Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

Research and Application of Booster Compressor for Air DTH Hammer in Deep Well

Renjie Zhang[1] , Xiuhua Zheng*[1], Hongyu Ye[2], Changgen Bu[1], Hongyan Ye[2],Yuanyuan Su [2]

1: Beijing Taili New Energy Technology Co., Beijing, 100010, P.R. China;

2: China University of Geosciences(Beijing), Beijing, 100083, P.R. China;

xiuhuazh@cugb.edu.cn(X.Z.); yehongyu0216@126.com(H.Y.); 15297578067@126.com(Y.S.); 353731573@qq.com(H.Y.); 1807147384@qq.com(R.Z.); bucg@cugb.edu.cn(C.B.);

*Correspondence: xiuhuazh@cugb.edu.cn

Keywords: Deep Wells, air DTH hammer drilling, lift water, booster.

ABSTRACT

The highest back-pressure can be maintained below 7MPa when drilling with air DTH hammer in deep Wells, but the lifting water pressure is very high when the water in the well bore needs to be pulled out after tripping in. When the well depth is 2500-3000 m, the lifting pressure is as high as 25-30MPa. At present, the maximum pressure of large displacement booster on the market is about 12-15MPa, which has large pressure redundancy for normal drilling and is too low pressure to lift water, making this booster costly but unable to meet the needs of lifting water. The author's team cooperated with the domestic manufacturers of deep well air DTH hammer drilling equipment, and jointly developed the high-pressure and large-displacement booster and ultra-high-pressure and small-displacement booster, which can not only achieve normal drilling operations, but also meet the requirements of drilling and water lifting, with low cost. This paper will comprehensively introduce the research and development achievements in this field, in order to promote the popularization of efficient air DTH drilling technology in China's geothermal industry.

1. INTRODUCTION

Geothermal energy is a kind of abundant, widely distributed, stable and reliable renewable energy, Qiao Y. et al (2022). Because of its stability, large reserve and wide distribution, it has been widely concerned in the field of building heating, Wang F.H. et al (2021). In addition, in order to promote the sustained and high-quality development of geothermal energy development and utilization, and make it play a more important role in the energy production and consumption revolution, the National Development and Reform Commission, the National Energy Administration and other eight ministries and commissions issued the "Several Opinions on Promoting the Development and Utilization of geothermal energy" , the NDRC. et al (2021). By 2025, the area of geothermal heating (cooling) will increase by 50 percent compared with 2020, and by 2035, the area of geothermal heating (cooling) and the installed geothermal power generation capacity will become twice as the level of 2025, the NDRC. et al (2021), the document said.

Air DTH hammer drilling is one of the contemporary multi-process air drilling techniques. At present, the conventional rock bit drilling that is recirculating and rotary ,has a long drilling period and low drilling efficiency, which can't meet the current demand of geothermal development. The air DTH hammer drilling technology has the characteristics of fast footage, low drilling cost, good aquifer protection effect, small well slope angle, and has the advantages of both gas drilling and impact drilling, Ge P.F. et al (2013) and Xiong J.Y. et al (2011). In addition, air DTH hammer drilling has incomparable advantages of rock bit and PDC bit, especially in preventing well deviation, reducing drilling parameters and reducing drilling time, Pu K.Y. et al (2021). It is an excellent choice to apply air DTH hammer drilling technology to drilling geothermal Wells.

The normal operation of the DTH hammer requires the booster compressor to provide enough air pressure and air volume, but the problem is that when the water output is increasing , the requirements for the exhaust pressure of the booster compressor will also increase. At present, the drilling depth of geothermal Wells , using air DTH hammer technology, is getting deeper and deeper, from 1000m to 2500m and 3000m.The deeper the well depth, the greater the drilling fluid column pressure in the well, and the difficulty of air DTH hammer drilling will also increase. In order to be able to make the air DTH hammer work under more drilling conditions, the research team has made unremitting efforts in the booster compressor. This paper will give a comprehensive introduction to the research and development achievements in this field to promote the popularization of high-efficiency air DTH hammer drilling technology in Chinese geothermal industry.

2. PERFORMANCE REQUIREMENTS OF BOOSTER COMPRESSOR FOR AIR DTH HAMMER DRILLING IN DEEP WELL

When drilling with the air DTH hammer, the air pressure and air volume provided by the ground must meet the conditions of the air DTH hammer. Air volume is mainly used to drive the DTH hammer reciprocating impact, drill rotation and cuttings return. Air supply is not only the basic condition to ensure the work of the air DTH hammer, but also an important factor to ensure whether the drilling can normally discharge cuttings, Shi J.J. et al (2021). Air pressure is mainly used to overcome the resistance along the whole flow channel , each local pressure loss and overcome the well water column pressure and provide the pressure required for air DTH hammer.In addition, when encountering larger debris particles ,which can't effectively be discharged, booster compressor can also effectively improve the gas pressure, timely clear hole and prevent drilling accident. The usual rule is that the higher the wind pressure, the faster the drilling speed. The required pressure also increases with the increase of well depth. For example, when drilling a Ø120mm well, the wind pressure is 1.4MPa for the depth of 150m and 1.7MPa for the depth of 200m.

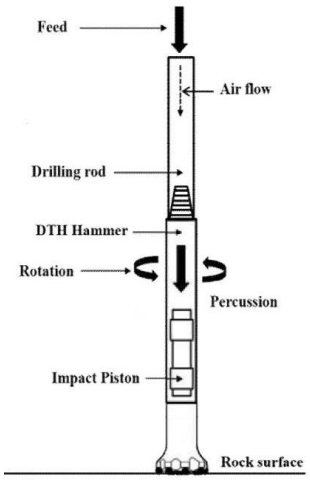

Figure 1: Drilling drawing of the drilling system of the DTH hammer, Kim D J et al (2019)

The air pressure volume required in the air DTH hammer drilling in the deep well can be calculated by the following formula ,Hu Y.L. et al (2018), and then determined according to the field conditions.

$$Q = 60k_1k_2\frac{(D^2-d^2)}{4}\pi v \quad (1)$$

Where:Q-air volume (m^3/min); The k_1-hole depth correction coefficient, as the hole depth was increased, increased annular gap pressure loss, leading a decrease in flow, generally take 1.05~1.1 when the depth is 100m~200m, 1.1~1.25 when 200m~500m, 1.25~1.5 when 500m~1000m, 1.5 when above 1000m; k_2-Air volume increase coefficient during water gushing in the hole, Related to the water inflow, When small and medium-sized water gushing, Take 1.5; D-Drilling diameter (m); The d-outer pipe of drill pipe (m); V-Upward return wind speed, 20 m/s ~ 25 m/s , Zhao H.X. et al (2016).

Air pressure calculation:

$$P = Q_2L + P_m + P_c + P_s \quad (2)$$

Where:P-air pressure (MPa); Q_2-pressure drop of dry hole per meter (generally 0.0015MPa / m); L-drill pipe length (m); P_m-pipe pressure loss (0.1MPa~0.3MPa); P_c-air DTH hammer pressure drop (MPa); P_s-water column pressure in borehole, Zhao H.X. and Wang Y.J.et al (2016).

2.1 Performance Requirements for The Booster Compressor During The Drilling Process

The performance requirements of the booster compressor during the drilling process are determined by different well depth and different water output. The required air volume and air pressure are determined by different well depth and water output. By the characteristic of the gas expansion, when the offered air pressure is enough to offset the back pressure caused by the borehole water output and the working pressure supplying the DTH hammer, then drilling can be continuously performed with the offered air pressure.

Table 1.Technical parameter table of air pressure and air volume during the common drilling process

Well hole diameter (mm)	Well depth (m)	Water discharge from strata (m^3/h)	Wind pressure (bar)	Wind volume (m^3/min)
311	500	20	30	30
216	1000	120	110	90
152	1500	100	100	90

2.2 Performance Requirements for The Booster Compressor During the Water Lifting Process

In the process of water lifting, the provided wind pressure should mainly deal with the water from the strata leaking into the well in the period of making a connection. If the water leak is very large, in the time of making a connection, the water can reach a very high height , the performance of the booster compressor will have very high requirement. When lifting water, about 10m in the well requires about 1bar pressure.

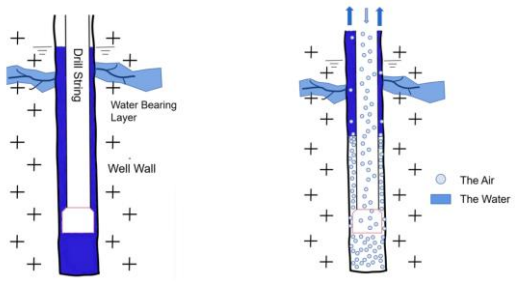

Figure 2: Schematic diagram of the water lifting process

3. CURRENT STATUS OF BOOSTER COMPRESSOR FOR AIR DTH HAMMER DRILLING

In the air DTH hammer drilling , the booster compressor can be used to improve the pressure level of the compressed air to improve the water lifting capacity , during the drilling process or the excessive pressure loss caused by the down-hole power drilling tools. The booster compressor is mainly a piston machine. At work, the reciprocating movement of the piston in the cylinder makes the gas inhalation, compression, discharge and other processes. The booster compressor can have a multistage compression mechanism.

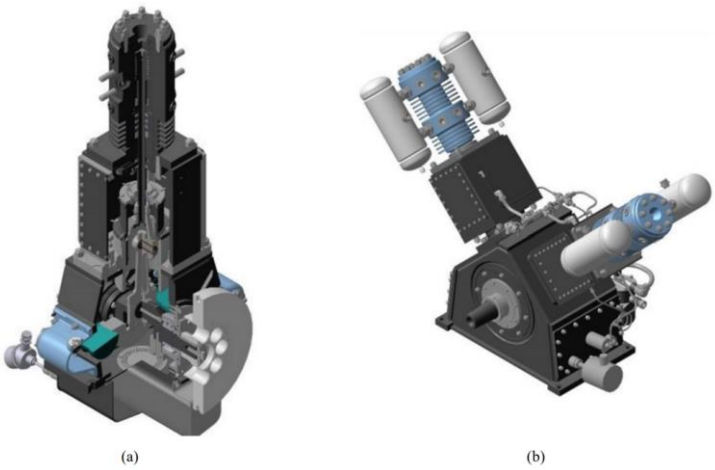

Figure 3: Single row (a) and double row (b) booster compressor mechanism ,A. A. Kotlov et al (2019)

At present, the most used Gardner Denver and Atlas Copco booster compressor in China, the parameter table is as follows. In April 2015, Denver Machinery introduced the JY 500 series booster compressor, which has more than 30 years of mature application experience, to China. GD's JY 500 booster compressor has a very rich industrial application in the Americas, widely serving oil drilling in oil fields, shale gas, coal bed methane and geothermal well industries. Since the introduction of JY 500 in China, its excellent performance has given it many compliments in China. The JY 500 host is a 7-inch dual action cylinder for the Y-type symmetrical balanced layout, dual cylinder single column. It has an industrial grade reciprocating piston compressor, which can meet the 24 / 7 heavy-load operation design, Caterpillar heavy-load condition diesel engine, ensuring the output rated flow under rated pressure. Atlas copco also has a good performance in all aspects. Its technical parameters are shown in Table 2.

Table 2.technical parameters table of booster compressor

The brand	The type	Nominal volume flow (m^3/min)	Inhale pressure (MPa)	rated discharge pressure (MPa)	shaft power (kW)
Gardner Denver	JY500	3.0	3.0	12.0	unknown
Atlas Copco	B18TT-62/3000	unknown	3.5	10.0	563

Type Denver JY500 is a kind of booster compressor with high pressure. However, in practical application, considering the protection of the machine and the field environment, the output pressure provided by the Denver JY500 supercharger and the gas flow rate are a little lower.

4. DEVELOPMENT AND APPLICATION OF BOOSTER COMPRESSOR

In view of the current application status of the domestic booster compressor, in order to ensure the sufficient gas flow in the drilling process, the gas flow rate of 120-150 m^3/min is generally required. Based on the actual production needs, the research team intends to develop a variety of booster compressors with a gas flow rate of 70 m^3/min and a pressure ranging from 70bar to 100bar to cope with a variety of working conditions. At present, it has developed a 70bar class, gas flow of 70 m^3/min supercharger, fully called DFW-2 / (33-35) -70 type air compressor. The booster compressor is two in parallel to provide 140 m^3/min of gas flow, such a large gas flow is enough to meet the gas cycle during the drilling process, and the greater the gas flow, the faster the air DTH hammer drilling. Another advantage is that two booster compressors are used to supply gas, when one compressor fails, the other one can help the gas cycle, avoid the drilling stop caused by the failure of the booster, and then speed up the drilling efficiency.

In the aspect of lifting water in deep well when using air DTH hammer, because the gas pressure equivalent to the liquid column pressure in the well, the research team developed VF-0.32/70-250 air compressor. The biggest advantage of this supercharger is that it can provide a gas discharge pressure of 250 bar, and the booster can handle more than 2000m water column.

4.1 DFW-2 / (33-35) - 70 Air Compressor

DFW-2 / (33-35) -70 reciprocating piston air compressor, which is mainly composed of compressor host, asynchronous motor, public frame, gas pipe road system, lubrication system, cooling system, instrument control system, automatic sewage system, electrical equipment, all equipment is installed on a public chassis, the base is installed on the level of the cement, is a fixed compressor.

Figure 4: DFW-2 / (33-35) -70 Reciprocating piston supercharger appearance diagram

Specific parameters of the compressor: nominal exhaust gauge pressure: 70 bar, nominal suction gauge pressure: 33-35 bar, nominal volume flow: 2 m^3/min, structure: reciprocating piston type, D type, cooling mode is air cooling, less oil lubrication.

4.2 VF-0.32/70-250 Air Compressor

Type VF-0.32/70-250 air compressor is the introduction of German MANNESMANN DEMAG (Mannesmann Demag) technology, and the production license of the company manufacturing the basic parts as the basic components of the product, equipped with noise reduction box, stainless steel pipe and two stage filter in the air outlet; using soft start; using PLC to control the pneumatic ball valve, the pneumatic ball valve using air drive, the reliability increases.

The nominal exhaust gauge pressure of the compressor: 250bar, the nominal suction gauge pressure: 70bar, the nominal volume flow: 0.32 m^3/min, structure: reciprocating piston type, V type, cooling mode is air cooling, less oil lubrication.

Table 3. technical parameters table of booster compressor

The brand	The type	Nominal volume flow (m^3/min)	Inhale pressure (MPa)	rated discharge pressure (MPa)	shaft power (kW)
XCMG	DFW-2/(33-35)-70	2	3.3-3.5	7	160
XCMG	VF-0.32/70-250	0.32	7	25	90

4.3 Application of Booster Compressor

The booster compressor studied is applied in the geothermal well of Runda hot spring in Yichun. The well in drilling encountered large formation water output, in 547m-642m well water output can reach 90 tons / hour, up to 120 tons / hour ,in order to ensure the formation of the water can be used for hot spring in the future, can not block the well here. The construction plan is drilling through the part of well here under a large water pressure. After that it would run casing for this part and cementing by the way of wearing shoes and hats.

The construction here still adopts the air DTH hammer drilling process. After lifting part of the water in the well, the drilling began. At first, we used one compressor whose rated discharge pressure is 12MPa. But when it comes to 641.89m, the compressor got breakdown. Then, it was intended to provide 140 m^3/min of gas for drilling by using two newly developed DFW 70 booster compressors in parallel, in order to meet the gas supply requirements of the 8-inch DTH hammer and improve the drilling efficiency. At the beginning, it worked. But the water leaking from strata was very quickly, and the two newly developed DFW 70 booster compressors in parallel couldn't stand up to the water pressure. In the end, we decided after thought that the air DTH hammer drilling stopped at 643m.

Figure 5: test of booster compressor on the spot

5.CONCLUSION AND OUTLOOK

The drilling process of deep well air DTH hammer has high requirements on wind pressure and air volume, mainly due to the wind pressure loss along the deep well, the difficulty in lifting water caused by water discharge and the need for large air volume for efficient drilling.

In order to deal with the drilling of the air DTH hammer of the large water pressure in the deep well, and reduce the failure rate and drilling cost, this paper introduces the developed 70bar class, gas flow 70 m^3/min booster compressor, fully called DFW-2 / (33-35) -70 air compressor and VF-0.32/70-250 air compressor with the maximum discharge pressure of 250bar.

On the basis of the booster compressor developed by the current research team, the exhaust pressure of the compressor will be continuously increased to 90-100bar at the level of 70 m^3/min air flow in the future, so as to further increase the available range of the booster compressor and provide more economical choices for a variety of air drilling conditions.

ACKNOWLEDGMENTS

This work was supported by Program of the Ministry of Science and Technology, Science and Technology Innovation Special Project of Xiongan New Area, Application Research of New Technologies for Efficient drilling and exploitation of Geothermal Resources in Xiongan New Area (Task No. 2022XAGG0500), National Natural Science Foundation of China (Grant No. 42172342) of "Study on the Reaction of Drilling fluid in EGS Reservoir Environment and Its Damage Mechanism", and National Natural Science Foundation of China (Grant No. 41872184) of "Properties of Colloid Gas Aphron Drilling Fluid and Its Mechanism of Loss and Formation Protection for High Temperature Geothermal Reservoir" .

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