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Corrosion Assessment of Offshore Oil Pipeline Based on Ultrasonic Technique

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Abstract:

In this paper, an intelligent ultrasonic inspection device for offshore pipeline inspection and a corrosion assessment of offshore pipeline software are developed to inspect the damage state of Chinese pipelines. The main function of the inspection system is ultrasonic signal pre-processing, data acquisition, de-noising and data compression in real time. The system includes a micro-computer, transducers, pre-processing circuit, digital signal processor (DSP), Field Programmable Gate Array (FPGA), storage device, USB interface and other components. The device can sprawl through the pipeline to be inspected together with the medium being transported therein. This paper will also explain the data analysis process, the corrosion assessment of offshore pipeline software, including examples of data recorded by the ultrasonic intelligent detection device for pipeline inspection.

Key words: pipeline inspection, ultrasonic inspection, corrosion assessment

Introduction

There are very vast networks of oil and gas pipelines which are buried underground in China. Those pipelines are prone to external and internal corrosion usually. If the pipeline corrosion is not inspected and maintained, the environment and safety can be threatened. It is very important to inspect the pipeline in time.

Because the inner pipelines are inaccessible for direct inspection and pipelines carrying oil and gas are normally buried underground, the assessment of extent of corrosion is very difficult. The pipeline inspection device is usually called 'pig'. There are some NDT methods such as magnetic flux leakage method[1,2], X-rays method, ultrasonic method[3,4], to be used to inspect the pipeline. Ultrasonic pulse-echo method is commonly used to detect metal loss and/or cracking of pipelines due to its good sensitivity to both internal and external imperfections and accurate thickness measurement ability. In this paper, a novel ultrasonic intelligent inspection 'pig' was developed. This paper also discussed the assessment method from the ultrasonic data of the pipeline.

Ultrasonic intelligent inspection device

Figure 1 shows the ultrasonic inspection device in recent study project. The ultrasonic intelligent inspection device has four parts: a system controller, power supply, ultrasonic measuring head, data acquisition and processor. The ultrasonic measuring head is used to fixup the ultrasonic transducers. The inspection device is used to acquire and store ultrasonic data in real time. The power unit supplies the system circuits. The driving force is water pressure. In order to acquire the accurate data the rubble bowls were joined for cleaning the inner wall of pipeline before the ultrasonic pig. Each mechanical part is composed of a cylindrical capsule supported by supporting stainless steel wheels. There are two odometer wheels held outside the capsule of the system controller to measure the traveled distance of the pig inside the pipeline. The odometer wheel keeps permanent contact to the pipeline's inner wall and generates electrical pulses for each 100 mm of traveled distance.

Figure 1 the ultrasonic inspection pig

Table 1 lists the values of experimental and measurement parameters. The ultrasonic sensors array component which is the most important part of the device contains 64 ultrasonic transducers and several environmental sensors including temperature sensors and rotary encoder which is used to record the slew rope of the ultrasonic pig in the pipeline.

Table 1 measurement parameters

Number of ultrasonic transducers	64
Ultrasonic transducers frequency	5MHz
Named wall thickness	14mm
Stand-off	20mm
Pulse repetition frequency	150Hz
Accuracy of corrosion depth	±0.5mm
Minimum defect diameter	Φ10mm
Minimum defect depth	1.0mm
Operation temperature	From 5℃ to 85℃

Ultrasonic transducers array

The ultrasonic sensors array component which is the most important part of the pig contains 64 ultrasonic transducers and several environmental sensors. It is used to collect all kinds of information including defects and working environment. The sixty four ultrasonic transducers mounted in a mechanical support in the capsule's plug are used in pulse-echo mode to measure the echo time propagation of the pipeline wall. As shown in figure 2, ultrasonic analog inspection unit include ultrasonic transducers array, ultrasonic transmitted and received circuits, channels selection network, and gain amplification circuit. The sixty four channels ultrasonic transducers are controlled by CPLD chip xc95144. The gain amplification of the ultrasonic signal, filtering, demodulation and other command signal are all controlled by the CPLD chip. Three operational amplifier chips AD603 are used to amplify the ultrasonic received signal.

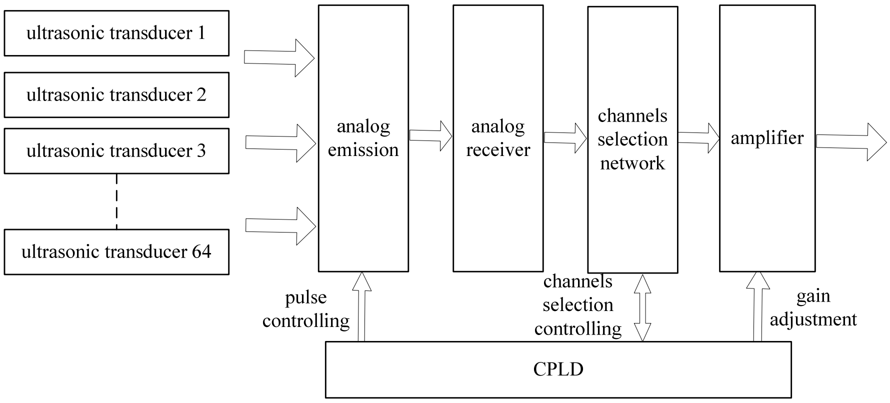


Figure 2 the diagram of ultrasonic analog inspection unit

Data acquisition and storage for pipeline inspection

Because the center frequency of the ultrasonic transducer is 5MHz, the sampling frequency must be more than twice as the center frequency, in order to obtain the accurate value of the pipeline thickness, the 40MHz sampling frequency was selected. The ultrasonic inspection device must pass along at least 10 km of pipeline in an inspection process and the non-cable driving style is adopted. Therefore, the chips must have characteristics of low power consumption and high speed of data storage. The ultrasonic inspection device will work at the high temperature in the oil pipeline, so the chips of data acquisition and storage must be heat resisting.

Figure 3 shows the ultrasonic inspection data acquisition and storage function. The board includes an A/D converting circuit, 8-channel analog input signals, DSP, FPGA, IDE hard disk and USB interface. Input signals include ultrasonic signals, temperature signals, pressure signals and location signals. The ultrasonic signals are filtered with the DSP module, and then compressed with other data in the FPGA. The FPGA controls the pipeline inspection data acquisition and the IDE hard disk to store the pipeline inspection data. When the inspection is completed, the pipeline inspection data are transported by USB interface which is controlled by FPGA. The A/D converter TLC5540 is selected to convert the analog signal to digital signal. It is a high-speed, analog-to-digital converter (ADC) that converts at sampling rates up to 40 megasamples per second (MSPS) and can maintain low power consumption and cost. The major circuit is a DSP chip TMS320C6713, a 225 MHz device delivering up to 1800 million instructions per second (MIPs) and 1350 MFLOPS. This DSP generation is designed for applications that require high precision accuracy.

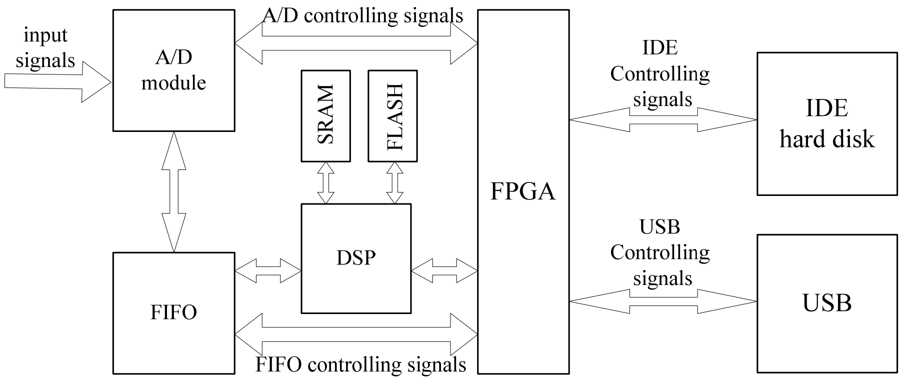


Figure 3 the diagram of the ultrasonic inspection data acquisition and storage

Data Analysis for pipeline

The ultrasonic data analysis software was developed to analyze and display the detected defects. It is made up of a number of functional modules that can be combined to configure different integrity management applications. These functional modules are composed of four parts: data preprocessing, data analysis, defect display and result output.

The first module is data preprocessing including data decomposition, separation and combining. Because the total inspection data must be beyond 100 GB, all the detected data in hard disks are firstly decompressed. And data of sixty four transducers were separated and other data, such as position information, temperature information, were combined for future use. The software can display certain signal at any time if only position information and channel number are provided.

The second module is data analysis including signal de-noising, wall thickness calculation, defect analysis and parameter calculation. The A-Scan signals were de-noised using median filtering and compensated by environmental error using wavelet neural network. The time of flight between the echoes from the inner and the back-wall is related to the pipeline thickness. The time of flight between the echoes from the inner wall and the first, from the first back-wall and the second back-wall, from the second back-wall and the third back-wall were measured. Signals of time domain were transformed into frequency domain Using FFT and wall thicknesses were calculated quickly. When wall thickness values of inspected pipeline were obtained, the defects were analyzed, according to the setting threshold of wall thickness. And then the features of defects such as position, length, width, depth, and type can be obtained.

The third module is defect display including A-Scan signal display, wall thickness display, defects display. The A-Scan signal, the value of wall thickness and defect data were all saved in the different database. When they were needed display, those data can be transferred from the database.

The fourth module is result output including all kinds of files, such as thickness file, defect file, report file for printing. These files were created automatically for search and analysis.

The software also offers a graphic interface that makes it very easy to use. In addition to generic graphical features such as measurement cursors, zooming, and color palette, it provides automated tools for defects display, report, and assessment.

According to standard API571, the software can classify all defects into five ranks according to their damage degree while the first rank is the best and the fifth is the most serious one. Four types of features including lying, environmental, pipeline and defect features are required. The defect features are provided by former feature database[5].

Figure 4 shows one of the major interfaces of the defect assessment software. It not only can display A-Scan signals of any channel and at any location, and report and sort extracted defect features, but also can show 2D image of selected defects. The signals, reports, and images can be saved, exported, and printed separately. Figure 5 shows the assessment report including caption, print time, detection position, pipeline defects, defect rank.

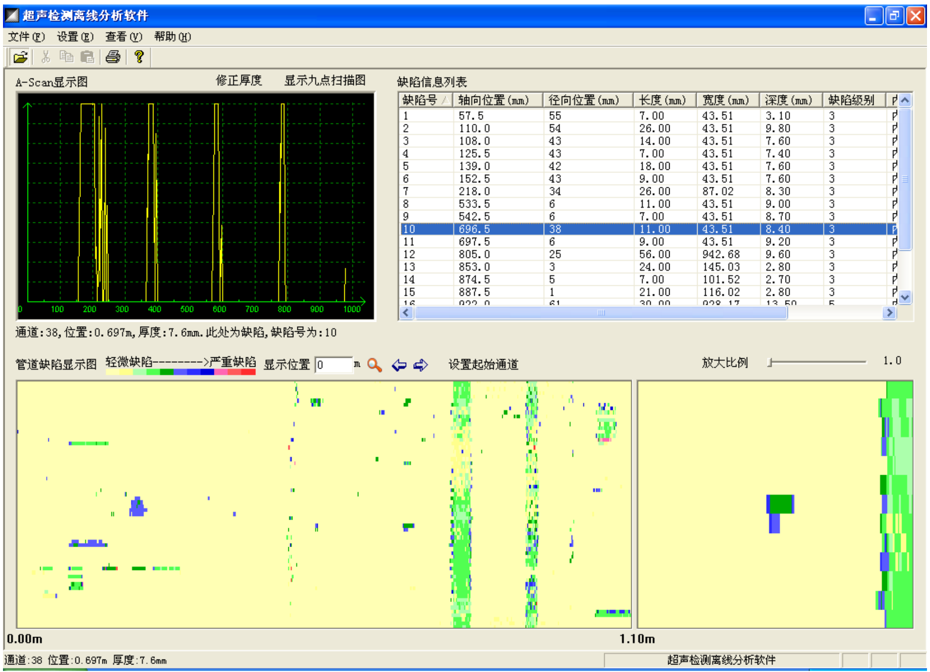
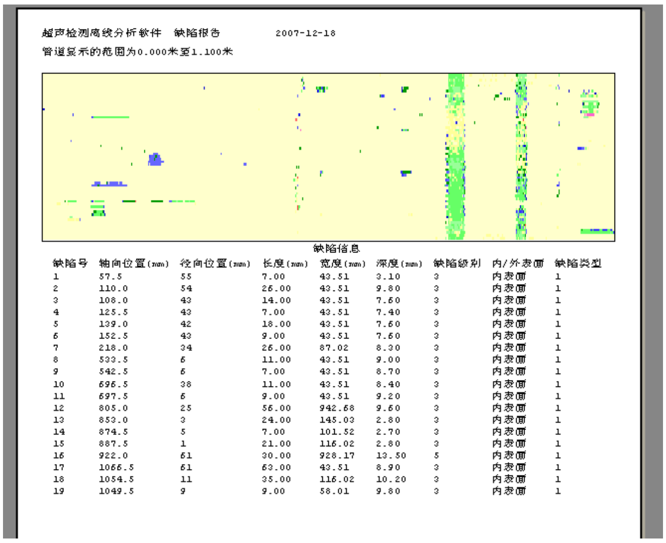


Figure 4 Main Interface of defect illustration software



超声检测离线分析软件　缺陷报告　　　2007-12-18

管道显示的范围为0.000米至1.100米

缺陷信息

缺陷号	轴向位置(mm)	径向位置(mm)	长度(mm)	宽度(mm)	深度(mm)	缺陷级别	内/外表面	缺陷类型
1	57.5	55	7.00	43.51	3.10	3	内表面	1
2	110.0	54	26.00	43.51	9.80	3	内表面	1
3	108.0	43	14.00	43.51	7.60	3	内表面	1
4	125.5	43	7.00	43.51	7.40	3	内表面	1
5	139.0	42	18.00	43.51	7.60	3	内表面	1
6	152.5	43	9.00	43.51	7.60	3	内表面	1
7	218.0	34	26.00	87.02	8.30	3	内表面	1
8	533.5	6	11.00	43.51	9.00	3	内表面	1
9	542.5	6	7.00	43.51	8.70	3	内表面	1
10	696.5	38	11.00	43.51	8.40	3	内表面	1
11	697.5	6	9.00	43.51	9.20	3	内表面	1
12	805.0	25	56.00	942.68	9.60	3	内表面	1
13	853.0	3	24.00	145.03	2.80	3	内表面	1
14	874.5	5	7.00	101.52	2.70	3	内表面	1
15	887.5	1	21.00	116.02	2.80	3	内表面	1
16	922.0	61	30.00	928.17	13.50	5	内表面	1
17	1066.5	61	63.00	43.51	8.90	3	内表面	1
18	1054.5	11	35.00	116.02	10.20	3	内表面	1
19	1049.5	9	9.00	58.01	9.80	3	内表面	1

Figure 5 Ultrasonic defect detection report

Conclusion

In this paper, a novel ultrasonic intelligent pig for pipeline inspection was designed. The ultrasonic inspection data acquisition system has eight channels for 64 channel ultrasonic transducers. The defect assessment software for pipeline was designed. The experimental results and discussion demonstrated the usefulness and effectiveness of ultrasonic intelligent pig for pipeline inspection.

Acknowledgement

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