



Post-yielding fracture mechanics of 3D printed polymer-based orthopedic cortical screws

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Abstract

The internal fixation of a fractured bone is generally achieved with bone screws during most orthopedic surgeries. Biodegradable screws have not received as much attention as they deserve. Biodegradable screws reduce the stress-shielding effect, screw failure, complex, painful revision surgery for screw extraction. The vital focus of the present research is to fabricate cortical bone screws using polylactic acid (PLA) by fused deposition modeling technology. The PLA cortical screws were manufactured with different infill patterns (triangular, honeycomb, grid, and concentric), keeping other parameters constant using three-dimensional printing. The mechanical behavior and fracture mechanism of different patterned cortical screws were observed based on compression testing and tensile testing of screws. Scanning electron microscopy (SEM) observed the surface topographical features, fracture behavior, and microstructure characterization of different patterned polymeric cortical screws were observed using SEM. Based on the SEM micrographs, mechanical characterization of compression and tensile testing shows the stress, fractures and fatigue cracks propagation at the bone screw interfaces by fractures copy. Moreover, it was observed that the fracture mechanism of ductile to brittle fracture was observed with variation in the infill pattern of the bone screw. The outcomes revealed that the cortical screw with honeycomb infill pattern has the highest compressive and tensile strength than other infill patterns. Honeycomb structured cortical screws have approximately 17% higher compressive strength and 30% higher tensile strength than the triangular patterned cortical screw due to higher bonding surface area at the intercalated layers.

KEYWORDS

compressive strength, cortical screw, fracture mechanism, fused deposition modeling, tensile strength

1 | INTRODUCTION

A bone fracture may happen due to accidents, stress fracture and aging. The treatment of fractured bone is repaired with the bone screws as bone screws are efficient means of

securing and retaining the accurate position of fracture parts for early mobilization and early union.^[1,2] The standard gold biomaterials for bone screws are metals like stainless steel, titanium, and cobalt-chromium. These metallic biomaterials cause bone screw related complications like

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A.A. Collyer



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Post-yield Fracture Mechanics D. G. H. Latzko, 1979 Post-Yield Fracture Mechanics T K Hellen, J.D. Landes, D.G.H. Latzko, D.E. McCabe, C E Turner, 1984-12-04 *Geologic Fracture Mechanics* Richard A. Schultz, 2019-08-08 This lively introduction to geologic fracture mechanics provides a consistent treatment of all common geologic structural discontinuities. It explores the formation, growth and interpretation of fractures and deformation bands from theoretical, field and lab based perspectives, bridging the gap between a general textbook treatment and the more advanced research literature. It allows the reader to acquire basic tools to interpret discontinuity origins, geometries, patterns and implications using many of the leading and contemporary concepts known to specialists in the field. Problem sets are provided at the end of each chapter and worked examples are included within each chapter to illustrate topics and enable self study. With all common geologic structures including joints, hydrofractures, faults, stylolites and deformation bands being discussed from a fresh perspective, it will be a useful reference for advanced students, researchers and industry practitioners interested in structural geology, neotectonics, rock mechanics, planetary geology and reservoir geomechanics. *The use of finite element techniques in post-yield fracture mechanics* T. K. Hellen, 1985 **Two-dimensional Test Cases in Post Yield Fracture Mechanics** E. M. Remzi, NAFEMS, National Agency for Finite Element Methods and Standards, 1990* *Post-yield fracture mechanics analysis of the combined thermal and mechanical loading of a centre cracked plate* T. K. Hellen, 1985 **Applied Mechanics Reviews**, 1977 **Teaching and Education in Fracture and Fatigue** H.P. Rossmann, 2003-09-02 This proceedings contains the best contributions to the series of seminars held in Vienna 1992, Miskolc, Hungary 1993 and 1994 and Vienna 1995 and provides a valuable resource for those concerned with the teaching of fracture and fatigue. It presents a wide range of approaches relevant to course and curriculum development. It is aimed particularly at NUREG/CR, U.S. Nuclear Regulatory Commission, 1978 Mechanical Properties of Solid Polymers Ian M. Ward, John Sweeney, 2012-10-22 Providing an updated and comprehensive account of the properties of solid polymers, the book covers all aspects of mechanical behaviour. This includes finite elastic behavior, linear viscoelasticity and mechanical relaxations, mechanical anisotropy, non linear viscoelasticity, yield behavior and fracture. New to this edition is coverage of polymer nanocomposites and molecular interpretations of yield. e.g. Bowden, Young and Argon. The book begins by focusing on the structure of polymers, including their chemical composition and physical structure. It goes on to discuss the mechanical properties and behaviour of polymers, the statistical molecular theories of the rubber-like state and describes aspects of linear viscoelastic behaviour, its measurement and experimental studies. Later chapters cover composites and experimental behaviour, relaxation transitions, stress and yielding. The book concludes with a discussion of breaking phenomena. **Post-yield Fracture Mechanics Analysis of Three-point Bend Specimens and Its Implications to Fracture Toughness Testing** G. G. Chell, G. M. Spink, 1975 Applied Stress Analysis T.H. Hyde, E. Ollerton, 2012-12-06 This volume records the proceedings of an

international conference organised as a tribute to the contribution made by Professor H Fessler over the whole of his professional life in the field of applied stress analysis. The conference held at the University of Nottingham on 30 and 31 August 1990 was timed to coincide with the date of his formal retirement from the post of Professor of Experimental Stress Analysis in the University. The idea grew from discussions between some of Professor Fessler's academic associates from Nottingham and elsewhere. An organising committee was set up and it was decided to invite contributions to the conference in the form of review papers and original research papers in the field of experimental theoretical and computational stress analysis. The size of the response both in papers submitted and in attendance at the conference indicates that the idea proved attractive to many of his peers, former associates and research students. A bound copy of the volume is to be presented to Professor Fessler at the conference dinner on 30 August 1990.

Dislocation Modelling of Physical Systems M.F. Ashby, R. Bullough, C.S. Hartley, 2013-10-22. *Dislocation Modelling of Physical Systems* contains the Proceedings of the International Conference held at Gainesville Florida USA on June 22-27 1980. The book emphasizes the growing interest in relating dislocation theoretic concepts to engineering problems. Topic areas chosen ranged from the fundamental such as properties of single dislocations to the more applied such as fracture. The papers are grouped specifically based on the main topics they discuss. These topics include fracture, point defects and dislocations, structure dependence of mechanical behavior, properties of single dislocations, plasticity and geometry of deformation, internal friction effects and boundaries.

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Table of Contents Post Yield Fracture Mechanics

1. Understanding the eBook Post Yield Fracture Mechanics
 - The Rise of Digital Reading Post Yield Fracture Mechanics
 - Advantages of eBooks Over Traditional Books
2. Identifying Post Yield Fracture Mechanics
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Post Yield Fracture Mechanics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Post Yield Fracture Mechanics
 - Personalized Recommendations

- Post Yield Fracture Mechanics User Reviews and Ratings
- Post Yield Fracture Mechanics and Bestseller Lists
- 5. Accessing Post Yield Fracture Mechanics Free and Paid eBooks
 - Post Yield Fracture Mechanics Public Domain eBooks
 - Post Yield Fracture Mechanics eBook Subscription Services
 - Post Yield Fracture Mechanics Budget-Friendly Options
- 6. Navigating Post Yield Fracture Mechanics eBook Formats
 - ePub, PDF, MOBI, and More
 - Post Yield Fracture Mechanics Compatibility with Devices
 - Post Yield Fracture Mechanics Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Post Yield Fracture Mechanics
 - Highlighting and Note-Taking Post Yield Fracture Mechanics
 - Interactive Elements Post Yield Fracture Mechanics
- 8. Staying Engaged with Post Yield Fracture Mechanics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Post Yield Fracture Mechanics
- 9. Balancing eBooks and Physical Books Post Yield Fracture Mechanics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Post Yield Fracture Mechanics
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Post Yield Fracture Mechanics
 - Setting Reading Goals Post Yield Fracture Mechanics
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Post Yield Fracture Mechanics
 - Fact-Checking eBook Content of Post Yield Fracture Mechanics

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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