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Finite Element Analysis of a Repaired Cracked Aluminium Plate with Piezoelectric Patches under Mechanical and Thermal Loading

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Abstract
In thin plate structures, the use of piezoelectric actuators for active repairs can significantly decelerate the progression of crack damage. The prevalent mode-I fractures, wherein tension causes the opening displacement leading to failure, undermine the structural integrity required for load support. This current research endeavors to explore how piezoelectric (PZT) actuators influence the repair efficacy of fractured structures. The ANSYS software was harnessed to conduct the study, employing the finite element method. Additionally, the study delved into the repercussions of thermal heating and performed a parametric analysis to gauge their impact on the restoration efficiency of the compromised structure. The outcomes unveiled that the application of a negative electric field through the PZT actuator effectively diminishes the stress intensity factor (SIF) at the crack tip. Moreover, it was determined that thermal stresses contribute to a 57% augmentation in SIF, posing a heightened risk of structural failure. The study's deductions emphasize the desirability of utilizing a slender actuator alongside optimally adjusted adhesive thickness to attain a more pronounced reduction in SIF.

Author Keywords
Active repair; PZT actuator; stress intensity factor

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References

- Kamat, Seri Rahayu, Hassan, Fatimah Md, Mahmood, Wan Hasrulnizzam Wan, Ani, Mohammad Firdaus
  Critical factors influencing project on effective maintenance, repair and overhaul (MRO) in aircraft aviation industry
  (2021) *Malaysian Journal on Composites Science and Manufacturing*, 4 (1).
- Abdulla, Mohammed, Hrairi, Meftah, Aabid, Abdul, Abdullah, Nur Azam
  Influence of Adhesive Curing Temperature and Geometrical Parameters on Composite Patch Repair of Cracked Structures
  (2024) *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 119 (1), pp. 1-12.
- Aabid, Abdul, Parveez, Bisma, Raheman, Md Abdul, Ibrahim, Yasser E., Anjum, Asraar, Hrairi, Meftah, Parveen, Nagma, Zayan, Jalal Mohammed
  A review of piezoelectric material-based structural control and health monitoring techniques for engineering structures: Challenges and opportunities
  (2021) *Actuators*, 10 (5), p. 101.
  MDPI
- Elahi, Hassan
  The investigation on structural health monitoring of aerospace structures via piezoelectric aeroelastic energy harvesting
  (2021) *Microsystem Technologies*, 27 (7), pp. 2605-2613.

- Elahi, Hassan, Munir, Khushboo, Eugeni, Marco, Abrar, Muneeb, Khan, Asif, Arshad, Adeel, Gaudenzi, Paolo
  A review on applications of piezoelectric materials in aerospace industry
  (2020) *Integrated Ferroelectrics*, 211 (1), pp. 25-44.

- Mishra, Ranjan Kumar
  A review on fracture mechanics in piezoelectric structures
  (2018) *Materials Today: Proceedings*, 5 (2), pp. 5407-5413.

- Anjum, Asraar, Hrairi, Meftah, Aabid, Abdul, Yatim, Norfazrina, Ali, Maisarah
  Examining the Efficacy of Finite Element Method for Detecting Damage in Aluminium Structures
  (2024) *Journal of Advanced Research in Applied Mechanics*, 120 (1), pp. 110-121.

- Aabid, Abdul, Hrairi, Meftah, Jaffar Mohamed Ali, Syed, Ibrahim, Yasser E.
  Review of piezoelectric actuator applications in damaged structures: Challenges and opportunities
  (2023) *ACS omega*, 8 (3), pp. 2844-2860.

- Jafari Fesharaki, Javad, Madani, Seyed Ghasem, 'id Golabi, Sa
  Best pattern for placement of piezoelectric actuators in classical plate to reduce stress concentration using PSO algorithm
  (2020) *Mechanics of Advanced Materials and Structures27*, (2), pp. 141-151.

- Fesharaki, Javad Jafari, Madani, Seyed Ghasem, 'id Golabi, Sa
  Effect of stiffness and thickness ratio of host plate and piezoelectric patches on reduction of the stress concentration factor
  (2016) *International Journal of Advanced Structural Engineering*, 8, pp. 229-242.

- Hai, Tran Thanh
  Static repair of multiple cracked beam using piezoelectric patches
  (2021) *Vietnam Journal of Mechanics*, 43 (2), pp. 197-207.

- Abuzaid, Ahmed, Hrairi, Meftah, Kabrein, Hashim
  Stress analysis of plate with opposite semicircular notches and adhesively bonded piezoelectric actuators
  (2020) *Vibroengineering Procedia*, 31, pp. 134-139.

- Kumar, Ritesh, Singh, Akhilendra, Tiwari, Mayank
  Life enhancement of cracked structure by piezoelectric patching underneath thermo-mechanical loading environment
  (2022) *Mechanics of Advanced Materials and Structures*, 29 (27), pp. 6231-6241.

- Abbood, Hayder M., Al Ghanimi, Abdulsattar K.
  Smart Materials Technologies and Applications in Mechanical Engineering and Renewable Energies
  (2019) *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 64 (2), pp. 196-205.

- Djemana, Mohamed, Hrairi, Meftah, Yatim, Norfazrina Hayati Mohd
  Improving electromechanical impedance damage detection under varying temperature
  (2022) *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 92 (1), pp. 123-133.

- Zaman, Izzuddin, Badrin, Muhammad Izzat, Salleh, Muhammad Mohamed, Manshoor, Bukhari, Khalid, Amir, Amin, Nasrul Amri Mohd, Sambu, Mathan, Samy, Yuwaraja
  Exploring the Influence of Geometrical Parameters on Piezoelectric Vibration Energy Harvester: From Experiment to Simulation Investigation
  (2024) *Journal of Advanced Research in Applied Mechanics*, 119 (1), pp. 37-52.

- Kumar, Ritesh, Singh, Akhilendra, Tiwari, Mayank
  Investigation of crack repair using piezoelectric material under thermo-mechanical loading
  (2020) *Journal of Intelligent Material Systems and Structures*, 31 (19), pp. 2243-2260.

- Kumar, Ritesh, Pathak, Himanshu, Singh, Akhilendra, Tiwari, Mayank
Modeling of crack repair using piezoelectric material: XFEM approach
(2021) *Engineering Computations*, 38 (2), pp. 586-617.

- Djemana, Mohamed, Hrairi, Meftah, Yatim, Norfazrina Hayati Mohd
Numerical Simulation of Electromechanical Impedance Based Crack Detection of Heated Metallic Structures
(2022) *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 94 (2), pp. 77-88.

- Abuzaid, Ahmed, Hrairi, Meftah, Shaik Dawood, MSI
Experimental and numerical analysis of piezoelectric active repair of edge-cracked plate
(2018) *Journal of Intelligent Material Systems and Structures*, 29 (18), pp. 3656-3666.

- Aabid, Abdul, Hrairi, Meftah, Abuzaid, Ahmed, Syed Mohamed Ali, Jaffar
Estimation of stress intensity factor reduction for a center-cracked plate integrated with piezoelectric actuator and composite patch
(2021) *Thin-Walled Structures*, 158, p. 107030.

- Kumar, R., Singh, A., Tiwari, M.
(2020) *Investigation of Crack Repair in Orthotropic Composite by Piezoelectric Patching*, [Online]. Available: https://doi

- Benyahia, Faycal, Albedah, Abdulmohsen, Abbes Bachir Bouiadjra, Bel
Elliptical and circular bonded composite repair under mechanical and thermal loading in aircraft structures
(2014) *Materials Research*, 17, pp. 1219-1225.

- Abuzaid, Ahmed, Hrairi, Meftah, Shaik Dawood, MSI
Modeling approach to evaluating reduction in stress intensity factor in center-cracked plate with piezoelectric actuator patches
(2017) *Journal of Intelligent Material Systems and Structures28*, (10), pp. 1334-1345.

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