DEVELOPMENT AND APPLICATION OF VISUAL LOGGING EQUIPMENT

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Abstract

The Hawkeye downhole TV logging technology has been widely used in casing damage detection and production well monitoring fileds. Aiming at the fact that downhole television transmits low-frame-rate black-and-white images on logging cables, a visual logging equipment capable of real-time transmission of smooth video images on logging cables has been designed. The logging system has the advantages of auto adaptive cable, high-speed rate and network and so on. First, in view of the slow transmission rate of the logging cable, an advanced high-speed cable transmission module is adopted. Secondly, the ground system and the downhole instrument were designed, and the downhole instrument was designed with a vacuum flask for the high temperature environment downhole. After testing, the visual logging equipment can achieve a transmission rate of 2Mbps on a 5500m armored seven-core cable, and can transmit downhole color video images with a resolution of 640*480 pixels and a video frame rate of 25fps in real time. Its application of an oil field in central China shows that it can clearly see clear well drop and borehole erosion images in real time. Compared with the traditional Hawkeye downhole TV, the visual logging equipment greatly enhances transmission performance. It has significant technical advantages in fault diagnosis of complex casing wells. It has broad application prospect in repairing casing damage wells, monitoring production wells, and evaluating effect of downhole operations and other fields.

Introduction

In the field of well logging, downhole TV logging is another discipline applied to well logging after electromagnetics, physics, and acoustics [1]. In the oil field, downhole TV logging technology is widely used in observation of casing fouling, cracks, deformation and corrosion, and the determination of damaged parts and wells falling in the ground because of its intuitive and visual features. In the field of geology, downhole TV logging technology can also identify cracks, holes, and stratigraphic structures in rock layers, which is conducive to geological exploration and analysis, and provides technical support for human exploration of new oil and gas resources .

Visual Logging refers to an imaging and logging technology that uses a planar array sensor to directly obtain downhole video images. It mainly includes visual light downhole TV, SWIR downhole TV and X-ray downhole TV (Visual Xray) [2-5].

At present, the application of visual logging mainly includes HawkEye downhole TV and fiber optic downhole TV.

Fiber-optic downhole televisions have clear and smooth images and good real-time performance because it transmit data over fiber optics. It have been widely used in wellbore detection, casing inspection, and production well status monitoring, but fiber-optic downhole TV needs to be equipped with special cables and logging vehicles that caused great inconvenience in air transport and coiled tubing operations. In addition to, it have high operating costs and poor adaptability to high temperature and corrosive downhole environments.

Hawkeye downhole TV is an imaging logging technology that transmits video images on logging cables. It can be

applied to high temperature, high pressure, and corrosive well fluid environments and is suitable for horizontal well with the help of coiled tubing[6]. However, although the Hawkeye downhole TV has made great progress in borehole condition adaptability, it can only transmit black and white images due to the limitation of the logging cable transmission bandwidth. The video frame rate of first generation product is only 3.5s/frame. After several generations of improvements, the frame rate has been increased to 1.1s/frame, but the real-time and fluency of the image are far behind that of the fiber-optic downhole television.

In recent years, with the development of electronic technology and communication technology, logging cable communication technology has been further developed. In 2015, the EVCAM company in the UK developed the Optis® HD Electric Line downhole TV logging system with a transmission rate of over 200 kbps. The system enables real-time transmission of color high-definition video on single-core and multi-core logging cables by use the latest downhole video technology, And highest real-time frame rate can reach 25fps[7]. In 2016, EV offshore Limited's Tobben Tymons and others issued a paper indicating that the combination of single-core cable high-speed remote transmission technology, video processing and storage technologies have greatly reduced operating costs and improved the efficiency of downhole TV operation. It expanded the application of downhole TV and brought oil and gas well monitoring to the video age[8].

A visual logging equipment for real-time transmission of color and high definition video on logging cable is designed in this paper. Its transmission rate on 5500m logging cable can reach more than 2Mbps. This article introduces its system composition, working principle and transmission characteristics. Field application results show that logging results of the visual logging system are real-time, high-definition. It provide a low-cost and high-efficiency logging means for the casing damage detection and engineering logging.

System composition of the visual logging equipment

Visual logging is an imaging logging technique used camera to obtain video images from the downhole. The system composition of visual logging equipment is shown in Figure 1.

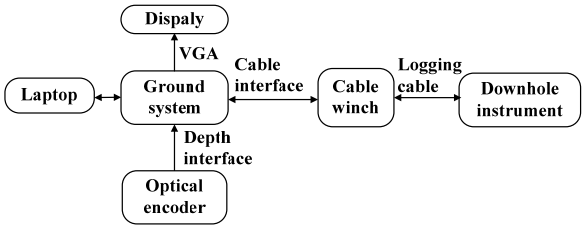

Figure 1. The composition of the visual logging system

The downhole instrument is a downhole video image acquisition, encoding and transmission device. The shape and structure of downhole instrument meets the requirements of borehole size, temperature resistance, pressure resistance and other environmental requirements. The downhole instrument is hoisted into the wellbore through cable winches and logging cables.

The function of the logging cable includes carrying the weight of the downhole instrument and put the downhole instrument into the well. the ground system supply power to the downhole instrument by logging cable. Logging cable is also the medium of the high speed network communication between the ground system and the downhole instrument.

The functions of the ground system include the power supply to the downhole instrument, the high speed network communication with the downhole instrument, the acquisition of the network video data flow and decoding, the cable depth measurement, the character superposition, the video storage and so on. In addition to, it also provides video display interface and network access interface.

The display is used to show character superimposed video images.

The optical encoder is connected to the cable depth measuring unit of the logging winch and provides the depth pulse signal to the ground system.

The laptop is connected to the ground system. It controls the network video encoding unit, depth measurement unit, video decoding unit and character superposition unit. besides, it can also preview, storage and playback video images in real time.

The composition and working principle of the ground system

The composition and working principle of the ground system is shown in Figure 2. The ground system is connected with the logging cable through the cable interface and further connected to the downhole instrument. Through the depth interface, it connects to the optical encoder of the winch depth measurement system. Besides, it connects to the computer through the network interface and connects to the display through the VGA display interface.

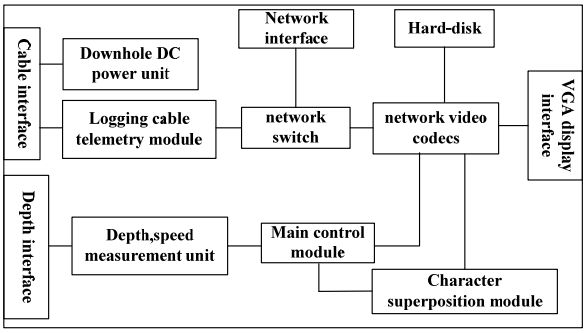

Figure 2. The function diagram of Ground system

After the ground system and the downhole instrument establish a high-speed network connection through the network high-speed transmission module and the logging cable, the network video stream from the downhole instrument is transmitted to the network video encoder for decoding through the network switch, and the decoded video signal is sent to the character superposition module,

which superimposes information such as depth, speed, and subtitles, and the output video is returned to the network video encoder for encoding, storage, and network transmission. The cable depth and speed measurement unit converts the pulses of the optical encoder into depth and speed of the downhole instrument, and is sent to the character superposition module by the main control module. The main control module is connected to the network video encoder and further connected to the computer. The instructions sent by the computer software control the work of the cable depth, speed measurement module and character superposition module. The downhole DC power unit supply to the downhole instrument by logging cable.

The downhole instrument composition and working principle

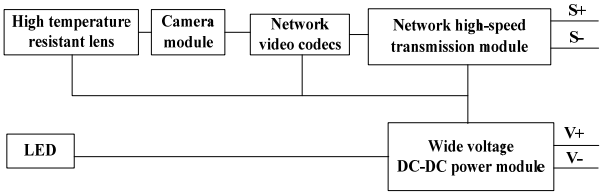

Figure 3. The function diagram of downhole instrument

The downhole instrument completes the acquisition, coding, and transmission of video images. Its composition is shown in Figure 3. The LED is used for downhole lighting. The video image acquired by camera module is compressed and coded by the network video codecs module, then it is transmitted to the ground system by the network high-speed transmission module by means of logging cable. Downhole instrument power adopts high voltage DC power from ground system. Wide voltage DC-DC power module completes DC-DC conversion, and provides the low voltage power to downhole modules.in addition to, In order to adapt to the downhole small-size working environment, all circuit modules are designed with a small size, and the maximum width is less than 30mm.

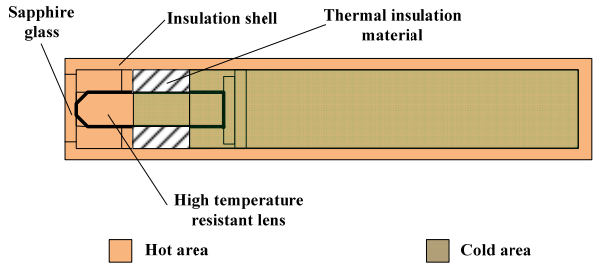

Figure 4. The structure diagram of downhole instrument

Because of the special downhole environment, the downhole instrument needs to work in a high temperature environment of 155℃. The downhole instrument uses a thermal insulation shell and a high-temperature resistant lens, and uses the structure of Figure 4 to achieve the long-term continuous operation in a high-temperature environment.

The high temperature lens is located in the hot zone at the front of the downhole instrument and transmits the optical signal to the camera module in the cold zone with the help of the optical structure. In this way, the camera module, the network coding module and cable network high-speed transmission module all work in the cold zone. Even in the high temperature environment inside the borehole, the temperature of the cold zone of the downhole instrument meets the ambient temperature requirement of the circuit work. By verifying, the downhole instrument with this structure can work continuously for more than 6 hours at 155℃.

Network high-speed transmission technology of logging cable

Logging cable downhole TV have the advantages of low cost, high reliability and strong borehole environment adaptability. However, due to the limitations of logging cable bandwidth and transmission rate, the image resolution and frame rate of downhole TV are difficult to improve. In recent years，with the development of logging cable high-speed remote transmission technology, ADSL, OFDM, TC and other cable transmission technologies have been applied to the development of logging cable high-speed transmission systems. The transmission rate of single-core logging cable increased to more than 300kbps, and the transmission rate of multi-core logging cables increased to about 1 Mbps. Usually, a dedicated downhole bus interface and communication protocol are used for these telemetry unit, which is suitable for a specific complete logging system. Its generality and compatibility are poor.

Logging cable network high-speed transmission technology combined with advanced cable adaptive technology, high-band utilization modulation and coding technology, data compression and inspection Error-correction coding and standard Ethernet interface, TCP/IP protocol and so on. It has three main advantages of cable self-adaptive, high-speed, networking. It can be connected with different types and lengths of single core / multi-core armored logging cable and transmits real-time color video.

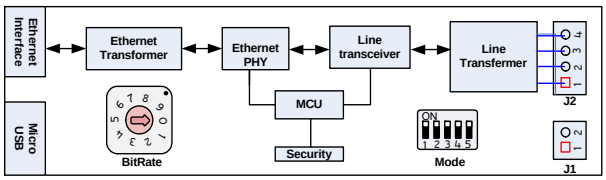

Figure 5. The sturcture diagram of network high-speed transmission module

The structure diagram of network high-speed transmission module is shown in Figure 5. As show in diagram, the Line Transformer coupling and isolation the signal; the Line transceiver completes framing and de-framing, encoding and decoding, modulation and demodulation, driving and transmission. Ethernet PHY, Transformer, interface provide Ethernet protocol support and network interface. The micro USB provides debugging and status monitoring, mode provides working mode setting and Bitrates sets network transmission rate.

Logging cable network high-speed transmission module

can be realized high-speed long-distance network transmission in the single-core and multi-core armored logging cable. On the seven core armoured logging cable of 5500m, the maximum transmission rate is over 2Mbps, which can transmit h.264 encoded HD video images very smoothly.

Application of visual logging equipment

(1) Downhole fishing

Figure 6. Downhole fish

It is an important application to apply the visual logging equipment to observation of underground objects. By observing the falling condition, we can further determine the fishing means, which can greatly improve the work efficiency. The application of visual logging system in an oil field in China is shown in Figure 6. It can clearly observe downhole falling objects and provide a reference for the next operation.

(2) Fault diagnosis of casing

Figure 7. Casing threads

Figure 8. Casing breaking

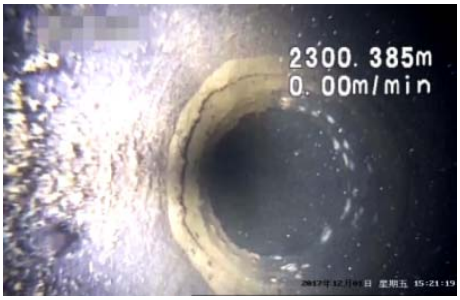

Figure 9.casing block

Another application of the visual logging system is to diagnose casing problems, including checking casing trips, casing breaking, perforation inspection and so on. The visualization of the visual logging system provides accurate technical means for detecting the dropout of the casing. The visual logging system was used to view the casing collars, as shown in Figure 7, and the casing threads were clearly visible. As shown in Figure 8, the equipment is used in a high-pressure gas well located in southwestern China. The wellhead pressure is 7Mpa, and the casing is found to be breaking at 2362m. Figure 9 shows the results of a well in eastern China, the Drift Well Gauge Tool was blocked near the depth of 2300m. Visual logging equipment was used to check the location of the resistance, and the video results were compared with the casing structure and the downhole tool to confirm that the cause of the resistance is the falling back of the plug connector guide, which is stuck in the casing and causes the inner diameter of casing to be smaller.

Conclusion

(1) A visual logging system that combines the advantages of low cost, good environmental adaptability of Hawkeys downhole TV technology and high transmission speeds of fiber-optic downhole TV have been designed. Its data transmission rate in 7-core armoured logging cable of 5500m can reach more than 2Mbps, and it can transmit the color and smooth downhole video in real time.

(2) The cable adaptation technology improves the compatibility of the visual logging system with different types of logging cable and further reduces the operating cost.

(3) The visual logging system can transmit real-time video images of the downhole, and can observe the conditions and dynamics in the well. It has broad prospects of application in the fields of casing detection, falling fishing, perforation inspection and production monitoring and so on.

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