ACTIVE AND PASSIVE ELECTRIC POTENTIAL CT METHODS INCORPORATING INVERSE ANALYSIS SCHEMES FOR CRACK AND DEFECT IDENTIFICATION

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ABSTRACT

The active and passive electric potential CT (Computed Tomography) methods incorporating inverse analysis schemes for crack identification using the inverse analyses are described. The active method uses the electric potential distribution observed on the surface of the body under electric current application to identify the cracks and defects. The inverse analysis methods were constructed based on comparison between the measured electric potential and that calculated using the boundary element method. The passive electric potential CT method, which does not require the application of the electric current, can be constructed by gluing piezoelectric film on the surface of a cracked structure subjected to mechanical load. The electric potential incurred by mechanical load was used to identify cracks and defects. The electric filed was calculated by applying the finite element method, which takes into account the coupled effect of the strain field and the electric field. The applicability of the passive electric potential CT method was examined numerically and experimentally for a two-dimensional through-crack model. It was found that a characteristic electric potential distribution appeared on the piezoelectric film. The crack can be identified from the electric potential distribution.

1. INTRODUCTION

Non-destructive and real-time damage monitoring is important for maintenance of structures such as, aircrafts, space structures or nuclear power plants. Non-destructive crack identification is recognized as a domain/boundary inverse problem [1], which deals with the estimation of an unknown boundary. There are many conventional NDT (non-destructive testing) methods, such as the ultrasonic method, the radiation method, and the eddy current method. The electric potential method one of those methods, which can be applied for monitoring of cracks and defects. Inverse analysis schemes can be incorporated in the electric potential method to identify the cracks and defects qualitatively and objectively. This paper describes the electric potential CT (computed tomography) methods incorporating the inverse analysis schemes for crack and defect identification.

2. ACTIVE ELECTRIC POTENTIAL CT MEHOTD

The present authors proposed the active electric potential CT (computed tomography) method for the detection and quantitative identification of cracks [2-4]. In this method the electric potential distributions observed on the surface of cracked body under electric current application is used to identify the crack. For the objective identification of the cracks, inverse analysis schemes based on inverse boundary integral equation method and also on the least residual between the measured and the computed electric potential distributions were applied. Many numerical simulations and experiments conducted showed the applicability of the method for the identification of cracks in two-dimensional and three-dimensional bodies [2-4]. The method was extended to the identification of cracks in dissilimar materials and anisotropic materials. The identification of interface delamination in carbon fiber reinforced composites was also made.

3. PASSIVE ELECTRIC POTENTIAL CT MEHOTD

On piezoelectric material electrical charge proportional to a change in mechanical strain is incurred. When the piezoelectric film is glued on cracked body, which undergoes mechanical load, electric potential distribution is incurred due to the piezoelectric effect without applying the electric current on the cracked body. Li et al. [5] made theoretical and numerical investigation on the development of crack identification technique for the structures on which piezoelectric material was installed.

In piezoelectric material mechanical and electrical effects are coupled. Finite element method can be applied to calculate the electric field on the piezoelectric film as well as the deformation field.

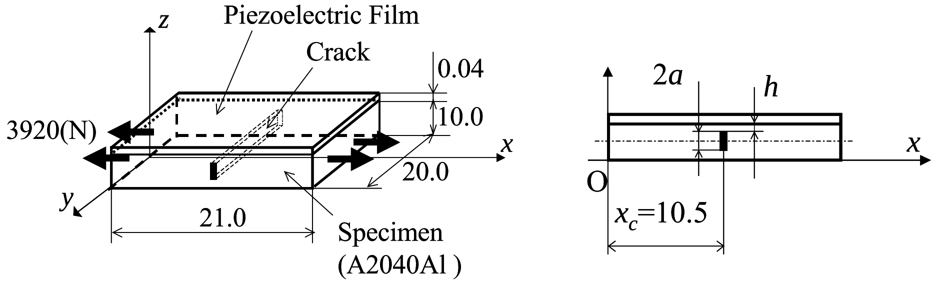

Fig. 1 A model with a through-thickness crack

The present method can be applied to structures or components subjected to mechanical load which gives rise to electric potential change on the piezoelectric film. As a simplest model under uniform tension, a through-thickness crack shown in Fig. 1 is employed. This model consists of an elastic substrate material and a PVDF film. The half crack length is shown by a, its location is designated by crack depth h from surface of the plate and longitudinal location x_c in the x-direction.

Figure 2 shows the electric potential distributions calculated using the finite element method for several crack lengths a, with keeping crack depth h constant. It is found from Fig. 2 that the electric potential value has two peaks symmetrical with respect to the crack location. The location of local minimum between the two peaks of potential coincides with location of the crack. It is also found that the peak value of electric potential ϕ_{max} increases with increase in crack length a.

As the inverse analysis method for identification of cracks, the least residual method was applied. In this method, the residual is evaluated between the computed electric potential distribution $\phi^{(c)}$ and the measured distribution $\phi^{(m)}$. The combination of crack location and size, which minimized R_s, was employed as the most plausible one among all the assumed combinations of the crack location and size.

For effective inverse analysis, a hierarchical calculation scheme was introduced, in which rough estimation was followed by detailed estimation using an optimization scheme.

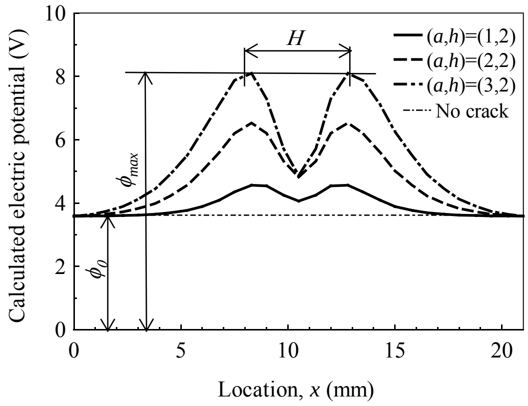

Fig. 2 Electric potential distribution calculated for several crack lengths a

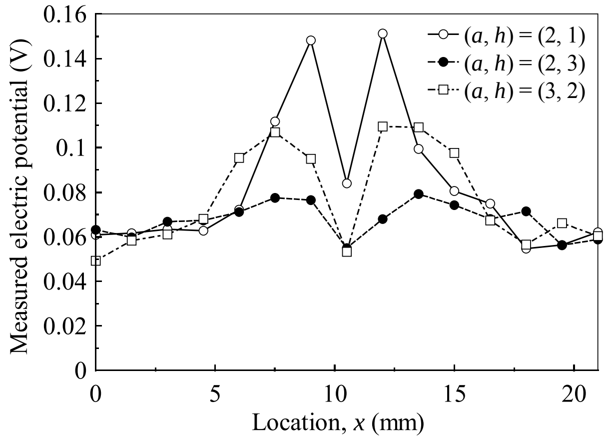

Fig. 3 Measured electric potential distributions

The electric potential distribution on the piezoelectric film was measured with contact type potential measurement method. Figure 3 shows the measured electric potential on the piezoelectric film for three combinations of crack length a and crack depth h. Two peaks are observed for each combination of length a and crack depth h. It is expected that the crack location and crack length can be estimated from the distributions.

Table 1 Estimated parameters of cracks

(a, h)		Parameters of crack			Residual
		A	h	x_c	$\mathbf{R_s}$
(2, 1)	Estimated	2.15	1.25	10.5	0.24
	Actual	2.0	1.0	10.5	
	Error (%)	7.5	25	0	
(3, 2)	Estimated	3.10	2.18	10.3	0.32
	Actual	3.0	2.0	10.5	
	Error (%)	3.3	9.0	1.9	
(2, 3)	Estimated	1.93	3.25	10.8	0.076
	Actual	2.0	3.0	10.5	
	Error (%)	3.5	8.3	2.9	

The least residual method was applied to estimate the crack location and the crack size. The estimated crack parameters using the least residual method are shown in Table 1. It is found from the table that the crack parameters can be estimated in a good accuracy and that the clectric potential CT method can be applied to the identification of the crack.

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