Ideas to Design an *in situ* Diamond Drilling Core Splitter within Soft Rocks*

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Abstract

Diamond drilled cylindrical rock (core) from the earth is usually extracted using a drill rig. This is followed by splitting, at the surface with the aid of diamond impregnated saw blade, for good visual examination before sampling for analysis. The challenges in core splitting are imperfect division, time consuming, labour intensive and dust generation. This paper studied the wireline system of core barrel assembly and the device used in splitting of core (core splitting machine) at the surface, to provide ideas which would help design a mechanism that would take care of the splitting of the core *in situ* (i.e. at depth during the drilling process). Modifications of the core barrel assembly of the wireline system are such that the outer tube assembly is designed to have two ball bearings moulded with it. The back end assembly is designed to have a latching system which could operate independently. Also a static diamond cutting blade is inserted in the core lifter to split soft rocks or saprolite (with hardness of less than 5 on the Mohr's scale) when a resultant feed force is applied. The stop ring in the inner tube should effectively grab the split core to prevent it from dropping and also protect the split core from washing away. Drilling at short intervals with controlled drill fluid usage is recommended in saprolite zone. Following the ideas provided, an *in situ* core splitter could be designed to eliminate hazards associated with conventional core splitting on the surface, save time and reduce dust generation.

Keywords: Design, *In situ,* Diamond drilling, Core splitter, Wireline system

1 Introduction

In diamond drilling, solid cylindrical rock (core) from the earth is extracted using a drilling rig. Currently, the largest percentage of core drilling is done with wireline system (Anon., 2011).

The extracted core is put into a core tray and transported to a core shed where splitting of the core is done with the aid of a diamond impregnated core saw blade. The cutting of the core into two halves is necessary to aid visual examination of the core for sampling. There is, however, a major challenge to geologists as the splitting of the core requires optimum attention to achieve a perfect and equal division especially in fractured zones. In soft rocks, splitting is usually done with a knife. This paper provides suggestions for the design of a mechanism that would take care of the splitting of core *in situ,* when desired, during drilling in soft rocks or saprolite with hardness of up to about 5 on the Mohr's scale without the rock fracturing into pieces.

Core drilling is useful for determination of stratigraphic sequence and types of lithology. For geotechnical purposes, the competency of a rock is determined to check if it could withstand engineering structures such as tunnels, buildings etc. In mineral exploration, a drilled core helps in exposing the rock of interest and the depth at which it is located for further analysis of the grade of the mineral of interest in the rock.

1.1 Mechanism of Core Drilling

The basic principle behind core drilling is that a drilling rig generates rotation and a force that drives tools consisting of a bit, core barrel assembly, and a series of drill rods into the ground. While drilling, rotational speed reaches 1000 rpm and so generates a pressure known as bit weight which helps to cut the rock into the core barrel. Retrieval of core barrels come in lengths of 1.5 m and 3.0 m, but could be extended beyond 6.0 m when drilling conditions permit it. The core is then removed from the inner tube assembly and carefully placed into a core tray for inspection and logging by the geologist. Core drilling is usually done by wireline systems (Anon., 2011).

1.2 Core Splitting

Core splitting is conducted using a rock saw or an impact core splitter machine. There is always the problem of obtaining a representative perfect split of the core. To avoid this problem, sometimes a portion of the entire core is analysed or small chips are collected along the length of the core for analysis of grade (Majoribanks, 1997).

In soft rocks, especially saprolites, in which minerals in the fresh rock had weathered or broken down into secondary minerals such as clay minerals (with hardness of about 1), a knife

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(usually with hardness of 2.5) is used to split the core (Greensillith, 1971 and Majoribanks, 1997).

2 Materials and Methods Used

2.1 Wireline Core Barrel

According to Anon. (2011), the wireline system of the core barrel has the ability to unlock the inner tube assembly with the use of a device called an overshot. When the tube is full, the overshot is lowered down the hole through the rod string to release the inner tube assembly and retrieve it from the hole by way of a wireline cable attached to the drill. Figs. 1a and 1b show the components of a wireline core barrel assembly for the outer tube and inner tube respectively whilst Tables 1 and 2 provide components of these core barrels and their functions for the outer tube and inner tube respectively (Anon., 2011). The external diameter of the inner tube is larger than the inner diameter of the bit but sufficiently less than the inner diameter of the outer tube so as to permit passage of fluid between the assembly and the outer tube (Pickard *et al*., 1958).

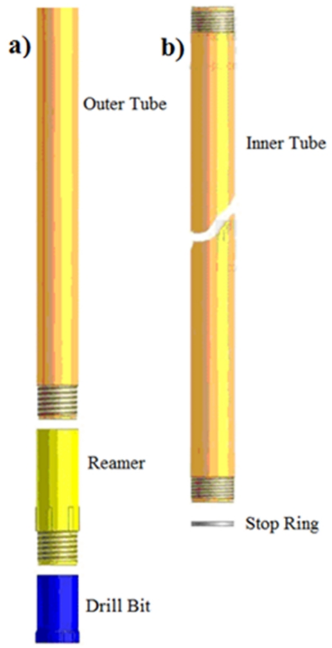

Fig. 1 Components of Core Barrel of the Wireline System (Anon., 2011): a) Outer Tube b) Inner Tube

2.2 Outer Tube Design

The outer tube assembly could be designed such that two ball bearings are moulded with it. The first ball bearing is positioned at the box end of the outer tube just after the landing ring while the second is positioned before the pin end of the outer tube (Fig. 2). These ball bearings should have higher load capacity and strength to withstand the load. They should also be heat resistant and resistant to damage on impact with rocks. The space between the bearings should be wide enough to allow drilling fluids to get to the bit.

2.3 Inner Tube Design

The inner tube assembly could be designed primarily to house the core and allow retrieval from the outer tube (Fig. 3). The back end assembly should have a latching system which operates independently to prevent an upward movement of the inner tube assembly as the core enters the inner tube. The inner tube assembly should also have a device inserted in the core lifter to split the core into two equal halves before it enters the inner tube.

2.4 The Core Lifter Design

2.4.1 Core Lifter

The core lifter should be moulded with an attachment of a splitting device, to cut the core into two equal halves as it passes through it into the inner tube, and by the help of a stop ring, it maintains its grip on the core to ensure it does not slip as the inner tube assembly is being retrieved out of the hole (Fig. 4).

2.4.2 *In situ* Core Splitting Blade

The blade for splitting core should be made of high-carbon steel which should be heat resistant and less ductile to withstand the impact of the core. The edge should have artificial diamond crystals which are held in place by a sintering blended metal powder. The thickness of the blade should be the same as what is currently used in the core splitting machine (1.6 mm), with the dimension across the blade dependent on the size of the core lifter. The blade is made static at the centre of the core lifter to split the core as it enters the inner tube. The cutting of core is done based on resultant feed speed generated by the penetration rate of the rig. The perfectly split core would travel through the core lifter into the inner tube. To avoid contamination, short runs are recommended so that the blade could be cleaned in between runs. Also controlled drill fluid usage ensures that saprolite does not wash away while in the firm grip of the stop ring within the inner tube.

Table 1 Components of Outer Tube of Wireline System and their Functions

Component	Function
Head Assembly	This is the most complex part of the core barrel and has many functions including latching the inner tube assembly in place, landing indication, and fluid circulation to the bit.
Stop Ring	This is the first of three pieces of check valve system which keeps the core sample from dropping out of the inner tube and assists in breaking the core at the base of the hole. It is locked into a groove inside the core lifter case and prevents the core lifter from being pushed up into the inner tube as the core sample is being captured.
Core Lifter	This is the second piece of the check valve system. It is designed to let the core sample move easily up into the inner tube. When the core is pulled back, the core lifter grips the sample which results in it being pulled down further into the taper of the core lifter case. This action forces the slot in the core lifter to close even tighter onto the sample, ensuring it does not slip as it is being retrieved out of the hole.

Source: Anon., 2011

Table 2 Components of Inner Tube of Wireline System and their Functions

Component	Functions
Locking Coupling	The box end thread varies to adapt to the selected drill rod and the pin end face. It is what contacts the opened latching system to keep the inner tube assembly locked (latched) in place at the bottom of the hole during the drilling process.
Adaptor Coupling	Allows the latching system to open fully and locks the landing ring in position inside the box end of the outer tube.
Landing Ring	It is positioned inside the outer tube to ensure the inner tube assembly is seated in the correct position for drilling. It is also heat treated to resist the impact damage from the inner tube assembly as it comes to rest.
Inner Tube Stabiliser	It sits inside the box end of the reaming shell and keeps the inner tube stable and centred inside the bit to receive the core sample. It has been designed to allow the drilling fluid to pass through to the bit which is critical for bit life.
Thread Protector	This is threaded onto the end of the outer tube to protect the threads and to house the inner tube stabiliser until the reaming shell and bit have been threaded on.

Source: Anon., 2011

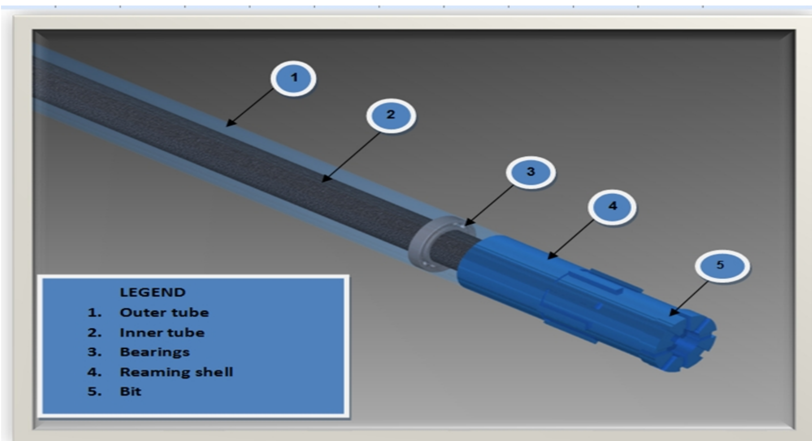

Fig. 2 A Section of the Outer Tube Assembly showing Location of Proposed Bearings (modified after Anon., 2011)

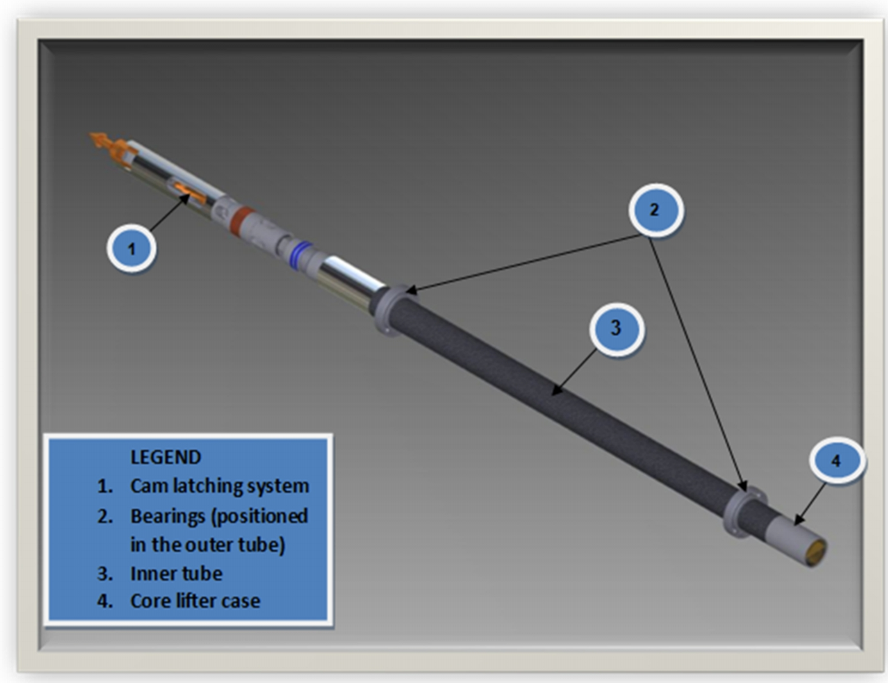

Fig. 3 Inner Tube Assembly showing Location of Proposed Bearings (modified after Anon., 2011)

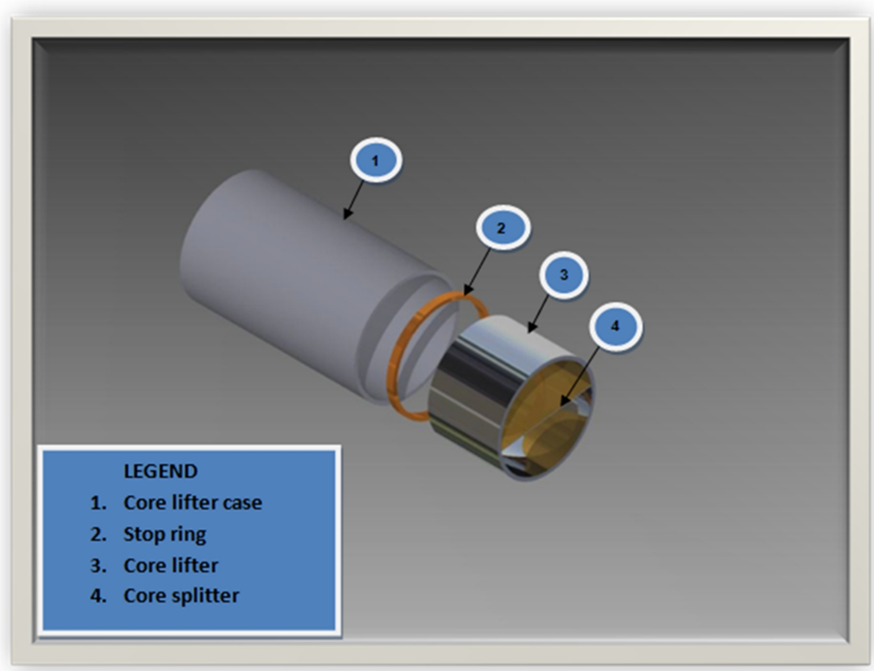

Fig. 4 Core Lifter Assembly showing the Location of Proposed Core Splitter (modified after Anon., 2011)

3 Results and Discussion

3.1 Mode of Operation of the Proposed Core Barrel

The operation of the proposed core barrel is similar to the wireline system which allows the inner tube to be retrieved by means of an overshot. The components and the various functions that make up the proposed core barrel are not different from the wireline system (Anon., 2011). The additional features of the proposed core barrel are ball bearings between the inner and outer tubes at distant ends to allow the inner tube to remain stationary and retain the core while the outer tube is being rotated by the drill string.

The proposed core lifter has an additional diamond edged blade which is positioned centrally to be acted on by a resultant feed speed which depends on ground conditions. At the appropriate intensity, this should be able to split the core into two equal halves before it enters the stop ring and then into the inner tube. The cylindrical core which has been split should pass through the bit, then to the core lifter case which serves as a primary check valve to ensure the core does not fall into the hole.

As in the conventional wireline system, an overshot should be sent down the hole through the drill string to retrieve the inner tube assembly when the run is completed. However, with the introduction of the *in situ* core splitter, the core that is emptied into a core tray is already split to await sampling and analysis. The currently used core lifter could be fixed instead, when *in situ* splitting is not required.

3.2 Design Implications

There are two methods of retrieving a core from a borehole during drilling. These are the conventional system and wireline system but the wireline system is the most efficient way of retrieving a core since it is less laborious, faster and more productive (Anon., 2011). The retrieved core is then cut or split into two halves and logged at a core shed. Problems associated with this method of core splitting are, unequal splitting, time consuming, labour intensive and generation of dust during cutting.

According to Anon. (2010), due to prolonged working of the operators at awkward positions, vibrations transmitted from cutting of core could build up to affect the spine, nervous systems and back injury. Additionally, injuries sustained on usually fingers due to manual handling of core are caused by violent reactions from blade jams during splitting.

Also devices used to reduce dust emissions from affecting the operator during core cutting are not efficient enough. Organiscak *et al*. (2000) recommended pressure cabins for drillers to reduce dust inhalation. However, there is no such cabins to isolate cutters because cutting or splitting of core at the surface is done at close range with maximum care to ensure equal splitting.

The proposed core splitting design would take care of the above challenges by incorporating the splitting process *in situ*, during drilling. To facilitate splitting *in situ*, additional features could be introduced so that the inner tube could be stabilised with the aid of two bearings positioned at both ends of the outer tube to keep the inner tube stable while the outer tube assembly rotates (Fig. 2). The designed core lifter which contains a blade with diamond edge could be positioned centrally and with the aid of resultant feed speed, the splitter could be dropped by a force to cut soft rocks and saprolite (with hardness at about 5 on the Mohr's scale) into two equal halves before the core enters the stop ring and then moves further into the inner tube. After splitting, the stop ring in the inner tube should effectively grab the split core to prevent it from dropping and washing away. Drilling at short intervals with controlled drill fluid usage is recommended in saprolite zone. To reduce cost, polycrystalline bit could be used to replace diamonds for coring in softer formations (Anon., 1992).

The proposed core lifter would allow the core to be split, when desired, and could be removed and replaced with the conventional core lifter when splitting is not required. This is because splitting of core outside the zone of mineralisation may not be necessary. Unfortunately, this method of *in situ* splitting of core would fail in harder rocks which are usually brittle.

4 Conclusions

An *in situ* core splitter could be designed to split soft rocks and saprolite of hardness below 5 on the Mohr's scale during the drilling process. This would eliminate hazards associated with conventional core splitting, save time and reduce generation of dust.

Features introduced so that the inner tube could be stabilised while the outer tube assembly rotates are controlled mechanisms to make the core stable for splitting *in situ* by a blade with diamond or polycrystalline edge attached to the core lifter. Positioned centrally, the blade facilitates equal splitting into two equal halves when a resultant force drops on the blade to cut soft rocks and saprolite.

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