Journal of Research in Science and Engineering (JRSE)
ISSN: 1656-1996 Volume-6, Issue-7, July 2024
DOI: 10.53469/jrse.2024.06(07).18

# Research on a New Type of Collar Eye Grinding Shoe Tool

**Guang Lv**

Tianjin Branch of CNOOC China Limited, Tianjin 300450, China

**Abstract:** ***Speed up is an eternal theme in drilling engineering. With the continuous increase of drilling depth, the encountered formations become increasingly complex. On the one hand, the mechanical drilling speed of difficult to drill formations needs to be improved. On the other hand, the sticking phenomenon of PDC drill bits, which are the main drill bits in oil drilling, urgently needs to be solved. To solve these problems, a torque impactor has been developed. Through on-site experiments, the mechanical drilling speed has been significantly improved.***

**Keywords:** Bohai Oilfield, Torque impactor, On site application.

## 1. Introduction

Speed up is an eternal theme in drilling engineering [1-4]. With the continuous increase of drilling depth, drilling encounters with increasingly complex formations. On the one hand, the mechanical drilling speed of difficult to drill formations needs to be improved. On the other hand, the sticking phenomenon of PDC drill bits, which are the main drill bits for oil drilling, urgently needs to be solved. Sticking causes torsional oscillation of the drill string and unstable drilling process. PDC drill bits based on shear rock breaking mechanism generally have sticking problems, with an average of once every 10 seconds. This intense and unstable drilling not only easily causes the composite cutting blade to collapse, leading to the failure of PDC drill bits, but also easily causes the drill bit to loosen, leading to underground accidents; Moreover, the supporting components of the drill string and the combination of downhole tools are subjected to harsh stress conditions, with low fatigue life, which also reduces drilling efficiency to a certain extent. To solve the above problems, a torque impactor has been developed, which is a new technology and equipment for composite drilling technology that combines mechanical shear, hydraulic, and torsional impact rock breaking methods. During the rotary drilling process, without affecting drilling, the torque impactor uses drilling fluid to drive the internal impact hammer to repeatedly twist and impact, converting some fluid energy into a certain frequency, circumferential twisting, and impact type mechanical rock breaking energy at the bottom of the well, and directly transmitting it to the drill head, thereby improving drilling speed. On the one hand, this tool solves the problem of PDC drill bit jamming, improves the energy transfer efficiency from the rotary drive system to the drill bit, and can also protect the drill bit. On the other hand, this tool adds a torsional impact rock breaking method on the basis of PDC shear rock breaking, making the rock breaking ability of PDC drill bits stronger and laying the foundation for expanding its new application fields.

## 2. Current Research Status at Home and Abroad

At present, the vibration of drill string at home and abroad is mainly studied by decomposing it into longitudinal, transverse, and torsional vibrations. Based on this, research is conducted on drill string under different stress conditions and boundary conditions, such as considering inner and outer annular drilling fluids, drilling speeds of different drill bits, drilling with different combinations of lower drilling tools, and drilling under different drilling parameters. The main research status is as follows:

Finnie and Bailey J.J were the first to approximate the natural frequency of a drill string without considering damping through experiments and trial and error methods in 1960.

In 1968, Dareing D.W and Livesay B.H published an article discussing drill string vibration, with a focus on the influence of drilling parameters such as external medium viscous damping, shock absorbers, and rotational speed on drill string vibration. The research object was extended to the entire drill string system from the drill bit to the overhead crane, and differential equations were solved to obtain the longitudinal vibration response of the drill string.

Dunayesky V. A's study in 1984 pointed out that if the drill string is in a dynamically stable state of rotating only around its own axis, its lateral vibration can be ignored. However, in an unstable state, the amplitude of lateral vibration continues to increase, and the drill string generates shear stress and bending moment. The author also studied the motion laws of the drill string in steady and non steady states, as well as parameter resonance in non steady states by decomposing the drilling pressure into static and dynamic components.

Fereidoun studied the dynamic stability of PDC drill bits under torsional and lateral vibration conditions by establishing models that consider drill string torsional vibration, drill bit lateral vibration, and drill bit drill string torsional lateral vibration, and changing parameters such as drill string type and drill bit size.

Based on the interaction model between the roller drill bit and the rock at the bottom of the well, Liu Qingyou used the displacement of longitudinal reciprocating motion at the bottom of the well as the lower boundary condition for the longitudinal vibration of the drill string. He established a dynamic model of the longitudinal vibration of the drill string generated during the drilling process using elastic rod theory and element method, and solved the model using numerical methods based on different initial and boundary conditions of actual drilling.

Wu Zebing started by establishing practical lower end conditions and focused on studying the longitudinal vibration of the drill string. Using finite element method, the overall mass and stiffness were calculated, and the overall damping matrix was proportional. The vibration equation of the drill string was obtained using Newton's method. In addition, the real lower end boundary conditions of the drill string were obtained through the interaction model between the drill bit and the rock, and the vibration differential equation was solved using Houbolt digital solution model.

Starting from the basic equations of oil and gas rod and pipe mechanics, Li Zifeng established mathematical models for longitudinal, torsional, and coupled vibrations of vertical well drill string. He studied the vibration state and causes of drill string and believed that when the vibration frequency of the drill bit is an integer multiple of the natural frequency of the drill string, the drill string will be in a resonant state.

Dawson et al. considered reducing static friction to reduce stick slip vibration, and studied stick slip vibration by establishing a simplified torsion pendulum model of the lower drilling tool assembly (BHA). Assuming that the rotational speed of the rotary table is constant and the vibration period is ignored, the propagation time of the torsional wave is considered as a function of the rotational speed, and the frictional resistance is treated as a function of the rotational speed in order to more accurately express the friction between the drill pipe and the wellbore. Their research has drawn an important conclusion: when the rotational speed reaches a critical value, the stick slip motion will disappear, which is consistent with the results obtained in the field.

A. Kylingstad and G W. Halsey established a BHA torsional pendulum model, treating the lower drilling tool as a mass concentrated flywheel and obtaining its motion equation. Research has shown that the maximum rotational speed at the drill bit during stick slip vibration can be greater than twice the normal rotational speed of the turntable. This dynamic rotational speed increases with the increase of turntable rotational speed, and the effect of this increase is most significant when the turntable rotational speed is at normal speed.

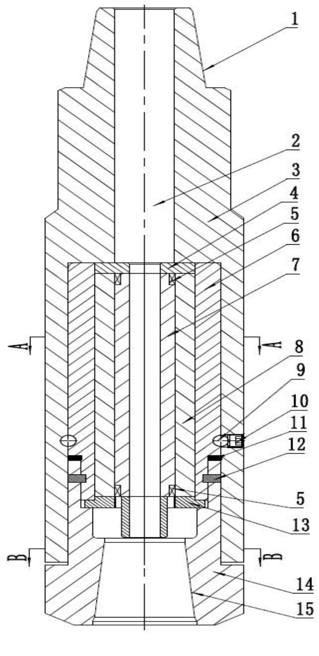
M. P. Dufeyte et al. studied the stick slip vibration behavior of drill pipes by analyzing synchronous measurement data of dynamic drilling underground and on the ground. The author's research suggests that stick slip vibration is a self oscillating vibration of the drill string, mainly caused by friction between the drill string and the wellbore wall and insufficient driving force of the drilling drive system to break the distortion of the drill string. It is related to the length of the drill string, the mechanical properties of the drilling system, the rotation speed of the rotary table, and the friction properties between the drill string and the wellbore wall.

Steve Barton et al. conducted research on drilling oscillators, which have been proven to reduce stick slip vibration and drill string friction, thereby enhancing drilling performance. By reducing the tension of the drill string, the drilling pressure is transmitted to the drill bit. It is mainly used for drilling directional wells, large displacement wells, horizontal wells, and soft hard interaction rock formations. Field tests were conducted using drilling oscillators to drill shale formations in vertical wells, curved wells, and horizontal wells. The results showed that the use of drilling oscillators resulted in a 30% increase in single drill bit footage, a 35% increase in mechanical drilling speed, an improvement in drilling efficiency, and a 15% savings in drilling costs.

G. Pelfrene et al. conducted a study on the dynamic behavior of drill rock contact and the design of drill bits, including the shape of the drill bit and the blade, based on full-scale indoor experiments and numerical simulation techniques. They established a semi empirical velocity dependent blade rock interaction model and predicted the relationship between different PDC drill bits and cutting speeds through drill bit design software. The results showed that the results obtained through drill bit design software were consistent with those obtained through full-scale drilling test equipment. Through the study of this model, it was believed that negative damping effect was the main cause of stick slip vibration, explaining the reasons for severe stick slip vibration and drill bit damage during high drilling pressure in hard ground. Combined with simulation analysis, it was shown that drill bit design had a great impact on stick slip vibration.

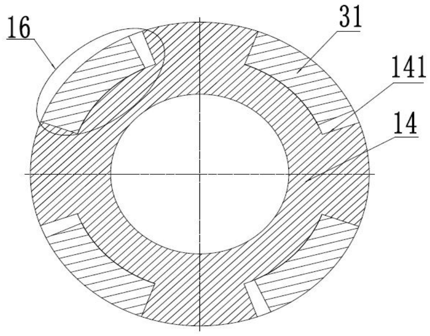
## 3. Tool Structure Design

The torque impact tool consists of an outer cylinder, upper blocking plate, bearing, inner cylinder, reversing valve, impact hammer, suspension structure, screw plug, pin, lower blocking plate, and lower joint. The upper blocking plate, bearings, inner cylinder, directional valve, impact hammer, suspension structure, screw plug, pin, lower blocking plate, and lower joint are all located inside the outer cylinder. The specific structure is shown in Figure 1. The B-B sectional view of the hydraulic oscillation short section is shown in Figure 2. The A-A sectional view of the torque impact tool is shown in Figure 3. The schematic diagram of torque impact tool 1 is shown in Figure 4, the schematic diagram of torque impact tool 2 is shown in Figure 5, and the schematic diagram of torque impact tool 3 is shown in Figure 6.



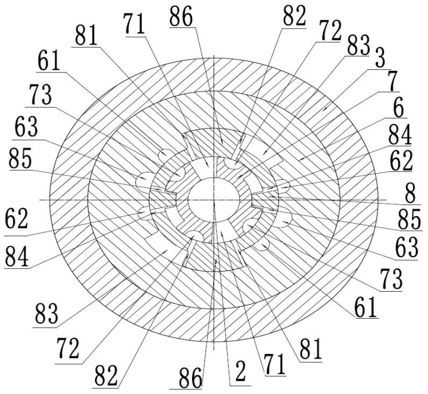
1. Male buckle, 2. Inner hole, 3. Outer cylinder, 4. Upper blocking plate, 5. Bearing, 6. Inner cylinder, 7. Reversing valve, 8. Impact hammer, 9. Suspension structure, 10. Screw plug, 11. Weld seam, 12. Pin, 13. Lower blocking plate, 14. Lower joint, 15. Female buckle

**Figure 1:** Schematic diagram of the structure of the torque impact tool



16. Keyway mechanism, 31. Outer cylinder keyway, 141. Lower joint keyway

**Figure 2:** B-B sectional view



61. Inner cylinder inlet a, 62. Inner cylinder inlet b, 63. Inner cylinder outlet 71, reversing valve inlet a, 72, reversing valve inlet b, 73, reversing valve inlet c, 81. Impact hammer inlet a, 82. Impact hammer outlet a, 83. Oil return chamber, 84. Impact hammer outlet b, 85, impact hammer inlet b, 86. Impact hammer head

**Figure 3:** A-A sectional view

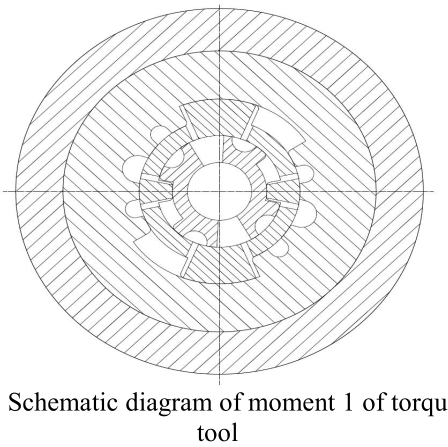


**Figure 4:** Schematic diagram of moment 1 of torque impact tool

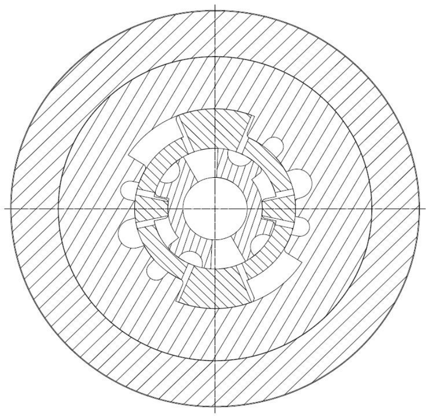


**Figure 5:** Schematic diagram of torque impact tool 2 at time

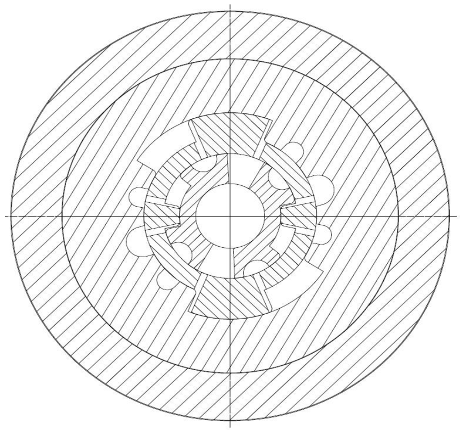


**Figure 6:** Schematic diagram of torque impact tool at time 3

The upper end of the outer cylinder is a male buckle, which is used to connect with the lower drilling tool. The keyway of the lower outer cylinder and the keyway of the lower joint cooperate with each other to form a keyway mechanism; The suspension mechanism is composed of several ball bearings, which realize the suspension of the inner cylinder and the outer cylinder. The inner cylinder and the outer cylinder can rotate in a circular manner, but cannot move axially; The two ends of the directional valve are equipped with bearings, which can reduce the friction between the directional valve and the impact hammer; The upper end of the lower joint has a keyway, which is used in conjunction with the keyway of the outer cylinder; Connect the lower female buckle to the PDC drill bit; The inner cylinder and the lower joint are connected by pins, and to further reduce the risk of the lower joint/PDC drill bit falling into the well, welding rods are used to weld between the inner cylinder and the lower joint; Finally, by utilizing the mutual cooperation between the upper blocking plate, inner cylinder, directional valve, impact hammer, and lower blocking plate, all the energy generated by the drilling fluid driving the impact hammer is periodically transmitted to the PDC drill bit, thereby solving the problem of "stuck slip" between the drill bit and the drill string, and improving the cutting and rock breaking efficiency of the PDC drill bit, effectively solving the problem of poor drillability in deep well formations.

Please refer to Figure 1 and Figure 6. The torque impact tool mainly consists of an outer cylinder (3), an upper blocking plate (4), a bearing (5), an inner cylinder (6), a reversing valve (7), an impact hammer (8), a suspension structure (9), a screw plug (10), a pin (12), a lower blocking plate (13), and a lower joint (14). The upper blocking plate (4), bearing (5), inner cylinder (6), directional valve (7), impact hammer (8), suspension structure (9), screw plug (10), pin (12), lower blocking plate (13), and lower joint (14) are all located inside the outer cylinder (3); The upper end of the outer cylinder (3) is a male buckle (1), which is used to connect with the lower drilling tool. The lower end outer cylinder keyway (31) and the lower joint keyway (141) cooperate with each other to form a keyway mechanism (16); The suspension mechanism (9) is composed of several ball bearings, which realize the suspension of the inner cylinder (6) and the outer cylinder (3). The inner cylinder (6) and the outer cylinder (3) can rotate in a circular manner, but cannot move axially; The directional valve (7) is equipped with bearings (5) at both ends, which can reduce the friction between the directional valve (7) and the impact hammer (8); The upper end of the lower joint (14) has a keyway, which is used in conjunction with the keyway (31) of the outer cylinder; Connect the lower female buckle (15) to the PDC drill bit; The inner cylinder (6) and the lower joint (14) are connected by pins, and to further reduce the risk of the lower joint/PDC drill bit falling into the well, welding rods are used to weld between the inner cylinder (6) and the lower joint (14); Finally, by utilizing the coordination between the upper blocking plate (4), inner cylinder (6), directional valve (7), impact hammer (8), and lower blocking plate (13), all the energy generated by the drilling fluid driving the impact hammer (8) is periodically transmitted to the PDC drill bit.

The working principle of the torque impact tool: For the convenience of analyzing the torque impact tool, it is assumed that its state at time 1 is as shown in Figure 4; The 2-time state is shown in Figure 5; The state at time 3 is shown in Figure 6; At the same time, after the hydraulic oscillation short section tool changes from time 1 to time 3, some inlet ports will become outlet ports. The hydraulic oscillation short section tool is connected to the drill bit; During the drilling process, the drilling fluid flows from the inner hole (2) of the outer cylinder (3) to the upper end face of the upper blocking plate (4), with the majority flowing into the inner hole (2) and a small portion flowing into the inner cylinder inlet a (61) and inner cylinder inlet a (62); Assuming the hydraulic oscillation short section tool is in a state at time 1, as shown in Figure 4, drilling fluid enters the inlet a (71) of the directional valve and the inlet a (81) of the impact hammer through the inner hole (2). The drilling fluid pushes the impact hammer (8) to rotate clockwise, and the directional valve (7) rotates clockwise along with the impact hammer (8) due to inertia; When the hydraulic oscillation short section tool rotates clockwise to the 2-time state, as shown in Figure 5, after the impact hammer (8) reaches the limit position, the impact hammer (8) gives a clockwise striking force to the PDC drill bit; At the same time, some drilling fluid enters the inlet a (61) of the inner cylinder and the inlet b (85) of the impact hammer. The drilling fluid pushes the directional valve (7) to continue rotating clockwise. Due to the bearing (5) between the impact hammer (8) and the directional valve (7), the friction between the two can be effectively reduced. After the directional valve (7) reaches its limit position, as shown in Figure 6, the impact hammer (8) can be reversed, that is, the impact hammer (8) will move counterclockwise next, and the previous inlet will become the outlet. In this way, the hydraulic oscillation short joint tool will continue to provide a periodic impact force to the PDC drill bit, thereby solving the problem of "stuck slip" between the drill bit and the drill string. Improve the efficiency of PDC drill bits in cutting and breaking rocks, effectively solving the problem of poor drillability in deep well formations.

## 4. On Site Application

### 4.1 Introduction to Basic Information of a Well

The Jinzhou 25-1/25-1 South Oil and Gas Field is located in the Liaodong Bay area of the Bohai Sea, with longitude ranging from 121°00′ to 121°15′ and latitude ranging from 40°15′ to 40°30′. It is 15km northeast of the Jinzhou 20-2 condensate gas field and approximately 322km southwest of Tanggu. The Liaodong Bay in the Bohai Sea is covered by sea ice in winter. The longest effective ice age (with ice all day) is 29 days, the shortest is 5 days, and the historical average is 16 days. The average first ice day is on November 23rd, and the average final ice day is on March 8th, with an annual average temperature of 13.6°C.

The 1/8 well area of Jinzhou 25-1 South Oil and Gas Field and the 10D and 14 well areas of Jinzhou 25-1 Oilfield are structurally located at the northern end of the Liaoning West Low Uplift, on the east side of the northern depression of the Liaoning West Depression. The Liaoxi No.1 Fault divides the structure into two sections, east and west. Jinzhou 25-1 Oilfield 10D, 14, and 15 are located on the west side of the Liaoxi No.1 Fault, Jinzhou 25-1 South Oil and Gas Field 1/8 well area is located on the east side of the Liaoxi No.1 Fault, and Jinzhou 25-1 South Oil and Gas Field 5 well area is located on the east high zone of the Liaoxi No.2 Fault. The overall structural form is a complex, northeast trending fault semi anticline.

### 4.2 Analysis of Test Results

On December 27, 2016, the torque impactor was used for the second opening (12-1/4"wellbore) operation in JZ25-19 well; To verify the on-site effectiveness of the hydraulic oscillation short section, adjacent wells C17 and C30 were selected as comparison wells. As shown in Figure 7, the mechanical drilling speed of C17 well was 21m/h, C30 well was m/h, and C19 well was 15m/h. The acceleration effect of the three wells was not significant compared to C19 drilling. The main reason was that the Bohai formation was too soft and the bit pressure was relatively small (1-2T). As shown in Figure 8, the torque of C19 well was the smallest among the three wells, indicating that the hydraulic oscillation short section can effectively reduce the torque of the drill pipe.

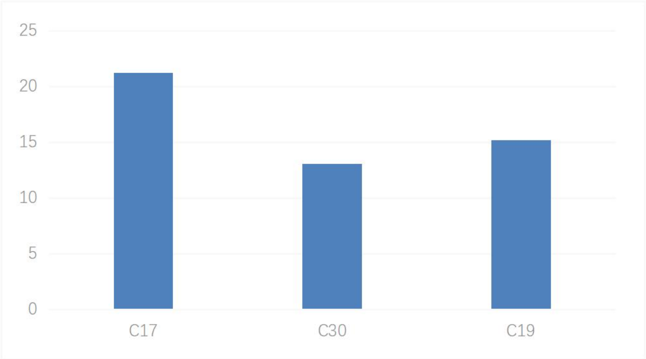


**Figure 7:** Comparison of mechanical drilling speeds

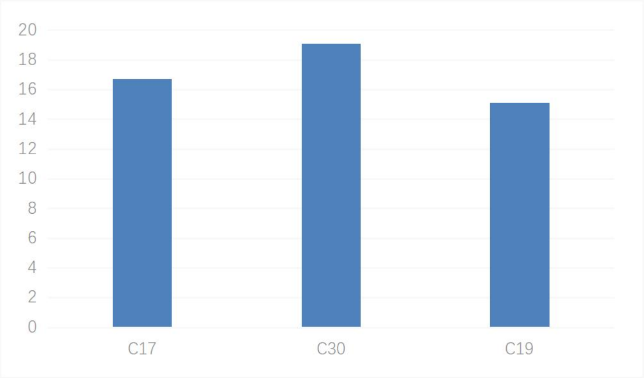


**Figure 8:** Torque Comparison

## References

[1] Wu Zhanmin, Feng Lei, Xia Zhongyue, etc Design and Construction of 3D Wells for Tight Sandstone Gas in Linxing Block [J] Petroleum Machinery, 2016,44 (7): 42-45.

[2] Zhu Yihui, Chen Jianbing, Li Bo, etc Wall mounted bistable jet torque impactor: China, ZL201520590790.3 [P], 2015-12-02.

[3] Tang Liping Research on the characteristics of stick slip vibration and vibration reduction methods of drill bits in deep hard formations [M] Chengdu: Southwest Petroleum University, 2012:1-2.

[4] Zhang Huaiwen, Ma Yujiao Research and Analysis on the Application of TorkBuster Torque Impactor [J] Liaoning Chemical Industry, 2012,41 (8): 841-843.