drilling operation is possible to get undamaged, in mechanical or physical sense, according to the technical tools and chosen technology of coring. Nowadays, different devices and some basic methods are used for the core withdrawal.

2. BASIC CORING METHODS

Coring is a drilling-technical operation which allows integral sampling of the drilled rock – a so-called core. Core is the highest quality part of material documentation of the well. Based on technical equipment used for coring, and based on a chosen coring technology, we can get mechanically undamaged core (or in physically unaffected condition). Individual techniques and technologies allow core-sampling of various types of rocks. There is equipment that can be used for coring, however, basic coring methods are:

- side coring,
- full face coring.

Side cores are taken by logging cable from open interval of the well by force of explosives (logging inside the well). It is carried out only rarely, if additional information on the rock side wall (and its condition) is needed.

Fool face coring is the most common coring method. Purpose of coring is to get a core. Coring method is chosen based on what information on deposit or rock the need to get. In wider context, laboratory analyses of core samples give us information which cannot be obtained from other sources (or it would not be efficient); this information is also much more accurate and correct than the data obtained from fragments or logging measurements.

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Information which we can get by analyses of core can be divided into three basic groups:

- geological,
- completion,
- engineering.

Geological information are used to add/update information in geological maps; they form a basis for detailed geological evaluation of drilled formations (petrology, sedimentary structure, texture, porosity, colour, permeability, age, depositing conditions, fractures, diagenesis, micro-elements, geochemical information, paleomagnetism, fluorescence etc.

Completion information serves for correct decision-making in completion stage, or in case of later repairs, starting with perforation. They allowed to choose proper perforation techniques, priming, decide on intensification work (acid treatment, cleavage etc.), choose proper completion liquid (compatible with the rock and it's isolating layers), choose proper sand control technique (granulometric analysis), give information on size of porosity and it's spreading, clay content, its morphology and spreading, on the deposit mineralogy, etc.

Engineering information allow deposit engineers to conduct exploitation in the right way, to determine exploitability, informed them on permeability heterogeneity, saturation, distribution of unexploitable oil from the deposit, etc. For interpreter of logging diagrams they offer data for calibration and fine resolution of calculation from logging measurements (density of particles), acoustic waves propagation speed, electrical properties, calcimetry, measurement gamma characteristics, etc. In addition to this, they offer geotechnical data, such as Poisson's relation, compressive strength, Young's modulus, relative hardness, tensile strength, and allow evaluation of the deposit rock under electronic microscope [1, 2].

3. CORING AFFECTING FACTORS

One, relatively the most important factor affecting successful coring is proper planning of coring and preparation. This is essential especially for coring of long interval or in complicated conditions. In order to achieve the desired effect, it is welcomed if quantitative and qualitative requirements of geologist are assessed on the presence of all parties involved (geological service, drilling department, drilling supervisor, technologist, and flushing supervisor).

Geologists presents conditions which must be kept doing coring from the point of view of analyses for which the core is drilled. The drilling department proposes suitable technical means and technology of coring in order to meet requirements of the geologist. From this proposal come another requirements which must be fulfilled in order to achieve the required goal [2].

Drilling department:

a) When choosing the equipment (core barrel, coring technology), they take into account requirements of the geologist (e.g. coring from a deposit, minimum contact of the core and drilling fluid, undamaged core, one of core or coring of longer section, continuous or discontinuous coring, special requirements for chemical composition of the drilling fluid, etc.).

b) Based on the knowledge of formation to be cored, and based on assumed condition of the well, they propose/determine stabilizing techniques for core barrel and drilling string (type, diameter and arrangement of stabilizers), taking into account curvature of the well, dog-legs, launders, coring technology.
c) Chooses suitable coring crown or bit depending on the rock to be drilled/cored and the decided technique and technology of coring. Today there is a large offer of coring crowns offering large range of properties which may positively influence quality of the core or the coring process itself.
d) Chooses another replaceable parts of core barrel necessary for coring, such as core breaker, inner pipe, inner pipe stabilizer, etc.
e) Selects other technical equipment needed for coring (tools for extraction/replacement of the core barrel inner pipe, cutting of the core barrel inner pipe with the core, pushing-out core from the core barrel, etc.).
e) Proposes a coring mode and related requirements for flushing/drilling fluid, hydraulic components, flushing pumps, quantity and quality of sinker bars, drives of the drilling set, requirements for preparation of the well prior to coring, mud treatment, etc.
f) Discusses with the drill supervisor all previous requirements, experience from coring of similar formations, experienced from the proposed machinery and coring technology, and any other remarks which may have influence on the result of the coring (bit type, used for the drilling of the same or similar formations in the same/similar locality, achieved results and other problems with the well such as losses of drilling fluid, expanded rock, etc.).
g) Mud supervisor presents his proposals too.
h) At the end, only requirements are summed up. It is determining whether equipment should be leased or purchased, or it is discussed whether the work could be carried out by a special servicing company as it may be too expensive to learn and from our own mistakes (and may not bring the desired result). The drilling department provides all necessary equipment on time and, if necessary, prepares a technological procedure.

Mud supervisor:

a) provides full materials needed for treatment of drilling fluid,
b) during the last run prior to coring ensures necessary control and treatment of drilling fluid for coring.

Drilling supervisor:

a) Informs the drill operators on the requirements for coring and points out other important moments for assembly and checking of core barrel, insertion, coring, retraction of the core barrel, pushing out the core, it's placing and description.
b) Controls drilling bit, how much it is worn down or damaged, and evaluates the last run drilling capacity (prior to coring), especially in relation to the following coring.
c) Prepares machines/equipment,especially mud pumps, purification equipment, drives.
d) Gives instructions for mechanical logging to be carried out during drilling.
e) If necessary, the cooperation with other departments makes all precautions for smooth/trouble-free chording.

Geologist:

a) specifies coring interval one time,
b) provides containers for deposition of the core,
c) makes arrangements for evaluation of the core at drilling spot and is transferred to a specialized laboratory (or core storage).

Planning all these activities related to coring establishes grounds for good/desired result, i.e. obtaining of core as per requirements of the geologist (even though result of coring can also be evaluated based on results of the core analyses in specialized laboratories). The less is the core influenced by the coring process, the better is the result [2].

4. TECHNICAL MEANS FOR CORING

Tools used for full face coring include: drilling machine, coring crown and core barrel. The coring crown is a drilling tool which drills the annular area keeping center in intact; this enables generation of core which passes through a crown to a core barrel. The core barrel is a tool in which the core is kept doing coring. At the same time it serves for a retraction of the core on the surface. Current design of core barrels is rather sophisticated, however, classic core barrel can be still considered a simple design-tool.

Until recently, side cores were taken only by use of logging cable and explosives. Currently it can be done using a special side-coring core barrel.

Coring crowns

Similarly to drilling bits, coring crowns can be divided based on how they disintegrate a rock; we recognize cutting, rolling and diamond crowns. All three groups of crowns are used for coring in deep wells, even though it using of rolling crowns is less and less frequent.

Counting crowns

Classic cutting coring crowns with a hard-metal solder-welded to the steel body are not used in today's deep drilling. However, for some special coring the crowns of similar construction are used, with a narrow bit (e.g. coring of coal).

Technology and manufacturing of this-type of crowns is similar to manufacturing of diamond bits. Crushed hard-metal is mixed with a powder to create a matrix; interconnection of the crushed metal, powder and the core body is achieved by powder metallurgical technique. Today's technology of manufacturing of these crowns is at high technical level. The crushed hard-metal has been replaced for diamond powder and chips, or the crowns are fitted with natural diamonds or synthetic/artificial diamonds made of elements known as PDC, TSP (Thermally Stable Polycrystalline), TSD etc., similarly to diamond coring crowns. However, they are intended mainly for industrial and mining use, not for deep drilling [1].

PDC coring crowns

The name PDC – Polycrystalline Diamond Compact-bits, or coring bits represents a group of tools which are fitted with cutting comments from a hard-metal (Tungsten Car-

bide), on which there is a thin layer of polycrystalline diamond. Profile of diamond and PDC crown matrix and similar, with very small differences due to different manufacturers. Some basic profiles are shown in Figure 1.

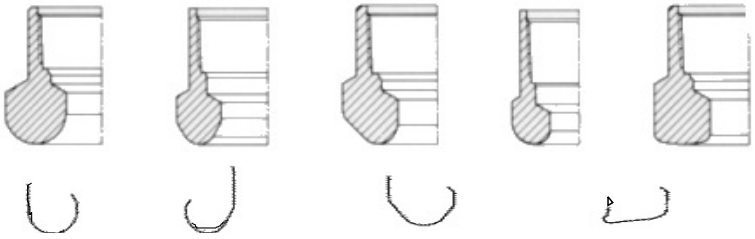


Fig. 1. Profiles of diamond and PDC coring crowns

Coring crown profiles are chosen based on hardness and strength of rock. Slim/thin profile of core crown is good for hard and brittle rock; rounded/flat profile is better to be chosen for harder and abrasive rock. All types of profiles, except for the flat one, a use for very soft and soft rock. It must be said that the manufacturers are modifying profiles in order to achieve maximum effect with the used cutting elements; the used computer modelling and experienced from drilling practice. The look of front side of surface of the coring crowns depends on number, shape, diameter and type of cutting elements, on shape of flushing channels, reinforcement of outer diameter and its length, plus on the way of flushing of the front part of the crown.

The more is the crown suitable for harder rock, the higher number of cutting elements it has and their diameter gets smaller. Type, number and diameter of the crown is always given by the crown characteristics. Button-shaped cutting elements most usually have their diameter of 19 mm, 13 mm, or 9 mm. They have various design ensuring their higher heat resistance or resistance against abrasive rock, or they are cutting larger fragments, have increased lifetime, efficiency and achieve better drilling parameters.

The importance of hydride hard-metal cutting elements in which small diamonds are fitted is visible in Figures 2–4. The chart (Fig. 5) documents dependency of damaged cutting elements (in percent) on the distance from the center to the reinforcement. Black line represents classic PDC bits, the blue one hybrid PDC bits, or coring crowns. It is mainly in referral and reinforcing elements which are well protected [2, 3].

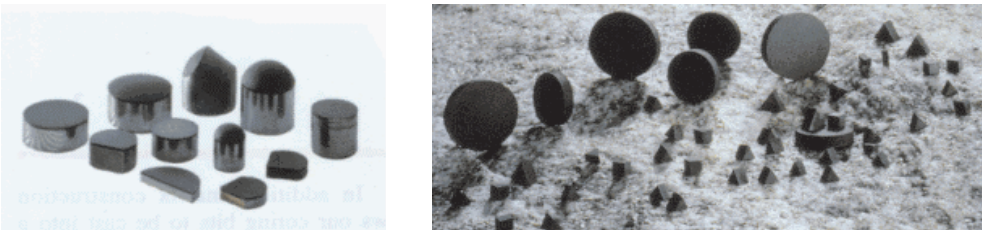


Fig. 2. DIAMAX cutting element samples

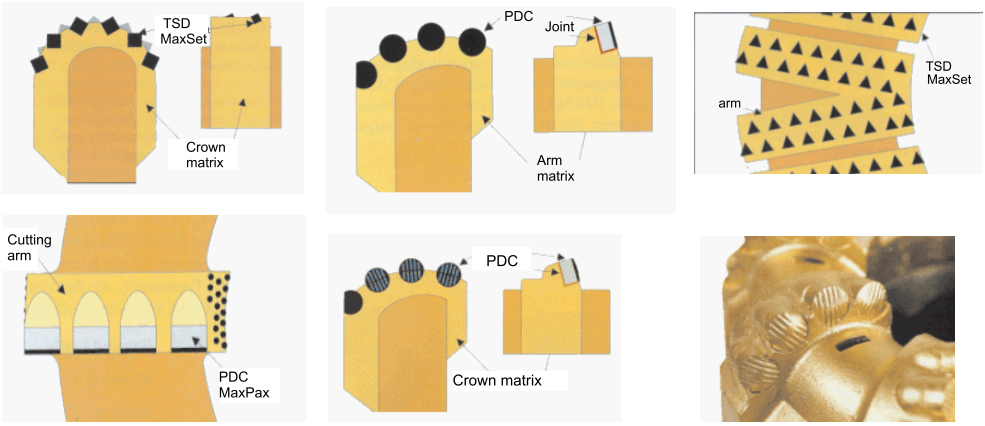


Fig. 3. Different PDC cutting elements, their arrangement and fitting (DIAMAX)

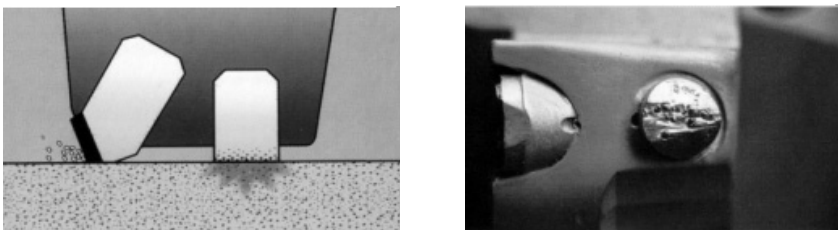


Fig. 4. Cutting elements found on hybrid crowns (HYCALOG)

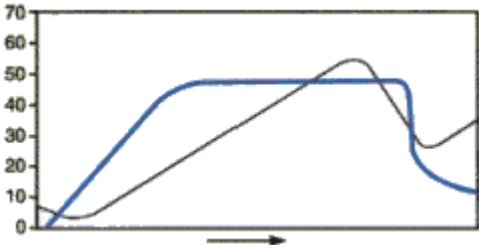


Fig. 5. Classic and hybrid PDC bit damaging comparison

Similar protection of cutting elements uses the company Security DBS under the name IMPACT ARRESTOR. They also manufacture of cutting elements using special technology (Fig. 6), which guarantees their increased lifetime. Polycrystalline diamond is not steamed to the bearing hard-metal, instead it is bonded to it (which makes it from two to three times thicker and increase is its strength by two to four times).

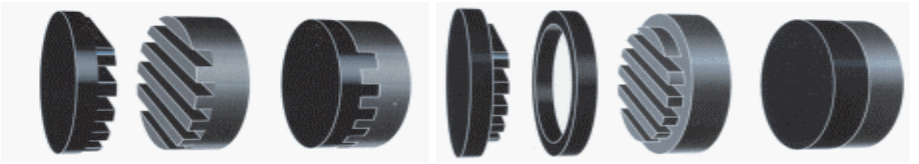


Fig. 6. Cutting elements Claw Cuter, and Ring Claw Cuter made by Security DBS

Recently, some special design coring crowns appeared on market. They are usable in classic core barrel or in connection with a special one. Structure of this crown reduces contact of core with circulating drilling fluid (Fig. 7).

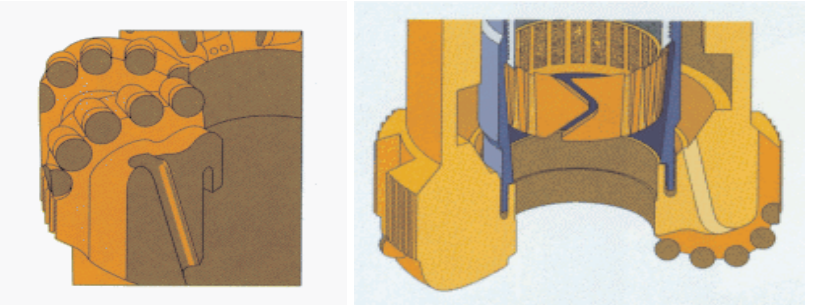
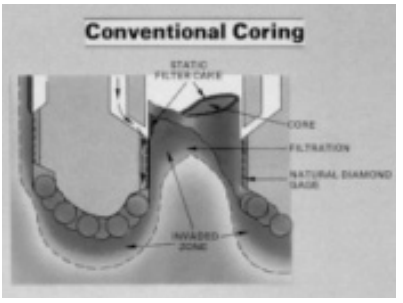


Fig. 7. Special construction of core bit reduces contact of core with drilling fluid

Crowns like these are manufactured by Security DBS, Eastman Christensen, Baker Hughes. Figure 8 shows comparison of classical front-flushed crown at the new design type.

a)



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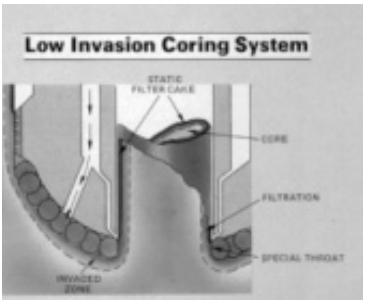

Fig. 8. Comparison of classical front-flushed crown at the new design type:
a) Conventional Coring; b) Low Invasion Coring System

Coring crowns and bits can be eccentric (or their arms does not form the same angle) or they can be spiral-shaped. This limits or avoids process movement of the crown during rotation, it's bed is smooth, core slick, brittle rocks are not mechanically damaged, bit does not vibrate, crown lifetime is longer and coring speed higher. The core and shape of the bed

comparison to the classic type can be seen in Figure 9. BHI manufactures these crowns and bits, known as AntiWhirl, marked as ARC, Security DBS with the name QP 13 or QP 19. Diamax uses no special marking. On the first glance it is hard to distinguish these bits from the classic ones. See the bits shown in Figure 10 [2].

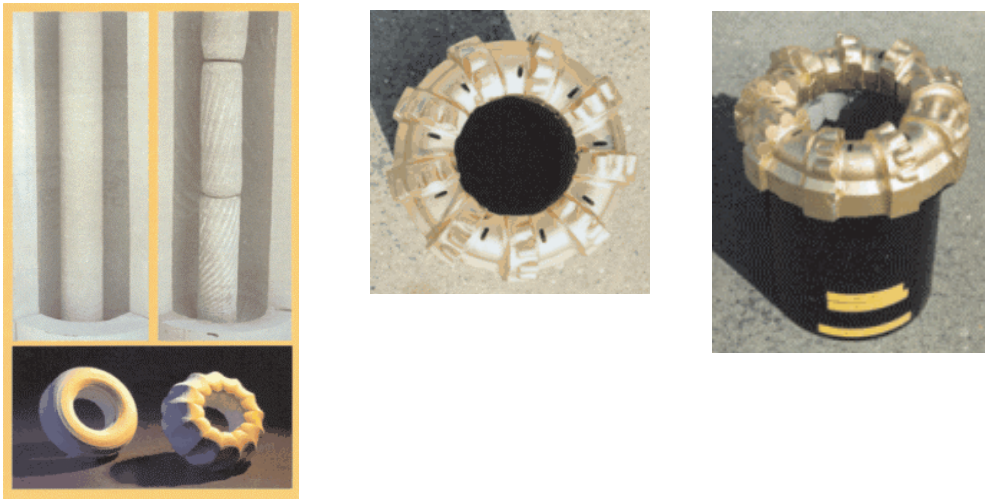

Fig. 9. PDC crowns by Diamax YG-10F

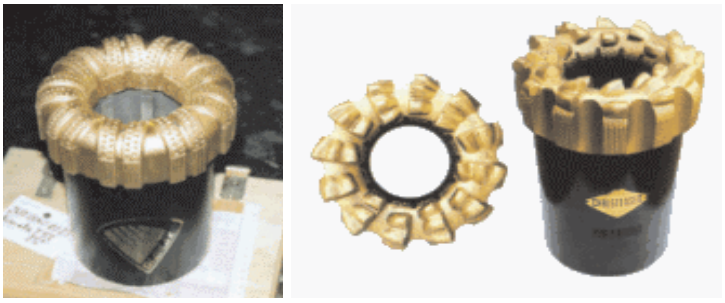

Fig. 10. TSD crown by Diamax YT-5S PDC crown by BHI ARC 476

The most modern bits used today are those allowing drilling and coring. The bit is embedded in a thick-wall core barrel (inner part of the bit). Prior to coring the inner part is retracted by overshot and the coring pipe is inserted by use of wire-line technique. After completion of coring the coring pipe is retracted and inner part of the bit and hidden inside again, so we may continue with drilling. These types are used for deep drilling by a „classical“ rotary method, plus when drilling with the technique „slimhole“. This type of bit/crown is shown in Figure 11 (model by BHI). It integrates advantages of the bits Anti-Whirl, with those with low effect of drilling fluid on the core [1].

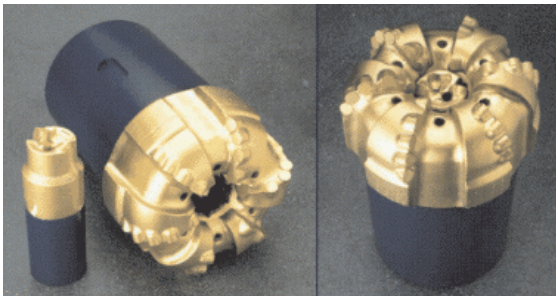

Fig. 11. Bit/crown

Rolling crowns

Rolling crown coring in our conditions was carried out using Polish core barrels PL 1 and PL 2. Their efficiencies was relatively low (between 50 to 60%) compared to the efficiency of core barrels Christensen. Hence, they are used less and less, until not used at all for deep drilling. The most commonly used crumbs were Polish four-roller and six-roller (Fig. 12).

a) b) c)

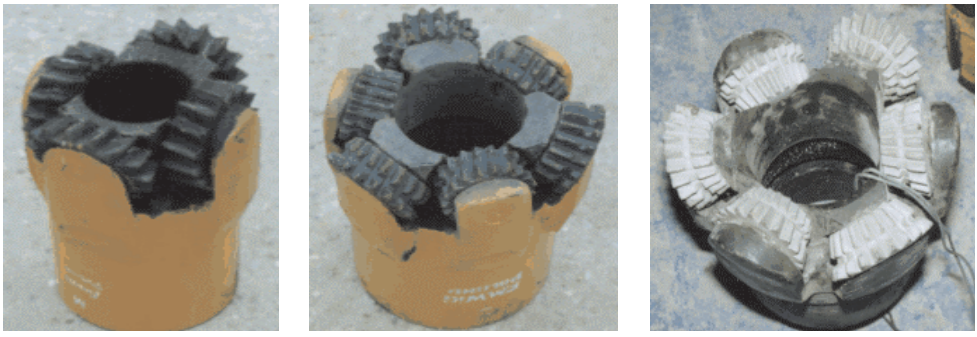

Fig. 12. Rolling crowns Glinik and the crown SBS
Explanations in the text

Figure 12a shows the four-roller M-type crown with the diameter of 216 mm (for soft rock). Figure 12b shows the six-roller S-type crown with the diameter 216 mm (four semi-hard rocks). Figure 12c shows the crown made by an Austrian company SBS, six-roller, diameter of 445 mm, for semi-hard rock.

Modern construction rolling bits/crowns fitted with hard-metal elements (tungsten carbide) have been developed for the modern method “coring during drilling”. Such bit as manufactured by the company RockBit Internacional Inc. (RBI) , Texas, USA (diameter of 12 ¼", for hard rock). The bit of this design can be seen in Figure 13. Central part of the bit is again retracted by wire-line technique, allowing coring pipe to be inserted. When coring is finished, the drilling pipe containing the core is pulled-out, central rolled goes in and drilling can continue [2].

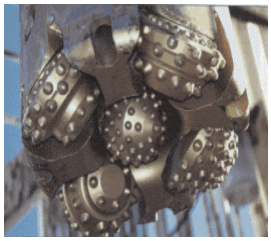

Fig. 13. Bit by RockBit Internacional Inc. (RBI)

Diamond crowns

Diamond crowns are the longest time used to coring crowns (Fig. 14). Disintegrating material – natural diamond is the hardest material used for disintegration of rock. However, it has its disadvantages too. In very soft and soft rock its too small cutting element can get burned (if not properly cooled by drilling fluid); in hard rock it can be damaged/broken as a result of careless handling of drilling string or due to its vibration.

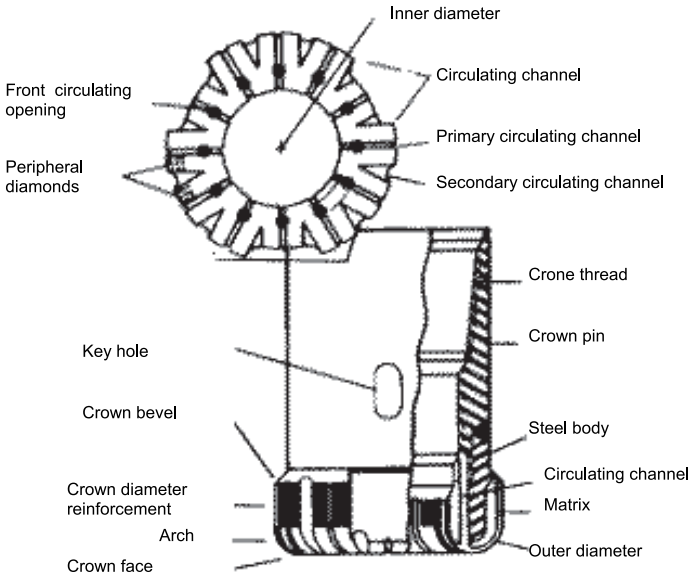

Fig. 14. Description of a diamond crown

Despite all this, diamond is the most commonly used material for coring in hard and very hard rock. Natural diamonds which are used in manufacturing of coring crowns a classified according to their core the coma size and shape. Most manufacturers use similar diamond classification, only with different naming.

The first group are rounded, mechanically and chemically treated natural stones. They have a higher heat and mechanical resistance.

The second group are natural cubicle stones suitable to soft rock (large bite).

The third group are octahedron-shaped natural stones, well crystallized, with sharp edges. They are very resistant against abrasion and graphitization.

The group four are diamonds which are transparent, multicolor, which additives (less valuable for jewel-manufactures). They have a highly integral crystal structure, are resistant against abrasion and have higher strength. They are used in hard and abrasive rock.

The fifth group of natural stones are diamonds with crypto-crystalline structure, with their inner structure very similar to synthetic diamonds. They have great strength and are used (combined with other stones) for coring in fractured and crushed rock.

The group number six consists of very small stones (approximately identical size) which are used in impregnated crowns. For this purpose, only some natural diamonds are used; mostly synthetic diamonds [4].

Size of diamonds is given in a number of stones per carat (carat [crt] = 0.2 gram).

Natural diamonds are also used for button-shaped cutting elements (making a mosaic). They form heat-stable cutting elements with high efficiency and long lifetime. They are used in formations with altering soft, abrasive and clay layers with sandstone or limestone benches.

The face of the crown can have various shapes, depending on the type of rock. Basic shapes are shown in Figure 15. Crowns can be made with front flushing (drilling fluid less influencing the core) and direct flushing.

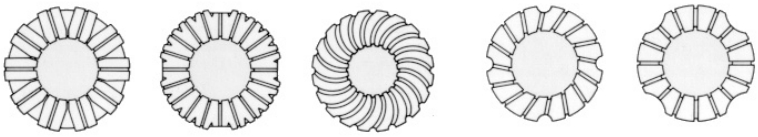

Fig. 15. Various shapes of modified face of coring crown

Direct flushing often washes away some parts of core (e.g. what coring not consolidated rock, coal, etc). The matrix, similarly to PDC crowns, is a product of powder metallurgy, hard and very resistant against abrasion. This feature is very important especially for diamond crowns, as the diamond is a small cutting element and creates small flushing and cooling channel. Hence, flushing fluid velocity is relatively high (even with less volumes used for coring) [2, 4].

Shape modification of crowns to increase the yield, reduce effects of flushing to the core, etc. as described for PDC crowns, is similarly applied in a diamond crowns too.

Diamonds are most often used for reinforcement of inner and outer diameter of coring crowns, depending on their design and intended use. Length of reinforcement of outer diameter depends on the intended use too. The crowns for heavily deflected and horizontal wells have much longer reinforcement than those for vertical wells. Additional reinforcement also stabilizes rotation movement of the crown.

Impregnated drilling crowns are used mainly in very hard and abrasive formations, but also in hard, heavily fractured and tectonically disturbed rock or in low-compacted breccias. They have a smooth run, longer lifetime and, in combination with submersible will motor at higher speeds they achieve very good coring speeds.

It must be noted that manufacturers of drilling tools are combining to use of disintegrating elements, natural and synthetic stones, in order to achieve maximum effect, long lifetime, high coring speeds and as little affected core is possible. Figures 16a–f shows some diamond, mosaic and combined bits.

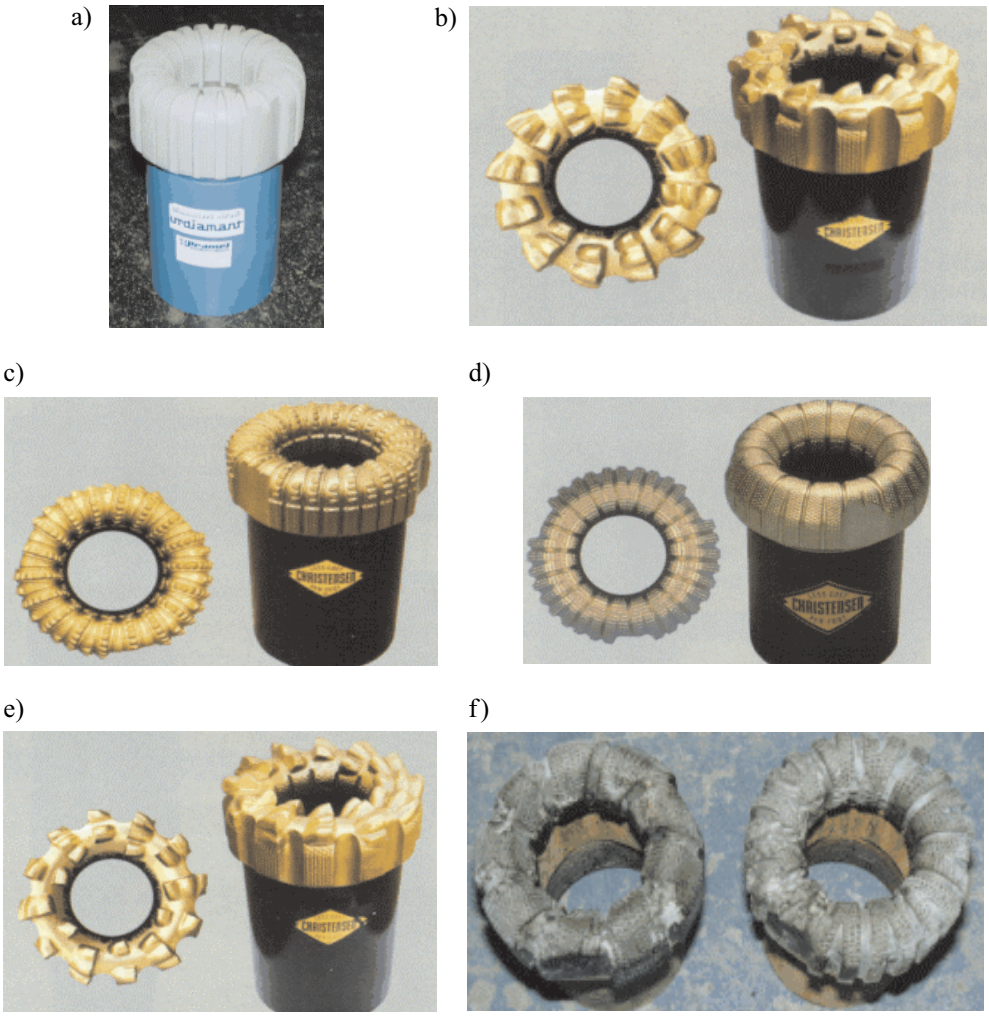

Fig. 16. a) Pramet Šumperk; b) BHI RC type PDC; c) BHI type C natural diamonds; d) BHI type SC BallaSe/ sintered diamond; e) BHI type ZC PDC/mosaic diamonds; f) Washed-away matrix Pramet Šumperk

Competition on market is relatively high, however, despite the fact that Slovakia is such a small country, we have offers from the companies like Security DBS, Baker Hughes Inteq (BHI), Diamax, Hycalog. In past, there were some problems with the crowns manu-

factured by Pramet Šumperk (stew quality, hardness of matrix and non-suitable design of crowns) [2].

More details can be found in company catalogs. For a selection of coring crowns, it is often important to consider practical experience.

5. CONCLUSIONS

Some methods and techniques, verified in day-by-day practise, are commonly used for qualitative withdrawal of a core in Slovakia. The paper presents describing these methods, techniques and division of the splitting of a rock mass onto a sample form.

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