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Study of the damage and failure of the shear ram of the blowout preventer in the shearing process

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ABSTRACT

The blowout preventer (BOP) is one of the most important pieces of well control equipment; the reliability and safety of the shear ram of the BOP significantly affect the control of oil and gas well. Once the BOP fails, a blowout accident may occur, resulting in a great loss of lives and properties. Both a numerical simulation and an experimental investigation the shearing of a drill pipe by shear rams in an emergency situation were investigated. The effects of the inclination angle of the cutting edges, chamfering, the V-shape angle of shear ram, and the diameter and length of the drill pipes were discussed. The study shows that the simulation results of the shearing process are quite consistent with the experimental results. The cross section of the drill pipe gradually becomes oval in shape with the increase in ram displacement due to squeezing. When deformation of drill pipe reaches the fracture criterion, the drill pipe will be torn along the blade surface and then fall off. Von Mises stresses and the plastic strain of the upper and lower rams increase with the increasing displacement of the rams. With the increase of the length and diameter of the drill pipe, the peak stresses of the upper and lower rams gradually decrease. The stresses of the rams first decrease and then increase with the increase in the blade angle, V-shape angle and edge chamfer angle. For the upper and lower shear rams, the optimal blade angles are 4° and 3°, respectively; the optimal V-shape angles are 163° for both rams, and the optimal edge chamfer angles are 45° and 15° for the upper and lower shear rams, respectively. Obvious plastic deformation of the rams' blade edges can be observed and measured after shearing operation. Thus, the shear ram should be checked and assessed before being used again.

1. Introduction

Blowout is a phenomenon in which uncontrolled formation fluid (crude oil and/or natural gas) jets flow on the ground or into the borehole in another formation that primarily occurs in the exploitation of oil and gas fields. There are various factors that cause blowout: high formation pressure, lower mud density, short borehole mud slurry column height, or other improper measures. Blowout is very dangerous in oil or gas mining accidents after pressure control systems have failed [1]. A blowout often leads to a catastrophic oil or gas fire, and the formation fluid may shoot more than 60 m high into the air [2], and sometimes the borehole-ejected gas containing hydrogen sulfide and other toxic gases poisons nearby populations.

The first response to a blowout is the use of blowout preventers to close the well [3]. Next, the drilling crew should pump heavy mud into the borehole to balance the formation pressure, thus allowing the influx fluids to be slowly circulated out under control.

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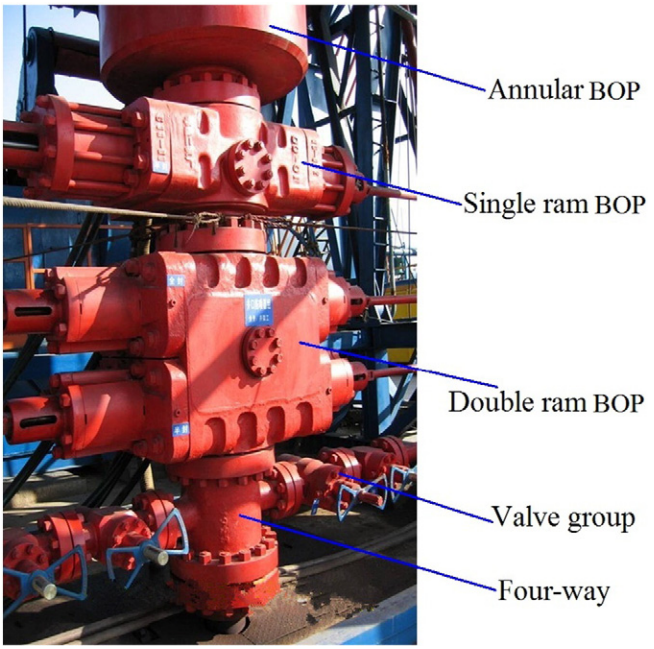

Fig. 1. BOP combination in a wellhead.

Improper oil well control can result in blowouts with quite substantial losses of valuable resources worth several millions of US dollars, and even worse, ruined equipment, environment disaster, and loss of lives around the rig [4,5].

There are two types of the commonly used BOP: one is annular BOP (universal BOP), and the other is ram BOP (single ram and double rams BOP, including shear BOP). As shown in Fig. 1, a blowout preventer is a type of mechanical device with specialized valves, which are typically redundantly installed in stacks to prevent the blowout of oil and gas wells, thereby preventing a catastrophic event. On Dec 23th, 2003, 243 persons were killed by gas poisoning resulting from the blowout accident in Kai county Chongqing China, which was called the 12.23 Accident.

The ram BOP is one of the most important pieces of well control equipment and has been widely used in drilling due to its convenience, safety and high reliability. Shear BOP is a type of ram BOP, which is mainly used in drilling, workover and oil testing. In an emergency, the shear BOP must cut off the drill pipe by closing the shear damper and sealing the wellhead. If the drill pipe is not cut in a short period of time, then a blowout will occur. One of the fatal causes of the 12–23 accident is that no shear BOP was used in the drilling process. High strength drill pipes are widely used to address various difficult developments in oil and gas fields. Such difficult developments result in greater challenges to the shearing ability of the shear BOPs. Therefore, the working reliability of the shear ram BOP is the key factor for successful shut-in. As a result, it is very important to study the shear capability of the shear ram BOP.

James Smither Abercrombie and Harry S. Cameron invented the ram BOP in 1922, and Cameron Iron Works introduced the ram BOP to the market in 1924 [2]. In 1986, NL Industries, Inc. invented a shear ram BOP that contains two opposed ram assemblies, and each ram assembly includes a bracket and a ram [6]. In 1990, the ГПК-350 × 35К2 shear ram BOP, was developed by the Azerbaijan Petroleum Machinery Research Institute and was used in oil and gas wells containing more than 6% of H_2S and CO_2; the upper ram plays a supporting role, and the lower ram performs the shearing, with both being driven by the hydraulic cylinder piston [7]. In 1992, Hydril designed and manufactured a new generation BOP group for Saga Company in Norway; the BOP was capable of shearing a drill pipe and a $9^5/_8$" casing pipe [8]. In 2001, the double shear ram BOP was designed by Cooper Cameron Corp.; this ram can easily cut off multi-

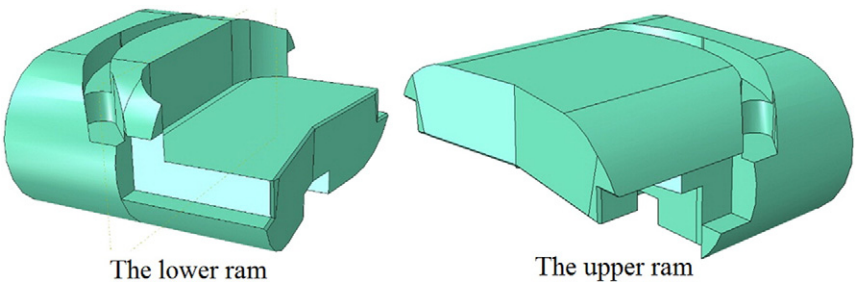

Fig. 2. Three dimensional models of the shear rams.