Qiang Tianpeng*
Far East Nondestructive Testing New Technology & Application Forum Council, China

Development of Non-destructive Testing Technology in China

Rozwój technologii badań nieniszczących w Chinach

ABSTRACT

This article puts forward the concept of three stages of NDT technology development in China; it also introduces the number of the NDT personnel and the issuance of certificates in China; with the special pressure equipment as the example to illustrate the scale of application of NDT technology in China; with the TOFD technology as the example to illustrate the present situation of application of new NDT technology in China; it introduces the situation of NDT instruments in China, including categories of the instrument products, number of the instrument production enterprises and the product characteristics, the instrument industrial policies of China; it introduces the universities and scientific research institutes in China that carry out NDT education and research, and their research fields, academic specialty and leaders; it introduces the present situation of NDT standards, the standard management system and number of standards, and formulation of NDT new technology standards in China; and it introduces the advanced concept on NDT put forward by Chinese scholars.

Keywords: *China, NDT, technical development*

STRESZCZENIE

Przedstawiono koncepcję trzech obszarów rozwoju technologii NDT w Chinach. Omówiono strukturę i liczebność personelu zatrudnionego w sektorze NDT oraz proces certyfikacji, akredytacji i standaryzacji w Chinach. Zakres stosowania technologii i wdrażania nowych rozwiązań NDT zaprezentowano na przykładzie procedur kontroli bieżącego stanu urządzeń ciśnieniowych i implementacji metody TOFD. W artykule przedstawiono także bieżący stan sektora produkcji i utrzymania oprzyrządowania NDT w Chinach, odnosząc się w tym do kategorii i właściwości wytwarzanych produktów, liczby przedsiębiorstw produkcyjnych i polityki przemysłowej. Na koniec odniesiono się do sektora badawczo-rozwojowego. Przedstawiono uniwersytety i instytuty naukowo-badawcze w Chinach, które prowadzą edukację i badania NDT. Omówiono obszary badawcze i specjalności akademickie liderów tworzących jednostki badawcze oraz koncepcję zaawansowanych rozwiązań NDT przyjmowaną przez chińskich uczonych. Ponadto przedstawiono obecny stan standardów badań nieniszczących, system zarządzania standaryzacją i liczbę norm NDT.

Słowa Kluczowe: *Badania nieniszczące w Chinach, Nowe technologie*

Professor
Qiang Tianpeng

1. Three stages of NDT technology development in China

Stage 1: Before 1980

There were very few applications, and very few professional personnel; it was weak in theory and poor in technology;

From 1954, China started to introduce NDT technology and equipment such as RT, UT, MT and PT from the former Soviet Union, which were used in such industrial fields as the electric power, metallurgy, mechanical and automobile manufacturing. And at the same time, China began to learn and digest and absorb the technology and imitate and develop the equipment; in 1957, the first ultrasonic flaw detector and the first magnetic particle flaw detector were developed; in 1958, film for industrial radiographic testing began to be produced; in 1959, the first X-ray machine was developed successfully; in 1960, the first portable Co60 ? ray detector was developed; and in 1964, penetrant flaw detection agent was developed successfully.

From 1966, NDT technology in China was at a standstill status. By 1980, the NDT technology of China is far behind that of the foreign countries.

Stage 2: 1980-2000

China learned and drew on the experience of foreign achievements, constructed the basis theory, technology and process systems or frames; the conventional NDT technologies became basically complete.

Since 1980, China started to open up to the outside world, and carried out large scale economic construction; and NDT technology application entered a rapid development stage: learning from America, Europe and Japan, China established and improved the conventional NDT theoretical system, industrial standard system, personnel training and assessment certification system, NDT equipment and material manufacturing system, and industrial NDT technology and process management system and quality control system. The scale of NDT technology application is gradually enlarged, the level is improved continuously, and the management is standardized day by day, which have met the demands of the national economic development and the demands of such fields as the mechanical manufacturing, energy and chemical industry, transportation, and national defense and military. Besides, the new technology research and application began to speed up: in 1986, the 36-channel acoustic emission instrument was developed; in 1988, the first digital ultrasonic flaw detector was developed; in 1991, X-ray real-time image-forming system was developed; in 1993, ?-ray source CT machine and the digital multi-frequency multi-channel eddy current testing instrument were developed; in 1995, industrial

*Corresponding author. E-mail: inloving@126.com

test linear accelerator was developed; and in 2000, metal magnetic memory diagnostic apparatus was developed.

Stage 3: 2000+

The stage of all-round development and ability and level improvement; the conventional NDT technology application scale is huge and increasingly standardized. The steps of learning, researching, perfecting and promoting new technologies are quickened; for example, new technology of X-ray detection – CR and DR; new technology of ultrasonic testing – TOFD, PAUT, guided wave, and EMA; new technology of electromagnetic detection - pulsed eddy current, magnetic flux leakage, magnetic memory, and infrared, laser, terahertz wave, etc. The application scale and level of a number of NDT new technologies are in the lead of the world. The varieties and categories of the NDT instruments and products are complete, and their quality and performance are further improved. The research and development of advanced instruments achieve results continuously.

2. Number of the NDT personnel and issuance of certificates in China

By 2015, about 340,000 NDT personal qualification certificates were issued by the respective departments of China.

There are several types of non-destructive testing certificates in China; in addition to the certificates issued by the Society for Nondestructive Testing, many government departments also issue the certificates for the non-destructive testing personnel within their jurisdiction. There are 7 main departments issuing certificates: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) (special equipment), railway system, Ministry of Industry and Information Technology (aeronautical and space and weapons), Ministry of Environment Protection (nuclear power system), Ministry of Water Resources, CAAC, China Electricity Council and China State Shipbuilding Corporation, etc. The top three fields that have issued most certificates are: the special pressure equipment (boiler, pressure vessel, pressure pipeline) industry has issued about 160,000 certificates; the second is the railway system, having issued about 80,000 certificates; and the third is the Society for Nondestructive Testing, having issued about 60,000 certificates.

3. Application of special pressure equipment NDT technology

In China, the special pressure equipment is the biggest user of non-destructive testing.

China is a large country of equipment manufacturing; there are over 20,000 enterprises that are engaged in special pressure equipment (boilers, pressure vessels, pressure pipelines) manufacturing, installation and repair. China is also a large country of using the pressure equipment; there are in-service 700,000 boilers, 3.5 million pressure vessels, 143 million gas bottles and 940,000km of pressure pipelines.

The industrial chain from design, manufacturing, detection to installation, modification and repair of the special pressure equipment, the annual output value is about 1 trillion yuan. Of which, the output value of special equipment non-destructive testing is over 20 billion yuan, with employees of over 100,000, qualification certificates of about 160,000. Of which, class III certificates make up 5%, issued to about 8,000 persons; and class I and class II certificates make up 95%.

4. Application of NDT new technologies

TOFD technology has been widely used in special pressure equipment manufacturing and in-service detection; digital radiography (DR and CR) technology is gradually being popularized; AUT/PA technology has been applied in long distance natural gas pipeline and submarine pipeline project since 2000; PAUT technology has achieved good results in the detection of wheel sets and in the application of various structural members in high-speed railway industry; magnetic flux leakage technology is applied in steel pipe manufacturing production lines; guided wave technology is applied in pressure pipelines; ultrasonic C scanning technology is applied in detection of thin-wall structures (metallic and non-metallic composite materials); laser speckle technique is applied in detection of composite materials, etc.

5. Examples of popularization and application of new technology - TOFD

In 2000, China began to research TOFD technology; in 2004, China First Heavy Industries used TOFD in pressure equipment manufacturing for the first time instead of radiographic photography; in 2007, AQSIQ approved some units that have technical abilities to use TOFD technology in pressure equipment manufacturing; in 2008, qualification training and assessment was started for TOFD personnel; at present, over 1500 TOFD level 2 certificates have been issued; in 2010, the Chinese TOFD standard was published, TOFD technology is widely used in manufacturing of special pressure equipment instead of radiographic photography; at present, TOFD technology has been applied in 90% of the newly-built spherical tanks; and TOFD technology has been applied in 50% of the thick wall vessels.

The coal liquefaction hydrogenation reactor that was welded at the site of Inner Mongolia, weighted 2040t, with wall thickness of 336mm, a diameter of 4812mm, and a height of 63mm, all the welds were detected by TOFD technique, which was implemented by China First Heavy Industries.

The dimethyl benzene column that was welded at the site of Hainan Province, weighted 3960t, with a height of 126.6m, a diameter of 10800mm, wall thickness of 96mm~142mm, having a total weld length of 3400m, it was made by Ningbo Tianyi Company; the vessel was transported to the site in 9 separate sections, fitted up and welded at high altitude; Jiangsu Zhongtechuangye Equipment Inspection Co., Ltd. implemented TOFD detection for all the welds.

6. NDT instruments and materials

There are a lot of NDT instrument manufacturing enterprises in China, with complete varieties. Over 800 enterprises are engaged in manufacturing of NDT instruments, equipment and materials; some instruments of new technology are produced and sold at the market, for example: TOFD, phased array, guided wave, acoustic emission, industrial CT, high-energy accelerator, DR, and pipeline pig.

According to the statistics, there are over 320 enterprises that

are engaged in ray (including X-ray, γ-ray, accelerator, CT) instruments and equipment production; over 220 enterprises that are engaged in ultrasonic (including conventional ultrasonic, TOFD, phased array, guided wave) instruments and probe equipment production; over 180 enterprises that are engaged in electromagnetic (magnetic powder, eddy current, magnetic flux leakage) instruments and equipment production; over 40 enterprises that engaged in production of penetrating equipment and materials; and over 100 enterprises that are engaged in producing instruments, equipment and materials of new technology.

7. Introduction to some advanced NDT instrument manufacturing enterprises and their products

1) RT: Dandong Aolong Radiative Instrument Co., Ltd. (X-ray machine/DR image-forming system); Beijing Research Institute of Automation for Machinery Industry (accelerator); NUCTECH Company Limited (accelerator/CT); Chongqing Zhence Science & Technology Co., Ltd. (CT); Sichuan Ruidi X-ray Digital Image Technology Co., Ltd. (DR); Lanzhou Sanlei Electronic Co., Ltd. (DR); Zhejiang Jinyun Image Quality Indicator Factory (image quality indicator/intensifying screen); Wenzhou Lucheng Nondestructive Testing Equipment Company (Film viewer / densitometer).
2) UT: Wuhan Zhong Ke Innovation Technology Co., Ltd. (TOFD/ultrasonic testing system); Nantong Union Digital Technology Development Co., Ltd. (TOFD/ultrasonic testing system); Guangzhou Doppler Electronic Technology Co., Ltd. (phased array instrument /probe); Shantou Ultrasonic Instrument Research Institute Co., Ltd. (phased array instrument /probe); Hangzhou Zheda Jingyi Electromechanical Technology Engineering Co Ltd. (magnetostrictive guided wave / steel plate ultrasonic testing system); Guangzhou Soundwel Technology Co., Ltd. (acoustic emission); Chengdu Zudao Science & Technology Co., Ltd. (high-speed railway wheel set UT/PAUT/EMT automatic detection system); Allrising Beijing Science & Technology Co. Ltd. (steel plate steel pipe UT/ET automatic detection system); Xi'an Jin Bo Testing Instrument Company (laser ultrasonic); Shandong Ruixiang Mould Co. Ltd. (test block).
3) Electromagnetic: Eddysun (Xiamen) Electronics Co., Ltd. (eddy current / integrated detection system); Shenyang Ligong University (MFL / pipeline pig); Wuhan Huayu Yimo Testing Equipment Co., Ltd. (MFL/steel wire rope/ pipeline);
4) PT Shanghai Chengyou Industrial Group Co., Ltd.; Wujiang Hyperd NDT-Material Co., Ltd.

8. The Chinese government implements the "Special projects of major scientific instruments and equipment development"

Although there are many instrument manufacturers in China, there is still a gap in the quality and performance of the instruments compared with the international advanced level. In order to change this situation, the Chinese government has implemented the "Special projects of major scientific instruments and equipment development". From 2011~2016, there have been more than 300 projects established, each project was invested with 50 ~100 million yuan. Of which there are nearly 30 projects of nondestructive testing instruments and equipment, involving such fields as electromagnetic, Radiography, ultrasonic, and optical areas, including: 3 projects of terahertz technology based equipment systems; 2 projects of X-ray technology-based tomography and 3-D microscopic imaging system; 2 projects of new-type phased array ultrasonic equipment; and others: electromagnetic ultrasonic equipment, 3-D magnetic flux leakage imaging system, millimeter wave imaging system, new-type thermal imaging instrument, and new-type leak detection instrument, etc.

9. R&D-type advanced NDT application enterprises

There are more than 5000 institutions or units and departments that apply NDT technology in China; and there are more than 1000 professional companies that are engaged in NDT. The following are some NDT application enterprises that have technical research and development capability and their technical characteristics: China Nuclear Power Operation Technology Corporation, LTD. (nuclear power detection, pipe ultrasonic imaging system, austenitic weld ultrasonic); CGNPC Inspection Technology Co., Ltd. (nuclear power detection, reactor detection/ robot); Langfang North Nondestructive Detection Company (NNDT) (long-distance pipeline detection, pipeline circumferential weld AUT/PA); China Petroleum Pipeline Inspection Technologies Co., Ltd (long-distance pipeline detection, pipeline inner detection/pipeline pig); Sinopec Long-distance Oil and Gas Pipeline Detection Co., Ltd. (pipeline inner detection/pipeline pig); the Testing and Failure Analysis Center of Aerospace Research Institute of Materials and Processing Technology (ultrasonic C scanning, laser holography); AVIC Beijing Institute of Aeronautical Materials Aviation Materials Testing Laboratory (ultrasonic C scanning, phased array); Jiangsu Zhongtechuangye Equipment Inspection Co., Ltd. (radiographic examination of tube to tube-sheet fillet welds, TOFD, phased array, local magnetic saturation eddy current, HF guided wave); China First Heavy Industries Dalian Hydrogenation Reactor Manufacturing Co., Ltd. (thick-wall weld TOFD, austenitic weld ultrasonic); Beijing Guodian Electrical Testing Technology Research Institute Co., Ltd. (in-service power plant boiler detection, piping guided wave detection, pipeline scale cinder detection); Jiangsu Fasten Material Analysis & Inspection Co., Ltd. (bridge sling/AE); China Classification Society Industrial Corporation (phased array).

10. Institutes and universities that carry out NDT research

There are more than 40 colleges and universities in China that have some 1000 undergraduate and graduate students of NDT detection every year. There are more than 50 research-type colleges and universities and institutes that are engaged in researches of NDT technology; the following are some academic leaders of the important institutions and their research areas and achievements: Professor Lin Shuqing of China Special Equipment Inspection and Research Institute (AE technology and equipment, TOFD process, structural health monitoring,

pipeline pig technique, pulsed eddy current technique, etc.); Professor Tian Guiyun of School of Automation Engineering, Nanjing University of Aeronautics and Astronautics (pulsed eddy current, electromagnetic stress determination); Professor Han Yan of North University of China Modern NDT Engineering Technology Research Center of Shanxi Province (digital signal processing (DSP) and CT reconstruction algorithm); Professor Xu Chunguang of School of Mechanical and Vehicle Engineering, Beijing Institute of Technology (ultrasonic stress measurement, robot-based detection technology); Professor Chen Zhenmao of School of Aerospace, Xi'an Jiaotong University (eddy current-based quantitative NDT); Professor Huang Songling of Department of Electrical Engineering, Tsinghua University (submarine pipeline inner detection, MFL 3-D imaging); Professor Zhou Zhenggan of Ultrasonic NDT Laboratory, Beihang University (air coupling ultrasonic, laser-generated ultrasonic, nonlinear ultrasonic); Professor Gao Xiaorong of NDT Research Center, Southwest Jiaotong University (high-speed railway detection technology and equipment); Professor Wang Jue of Chongqing University (industrial CT); Professor Liu Songping of Beijing Aeronautical Manufacturing Engineering Research Institute (composite material detection); Professor Kang Yihua of School of Mechanical Science and Engineering, Huazhong University of Science and Technology (super magnetization MFL detection); Professor Zhang Yan of Physics Department, Capital Normal University (infrared/terahertz wave); professor Lu Chao of Key Laboratory of Ministry of Education of China for NDT Technology (Nanchang Hangkong University), (NDT technology and process); professor Zeng Zhiwei of School of Aerospace Engineering, Xiamen University (numerical simulation of eddy current).

11. The Chinese non-destructive testing standards organization

Standardization Administration of China is responsible for management of the national standards. Many departments formulate industrial standards respectively, now more than 350 NDT standards have been formulated and promulgated; the departments that have formulated quite a few non-destructive testing standards include: machinery, aerospace, aviation, railways, nuclear industry, military products, electric power, petroleum and natural gas, etc. There are three NDT standardization administration organizations that are more influential:

1) National Technical Committee on Non-destructive Testing of Standardization Administration of China(CSBTS/TC56). It is responsible for national standards: GB/T and some standards of machinery industry: JB/T (NB/T); and now it has promulgated over 140 standards.
2) Sub-committee on Non-destructive Testing Instrument of National Technical Committee on Test Machines of Standardization Administration of China (TC122 / SC1); it is responsible for ISO/TC135 instrument parts; it has promulgated and is formulating more than 40 standards.
3) China Standardization Committee on Boilers and Pressure Vessels (SAC/TC 262); it is responsible for formulation and management of the non-destructive testing standards of special pressure equipment; now it has promulgated 14 standards: NB/T47013.1-14.

12. Non-destructive testing new technology and method standards

GB/T series: The following have been promulgated: TOFD (GB/T23902), CR (GB/T 26642), magnetostrictive guided wave (GB/T28704), pulsed eddy current (GB/T28705), phased array (GB/T32563). The following are under preparation: X-ray digital imaging, guided wave, and magnetic flux leakage.

NB/T47013 series: The following have been promulgated: TOFD (NB/T47013.10); DR (NB/T47013.11); magnetic flux leakage (NB/T47013.12), pulsed eddy current testing (NB/T47013.13); the following will be promulgated soon: CR (NB/T47013.14); and the following is under preparation: PAUT (NB/T47013.15).

13. Advanced concepts of NDT

The following advanced concepts on NDT technology are put forward by the Chinese scholars:

1) Dr. Geng Rongsheng, former director of Chinese Society for Nondestructive Testing, has pointed out: green NDT is the inevitable course of development, which must be vigorously promoted and advocated. The connotation of green includes: energy conservation and emission reduction, environmental protection and sustainable development.
2) Professor Shou Binan, secretary-general of China Standardization Committee on Boilers and Pressure Vessels, advocates the concept "the failure mode-based NDT": in order to improve the validity and reliability of NDT technology application, when formulating the standard, the selection of NDT methods, the technical parameters and the determination of the detection ratio shall be considered based on the structure's failure mode and failure probability.
3) Mr. Lin Junming, researcher and director of the Electromagnetic Committee, Chinese Society for Nondestructive Testing, points out the importance of "modern NDT integrated system" development: to improve the detection accuracy, efficiency and reliability, the main development direction of the instrument system is comprehensive integration of mechanical and electrical integrated.