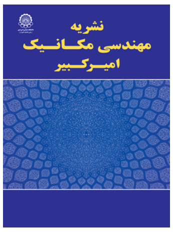

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Condition monitoring of defective single lap adhesive joint using carbon nanotubes

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ABSTRACT: Adhesive joints have been employing in engineering structures such as marine, aerospace, automotive, oil, and gas industry. Since the joints are the weakest part of engineering structures, the fracture possibility in the adhesive joint is high. Therefore, structural health monitoring of adhesive joint is an important issue. The aim of this paper was condition monitoring of damage in the single lap adhesive joint by multiwall carbon nanotubes. This work is carried out by recording the electrical resistance change during the mechanical loading. This damage propagation is observed as a crack extension in the adhesive joint. Firstly, carbon nanotubes with 9 wt.% are dispersed in an epoxy resin by an ultrasonic device. Then, the hardener is added to the nono-adhesive. The obtained material is immediately poured into a single lap adhesive joint mold. The defective adhesive joints were manufactured with circular and square defects in different sizes i.e. 10%, 30%, and 70% overlap area. The specimen is subjected to a tensile test and electrical resistance changes are recorded during the shear load. The results showed that the maximum value of relative resistance change is occurring in the adhesive joint comprises of square defect with 30% overlap area of defect. In this situation, the crack was propagated in nano-adhesive and a small part of a crack was extended from the defect boundary.

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1. INTRODUCTION

Adhesive joints are employed for joining components in various industries such as marine, aerospace, automotive, oil, and gas industry. In comparison to traditional mechanical fastening approaches has advantages such as uniform stress distribution around the bonding area which increase their capabilities in real applications. However, the evaluation of adhesive joints requires complicated methods like nondestructive inspections [1, 2]. The emergence of nanotechnology has enabled the tailoring of a variety of functional properties through nanoscale modification. Due to their physical properties, they have some extraordinary features such as electrical and mechanical properties. Among these nanoscale particles, carbon nanotubes have found use in many structural health monitoring applications [3-5], including damage sensing of composite structures [6].

The present study evaluates the different fracture mechanisms of the defective single lap adhesive joints by carbon nanotubes. For this purpose, an alternating current under quasi-static loading conditions was used for all specimens.

2. EXPERIMENTAL

Fig. 1 shows Single Lap adhesive Joint (SLJ) specimens that are prepared for electro-mechanical experiment. The adhesive layers comprise multiwall-carbon nanotubes with 9 wt.% as nanoparticles and epoxy adhesive as a polymer matrix. The adherents are manufactured according to the ASTMD5868-01 standard with a thickness t = 3 mm, length La = 102, and width w = 25 mm. The mechanical properties are given in Table 1. To assess the effects of macroscopic defects on the electrical response of the SLJs, three different sizes (10%, 30%, and 70% overlap area) and two shapes (circle and square) of defects, with td = 1 mm thickness, are embedded in the center of the adhesive layer. Non-conductive end tabs made of fiberglass/Araldite 2015 and polyamide are attached to the adherents by Araldite 2015 to make an alignment in the universal tensile machine so that the centerline of the upper and lower tabs pass through the middle of the adhesive. The electrical and mechanical measurement setup is illustrated in Fig. 2. Left is the SLJ-specimen, in universal tensile test machine which, on one side, is connected to the input analog amplifier chain as part of the resistance measurement hardware. The other side is connected to the output of the measurement hardware, applying a digitally generated sine signal. In the digital domain, the measurement platform also provides the algorithms necessary for signal processing, e.g. down-conversion of the acquired signal. Via the shunt resistance of $R_s = 50\ \Omega$, a voltage reading is recorded which is proportional to the resistance of the sample.

3. RESULTS AND DISCUSSION

Fig. 3 shows the fracture surface for defective SLJ specimens after shear load. It reveals that crack propagated from adhesive and defect boundary or extended from the intersection between adherend and adhesive. General

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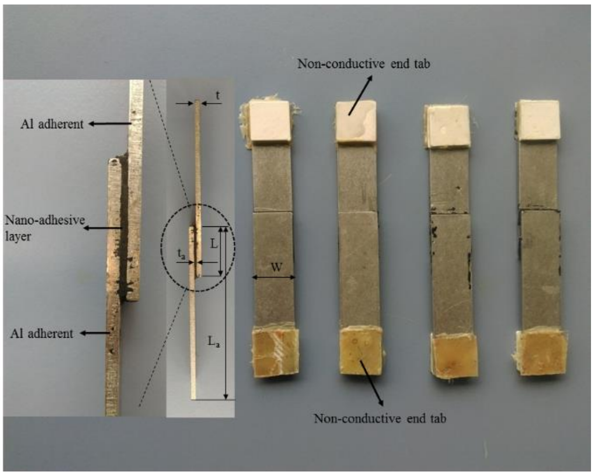

Fig. 1. Single lap adhesive joint specimens

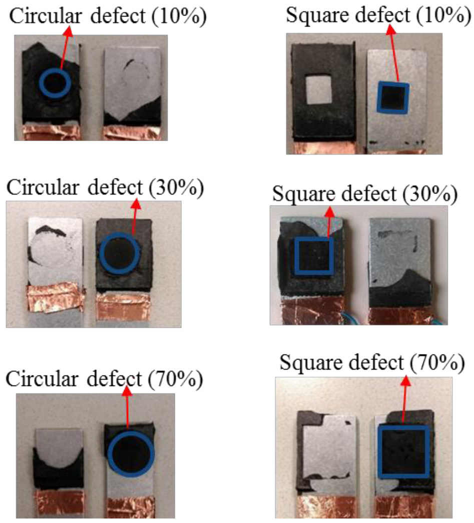

Fig. 3. Fracture surface of defective adhesive joint

Table 1. Mechanical properties of AL-Mg3

Poisson's ratio	Elastic modulus	Ultimate strength	Yield strength
0.33	68 GPa	330 MPa	280 MPa

Table 2. Impedance change for defective adhesive joints

Defect size	*ΔR/R* (%) in SLJ with circular defect	*ΔR/R* (%) in SLJ with square defect
10%	18%	3.5%
30%	15%	220%
70%	6%	7%

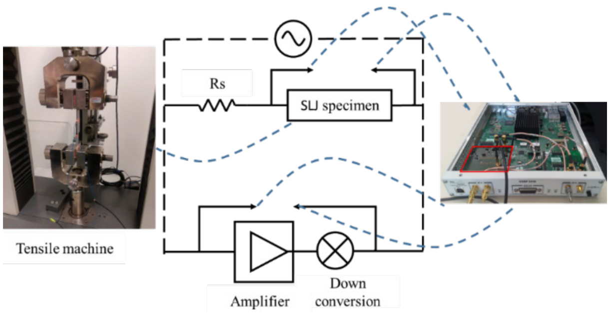

Fig. 2. Electrical measurement setup during the tensile test

impedance changes ($\Delta R/R$) are shown in Table 2. It seems the SLJ with 30% square defect area displays the highest $\Delta R/R$ by 220%. The correlation between $\Delta R/R$ and shear load versus recorded displacement during the tensile test are shown in Fig. 4. It is seen by increasing the shear load, the $\Delta R/R$ has increased. A sharp increase in resistance occurs at displacement d=0.32 mm and F/F_{max}=80%. It is induced by the change in crack direction in the defect boundary.

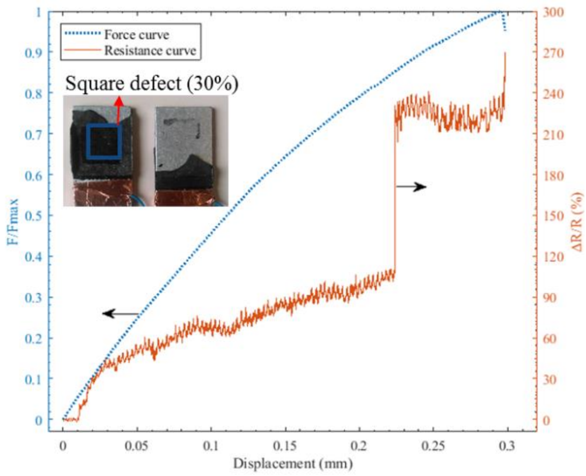

Fig. 4. Mechanical and electrical response of SLJ including 30% square defect area

4. CONCLUSIONS

The presented study focuses on the condition monitoring of defective SLJs using conductive nano-adhesive. Conductive nano-adhesive was prepared by 9 wt.% carbon nanotubes. The electro-mechanical analysis was studied for defective adhesive joints with defect areas of 10, 30, and 70% in circular and square shapes. The results showed that the maxim change in impedance occurs when the crack extends in square defect with 30% defect area.

5. ACKNOWLEDGMENT

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