

This Agreement is between the author (Author) and ProQuest LLC, through its UMI® Dissertation Publishing business (ProQuest/UMI). Under this Agreement, Author grants ProQuest/UMI certain rights to preserve, archive and publish the dissertation or thesis, abstract, and index terms (the Work) provided by Author to ProQuest/UMI.

Section I. License for Inclusion of the Work in UMI® Publishing Program.

Grant of Rights. Author hereby grants to ProQuest/UMI the **non-exclusive**, worldwide right to reproduce, distribute, display and transmit the Work (in whole or in part) in such tangible and electronic formats as may be in existence now or developed in the future. Author further grants to ProQuest/UMI the right to include the abstract, bibliography and other metadata in the ProQuest Dissertations & Theses database (PQDT) and in ProQuest/UMI's Dissertation Abstracts International and any successor or related index and/or finding products or services.

UMI® Publishing Program - Election and Elements. The rights granted above shall be exercised according to the publishing option selected by Author in Section III, Author Options, and subject to the following additional Publishing Program requirements:

- **Redistribution of the Work.** Except as restricted by Author in the publishing option selected, the rights granted by Author automatically include (1) the right to allow sale and distribution of the Work, in whole or in part, by agents and distributors, including but not limited to commercial retail outlets and (2) the right to make the Abstract, bibliographic data and any meta data associated with the Work available to search engines and harvesters.
- **Restrictions.** ProQuest/UMI will use commercially reasonable efforts to restrict the distribution of the Work as provided under the publishing option selected by Author or as later elected by Author through direct contact with ProQuest/UMI. Such election is subject to Author's Degree Granting Institution Directives (see below). With respect to restrictions requested after submission of the Work, Author acknowledges that ProQuest/UMI cannot recall or amend previously distributed versions of the Work.
- **Removal of Work from the Program.** ProQuest/UMI may elect not to distribute the Work if it believes that all necessary rights of third parties have not been secured. Refer to the website http://www.proquest.com/products_umi/dissertations/ for information about copyright and your dissertation or thesis. If Author's degree is rescinded, and the degree-granting institution so directs, ProQuest/UMI will expunge the Work from its publishing program in accordance with its then current publishing policies.
- **Degree Granting Institution Directives.** Author is solely responsible for any conflict between policies and directions of Author's degree-granting institution, Author's choice of publishing model, and/or any restriction Author places on the use of the Work. For the avoidance of doubt, ProQuest/UMI is not responsible for access to the Work that is provided by Author's degree-granting institution through its library or institutional repository. Author must work directly with Author's degree granting institution to ensure application of

any restrictions to access relating to the Work by Author's degree granting institution.

Copyright and Deposit with the Library of Congress. At Author's option and upon payment of the applicable fee, ProQuest/UMI will submit an application for registration of **Author's copyright** in the Work in Author's name. In addition, regardless of whether copyright registration of the Work is sought, ProQuest/UMI may make a copy of the Work available to the Library of Congress in digital, microform or other format as required by the Library of Congress.

Publishing Fees and Royalties. Author shall remit the publishing fees and the optional copyright registration fees as appropriate for the publishing option chosen by Author, and as specified by Author's degree-granting institution. Except as provided under the Traditional Publishing option, no royalties shall be due from ProQuest/UMI to Author.

Delivery of the Work. Author shall provide to ProQuest/UMI the Work and all necessary supporting documents during the online submission process, according to the Instructions accompanying this agreement.

Rights Verification. Author represents and warrants that Author is the copyright holder of the Work and has obtained all necessary rights to permit ProQuest/UMI to reproduce and distribute third party materials contained in any part of the Work, including all necessary licenses for any non-public, third party software necessary to access, display, and run or print the Work. Author is solely responsible and will indemnify ProQuest/UMI for any third party claims related to the Work as submitted for publication.

Section II-A. Rights pursuant to Traditional Publishing.

Author's election of Traditional as the Type of Publishing confirms Author's choice to have ProQuest/UMI publish the Work according to the Traditional Publishing option described below.

Traditional Publishing. ProQuest/UMI may exercise the rights granted under Section I above including through the sale of individual copies of the Work in tangible or electronic media and/or as part of electronic database and reference products or services.

Publishing Fees and Royalties. Author's payment of the dissertation or thesis publishing fee is a one-time, up-front fee. Author's institution may assess additional fees to be collected along with the publishing fee. ProQuest/UMI will pay royalties of 10% of its net revenue from sales of the Work, conditioned on Author maintaining a current address on record with ProQuest/UMI. Royalties will be paid when accrued earned royalties reach \$25.00. If, after 25 years, earned royalties do not accrue to at least \$25.00, ProQuest/UMI's royalty payment obligation will cease.

Section II-B. Rights pursuant to Open Access Publishing PLUS.

Author's election of Open Access Publishing PLUS as the Type of Publishing confirms Author's choice to have ProQuest/UMI publish the Work according to the Open Access Publishing PLUS option described here.

Open Access Publishing PLUS. In addition to the rights granted under Section I of this UMI® Publishing Agreement, ProQuest/UMI may reproduce, distribute, display and transmit the Work in electronic format in the ProQuest Dissertations & Theses database, where it may be made available for free download. A subset of the ProQuest Dissertations & Theses database, currently known as PQDT Open, may be accessed by the academic community as well as through major search engines and open access harvesters. ProQuest/UMI may also provide an electronic copy of the Work to Author's degree-

granting institution where it may also be posted for free open access. Learn more: <http://www.proquest.com/en-US/products/dissertations/epoa.shtml>

Copy Sales. ProQuest/UMI and its agents and distributors may offer copies of the Work for sale in tangible media, including but not limited to microform, print and CD-ROM, as well as in electronic format either individually or as part of its electronic database and reference products and services. No royalties shall be due to Author.

Publishing Fees. Author's payment of the additional Open Access Publishing PLUS fee is a one-time, up-front fee in addition to the UMI® dissertation or thesis publishing fee. Author's institution may assess additional fees to be collected along with the Open Access and publishing fee.

Section III. Publishing Options & Signature

Select the publishing options below that best fit your interests and scholarly publishing obligations.

Traditional Publishing

- I want to make my work widely available and I want to be eligible to receive royalties on the sale of my work.
- I understand that I must maintain a current mailing address with ProQuest/UMI in order to be eligible to receive royalties.
 - I understand that the ProQuest/UMI fee for Traditional Publishing is \$25 for Master's thesis and \$25 for Doctoral dissertations.
 - I understand that my graduate institution may pay all or a portion of the total fee as well as may require additional fees in association with my submission to ProQuest/UMI.

Open Access Publishing PLUS

- I want the broadest possible dissemination of my work, and I want to provide free global access to the electronic copy of my work via the internet.
- I understand that I will not be eligible to receive royalties.
 - I understand that the ProQuest/UMI fee for Open Access Publishing PLUS of Master's thesis is \$120 and for Dissertations is \$120, and that my graduate institution may pay all or a portion of the total fee as well as may require additional fees in association with my submission to ProQuest/UMI.

SELECT PUBLISHING OPTIONS

I want my work to be available as soon as it is published

- Yes
- No – I would like access to the full text of my work to be delayed for the following period of time:
- 6 month embargo
 - 1 year embargo
 - 2 year embargo

Note: Most institutions have delayed release (embargo) policies, please consult with your Graduate School/Program, if you need to delay the release of your work. Access to the full-text of your work will be delayed for the time period specified above, beginning from the date that we receive your manuscript at ProQuest/UMI. During this time, only your citation and abstract will appear in the ProQuest Dissertations & Theses Database (PQDT).

I want major search engines (e.g. Google, etc...) to discover my work. Learn more: <http://www.proquest.com/en-US/products/dissertations/google.shtml>

- Yes
- No

I want my graduate work to be sold by third party retailers in addition to ProQuest/UMI. (Note: If Traditional Publishing is chosen above, all sales are eligible to accrue royalties.)

- Yes
- No

Acknowledgment: I have read, understand and agree to this UMI® Publishing Agreement, including all rights and restrictions included within the publishing option chosen by me as indicated above.

REQUIRED Author's signature Youliang Guan Date 01/15/2014

(Print Name) Youliang Guan

Institution conferring degree Virginia Tech

Questions: Our Author Relations Team is available by phone at (800) 521-0600 ext.7020 or by email at disspub@proquest.com
Need help selecting a subject heading? Contact our editors at (800)-521-0600 ext. 4883 (Social Sciences/Humanities) or ext. 2209(Sciences/Engineering)

Dissertation/Master's Thesis Submission Form

Please print clearly in block letters

 M (Master's Thesis) D (Dissertation)**Personal Information**

Last Name Guan Middle Name or Initial _____
 First Name Youliang Country (ies) of Citizenship CHINA

Degree & Dissertation Information

Title of Dissertation/ Thesis Crack path selection and shear toughening effects due to mixed mode loading and varied surface properties in beam-like adhesively bonded joints

Institution conferring degree Virginia Tech Degree awarded (abbreviate; e.g., Ph.D.) Ph.D.

College, School, or Division College of Engineering Year degree awarded 2013

Department or Program Engineering Science and Mechanics Year manuscript completed 2013

Advisor/Committee Chair David A. Dillard

Committee Member Romesh C. Batra Committee Member John G. Dillard

Committee Member John J. Lesko Committee Member Robert L. West

Committee Member _____ Committee Member _____

Language of manuscript English

Primary Subject Category: Enter the 4-digit code and category name from Guide 2 that most closely describes the disciplinary area of your research. Code 0794 Category Material Science

You may suggest two additional subject categories that may aid in the discovery of your work in our digital database.

Code 0537 Category Engineering Code 0548 Category Mechanical

Provide up to 6 keywords or short phrases for citation indices, library cataloging, and database searching.

strain energy release rate fracture energy double cantilever beam

adhesively bonded joints crack path selection mode mixity angle

Current Contact Information Current Email Address leoguan@vt.edu

Street Address (line 1) 200 Jefferson St. Apt. D

Street Address (line 2) _____

City Blacksburg State/Province VA Daytime Phone 5403154653

Country USA Postal Code 24060 Evening Phone 5403154653

Permanent Contact Information

Permanent Email Address guanyouliang@gmail.com

Street Address (line 1) Xin-Hua-Ren-Jia, District B, Bei-Gong-Ji-Jie St. Town of Wafangdian

Street Address (line 2) Building 3, Unit 6, Room 701

City Dalian State/Province Liaoning Future Phone +86 411 84482890

Country CHINA Postal/ZIP code 116300 Alternate Future Phone +86 13084150628

THIS PAGE MUST ACCOMPANY YOUR MANUSCRIPT AND THE REST OF YOUR SUBMISSION MATERIALS
 Attach additional, separate copies of your Title Page and Abstract to this form

Guide 2: Subject Categories

The ProQuest Dissertations and Theses (PQDT) database and the ProQuest/UMI citation indices are arranged by subject categories. Please select the one category below that best describes your field of research or creative work. You may add one or two additional categories on your submission form that will also be associated with your work as secondary subjects.

Arts, Business, Education, Humanities, and Social Sciences

AREA, ETHNIC, AND GENDER STUDIES

African American studies	0296
African studies	0293
American studies	0323
Asian American studies	0343
Asian studies	0342
Baltic studies	0361
Black studies	0325
Canadian studies	0385
Caribbean studies	0432
Classical studies	0434
East European studies	0437
Ethnic studies	0631
European studies	0440
French Canadian culture	0482
Gender studies	0733
GLBT studies	0492
Hispanic American studies	0737
Holocaust studies	0507
Islamic culture	0512
Judaic studies	0751
Latin American studies	0550
Middle Eastern studies	0555
Native American studies	0740
Near Eastern studies	0559
North African studies	0560
Pacific Rim studies	0561
Regional studies	0604
Scandinavian studies	0613
Slavic studies	0614
South African studies	0654
South Asian studies	0638
Sub Saharan Africa studies	0639
Women's studies	0453

BUSINESS

Accounting	0272
Arts management	0424
Banking	0770
Business	0310
Entrepreneurship	0429
Finance	0508
Management	0454
Marketing	0338
Sports management	0430

COMMUNICATIONS AND INFORMATION SCIENCES

Communication	0459
Information science	0723
Journalism	0391
Library science	0399
Mass communication	0708
Technical communication	0643
Web studies	0646

FINE AND PERFORMING ARTS

Art criticism	0365
Art history	0377
Cinematography	0435
Dance	0378
Design	0389
Film studies	0900
Fine arts	0357
Music	0413
Performing arts	0641
Theater	0465
Theater history	0644

EDUCATION

Adult education	0516
Art education	0273
Bilingual education	0282
Business education	0688
Community college education	0275
Continuing education	0651
Curriculum development	0727
Early childhood education	0518
Education	0515
Education finance	0277
Education policy	0458
Educational administration	0514
Educational evaluation	0443
Educational leadership	0449
Educational psychology	0525
Educational technology	0710
Educational tests & measurements	0288
Elementary education	0524
English as a second language	0441
Foreign language instruction	0444
Gifted education	0445
Health education	0680
Higher education	0745
Higher education administration	0446
History of education	0520
Home economics education	0278
Industrial arts education	0521
Instructional design	0447
Language arts	0279
Mathematics education	0280
Middle school education	0450
Multicultural education	0455
Music education	0522
Pedagogy	0456
Performing arts education	0457
Philosophy of education	0998
Physical education	0523
Reading instruction	0535
Religious education	0527
School counseling	0519
Science education	0714
Secondary education	0533
Social sciences education	0534
Sociology of education	0340
Special education	0529
Teacher education	0530
Vocational education	0747

HUMANITIES

HISTORY

African history	0331
American history	0337
Ancient history	0579
Asian history	0332
Black history	0328
Canadian history	0334
European history	0335
History	0578
History of Oceania	0504
History of science	0585
Latin American history	0336
Medieval history	0581
Middle Eastern history	0333
Military history	0722
Modern history	0582
Russian history	0724
World history	0506

LANGUAGE & LITERATURE

African literature	0316
American literature	0591
Ancient languages	0289
Asian literature	0305
Canadian literature	0352
Caribbean literature	0360
Classical literature	0294
Comparative literature	0295
English literature	0593
French Canadian literature	0355
Germanic literature	0311
Icelandic & Scandinavian literature	0362
Language	0679
Latin American literature	0312
Linguistics	0290
Literature	0401
Literature of Oceania	0356
Medieval literature	0297
Middle Eastern literature	0315
Modern language	0291
Modern literature	0298
Rhetoric	0681
Romance literature	0313
Slavic literature	0314

PHILOSOPHY AND RELIGION

Aesthetics	0650
Biblical studies	0321
Canon law	0375
Clerical studies	0319
Comparative religion	0618
Divinity	0376
Epistemology	0393
Ethics	0394
Logic	0395
Metaphysics	0396
Pastoral counseling	0397
Philosophy	0422
Philosophy of Religion	0322
Philosophy of science	0402
Religion	0318
Religious history	0320
Spirituality	0647
Theology	0469

LAW AND LEGAL STUDIES

Alternative dispute resolution	0649
Intellectual property	0513
International law	0616
Law	0398
Patent law	0562

SOCIAL SCIENCES

Archaeology	0324
Area planning and development	0341
Criminology	0627
Cultural anthropology	0326
Demography	0938
Economic history	0509
Economic theory	0511
Economics	0501
Economics, Commerce-Business	0505
Economics, Labor	0510
Folklore	0358
Forensic anthropology	0339
Geography	0366
Individual & family studies	0628
International relations	0601
Labor relations	0629
Military studies	0750
Organization theory	0635
Organizational behavior	0703
Peace studies	0563
Physical anthropology	0327
Political Science	0615
Public administration	0617
Public policy	0630
Recreation and tourism	0814
Social research	0344
Social structure	0700
Social work	0452
Sociolinguistics	0636
Sociology	0626
Transportation planning	0709
Urban planning	0999

INTERDISCIPLINARY

Alternative energy	0363
Biographies	0304
Climate change	0404
Cultural resources management	0436
Energy	0791
Food science	0359
Home economics	0386
Information technology	0489
Multimedia	0558
Museum studies	0730
Sustainability	0640
Textile research	0994
Wood sciences	0746

Behavioral, Natural, and Physical Sciences

AGRICULTURE

Agriculture	0473
Agriculture economics	0503
Agronomy	0285
Animal diseases	0476
Animal sciences	0475
Fisheries and aquatic sciences	0792
Forestry	0478
Horticulture	0471
Plant pathology	0480
Plant sciences	0479
Range management	0777
Soil sciences	0481
Urban forestry	0281
Wildlife management	0286

ARCHITECTURE

Architecture	0729
Architectural engineering	0462
Landscape architecture	0390

BEHAVIORAL SCIENCES

Animal behavior	0602
Behavioral sciences	0384
Clinical psychology	0622
Cognitive psychology	0633
Counseling psychology	0603
Developmental psychology	0620
Experimental psychology	0623
Occupational psychology	0624
Personality psychology	0625
Physiological psychology	0989
Psychobiology	0349
Psychology	0621
Quantitative psychology and psychometrics	0632
Social psychology	0451

BIOLOGICAL SCIENCES

Biochemistry	0487
Bioinformatics	0715
Biology	0306
Biomechanics	0648
Biophysics	0786
Biostatistics	0308
Cellular biology	0379
Developmental biology	0758
Endocrinology	0409
Entomology	0353
Evolution & development	0412
Genetics	0369
Histology	0414
Limnology	0793
Microbiology	0410
Molecular biology	0307
Morphology	0287
Neurosciences	0317
Parasitology	0718
Physiology	0719
Plant biology	0309
Systematic biology	0423
Virology	0720
Zoology	0472

ECOSYSTEM SCIENCES

Ecology	0329
Macroecology	0420
Paleoecology	0426

ENGINEERING

Aerospace engineering	0538
Artificial intelligence	0800
Automotive engineering	0540
Biomedical engineering	0541
Chemical engineering	0542
Civil engineering	0543
Computer engineering	0464
Computer science	0984
Electrical engineering	0544
Engineering	0537
Geological engineering	0466
Geophysical engineering	0467
Geotechnology	0428
Industrial engineering	0546
Mechanical engineering	0548
Mining engineering	0551
Naval engineering	0468
Nanotechnology	0652
Nuclear engineering	0552
Ocean engineering	0547
Operations research	0796
Packaging	0549
Petroleum engineering	0765
Plastics	0795
Robotics	0771
System science	0790
Materials Science	0794

ENVIRONMENTAL SCIENCES

Conservation biology	0408
Environmental economics	0438
Environmental education	0442
Environmental engineering	0775
Environmental geology	0407
Environmental health	0470
Environmental justice	0619
Environmental law	0439
Environmental management	0474
Environmental philosophy	0392
Environmental science	0768
Environmental studies	0477
Land use planning	0536
Natural resource management	0528
Water resources management	0595
Wildlife conservation	0284

GEOSCIENCES

Aeronomy	0367
Atmospheric chemistry	0371
Atmospheric sciences	0725
Biogeochemistry	0425
Biological oceanography	0416
Chemical oceanography	0403
Continental dynamics	0406
Geobiology	0483
Geochemistry	0996
Geographic information science and geodesy	0370
Geology	0372
Geomorphology	0484
Geophysics	0373
Hydrologic sciences	0388
Marine geology	0556
Meteorology	0557
Mineralogy	0411
Paleoclimate science	0653
Paleontology	0418
Petroleum geology	0583
Petrology	0584
Physical geography	0368
Physical oceanography	0415
Planetology	0590
Plate tectonics	0592
Remote sensing	0799
Sedimentary geology	0594

HEALTH AND MEDICAL SCIENCES

Aging	0493
Alternative medicine	0496
Audiology	0300
Dentistry	0567
Epidemiology	0766
Gerontology	0351
Health care management	0769
Health sciences	0566
Immunology	0982
Kinesiology	0575
Medical ethics	0497
Medical imaging and radiology	0574
Medicine	0564
Mental health	0347
Nursing	0569
Nutrition	0570
Obstetrics and gynecology	0380
Occupational health	0354
Occupational therapy	0498
Oncology	0992
Ophthalmology	0381
Osteopathic medicine	0499
Pathology	0571
Pharmaceutical sciences	0572
Pharmacology	0419
Physical therapy	0382
Public health	0573
Public health occupations education	0500
Speech therapy	0460
Surgery	0576
Toxicology	0383
Veterinary medicine	0778

**MATHEMATICAL AND
PHYSICAL SCIENCES**

Acoustics	0986
Analytical chemistry	0486
Applied mathematics	0364
Astronomy	0606
Astrophysics	0596
Atomic physics	0748
Chemistry	0485
Condensed matter physics	0611
Electromagnetics	0607
High temperature physics	0597
Inorganic chemistry	0488
Low temperature physics	0598
Materials science	0794
Mathematics	0405
Mechanics	0346
Molecular chemistry	0431
Molecular physics	0609
Nanoscience	0565
Nuclear chemistry	0738
Nuclear physics	0756
Optics	0752
Organic chemistry	0490
Particle physics	0798
Physical chemistry	0494
Physics	0605
Plasma physics	0759
Polymer chemistry	0495
Quantum physics	0599
Statistics	0463
Theoretical mathematics	0642
Theoretical physics	0753

Crack path selection and shear toughening effects due to mixed mode loading and varied surface properties in beam-like adhesively bonded joints

Youliang (Leonardo) Guan

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Engineering Mechanics

David A. Dillard – Chairman

Romesh C. Batra

John G. Dillard

John J. Lesko

Robert L. West

December 9, 2013

Blacksburg, VA, 24061

Keywords: Strain energy release rate, double cantilever beam (DCB), fracture energy, adhesively bonded joints, crack path selection, mode mixity angle, shear toughening effect, cohesive zone model, fracture mechanics, locally weakened interface, crack steering, maximum traction, damage evolution, softening law, cohesive element, extended finite element method (XFEM), epoxy adhesive, dual actuator load frame, silane treatment

Copyright 2013, Youliang Guan

Crack path selection and shear toughening effects due to mixed mode loading and varied surface properties in beam-like adhesively bonded joints

Youliang Guan

Abstract

Structural adhesives are widely used with great success, and yet occasional failures can occur, often resulting from improper bonding procedures or joint design, overload or other detrimental service situations, or in response to a variety of environmental challenges. In these situations, cracks can start within the adhesive layer or debonds can initiate near an interface. The paths taken by propagating cracks can affect the resistance to failure and the subsequent service lives of the bonded structures. The behavior of propagating cracks in adhesive joints remains of interest, including when some critical environments, complicated loading modes, or uncertainties in material/interfacial properties are involved. From a mechanics perspective, areas of current interest include understanding the growth of damage and cracks, loading rate dependency of crack propagation, and the effect of mixed mode fracture loading scenarios on crack path selection. This dissertation involves analytical, numerical, and experimental evaluations of crack propagation in several adhesive joint configurations. The main objective is an investigation of crack path selection in adhesively bonded joints, focusing on in-plane fracture behavior (mode I, mode II, and their combination) of bonded joints with uniform bonding, and those with locally weakened interfaces.

When removing cured components from molds, interfacial debonds can sometimes initiate and propagate along both mold surfaces, resulting in the molded product partially bridging between the two molds and potentially being damaged or torn. Debonds from both adherends can sometimes occur in weak adhesive bonds as well, potentially altering the apparent fracture behavior. To avoid or control these multiple interfacial debonding, more understanding of these processes is required. An analytical model of 2D parallel bridging was developed and the interactions of interfacial debonds were investigated using Euler-Bernoulli beam theory. The numerical solutions to the analytical results described the propagation processes with multiple debonds, and demonstrated some common phenomena in several different joints corresponding to double cantilever beam configurations. The analytical approach and results obtained could prove useful in extensions to understanding and controlling debonding in such situations and optimization of loading scenarios.

Numerical capabilities for predicting crack propagation, confirmed by experimental results, were initially evaluated for crack behavior in monolithic materials, which is also of interest in engineering design. Several test cases were devised for modified forms of monolithic compact tension specimens (CT) were developed. An asymmetric variant of the CT configuration, in which the initial crack was shifted to two thirds of the total height, was tested experimentally and numerically simulated in ABAQUS®, with good agreement. Similar studies of elongated CT specimens with different specimen lengths also revealed good agreement, using the same material properties and cohesive zone model (CZM) parameters. The critical specimen length when the crack propagation pattern abruptly switches was experimentally measured and accurately predicted,

building confidence in the subsequent studies where the numerical method was applied to bonded joints.

In adhesively bonded joints, crack propagation and joint failure can potentially result from or involve interactions of a growing crack with a partially weakened interface, so numerical simulations were initiated to investigate such scenarios using ABAQUS®. Two different cohesive zone models (CZMs) are applied in these simulations: cohesive elements for strong and weak interfaces, and the extended finite element method (XFEM) for cracks propagating within the adhesive layer. When the main crack approaches a locally weakened interface, interfacial damage can occur, allowing for additional interfacial compliance and inducing shear stresses within the adhesive layer that direct the growing crack toward the weak interface. The maximum traction of the interfacial CZM appears to be the controlling parameter. Fracture energy of the weakened interface is shown to be of secondary importance, though can affect the results when particularly small (e.g. 1% that of the bulk adhesive). The length of the weakened interface also has some influence on the crack path. Under globally mixed mode loadings, the competition between the loading and the weakened interface affects the shear stress distribution and thus changes the crack path. Mixed mode loading in the opposite direction of the weakened interface is able to drive the crack away from the weakened interface, suggesting potential means to avoid failure within these regions or to design joints that fail in a particular manner.

In addition to the analytical and numerical studies of crack path selection in adhesively bonded joints, experimental investigations are also performed. A dual actuator load frame (DALF) is used to test beam-like bonded joints in various mode mixity angles. Constant mode mixity angle tracking, as well as other versatile loading functions, are developed in LabVIEW® for use with a new controller system. The DALF is calibrated to minimize errors when calculating the compliance of beam-like bonded joints. After the corrections, the resulting fracture energies (G_c) values are considered to be more accurate in representing the energy released in the crack propagation processes. Double cantilever beam (DCB) bonded joints consisting of 6061-T6 aluminum adherends bonded with commercial epoxy adhesives (J-B Weld, or LORD 320/322) are tested on the DALF. Profiles of the G_c values for different constant mode mixity angles, as well as for continuously increasing mode mixity angle, are plotted to illustrate the behavior of the crack in these bonded joints.

Finally, crack path selection in DCB specimens with one of the bonding surfaces weakened was studied experimentally, and rate-dependency of the crack path selection was found. Several contamination schemes are attempted, involving of graphite flakes, silicone tapes, or silane treatments on the aluminum oxide interfaces. In all these cases, tests involving more rapid crack propagation resulted in interfacial failures at the weakened areas, while slower tests showed cohesive failure throughout. One possible explanation of this phenomenon is presented using the rate-dependency of the yield stress (commonly considered to be corresponding to the maximum traction) of the epoxy adhesives. These experimental observations may have some potential applications tailoring adhesive joint configurations and interface variability to achieve or avoid particular failure modes.