The research of penetration testing in the FRP pipe applications

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Abstract. In this paper, for the first time will be introduced to the penetrant metal nondestructive testing technology in FRP pipe non-destructive testing, glass fiber reinforced plastic are verified through the SEM surface sine qua non of penetrant testing. Through the prefabricated crack, glass fiber reinforced plastic materials available to the nondestructive testing methods for crack detection. By penetrant testing of glass fiber reinforced plastic, partial fluorine polyethylene and rigid polyvinyl chloride (PVC) for inspection, to find obvious crack.

1. Introduction

Glass Fiber Reinforced plastic products, commonly known as glass Fiber Reinforced plastic abbreviations FRP (Fiber Reinforced Plastics), is a kind of Fiber Reinforced plastic is the general, common glass Fiber after dipping unsaturated resin after curing polymer Reinforced material. According to the different kinds of unsaturated resins, it can be divided into: polyester fiberglass, epoxy glass steel and phenolic glass steel. According to different fiber, it can be divided into glass fiber reinforced composite plastic [1] (GFRP), carbon fiber reinforced composite plastic [2] (CFRP), boron fiber reinforced composite plastic, etc. Glass fiber reinforced plastic materials, the diameter of the fiber is very small, plays a role of stress in the whole is responsible for the materials, the vast majority of the outside world under load, because the fiber is a brittle material, the fracture strain is about less than thirty over one thousand, easy to damage, fracture and from corrosion. The base body mainly ACTS as a bonding fiber, and its strength and modulus are much lower than the fiber, but the matrix can withstand large deformation and have good viscoelasticity and elastoplastic properties for ductile material. The combination makes the composite materials have the advantages of light and hard, non-conducting, stable performance, high mechanical strength and corrosion resistance. Markova and other [3] have studied the glass fiber board in the natural environment and acid environment treatment, the longitudinal bending performance of the sample, the glass steel has replaced the steel in many fields, such as automobile, ship shell, etc.

Glass steel pressure pipe due to the nature itself materials prone to aging, show the impact resistance performance is poor, eventually leading to the composite material structure performance is decreasing, even may cause great economic losses. Researchers to study for a long time, glass steel pressure vessel combined with practical experience summed up the various damage forms of the glass fiber reinforced plastic, such as matrix cracking, interface separation, fiber debonding and fiber breakage, etc. [4]. In order not to cause material damage, nondestructive testing techniques are used to test equipment performance.
NDT (Non-destructive Testing) is defined as: on the premise of not damaging the specimen, by means of physical or chemical method, with the help of advanced technology and equipment, the structure of the internal and surface of the specimens, nature and the state inspection and test methods.

Nondestructive testing is based on the development of modern science and technology. During the development of nondestructive testing technology, there are three stages: discovery stage, detection stage and evaluation stage. Nondestructive testing techniques have been developed over the years, and there are many relatively mature nondestructive testing methods at home and abroad, such as the four major nondestructive testing techniques: radiation, ultrasonic, magnetic powder and penetrating detection. Later, visual inspection, eddy current detection and magnetic leakage detection were introduced, and the detection of sound emission and phased array detection were developed with the development of technology. It is the four major conventional nondestructive testing techniques for the manufacturing quality of the pressure metal special equipment and the most commonly used nondestructive testing methods. RT and UT are mainly used to detect internal defects of specimens, and MT and PT are mainly used to detect surface defects of specimens. The non-destructive testing method of plastic pipe and equipment is mainly visual inspection, ultrasonic detection and ray detection.

Glass fiber reinforced plastic equipment due to the characteristics of material itself, its products performance difference is bigger, the factory inspection qualified products will appear leakage phenomenon in the process of practical application, and appear leakage often has reached the point of irreparable. Early prevention of leakage will need to find micro cracks, micro cracks and testing technology is commonly used in penetrant testing, liquid penetrant will try to introduce FRP equipment, and explore the characteristics of glass surface is suitable for penetrant testing is particularly important.

Based on FRP pipe, FRP lining partial fluorine ethylene and glass fiber reinforced plastic lining rigid PVC pipe as the research object, using penetrant testing, metal materials commonly used nondestructive testing technology is introduced into the glass fiber reinforced plastic material of surface crack detection test, and two kinds of glass fiber reinforced plastic and observed by a scanning electron microscopy (SEM) plastic surface morphology and analysis, at the same time, the prefabricated crack on the glass fiber reinforced plastic penetration test feasibility in FRP nondestructive testing, and puts forward requirements for glass fiber reinforced plastic products processing.

2. Experimental

2.1. Materials
FRP pipeline, FRP - PVDF pipeline for fiberglass reinforced plastics, frp-upvc pipeline, yade chemical equipment (Shanghai) co., LTD.
Cleaning agent, osmotic agent, imaging agent, Shanghai xinmeida flaw detection equipment co. LTD.

2.2. Equipment and instruments
Scanning electron microscope, Quanta 650, Czech, FEI;
Slicer, CUT 5062, SLEE, Germany.

2.3. Sample preparation
FRP, FRP - PVDF and FRP - UPVC tubing. Solid samples using slice mechanism for 20 μm thick sheet, set aside.

2.4. Penetration test
The test method is based on the NB/T 47013.5-2015 pressure equipment nondestructive testing part 5: penetration detection. The pipe pretreatment is used to clean the surface of the surface with cleaning
agent. Apply osmotic agent, the osmotic temperature range of 5°C ~ 50°C, lasts for no less than 10min. Dry treatment, remove excess penetrant, apply imaging agent, observe.

3. Results and discussion

3.1. Pipeline surface analysis
FRP early NDT research using X-ray, ultrasonic testing method, later will be introduced to the acoustic emission detection of glass fiber reinforced plastic resin cracking of pressure vessel, fiber breakage and acoustic signal recognition made some breakthrough. In the 1990s, the technology of ultrasonic scanning of composite materials was taken seriously, and it was widely used in the field of outdoor rapid detection. In the new century, computerized tomography is applied in FRP materials, which can be used to detect cracks, inclusions, stomata and stratified [5]. Infiltration failure is one of the reasons for the failure of polymer materials. In order to check whether there is an infiltration phenomenon that needs to be permeated, the surface of the material is selective.

No defects were found in the appearance of the three selected pipes. Select FRP piping for radial sampling, as shown in figure 1. The exterior observation of FRP pipe is two kinds of compound pipe of different materials. Through the SEM, the left of the pipe is shown in figure 1, the outer material of the pipe is shown, the middle image is the transition section, and the most right is the inner tube. Can clearly see from the picture the composite pipe of FRP pipe differences for the adding amount of glass fiber is different, the outer pipe main mechanical force to add a lot of fiber, plays a role of anti-corrosion lining the main fiber need not too much.

![Figure 1. Radial SEM image of FRP piping.](image1)

In order to verify the applicability of seepage detection in FRP piping, it is necessary to confirm whether the material of such pipeline and composite pipeline meets the conditions of penetration testing. The surface morphology of FRP, FRP-UPVC and FRP-PVDF were observed by SEM, and the characteristics of the three materials were to be prepared. The surface images of the three kinds of tubes were shown in figure 2. It can be seen from the figure that the surface of FRP is remarkably smooth and smooth than the surface of the other two kinds of materials. From the SEM images, the FRP surface can be judged to meet the requirements of penetration detection.

![Figure 2. SEM images of FRP (left), FRP - UPVC (middle) and FRP-PVDF (right).](image2)

The surface of the FRP-PVDF shows the surface of most plastics, and some of the mustard structure should be formed in the process of pipeline processing. Because of its molecular structure, FRP-PVDF has a relatively flat surface and a small uniform shallow pit, which is caused by shrinkage of materials and stress relaxation in the process of material processing.
FRP material surface is smooth, when the surface crack of material damage or will be introduced to the internal fiber layer, porosity will further increase, at the same time, also facilitate the defect amplification of penetration test more intuitive display defect position improve the sensitivity of permeability test, FRP lining structure as shown in figure 3.

Can be seen from the figure 3 cellulose in FRP surface enlarge figure can clearly see the distribution, can be seen from the diagram of cellulose in glass fiber reinforced plastic distribution more uniform and no winding and crosslinking. From the fiberglass scan, the fiberglass diameter is 23 μm, and the fiber is smooth and smooth.

3.2. Penetration detection
Before penetration testing, the surface of the sample must be processed to remove impurities or liquid contaminants that affect the experiment. The wet properties on the surface of non-metal specimens are different from the wet properties of the metal specimen surface. Before penetration testing of non-metal specimens, it is necessary to prefabricate the crack verification penetration test to satisfy this non-metal specimen [6].

Since all kinds of non-destructive testing methods have their own scope and limitations, new nondestructive testing methods have been continuously developed and applied. Generally, any physical, chemical, or other possible technical means may be developed into a nondestructive testing method, as long as the basic definition of nondestructive testing is met.

The FPR specimen was compressed, so that the surface of the surface was obviously cracked, and the permeation test was carried out, as shown in figure 4.

Can be seen from the graph, through the prefabricated crack penetration testing process can be clearly detected crack defects, can support penetrant test can be used in FRP material near the surface of the crack detection. In order to better verify the detection effect of osmotic detection in pipe, the permeation test of polymer materials of three kinds of materials is carried out, and the results are shown in figure 5. It can be seen from the figure that there are no obvious cracks in the three materials. The red stripe of the FRP image in the figure is not a crack in the process. Penetrant testing can effectively detect the defects on the surface of the sample and potholes, you can see from the picture the reflect on the crack of the penetrant test is quite sensitive and can see in the FRP - UPVC imaging figure some red dot, this is Nick, processing or the installation process pipeline penetration test can be
obviously visible reaction material form of near surface defects. When the pipe is processed or used in the process of scratches or cutting, the penetration detection can be found better, providing an intuitive data support for early warning and precautionary prevention. From FRP diagram in figure 5 shows that there are some red dots appear, this means there are some holes, usually by appearance test, may be difficult to find a small hole should be the cause of the curing process, these holes will be one of the causes of leakage, it is only by penetrant test found holes, and carries on the repair will reduce the possibility of leakage failure.

The penetration test can not only detect cracks in the surface of glass steel, but also have some applicability to the plastic pipe. It can be seen from FRP-UPVC that some scratches also show that the test results of the permeation test are verified because of the fragile installation process of UPVC materials. It can be seen from FRP-PDPE materials that there are no obvious cracks and defects in surface formation.

![Figure 5. Permeation test of FRP, FRP-UPVC and FRP-PVDF.](image)

### 4. Conclusions

Penetration testing is the most frequently used conventional nondestructive testing method, it is introduced into the polymer down especially of glass fiber reinforced plastic equipment, the use of glass fiber reinforced plastic equipment and safety protection will play a role in promoting further. In terms of high polymer material non-destructive testing technology also has a certain reference value, develop metal nondestructive testing technology out into the polymer materials by technical means the corresponding detection, in order to achieve the online non-destructive testing of polymer materials, to improve the detection and maintenance cost driven.

The surface morphology of three kinds of polymer materials was analyzed by scanning electron microscopy, and the determination of surface cracks applied to three kinds of materials was determined by the test of penetration test. Through the prefabricated cracks, the reagent of the metal penetration test is proved to be able to directly reflect the defect position. Finally, the penetration test was used to detect the near surface of three specimens without obvious cracks. The next step will be to study the research and penetration detection sensitivity of macromolecule material.

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