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Abstract
Cloud testing is a new concept of Non-destructive Testing (NDT). It is based on cloud computing and NDT integrated testing techniques. It combines testing methods, information sharing and remote control techniques. The emergence of NDT integrated technology is an indication of cloud testing. Present status and future development of NDT integrated technology are analysed. Possibility and key issues of establishing cloud testing technique are discussed. Cloud testing technology collects, saves and processes data from cloud client side. Functions of cloud client are NDT signal processing, saving, evaluation, prediction and information feedback. Users can share software and hardware resources. High efficiency and convenience with cloud testing are enjoyed by users in different locations. It is point out that cloud testing is the trend of the development of Non-destructive Testing and Evaluation Techniques.

Keywords: Non-destructive testing (NDT), Cloud testing, NDT integrated technology, Internet

1. Introduction
The concept of integrated innovation technology have begun to attract significant attention from industry. It is the concept of integrated innovation that there was nothing innovation on each individual technique itself than the new product as a whole which integrated a great number of different functions. Apple's soul, the former CEO Steve Jobs led his team to take advantage of the integrated innovation technology to extreme. They integrated many new features, such as telephone, games, music, movies, etc. into their products and optimize the product design with his maverick, almost "brutal" perfectionist thinking.
Many works have been done for integrated innovation in non-destructive testing fields, for example, Renken C.J and Selner I. H tested metal tubes combined ultrasonic and pulse- eddy-current methods in 1966 [1]. Young-won song and Satish S. Udpa combined ultrasonic and eddy current images to increase the reliability [2]. Chen Jimao and Zhang Yin integrated sonic and ultrasonic testing techniques into a portable device in China in 2002 [3].
Recently, industrial products based on composite or integrated testing techniques were developed one after another all over the world by the NDT manufacturers. Bowing International Company developed ultrasonic and flux leakage integrated testing systems for steel pipe quality inspection on-line. The two combined techniques are highly complementary. Canadian R&D Tech's production , TC5700 tube portable detector, integrated eddy current, remote field, magnetic flux leakage and ultrasound technologies. ABB has also developed eddy current and ultrasonic integrated systems. Olympus Corporation developed WorkStation 2000 and PowerStation testing systems, which integrated eddy current and ultrasonic testing. It consists of three main components, namely, basic components, the control panel and front-end standard components. Users can switch the functions of ultrasonic and eddy current easily by replace the corresponding front-end modules. Germany's Thomas H. Metal. used ultrasonic and eddy current testing techniques in same rail detection system to detect defects in different components in 2007. The testing results obtained by these two testing techniques for the same defect can be used as an evidence to support each other. However, the apparatuses or equipments above mentioned, are either simply cobbled the
hardware together, or failed to synchronize data acquisition, hence they cannot achieve true integration and multi-data fusion.

A new concept of NDT integration technology was proposed by EddySun Corporation in 2003. In the same year, SMART-2003 Magnetic Memory / Eddy Current integration testing system was developed by Eddysun Corporation. The data acquisition for magnetic memory and eddy current testing could be accomplished almost at the same place and in the same time by this system. And most hardware and software in the system are shared by these two testing methods. It was achieved the integration in both utility functions and hardware plus software that the SMART-2003 became the first integrated NDT equipment with multi-data fusion function in industry. This equipment was widely applied to test armored cars and had found an increasingly wide utilization in Remanufacture fields. Afterwards the new types of integrated NDT equipment, the SMART-2004 and the SMART-2005 emerged as the times required, which either with multi-NDT-techniques or portable. In 2008, the term ‘integrated NDT technology’ was adopted as a NDT terminology was wrote in the Chinese National Standards, in which Eddysun Corporation played a leading role.

Integrated NDT device based on internet technology is available in market also. EEC-2008net electric/sonic testing system with the internet and integrated technology developed by Eddysun Corporation has been used in nuclear power station. It has the characters of novel, high efficiency, portable and connected to local network in order to insure the safety of data. The EEC-2008net system has the essential features of the cloud testing, the above advanced concept.

The concept of cloud testing originates from integrated testing technology and cloud computing. Cloud computing evolved from concept to actual behavior and went into people’s lives. Cloud computing can provide users with reliable, custom, and maximize the resource utilization of services. It is a new distributed computing model. National Institute of Standards and Technology in USA defined cloud computing: Cloud computing is a model that it is a public collection and access a configurable computing resources easily (e.g., networks, servers, storage devices, applications and services). These resources can be provided quickly and released, while minimizing administrative costs or service provider intervention.

Cloud testing based on cloud computing is a new generalized concept about testing, which consists of a variety of physical and chemical detection methods. It is a trend of NDT integration technology and takes advantage of computer technology, network technology and the development of electronic technology. Various NDT and control equipments have been connected to Internet and Internet of Things in order to share resources and information, and to realize remote control, to offer higher efficiency and lower cost service to users.

2. NDT integrated innovation

It is difficult or hardly to evaluate an object in its entirety using one single NDT method. Usually multi NDT methods are needed. In order to increase the reliability and efficiency, lower testing cost, and to achieve testing entirely, it is better to apply the integrating NDT technique which integrated several NDT methods.

There were so called five conventional NDT methods, namely, Ultrasonic, eddy current, X-ray, magnetic, and penetration. Each method of these has different detection principle, corresponding to different characteristics, and limitations. For example, the ultrasonic testing method, which is one of the most widely used one, could be used to test components of metallic, non-metallic and composite materials to evaluate their internal continuity non-destructively, and it is harmless to humans and environment and can be used for on-site testing. However, there are some shortages such as, coupling is necessary
needed, surface pre-processing is also necessary for components with rough surfaces, and there is dead-zone for testing etc. X-ray testing technology adapts for variety materials, inspection of surface and structure and needs no special requirements. It can be applied to a variety of products. However, the sensitivity of X-ray testing for plane flaws is low, and the X-ray testing is harmful to human body and is with high cost.

Eddy current testing technique has the advantage of high speed, non-contact and requiring no coupling. But it is limited to test conductive materials and can only detect surface and subsurface defects, and hard to test complicate shaped objects.

Magnetic Testing method has the advantage of offering intuitive visible display of the shape, location, and size of the defect with high sensitivity. There is almost no limitation on size and shape of the specimen, while with fast, simple, and low-cost testing. But it is only suitable for ferromagnetic materials, and only for finding the surface and near surface defects. The detectable depth is generally 1 ~ 2 mm. Especially it needs demagnetization and cleaning after testing.

Penetration testing method has the advantage of no limitation on geometry, size, chemical composition and internal structure of the specimens. One operation can detect all open defects on the surface simultaneously. Its limitation is that it can only detect opening surface defects.

With the development of digital electronic technology, and wide application of FPGA, ARM and DSP integrated electronic devices, it becomes possible and feasible to develop and manufacture new NDT integrated technology products. Although the principles of detection and the signal extraction and processing methods are different for different NDT methods, but as an electronic apparatus, there are some common characters and similarities for the various testing instruments, such as the electrical circuits of signal generation, of data acquisition, of signal amplification, of signal and data displaying, saving, and such as some modules of software, etc., which are very similar and even the same for different NDT methods. Hence it is possible to form an open platform of digital signal processing to execute these common missions. With the platform, plus the individual parts for signal emitter, receiver and processor of deferent special NDT methods, the NDT integration technique was achieved.

The NDT innovative integrations are mainly to integrate a variety of methods in three levels, the first level such as electromagnetic method integration to integrate eddy current, magnetic flux leakage and magnetic memory methods, acoustic method integration to integrate acoustic impedance, acoustic pulse, sound vibration and ultrasound acoustic methods. Then the second level is to integrate mechanical and electrical technology in sense of mechatronics, such as the new train hollow shaft integration testing system to integrate ultrasonic, eddy current, magnetic memory methods. The third level is integration of internet network and NDT technologies, by Ethernet, Internet, networking or cloud platform, data merges into the NDT service center or cloud to carry out storage, analysis and processing.

### 3. The process of development of NDT integrated technology
The development of NDT integration technology can be summarized as three procedures briefly:
The first stage is the initial integration of NDT. It was only to put two or more different detection methods together into one machine, neither data exchange nor other association among each testing methods.
The second stage is based on modularization, that is to achieve integration by using NDT card. It is to integrate the specific method by plugging in its function module card into the PCI slot when need to add a new function in the apparatus. The second stage is in developing now. The different modules share some of the circuit, and also fusion of test data, different results can be displayed on screen simultaneously while the results have also been integrated, that is, fusion results obtained through different detection methods and the results are fused in the data fusion center, make a comprehensive judgement. This is a higher level of integration. Another phase of this stage is to use the common part of different testing instruments, with the Ethernet as the transport means to form an open digital information processing platform, allowing the control signal, data acquisition, system software, visualization and other common parts shared. It should provide for a variety of high-speed information transmission connection. For example, 2008 net system developed by EddySun Corporation has two main connection ways, namely the Universal Serial Bus (USB) and Ethernet network connections respectively.
1) Hi-Speed USB interface. Maximum transmission speed up to 480Mbps, Plug and Play and hot swap capabilities, Length of USB device connection cable up to 5m, connect tiered star topology through USB hubs. A host can connect up to 127 USB devices, and up to 5 stages of topological connection, so it’s very suitable as a communication interface between the host and testing instrumentation. USB bus-based approach, integrating multiple different performance testing instruments, each instrument can also have multiple channels, composed of multi-channel detection data acquisition system.
2) Industrial Ethernet mode. Industrial Ethernet is technically compatible with the commercial one, but the selection of materials, product strength and applicability should be able to meet the needs of the industrial field. Ethernet technology is widely used for all supported programming languages; hardware and software is rich in resources; easy to connect to the Internet, office automation and industrial control network, the network seamlessly; broad space for sustainable development and so on. The multi-block test board through different hosts connected by Ethernet, each plate supports multiple channels, using different detection network interface chip between the plates (100M/10M adaptive), and the software using TCP / IP or UDP agreement. Currently running or planning to run 3G/4G/5G ... ... Its performance will be improved further by communication.
The structure of NDT integrated testing system based on Network is shown in Fig.1. Each detector is equipped with network interface and can be composed of Ethernet LANs. It access Internet with the network switch or router. LAN is both as control bus and the Internet subnet. Multiple testing equipments are connected through the network cable and hub. The monitoring host can be either one of a machine within the LAN or a remote host connected to Internet.
NDT integration technology based on network enables data collection, analysis and other multi-platform operating simultaneously. It combines software, hardware, and data resource sharing and achieves real-time rapid transportation in far distance for raw data, application analysis software, file archives (such as inspection reports). It can upgrade the software online in time for equipment and provide remote training services and network testing for technical staff, technical support and application, installation, commissioning guidance. The detection accuracy and inspection efficiency on-site is
improved greatly. Particularly, the database is established to facilitate the detection. It is significant for health monitoring and evaluation of the important components. Detection system can fully meet the actual needs, and obtain reliable test results with high test speed.

Fig. 1 is the model of NDT integrated network.

Fig. 2 is the sketch of the EEC-2008net system application scene. EEC-2008net system is the web-based NDT integrated system, developed by EddySun Corporation for Daya Bay Nuclear Power Station. The combination of network with NDT equipments has great potential and advantages.

Fig. 2 is the EEC-2008net testing system application in LingAo nuclear station.
The third stage is in the near future. The further development of NDT integration technology will be leading to the cloud testing. There is no consensus among academic scholars on the specific definition of cloud computing currently. But generally speaking, the definition of cloud computing is divided into narrow and broad senses.

Narrow definition of Cloud computing refers to build data centers or supercomputers through distributed computing and virtualization technology, providing free rent on-demand through the network, and scalable approach to technology developers, enterprise customers with data storage, analysis and scientific computing and other services.

Generalized definition of Cloud computing is that it provides customers with different types of online software services through establishment of a cluster of servers, hardware leasing, data storage, calculation and analysis of different types of services.

Generalized cloud computing includes more manufacturers and service types. Network resources are called "cloud", "cloud" of resources in the point of view of user appears to be infinitely scalable, and can be used on demand, pay-per-use.

The principle of cloud detection is to make distributed computing across a large number of computers, rather than the local computer or remote server, data center operations and the Internet is similar. In essence, cloud detection is the client's smart sensors through close, long-range connections to obtain storage, computing, processing, database, and interactive services.

Fig. 3 (a) is an Ethernet-based NDT integrated system diagram. Fig. 3 (b) is the cloud testing diagram. It can be seen that the cloud detection saves more hardware resources. The client can be simplified in a large extent and the client service make requests to the cloud without having to care how. NDT and evaluation system from the perspective of the instrument will no longer be small and complete system, but "clouds", with minimal hardware by wireless means. The testing data will be transmitted to the cloud, then processed and return back to the terminal. Cloud features include: reception, detection, filtering, information fusion, storage, expert system evaluation, feedback, communication, sharing and so on.

That can be said, the cloud testing is a prospective testing and evaluating technique to improve work efficiency and quality, and to avoid duplication of work, which is aggregated all wisdom and power of mankind, and projected the so-called roots spirit by the accumulation of knowledge and keeping up with the times. Besides, the cloud testing can optimize the hardware of testing equipment, a significant reduction in costs, allowing users to experience faster, more direct and better. It will overthrow the people's tradition detection thinking. In some ways, cloud detection technique including a multi-disciplinary will be a gene which would lead to a revolution in testing industry.

We would imagine, by implementing the plan named Eddysun 2011, decomposition the NDT instruments, such as of the ultrasound, eddy current instrument, acoustic
impedance instruments (sure it can be extended to other testing and measurement fields) in the point of view of integrated technology, the common part of them would be designed to a public shared mode (such as ultrasound and acoustic emission, eddy current and magnetic memory, one for active transmit/receive mode, the other is passive receive mode). Users only need to have a cloud-terminal based on NDT then they would have super-power with a similar virtual instrument with a variety NDT capabilities. It needs to manage, use, development, manufacturing, and even research the theory of collaborative in order to achieve better development for cloud testing.

4. The features and questions of cloud testing

Resource on demand service could be provided by cloud testing in the short time. Cloud testing can avoid excessive use of resources. It is composed of parallel distributed system and virtualization of computing resources. It is characterized by resource service pool, and storage, compute, and memory, network resource, dynamically allocated according to user needs through virtualization technology. Users can purchase service resources, expansion of processing capacity at any time based on actual demand quickly and flexibly. Cloud detection resources are called by using a variety of client software and broadband network. Resource service can be monitored, reported to the user and service provider, and charge depending on the type of use (such as bandwidth, number of active users, storage, etc.). Failure nodes can be detected automatically, the system can continue to work through data redundancy and provide high quality services to achieve service level agreement requirements.

The first problem of cloud testing to need to be overcome is security issues. The processing time of an intensive data by single instrument would be reduced and the efficiency be improved as tasks are assigned to each node of calculation. It is more concerned on the security of sensitive data transmitted to the cloud end by users. (Of course, for this purpose, using LAN is a better choice, but it would lose part of the shared resource). The second one is reliability problem. The cost of physical hardware and the risk of early stage capital investment would be reduced through resources leasing service. The reliability to employ cloud detection by users is relayed on the quality of cloud detection itself, although users need not to pay attention to the maintenance of the software and hardware. The third issue is maintainability. Cloud detection software provides professional management and maintenance services, reducing the average daily maintenance and management software platform costs for users. Are all the software applications suitable for testing development and application in the cloud environment? While how to migrate the previous software applications to cloud detection environment, it will be a long run cycle. The fourth is interactive. Users request cloud testing services dynamically based on business need, peak load handling and release of resources during off-peak period. Cloud computing service providers can expand the limited number of cloud testing services actually, and the interaction between cloud testing services is poor, how to coordinate? These key technical issues must first consider and resolve for establishment and implementation of cloud detection.

The NDT staff’s role is irreplaceable. Cloud testing technology plays an important role for training inspectors. The future users will more concerned about service, which requires providing a reliable detection of conclusions, in spite of what method and equipment are used. In addition, the same as the development of mobile phones, the proportion of hardware costs will become more and more less than the proportion of testing assessment services. (Do you feel difficult to buy a mobilephone without the Internet, games and other features? Perhaps, you can design different grades or a special "fool" cloud detection terminal to meet the needs of different users). Should consider the management of innovation, some European countries like digital phone marketing model, integrated NDT sensor terminal to the "zero cost" to
provide property owners, then demand payment of inspection fees. From the present point of view, it is a lengthy process to achieve the above technology, management, marketing model of innovation. It is need to integrate all factors from the research and development of equipment, testing projects, user and other parties, etc.. In particular, it is necessary to change the people’s traditional attitudes. It could be predicted that there is a long long way for cloud testing to improve the industrial structure.

5. Conclusions and outlook

NDT integration technology is an integrated innovation. It can improve the detection efficiency, reliability and conserve resources, and maximize the integrity of test results. Cloud testing is a trend of NDT integrated technology. Cloud testing combines with the NDT integration technology and the latest development results of sensor technology, network technology, communication technology and computer technology, etc., and provides more convenient and more efficient service for users. Users can share software and hardware resources by cloud service, but also enjoy the convenience of network services and experience.

References