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# Research Progress of High-Frequency Vibration Tools Used in Stuck Pipe Recovery

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## Abstract

One challenging and costly operation in drilling and workover job is the recovery of stuck BHAs and other devices, and conventional fishing BHAs are sometimes unsuccessful since the well profile becoming more and more complex. Application of high-frequency vibration tools provides an efficient way to solve this problem, one surface high-frequency vibration tool and two downhole high-frequency vibration tools were introduced, including basic structure, working principle, use method and application results. With the increasing number of extended-reach wells and horizontal wells, demand of fishing job is also increasing, and high-frequency vibration tools have broad prospects for development.

**Key words:** Vibration tool; Fishing operation; Stuck pipe recovery; Pressure impulse

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## INTRODUCTION

Stuck pipe has been a problem hard to avoid in drilling and workover jobs since the first wells were drilled. It is reported that the problem of stuck pipe is estimated to cost operators more than US$1 billion a year in lost rig time, lost production, the cost of fishing operations, and lost tools, Statistical results of the mid-90s since the last century show that fishing job accounts for 25% of global drilling costs[1]. In addition, duo to the large friction between the fishing strings and wellbore in extended-reach wells and horizontal wells, chances of recovery in these wells are even smaller, and conventional jarring tools are time-consuming and sometimes unsuccessful.

Research results show that vibration can reduce friction[2-5], so high-frequency vibration tools has been developed to recover stuck pipes since the mid-1980s[6]. high-frequency vibration tool consists of two types: Surface high-frequency vibration tool and downhole high-frequency vibration tool, research development and application of both tools were introduced in this article, and downhole high-frequency vibration tool is future direction.

## 1. SURFACE HIGH-FREQUENCY VIBRATION TOOL

Eccentric weight oscillator is one kind of surface high-frequency vibration tool firstly used in oil industry, the basic structure of which is shown in Figure 1[7].

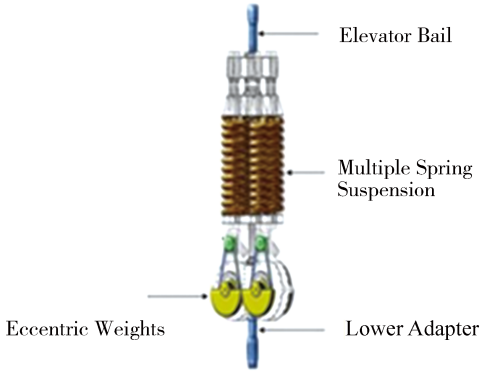


**Figure 1**
**Structure of Eccentric Weight Oscillator**

Eccentric weight oscillator uses a pair of eccentric weight powered by electric or hydraulic motor, the eccentric weight rotated in opposite directions so that horizontal components of the eccentric force cancel each other, but vertical component of the eccentric force adds together. This generates a pure axial sinusoidal force that transmits down to the stuck pipe as a series of alternate tension and compression waves, and this will cause a series of rapid impact force at the stuck point. When vibration frequency equals to the resonant frequency of the work string, the vibration power generated at the eccentric weight oscillator will transmit down to the stuck pipe with little attenuation except loss on overcoming friction resistance, thus the vibration power can be transmit to the stuck area efficiently which will enhance the efficiency of stuck pipe recovery greatly.

When the eccentric weight oscillator is used, it is hanged from the elevators on the traveling block and attached to the exposed tubular above the rig floor through the lower adapter.

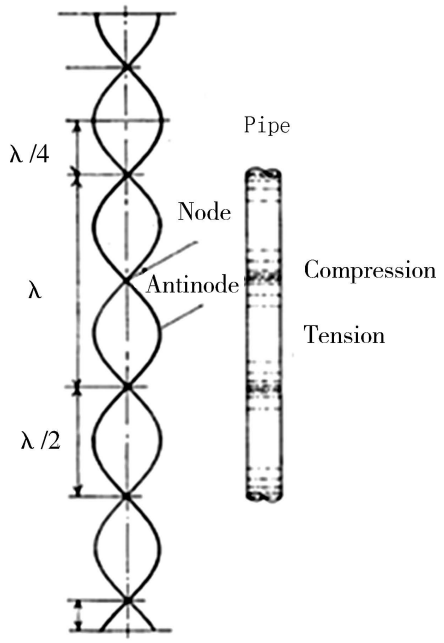


**Figure 2**
**Idealized Representation of Longitudinal Standing-Wave Pattern**

The advantages of the eccentric weight oscillator are obvious: (a) The operation is conducted at surface which is convenient; (b) The operation can be quickly applied with little preparation which will improve the chance of recovery, since the chances of recovery decay with time; (c) Even the operation failed it will not make the situation worse. The disadvantages of the eccentric weight oscillator can't be neglected: the generated axial sinusoidal force attenuates along the pipe which gives a limitation to the application of this tool, more research should be made toward the effect of wellbore geometry on damping of vibration. According to the field tests the deepest depths from where the stuck liner, drill pipe and tubing are successfully recovered are 1,067 m, 2,377 m, and 3,353 m, respectively.

The eccentric weight oscillator has been largely used in the recovery of stuck liner, tubing, and drill pipe since 1984, the success ratio for each is 62%, 19%, and 25%, respectively[8].

## 2. DOWNHOLE HIGH-FREQUENCY VIBRATION TOOL

Experimental and research results show that the smaller the distance between the vibration tool and the point of stuck the better chance of recovery is, so downhole high-frequency vibration tools are developed recent years. There are two vibration tools of this kind introduced below: Downhole Impulse Tool used in the recovery of stuck retrievable packers and Fishing Agitation Tool.

### 2.1 Downhole Impulse Tool

Retrievable packers are designed to be retrieved either by straight pull, or by overpull after rotation, but problems such as corrosion of the packers, impaired production strings, sand and debris on top of the packer will decrease the chance of retrieval, and the mandrel would apart from the packer because of high impact force generated by fishing jar. Downhole Impulse Tool provides an efficient way of recovering the retrievable packers.

Downhole Impulse Tool use a dart system and a weight bar with spring to generate pressure impulse as shown in Figure 3[9], when fluids flow through the Downhole Impulse Tool, the fluid makes the dart go down to the dart seat, and this pushes the weight bar go down to compress the spring. Then the seat opens and the spring release, the weight bar then goes back to the original position. As above proceeds repeat, a series of pressure impulse generated and acts on the stuck retrieval packers. The frequency of the impulse could be varied from 12 Hz to 18 Hz according to the pump rate. Downhole Impulse Tool can be activated in any time and is independent of overpull which makes it to be a preferable choice for high-angle deviated wells.

The Downhole Impulse Tool uses only solid-free fluids such as water and brine since solid particles may cause a failure sealing to the dart system, So studies should be made to solve this problem to facilitate its use on-site.

In one on-site application, a 73 mm tubing was cut at 63 m depth in 139.7 mm casing, one tubing joint, one packer and seven centralizer blades were left in the hole. The downhole impulse tool combined with a overshot was run into the hole through 73 mm tubing, after 33 minutes, the fish was free.

In another on-site application, a 73 mm tubing was cut at the depth of 27 m, a 9.8 m long tubing and a packer was

left in the hole, the Downhole Impulse Tool in conjunction with the overshot was run into the hole, when the overshot catched the fish, the Downhole Impulse Tool started working, the packer was freed within 15 minutes with the maximum overpull of 159 kN.

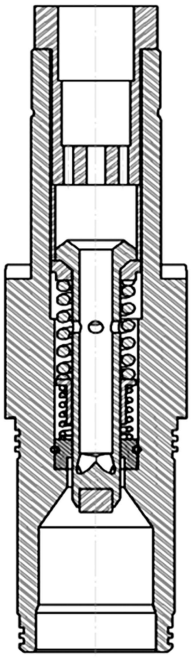

**Figure 3**
**Structure of Downhole Impulse Tool's Dart System**

## 2.2 Fishing Agitation Tool

The Fishing Agitation Tool consists of 3 parts as shown in Figure 4: Power section, valves and bearing system, and oscillation sub[10].

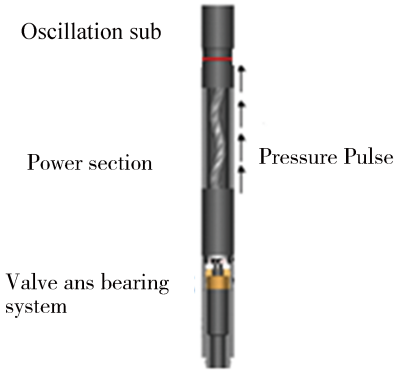


**Figure 4**
**Structure of Fishing Agitation Tool**

Power section is a 1:2 single-head screw motor, when the drilling fluid pumped through the motor, high pressure drilling fluid drives the rotor rotate around axial of the stator so as to transmit hydraulic energy into mechanical energy.

Valves and bearing system which is placed at the lower section of the power section is the structure generates pressure pulses travel axially in both directions. Valves and bearing system consists of two parts: Movable valve plate connected to the rotor and stationary valve plate, there is a round hole served as the channel of drilling fluid in both center of movable valve plate and stationary valve plate. According to theory of screwdrill[11], when the single-head screwdrill works, cross section of rotor will do approximately linear reciprocating motion. Therefore, when the motor is working, the round hole is periodically interleaved as movable valve plate driven by rotor makes reciprocating motion on stationary valve plate, then the pressure pulses are generated as shown in Figure 5.

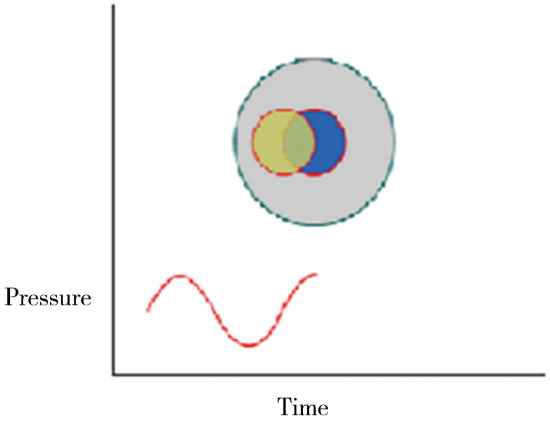


**Figure 5**
**Pressure Pulses**

Oscillation sub is comprised of a sealed mandrel and a spring outside of the mandrel, when pressure is applied to the lower face of the mandrel, the mandrel moves and compresses the spring. When the pressure releases, the mandrel travels back to original position. Above process repeats as the pressure pulses acting on the mandrel, so the strings in the vicinity of the fishing agitation tool make axial reciprocating movement.

When the fluid pumped through the fishing agitation tool, axial oscillation happens and the frequency of which varied from 12 Hz to 26 Hz depending on the tool size and pump rate, the oscillation sub keeps the strings in continuous reciprocating movement, so the static friction between the strings and wellbore will be changed to dynamic friction which largely reducing the friction. In order to maximize chances of recovery of stuck pipe, the Fishing Agitation Tool is usually used in conjunction with jarring, which is called super fishing BHA shown in Figure 6[12].

When the super fishing BHA is used downhole, after activating the jar upward, pumping the fluid through the fishing BHA, sufficient overpull should be made to keep the strings in full extension that the oscillations will not be attenuated, if jarring upwards only can't free the fish, compressive load should be applied to make sure the strings are all in compression state, so the oscillations would not attenuate, above procedure repeated until the fish is free.

The Fishing Agitation Tool has been widely used in recovery of stuck pipe, retrieval of surface and intermediate casing, packer and electric submersible pump, and better results have been obtained.

In one case, a 30 m long directional BHA with a radioactive source was stuck in a directional well in Saudi Arabia, there is no success after utilizing conventional fishing tool for 13.5 hours, a fishing BHA with the Fishing Agitation Tool was used after 34 hours, a tension load was applied with the pump rate of 794 L/min, the stuck BHA was free within a few minutes.

In another case, an electric submersible pump was stuck in a production well at the depth of 1,400 m, the production well is a directional well with "S" type wellbore profile, the electric submersible pump was stuck at the second build section with an inclination angle of 54°, the use of jarring operation through coiled tubing rig and hydraulic workover rig was not successful. The Fishing Agitation Tool in conjunction with a jar was used, oscillations were detected when 89 kN of overpull is applied with pump rate of 126 gal/min (477 L/min), the overpull was added by an increment of 89 kN, and movement of the fishing BHA was noted when the overpull reached to 578 kN, and the pump rate reached to 715 L/min during these time, for the rest fishing operation only no more than 116 kN was needed.

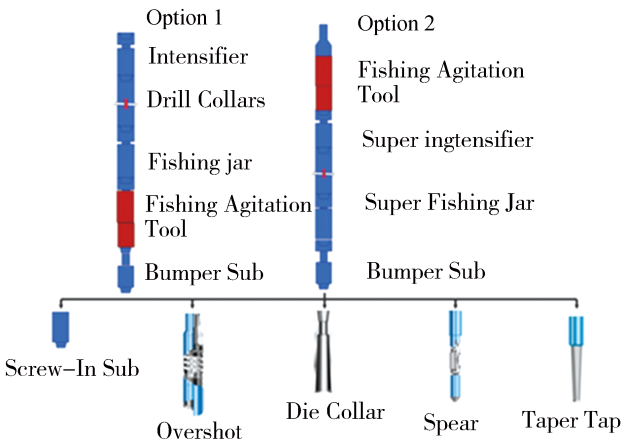


**Figure 6**
**Structure of typical super fishing BHA**

## CONCLUSION AND RECOMMENDATIONS

(a) Recovery of stuck pipe and other device is a challenging and costly operation in drilling and workover jobs, high-frequency vibration tools provide a new idea to this problem, and satisfactory results have been got.

(b) High-frequency vibration tool can be divided into two types: Surface high-frequency vibration tools and downhole high-frequency vibration tools, Compared to surface high-frequency vibration tools, downhole high-frequency vibration tools can be set as close to the point of stuck as possible, thus having the maximum chance to recover the stuck pipe and other devices, downhole high-frequency vibration tool is the future direction of development, and more theoretical studies should be made toward this technique.

(c) In order to reach and maximize higher paying zones, more and more complex wells such as extended-reach wells and horizontal wells will be drilled, fishing problems in these wells are hard to avoid, thus the prospect of high-frequency vibration tools is bright, it's important to summarize the achievement of the former research for following study.

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