UNIVERSITI PUTRA MALAYSIA

IMPACT BEHAVIOUR OF COMPOSITE PLATE WITH EMBEDDED PIEZOELECTRIC SENSOR

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair : Mohd Roshdi Hassan, PhD

Faculty : Engineering

In engineering sciences, control and maintenance of the composite structures against environmental impacts is very important. Sensors are used for identifying impact location on the composite structures. Piezoelectric sensors are applied in two forms; bonded (on the composite) and embedded (in the composite) for identifying impact location. Regarding to importance of embedding the sensors in the composite plate, in this study, at first, a PZT sensor (PIC155) was embedded in four layers of woven fibre glass using cut-out method. For evaluating behaviour of the output voltage versus distance of impact point from the sensor, many points on the composite plate were impacted and the output voltage was detected. Three samples were fabricated in

this study. Sample 1 included a PZT sensor and four layers of fibreglass in which all the fibres of layers were parallel (0/90/90/0). Sample 2 included a PZT sensor and four layers of fibre glass in which fibres of the first and the forth layers (bottom and top of the plate) made an angle of 45^o with fibres of second and third layers (45/90/90/45). Results of impact tests on sample 1 showed for the points by the minimum distance (10mm) from PZT sensor the maximum voltage (5.7 V), and for the points by the maximum distance (60mm) from PZT sensor the minimum voltage (0.96 V) was gained. Results of impact tests on sample 2 showed for the points by the minimum distance (10mm) from PZT sensor the maximum voltage (8.7 V), and for the points by the maximum distance (60mm) from PZT sensor the minimum voltage (3.5 V) was gained. Therefore, the output voltage of the sensor had indirect relation with distance of the impact point from the sensor. When the impact point distance from sensors increased, the output voltage decreased. The difference of output voltage between sample 1, and sample 2 was because of different velocity of wave propagation in sample 1 (c_1=1058.78 m/s) and sample 2 (c_2=1745.87 m/s) caused by deferent orientation of sample 1 (0/90/90/0) and sample 2 (45/90/90/45). For identifying impact location on the composite plate with a PZT Patch, impact happened on the random points of the composite, and the locus of the impact point was identified by output voltage. The locus of the impact was a circle that R was radius and sensor was the centre. It should be mentioned that R was calculated by output voltage. Sample 3 included two PZT sensors and four fibre glass layers (orientations of the third sample was the same as the second sample). For identifying impact location using two sensors, output voltages of the sensors were analysed. Results of impact tests on sample 3 showed when the impact point distance from sensor 1 increases (from 2 to 12 cm), and from sensor 2 (from 12 to 2cm) decreases,

V_1 decreases (from 7.98 to 0.8 V), and V_2 increases (from 0.72 to 7.6 V), respectively. Results showed that the locus of the impact point was crossing points of the two circles with radii R_1 and R_2. R_1 and R_2 were calculated by output voltages. Therefore, by supposing one of the two sensors as the origin of the Cartesian coordinate, the impact location can be identified.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KELAKUAN HENTAMAN PLAT KOMPOSIT BERPENGESAN PIEZOELECTRIK TERTANAM

Oleh

MOHAMMAD MEHDI SALEHI DEZFOULI

Januari 2011

Pengerusi : Mohd Roshdi Hassan, PhD

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Dalam sains kejuruteraan, pengetahuan dan penyelenggaraan dalam mengawal struktur komposit terhadap kesan persekitaran sangat penting. Pengesan telah digunakan untuk mengenalpasti lokasi impak pada struktur komposit. Pengesan piezoelectrik diterapkan dalam dua bentuk; Berikat (pada komposit) dan tertanam (dalam komposit) untuk mengenalpasti lokasi impak. Sehubungan dengan pentingnya penanaman pengesan di plat komposit, dalam kajian ini, pada permulaanya, satu pengesan PZT (PIC155) telah di tanam diantara empat lapisan dari kaca serat tenunan menggunakan kaedah "cut-out". Untuk menilai perilaku

voltan keluaran versus jarak titik impak dari pengesan, banyak titik-titik pada plat komposit diberi kesan impak dan voltan keluaran dikesan. Tiga sampel dibuat dalam kajian ini. Sampel pertama memasukkan pengesan PZT diantara empat lapisan kaca serat di mana semua lapisan serat yang sejajar (0/90/90/0). Sampel kedua memasukkan pengesan s PZT diantara empat lapisan kaca serat di mana lapisan pertama dan keempat (lapisan atas dan bawah) membuat sudut 45^{o} dengan lapisan kedua dan ketiga (45/90/90/45). Keputusan bagi ujian impak bagi sampel 1 menunjukkan, bagi titik impak yang minimum (10mm) dari pengesan PZT, voltan maksimum (5.7 V) telah diperolehi, dan bagi titik yang mempunyai jarak maksimum (60 mm) dari pengesan PZT, maka voltan minimum (0.96 V) telah diperolehi. Keputusan bagi ujian impak bagi sampal 2 menunjukkan, bagai jarak impak yang minimum (10 mm), voltan akan menunjukkan maksimum (8.7 V), sementara bagi titik yang jarak maksimum (60 mm) dari pengesan PZT, voltan minimum (3.5 V) akan diperolehi. Oleh itu, voltan keluaran dari pengesan mempunyai hubungan dengan jarak impak dari pengesan. Apabila jarak impak bertambah dari pengesan, maka voltan keluaran akan berkurangan. Perbezaan voltan keluaran bagi sampel 1 dan sampel 2 adalah disebabkan oleh perbezaan halaju perambatan gelombang dalam sampel 1 (c_1=1508.78 m/s), dan sampel 2 (c_2=1745.87 m/s) yang disebabkan oleh perbezaan orientasi bagi sampel 1 (0/90/90/0), dan sampel 2 (45/90/90/45). Keputusan ujian kesan pada berbagai titik dari dua sampel menunjukkan bahawa voltan keluaran dari pengesan mempunyai hubungan langsung dengan jarak dari titik impak untuk pengesan. Untuk mengenalpasti lokasi berdampak pada plat komposit dengan Patch PZT, kesan yang berlaku pada titik-titik rawak dari komposit, dan tempat kedudukan dari titik impak dikenalpasti dengan voltan keluaran. Lokasi impak adalah pada lingkaran yang R adalah jejari dan pengesannya ditengah. Perlu disebutkan bahawa R dikira oleh voltan output. Sampel ketiga adalah memasukkan dua pengesan PZT pada empat lapisan serat kaca (orientasi sampel ketiga adalah sama dengan sampel kedua). Untuk mengenalpasti lokasi kesan impak menggunakan dua pengesan, voltan keluaran daripada pengesan dianalisis. Keputusan ujian impak pada sampel 3 menunjukkan, apabila jarak tempat titik impak dari pengesan 1 meningkat (dari 2 ke 12 cm), dan dari pengesan 2 (dari 12 ke 2cm) mengurang, V1 tealh mengurangkan (dari 7.98 ke 0.8 V), dan V2 telah meningkat (dari 0.72 ke 7.6 V), masing-masing.

Keputusan kajian menunjukkan bahawa lokasi impak adalah titik persimpangan dua lingkaran R_1 dan R_2 . R_1 and R_2 adalah jejari bagi dan sensor. R_1 dan R_2 dikira oleh voltan keluaran. Oleh kerana itu, dengan mengandaikan salah satu pengesan sebagai asal bagi koordinat Cartes, lokasi kesan dapat dikenalpasti.

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I certify that a Thesis Examination Committee has met on to conduct the final examination of Mohammad Mehdi Salehi Dezfouli on his Master of Science thesis entitled IMPACT BEHAVIOUR OF COMPOSITE PLATE WITH EMBEDDED PIEZOELECTRIC SENSOR in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the students be awarded the relevant degree. Members of the Examination Committee are follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

MOHAMMAD MEHDI SALEHI DEZFOULI

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