論文 / 著書情報
Article / Book Information

題目(和文)	薬液環境で用いるFRP製機器のRBIに資する非破壊検査の適用に関する研究
Title(English)	
著者(和文)	草野正大
Author(English)	Masahiro Kusano
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10137号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:久保内 昌敏,伊東 章,多湖 輝興,渕野 哲郎,青木 才子,水谷 義弘
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10137号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Non-destructive testing method for RBI of FRP equipment under chemical solutions

Masahiro Kusano

Department of Chemical Engineering

Tokyo Institute of Technology

FRP (Fiber Reinforced Plastic) equipment under chemical solutions degrades due to penetration of the solution and corrosion of the resin and fiber. In order to continue operating equipment under a severe condition for several decades, appropriate maintenance and non-destructive testing (NDT) are needed. However, NDT for FRP equipment is hardly performed except for a visual inspection because an appropriate NDT method for FRPs under solutions has yet to be determined.

In addition, chemical companies have recently started considering introducing Risk Based Maintenance (RBM) and Risk Based Inspection (RBI) into their plants as a screening standard for maintenance. RBM and RBI standardize on risks of all components in the plant to decide the priority of maintenance and to select the most effective inspection method for risk reduction. A large number of metals have been used as construction materials in chemical plants so that failure databases and knowledge help to evaluate the risk of metal equipment. On the other hand, compared with metal materials, the lack of knowledge and information on FRPs makes risk evaluation difficult.

In this thesis, the risk of FRP equipment was eliminated based on detailed degradation analyses of several FRP tanks used in chemical plants. Then, ultrasonic testing (UT) was applied to the FRP tanks to confirm the appropriateness and precision as NDT for FRPs. Furthermore, a relative new optical analysis method, Terahertz spectroscopy, was also used to evaluate penetration of chemical solutions into resin. Finally, the risk after inspection was decide based on the preciseness of a NDT method. These results will greatly help to introduce RBM and RBI on FRP equipment in chemical plants.

This thesis is composed of 8 chapters as below:

Chapter 1 Introduction

In this chapter, degradation and maintenance of FRP equipment in chemical plants is introduced in detail. The purpose and the direction of this study are also shown here.

Chapter 2 Degradation analyses of FRP equipment in chemical plants

Three kinds of samples from FRP tanks that contained sulfuric acid, sodium hypochlorite and, hydrochloric acid aqueous solutions for many years in chemical plant were analyzed by visual observation, Scanning Electron Microscope (SEM), Energy Dispersive x-ray Spectroscopy (EDS), FT-IR and mechanical strength testing. The degradation behavior mainly depended on the solution types. The degradation phenomena, speeds and mechanisms were discussed here.

Chapter 3 The failure probability evaluation of FRP equipment

The failure probability of FRP equipment was evaluated based on the degradation analyses in chapter 2. The concept of limit state function that strength and load were described as probability density function was applied on the evaluation. The data of degradation analyses help to predict the strength and thickness of FRP equipment. While the expected value was assigned to the average of normal distribution, a certainty of the value was described as standard deviation. This process successfully shows the failure probability of FRP equipment.

Chapter 4 Ultrasonic testing for FRP equipment

Ultrasonic testing (UT) was applied on FRP tanks analyzed in chapter 2 to evaluate its performance and measurement precision for NDT. The effect of some factors such as ultrasonic propagation in FRPs and inspection conditions on the inspection result was discussed. The roughness of inner surface of tanks and the contained liquid decreased the precision of UT.

Chapter 5 A ultrasonic pitch-catch method for simultaneous thickness measurement of the pristine part and corrosion layer

A general UT method using a normal probe cannot measure thickness of a specimen composed of a pristine part and a corrosion layer. In order to solve this problem, a new method using two angle probes with pitch-catch arrangement was proposed. The validation of this new method was confirmed by measuring a two layered model sample and comparing the results with true values.

Chapter 6 Terahertz spectroscopy for FRP degradation under chemical solutions

Since Terahertz spectroscopy is a promising tool to evaluate water content in a non-conductive material, it is expected that the spectroscopic technique also can measure penetrants in FRPs. In this chapter, transmission spectra of thermosetting resin specimens immersed in acidic and basic solutions were acquired by Terahertz time-domain spectroscopy (THz-TDS) and their complex refractive index spectra were measured. The complex refractive index increased with penetrants such as water and acids in the resin. Furthermore, in the imaginary part of the complex refractive index, acid penetrants caused lager increment in higher frequencies. This spectral feature can help to identify penetrants such as acids.

Chapter 7 Inspection updating of the failure probability

The failure probability of FRP equipment was eliminated in chapter 3. In this chapter, the probability was updated based on inspection data such as UT in chapter 4. The update procedure was derived from Bayesian statistics. The updated probability reflects both the degradation analyses in chapter 2 and inspection data by NDT methods discussed in chapters 4 – 6. Inspection effectiveness was also proposed for selecting an appropriate NDT method on a risk target of FRP equipment.

Chapter 8 Conclusion

The conclusions obtained in this work were summarized here.