A Study of Contact Interface for an Anti-Rotation Rivet Using Ultrasonic Detection

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(Received 16 December 2016; accepted 19 February 2018)

This work measures the contact area between an anti-rotation rivet and an aluminum plate under different riveting loads based on the regional scanning of ultrasound. The contact image is a novel disclosure for the anti-rotation rivet contact. The 2D maps show an apparent change not only in area sizes but also in contact shapes under various normal forces applied. The 3D contact images also provide useful information to show the intensity of contact.

The contact area between the anti-rotation rivet and the aluminum is calculated using an image analysis software package. The range of contact areas varies from 6.3 mm$^2$ to 57.2 mm$^2$, depending on the applied forces and the definition of the contrast ratio. Furthermore, a calibration of data fitting is performed to provide a useful polynomial equation for contact area estimation. In addition, maps of both a reflection coefficient and a pressure contour distribution are presented. The range of peak contact pressure varies from 7.1 MPa to 11.2 MPa.

1. INTRODUCTION

Prior to the wide application of welding and bolt technology, many metal structure buildings were fixed by riveting, such as the Eiffel Tower and the Sydney Harbor Bridge. Previously, many metal structure buildings were fixed by riveting, such as the Eiffel Tower and the Sydney Harbor Bridge. Previously, some car chassis were fixed by riveting. In modern car manufacturing, self piercing rivets (SPR) are widely used for aluminum plates by using self piercing rivets by Hoang et al. and Abe et al. It is well known that the fracture behavior occurs significantly depending on the stress state. Numerous studies on the stress concentration of two-dimensional plates with circular holes subjected to several loading types were summarized in the literature. Eddy current detection is the most common method used to examine riveting in conventional structure. He et al. used a pulsed eddy current technique to examine the defects in multi-layer structures of aircrafts. Diraison et al. and Liu et al. used an eddy current method to investigate the aircraft lap-joint riveting. However, the conventional rivets were not the subject in this study. Instead, an anti-rotation rivet with special contact surface which has the ability of torsional resistance was the focus of this work.

Conventional rivets are fasteners that are used to affix two work pieces mechanically and permanently. Rivets usually consist of a head (or flange) and a shaft that is inserted into a hole of the affixed parts. They can support tension forces parallel to the shaft and shear forces perpendicular to the shaft depending on the material limits of the rivet and the structures being affixed. Yan et al. performed experimental investigation for the shear strength of self-piercing rivet connections and suggested a design method for thin-walled steel structures. Recently there were a few patented rivets proposed to provide torsion resistance, which were used for special applications. In this application, the rivets were designed to have a corrugated surface, which can comprise ridges having height. The ridges were comprised of inclined ramps sloping from the contacting side to the height of the ridge. It was not only to support high shear force and tension force, but also to prevent rotation for the purposed rivets. The characteristic for these rivets was to provide ability of anti-rotation.

There was almost no research concerning these special purposed rivets. In this work, the objective was to study the contact interface for the anti-rotation rivet, the measurement of the contact area and the estimation of contact pressure. While studying the contact stress, there was no doubt that contact area size plays an important role in doing relative studies.

In contrast with the usual single contact between two common objects, an anti-rotation rivet usually has several contact points between the rivet and the workpiece. It was difficult to apply theoretical models to predict the multiple contact regions between two objects. An efficient and convenient method to investigate the contact interface and to measure the area size was to use both ultrasonic scanning and signal processing. A sin-

NOMENCLATURE

- $A$: contact area
- $R$: reflection coefficient
- $z_i$: acoustic impedance
- $\omega$: angular frequency
- $K$: stiffness of interface
- $p$: contact pressure
- $u$: mean surface roughness
- $UPR$: ultrasonic pulse receiver
- $FFT$: Fast Fourier Transform
- $PIA$: Power Image Analysis
- $c_i$: polynomial parameters of equation
- $q$: arbitrary constant
- $S_j$: the jth signal amplitude.
- $f$: focal length in water
- $c_w$: speed of sound in water
- $f$: ultrasonic frequency
- $D$: transducer element diameter

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