Design and Developed of High Performance Rotary Head Module for Core Drill Rig

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Abstract. Fossil fuel, especially oil, represents the engine of nowadays life. Oil companies work hard in order to extract it from subsurface hydrocarbon reservoirs. The operations at which oil is being extracted from these reservoirs are referred to as drilling operations. Drilling operations are per-formed with the means of drilling rigs. However, due to the high demand for oil, drilling for oil becomes more challenging and oil companies are always looking for the most effective extraction methods and are they moving toward the precious control of the drilling operation for different type of requirement and conditions. This paper aimed for the manufacturing of High-performance Rotary Head module of Core Drill equipment which is used for geological purposes. The fallow target criteria will be going to achieve which includes the rotation speed, rotation torque, gripping force, and speed change at different stages. In our study we find out that the rotational speed of head is greater than 1200 rpm and maximum torque generated is greater than 160 kgf.m also the drill rod breaking power is equal or higher than 6 ton. After the complete study it is certain that the rotary head module will be used for future use.

1. Introduction
Rotary drilling rig is a kind of pile drilling machinery which is suitable for deep-hole piling in building foundations, and is also widely used in different foundation constructions. A typical structure of a drilling rig is shown in ‘figure 1’. It consists of rotary head, gear box, mast, swivel body, sand reel, rotary table, hydraulic system and electrical system [1]. Core drilling is used in a variety of fields to identify underground exploration. The equipment used for such core drilling has different shapes and functions depending on the manufacturer, but it is similar to the general drilling equipment and it is distinguished from general core drilling.
The geologic drilling rig is a device used for a general purpose drilling rig, used to take samples (core) of rock by using high rotational speed. Therefore, it is necessary to perform a high-speed rotation of 1,000 rpm or more, to continuously grasp (clamp) the drill rod while working, and to develop a device capable of changing the number of revolutions according to working conditions.

In order to increase the work efficiency, we design and manufacture the high speed rotating structure so that we can build up the foundation for commercialization by accumulating know-how about core drill. Torque of the Core the Drill, and the tensile Force are key performance indicators. For the performance of the Core Drilling machine we check the performance of the "Rotary Head" module are indicated by number 5 in the ‘figure 2’ which is installed in the drilling rig. The main performance listed above depends on the "Rotary Head" module.

Archaeological records show that as early as 3000 B.C., the Egyptians may have been using a similar technique. Leonardo Di Vinci, as early as 1500, developed a design for a rotary drilling mechanism that bears much resemblance to technology used today. Despite these precursors, rotary drilling did not rise in use or popularity until the early 1900's [2, 3].
Although rotary drilling techniques had been patented as early as 1833, most of these early attempts at rotary drilling consisted of little more than a mule, attached to a drilling device, walking in a circle! It was the success of the efforts of Captain Anthony Lucas and Patillo Higgins in drilling their 1901 ‘Spindletop’ well in Texas that catapulted rotary drilling to the forefront of petroleum drilling technology [4].

2. Designing and Mathematical Calculation of Rotatory Head Components

In the designing process two main component are design which is rotatory chuck and the transmission system for efficient rotation and power transmission of drilling rig. For rotatory chuck we Increase the number of jaws and the size of the ground plane to increase the gripping force of the rod. To maintain the rotational force of the rotatory head thrust bearing has been used which is the ideal for our designing condition [5, 6]. The 2D and 3D of rotatory chuck with swivel body are shown in ‘figure 3’.

![2D and 3D diagram of rotatory chuck with swivel body](image-url)

**Figure 3.** 2D and 3D diagram of rotatory chuck with swivel body

| Swivel Body | TC Oil-Seal OD300 ID260_20T |
|-------------|-----------------------------|
| Shock Absorber Shaft | Grease nipple-1/8 inch |
| Shock Absorber Cap | TC_Oil_Sea ID230 OD260_16T |
| shock absorber tube | Hex Bolt M12 x 110L |
| Taper Roller Bearing 32948 | Bolt M12 x 65L |
| Swivel Body | SKY OD260 ID240 |
| Swivel_Lower Cap | SKY OD80 ID70 |
| Swivel_Upper Cap | D90 Snap Ring |
| Shock absorber Rubber | G-70 O-Ring |
| M230 Nut | Hex Bolt M20 x 80L |
Force Calculation for chucking is to perform in which we measure the gas spring minimum initial force from the diagram through formulas and the value of forces are shown in the Table 1. Where Fc represent the chuck force of the drill rig. The complete model of rotary head module was initially design in solid-works for the required amount of rotational speed and gripping force. The model consist of many parts which is indicated in Figure. 3 above with numbering from 1 to 21. One end of the rotary head module is screw type which will connected to the Kelly Bars and there dimesons are 150*150*250 (mm), the other end of module is connected to hammer and it’s a box type connection as we can see from the assembly diagram in ‘figure 4’.

**Figure 4.** Mathematical model of rotary drill module in solidworks

3. Transmission Design for Improving Rotary Head Operating Force

Geological drilling Core drill is operated at a constant speed, which often causes a decrease in work speed or breakage of drill when faced rocks or obstacles in the ground. In this task, we have developed and installed a manual transmission that can control the output manually according to the condition of the object for sampling, so as to enhance the commerciality of the rotary head.

It is designed to increase the performance by controlling the output by designing and installing the 4-speed gearbox as a model of the manual transmission for the vehicle. The core drill transmission is considered to be suitable for non-clutch type manual transmission, and the basic type is a basic model
of 4-speed manual transmission for vehicle. For the experiment three types of gear shifting has been used to find out the best suitable option for our design which are, selective shifting type, continuously shifting type and synchronized type.

Selective folding type (Perturbation gear type) in which shift is possible by simply pushing gear shown in Figure 5. These type are good for speed control but it has a big disadvantage when there is a lot of noise and the stage is changed that gears are difficult to fit.

![Figure 5. Selectable folding Perturbation gear transmission system](image)

Always-on (Regular combination) Improved type of Selective-fold Gearbox. The gears are always, in engagement with is the auxiliary gear, which is powered by the Input Shaft. Since the Gears are not fixed to the main shaft, they are Free to The Rotate and need of "Dog Clutch" for the Engagement of Gear which are mostly used in high-torque and high-speed vehicles. Figure 6 shows the working mechanism of transmission type.

![Figure 6. Selective-fold Gearbox transmission system](image)

Synchronous expression (Synchronous combination) in which Gear and spindle are connected smoothly by sleeve and synchronizer ring and the power is transmitted in different gears shown in ‘figure 7’.
Figure 7. Synchromesh manual transmission system components

The final design of transmission module is shown in the ‘figure 8’, which consist of total of 29 components along with the numbering and names in the below figure.

Figure 8. Final Design of transmission system
4. Experimentation and Results
The following equipment’s are used to find the different parameters during the test.

a. Rotational speed - Measurement using tachometer Stable fixed structure when rotary head is mounted. Measure the rotational force of the lower ground surface when rotating the rod on the rotary head.

b. Rotational torque - Pressure measurement with hydraulic actuator Maximum rotational torque: 160 kgf * m (45.3 bar pressure when achieving torque cylinder target)

c. Gripping force - Measurement of gripping force by drawing test through linear hydraulic drawing device Gripping force: 6,000 kgf or more (pressure when gripping force cylinder target is reached 101.9 bar)

d. Checking the speed change stage - Four speed shift mode.

Figure 9. Assembly of Rotary Head for Performance Test

Complete assembly of Rotary Head for Performance Test and there setup are shown in the Figure 9. In the whole setup there are three main components which are indicated through numbers from 1 to 3.

① Rotary head (Body) - equipped with the high-speed motor and transmission performed the performance test after mounting the test rod.

② Cylinder for measuring rotational torque - the performance instrument measured torque during rotational motion.

③ Cylinder for gripping force measurement – Measure this values in case of maximum torque the chuck (Jaw) rod is pulled out.

5. Summary of Results
From the study we find out the following results that the drilling rotation speed of the Core Drill is about 100 rpm. However, the Rotary Head of the Core Drill has been developed in this study to exhibit a rotational speed comparable to that of overseas competitors at 1,200 rpm. In order to realize the high rotational speed, it is necessary to design the mechanism that can maintain the speed stably, and it is necessary to design the structure that can cancel the rotational force and the centrifugal force.

By integrating hydraulic system design technology into the design technology of the drilling rig that we possess, we have accomplished the results through this development task and it is an opportunity to reduce the technology gap with related overseas technology. The design of Chuck (Jaw) for rod grip, which is a major performance part of Rotary Head, is designed as Nitro Gas spring type that is used overseas, so that it can overcome the compatibility part when exporting from abroad.
We also find out our final requirement of the study which is the rotational speed of head is greater than 1200 rpm and maximum torque generated is greater than 160 kgf.m also the drill rod breaking power is equal or higher than 6 ton. Our key performance indicators compare to other world class company are compared in the below Table 1. So by using our study in future we can manufacture the drilling module with in Korea which will fulfill the requirement of world top class companies.

**Table 1.** Study achievements and there comparison with world top class companies

| Key Performance Indicators | Unit  | Development Target | World-class (Company/ Country) | weight (%) |
|----------------------------|-------|--------------------|---------------------------------|------------|
| 1. Rotation Speed          | Rpm   | 1,200 More than    | 1,342 (Bo Art Longyear / USA)   | 30         |
| 2. Maximum Rotational Torque | kgf * m | 160 More than | 215.985 (Bo Art Longyear / USA) | 30         |
| 3. Drill Rod Gripping force | ton   | 6 More than        | 7.658 (Bo Art Longyear / USA)   | 20         |
| 4. Shift number             | Only  | 4 More than        | 4 (Bo Art Longyear / USA)       | 20         |

6. References

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