Polymer Core Composite Conductor (PCCC) Research at the University of Denver

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Outline

- Current PCCC Research at University of Denver
- Past Composite Insulator Research
- In-service Stresses on PCCC Conductors
- Most Recent PCCC Research Contributions
- Recent Proposal to National Institute of Standard and Technology (NIST)
- Q/A
- Brian Burks' presentation

Definition of Polymer Core Composite Conductors (PCCC)

- **If the load bearing component of a high voltage conductor is a Polymer Matrix Composite (PMC) based on E-glass/ ECR-Glass/Carbon/Kevlar/etc. fibers (individually or in combination), and the polymer is a RT epoxy, HT epoxy, PEEK, Polyimide, etc.**

- **Present overhead electrical conductors are based on either the Aluminum Conductor Steel Reinforced (ACSR) or Aluminum Conductor Steel Supported (ACSS) designs, in which a steel core is surrounded by strands of hardened Aluminum.**

Aging of Polymers and PMCs

- **All polymers are ultimately susceptible to chemical degradation under exposure to various conditions even in commonly encountered environments!**
- **Polymers will especially rapidly degrade in extreme environments!**
- **When exposed to high temperatures, water, oxygen, ozone, UV, etc., weak Wan der Waals bonds will break.**
- **Bond breaking may also occur in polymer backbone bonds to lower the average length of the polymer chain.**

- **Bond rupture (scission) will significantly reduce mechanical, electrical and thermal properties of polymers and their composites with glass, carbon, Kevlar, boron, etc. fibers.**

Current PCCC Research at DU

- The Electric Power Research Institute (EPRI) together with several US, UK and Canadian power utilities have been performing a number of full scale mechanical and electrical tests on various designs of conductors. The objectives of the project is to provide the participants with vital information on selecting, designing, installing, operating, and maintaining the HTLS (High Temperature Low Sag) conductors.

- **However, no fundamental research leading to better understanding of the long term behavior (up to 50 years) of the Polymer Core Composite Conductors (PCCC) and to the development of a reliable measuring / monitoring technique has been performed.**

Current PCCC Research at DU

- **Title:** "**Investigation of Long-Term Structural Integrity of High-Temperature, Low-Sag Composite Conductors"**
- **Sponsors:** **Western Area Power Administration** (Mr. R. Clarke and Mr. A. Turner) and **Tri-State Generation and Transmission Association** (Mr. A. Mander and Mr. S. Anderson)
- **Starting Date:** June 2008 (for three years)
- **Goals:** To improve our understanding of the long-term behavior of PCCC conductors under in-service conditions.
- **Accomplishments so far:** 2 large reports submitted, three journal publications accepted for publication, one MSME degree granted

Why should we (DU) be treated seriously when dealing with PCCC?

- **Our extensive (30 years) experience with application of polymers and polymer matrix composites in extreme environments (multiple large projects for EPRI, major US utilities, NASA, Air Force, NSF, etc.)**

- **Our already significant contributions to non-ceramic composite insulator technology**

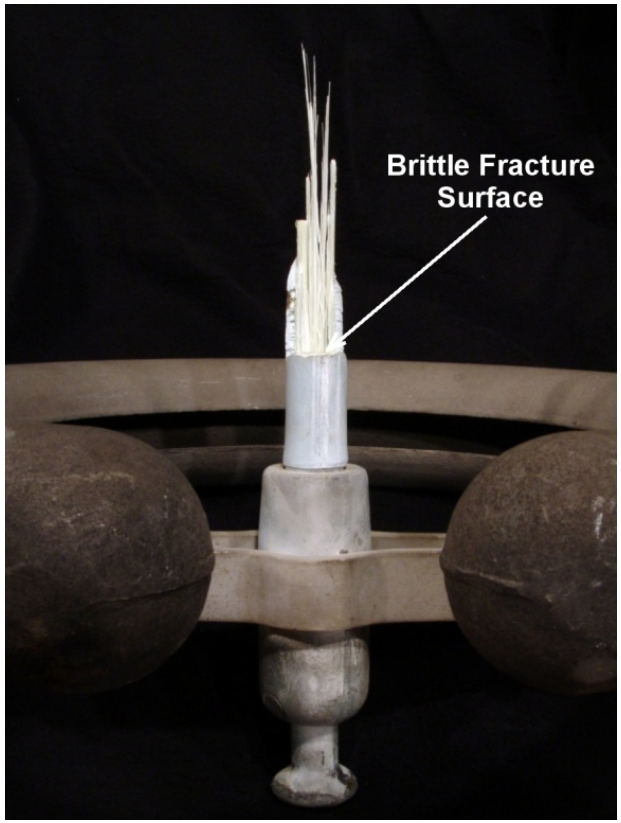
Past Non-Ceramic Insulator Research at DU

- **Between 1993 and 2006, major research efforts were undertaken in Kumosa's research group initially at OGI and then at DU in the area of high voltage composite insulators.**
  - **For:**

EPRI - 5 large consecutive contracts, BPA - 4 contracts, WAPA- 4 contracts, Alabama Power - 3 contracts, PG&E -3 contracts, NRECE- 1 grant, Glasforms, Inc. - 2 contracts, and NGK-Locke - 1 contract.

Past Composite Insulator Research at DU

- In spite of many benefits, which the insulators can offer in comparison with their porcelain counterparts, they can fail mechanically in service by rod fracture, and electrically by flashover.
- One of the mechanical failure modes of the insulators is a failure process called **"brittle fracture"**, which is caused by the stress corrosion cracking (SCC) of their GRP rods .



Our Contributions to Insulator Technology

- Explanation of 345kV and 500kV brittle fracture failures experienced by WAPA and PG&E,
- Identification of the type of acid responsible for brittle fracture,
- Simulation of brittle fracture with and without high voltage,
- Identification of several critical conditions leading to brittle fracture and other mechanical and electrical failure modes,
- Providing rankings of the commonly used GRP rod materials for their resistance to stress corrosion cracking (brittle fracture), moisture absorption, surface mechanical damage, leakage currents, ozone/water acid degradation, etc.
- Recommendation of numerous experimental and numerical procedures critical in the insulator design process.

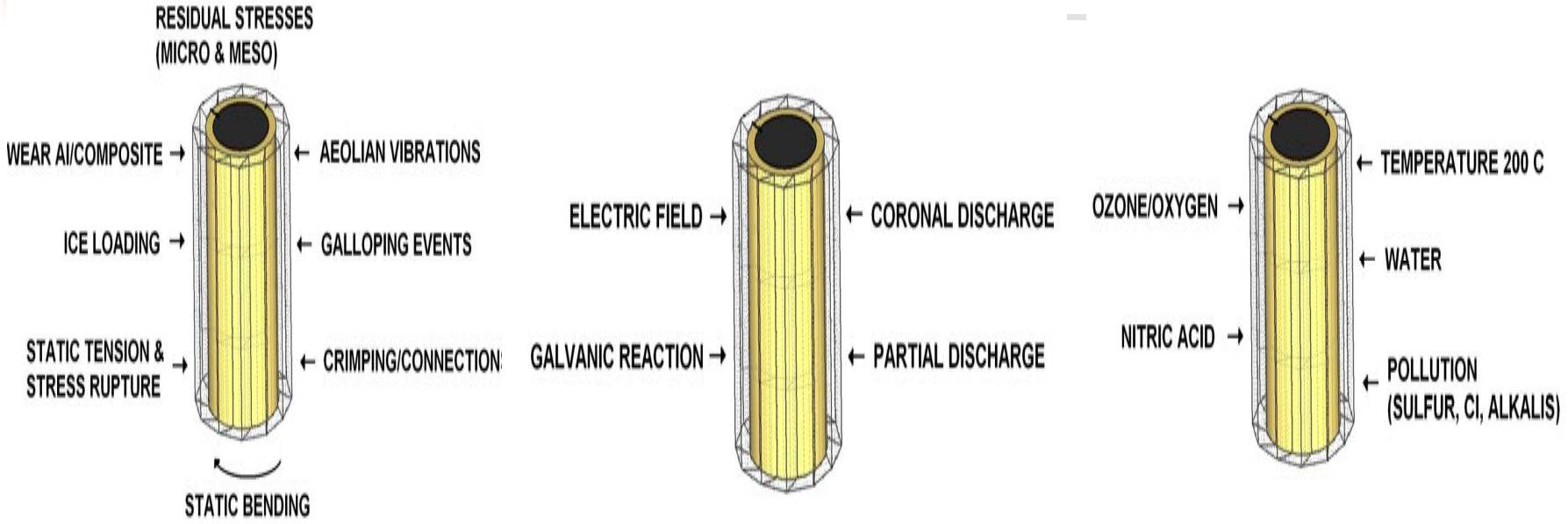
- **Published in 40 international journal papers including 10 review papers in IEEE journals.**

Insulator Website

- **If you want to know more about our research on high voltage insulators (and our other research projects, research facilities, etc.) go to:**

http://www.engr.du.edu/CFAMS/CFAMS_Downloads.htm

In-Service Stresses on PCCC Conductors



- **In-service, PCCC conductors are subjected to the combined action of <u>severe(!)</u> mechanical, electrical and environmental (chemical) stresses.**

In-service Stresses on PCCC Conductors

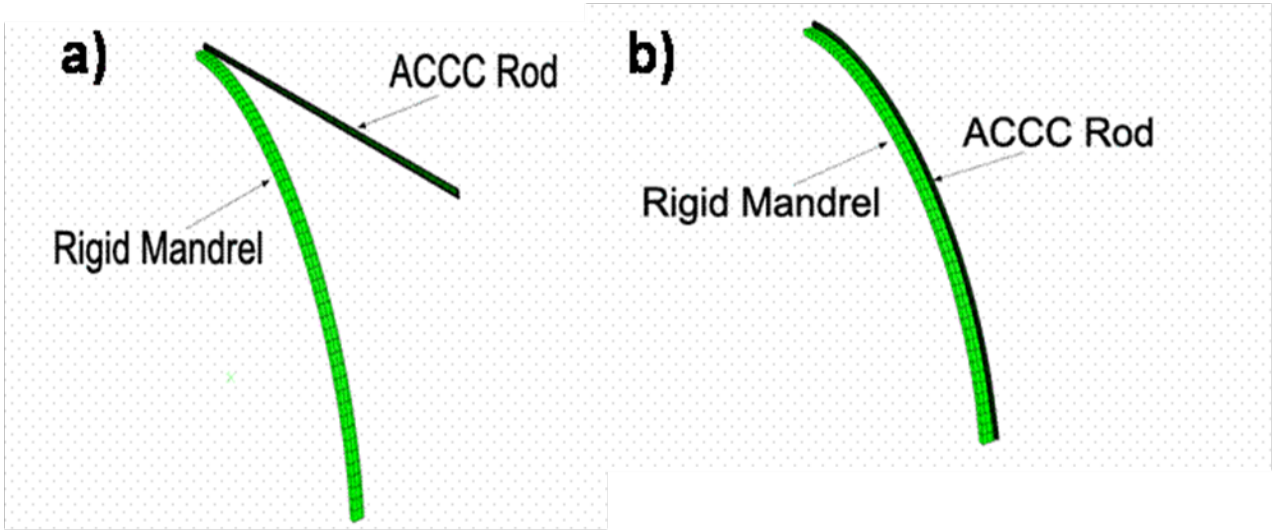
- We are slowly beginning to understand the individual effects of all those stresses on the conductors. **However, the combined effect is unknown at present.**

- The chemical stresses can be truly damaging to PCCC conductors due to their prolonged exposure to elevated temperatures up to 180°C in air/ozone/moisture/pollution.

- Physical and chemical aging of the composite core will occur at elevated temperatures with time leading to the reduction of mechanical and electrical properties of the carbon/epoxy core and the ECR-glass/epoxy.

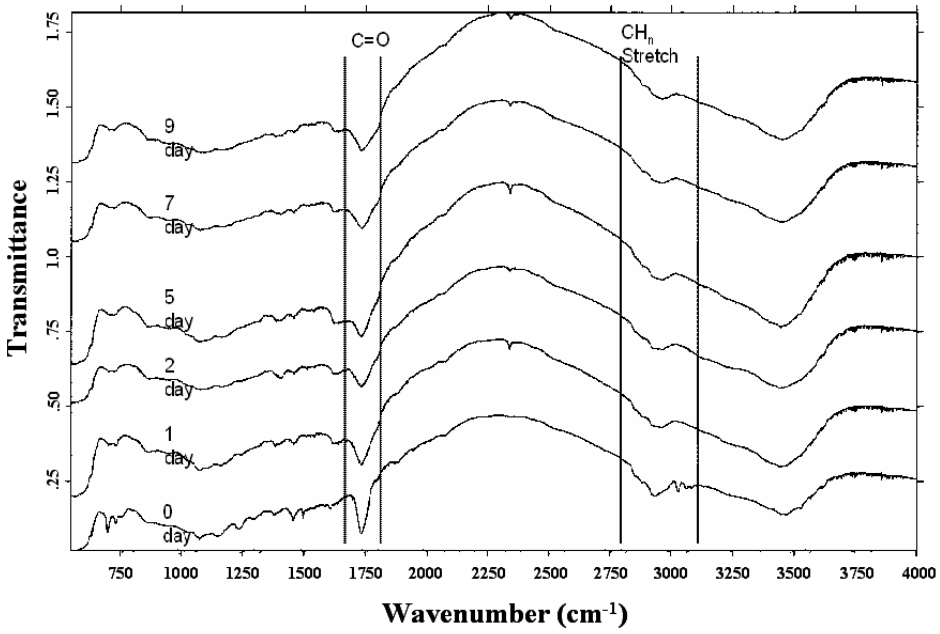
Recent PCCC Research Findings at DU

- We have successfully addressed the effects of excessive bending loads related to spooling on damage initiation and progression in ACCC rods. (The other PCCC designs have only been briefly evaluated.) The results of our ACCC research have just been accepted for publication in the IEEE TDEI and in Composites Science and Technology (the #1 Composites journal).



Recent PCCC Research Contributions at DU

- **We have also shown using Fourier Transform Infrared Spectroscopy (FTIR) that the exposure to ozone will drastically affect the chemistry of various thermosetting resins (including epoxies) used on transmission lines.**



FTIR analysis of composites exposed to ozone; transmission spectra for E-glass/epoxy for successive periods of exposure to ozone

Recent Proposal to NIST

"Development of Measuring Technologies for Monitoring In-Service Performance and Lifetime of PCCC Conductors"

Proposal submitted to: NIST/Department of Commerce

Funding Opportunity: 2009-NIST-ARRA-MSE-Research-01

Period of Performance: Three years

Total amount requested: $1,500,000

Principal Investigator: Dr. Maciej Kumosa

Recent Proposal to NIST/Goals

- To perform a large scale interdisciplinary fundamental study on the structural integrity of PCCC conductors (all possible designs!!) subjected to long-term in-service conditions.
- To develop new measuring techniques, which will be used to evaluate the individual and combined effects of mechanical, electrical and environmental stresses on the conductors.
- To use nanotechnology to predict the lifetime of the conductors and to improve their in-service performance.
- To improve our understanding of the effects of high voltage electrical fields on the structural integrity of PCCC conductors.
- To improve the level of confidence among the potential users of PCCC conductors.

Conclusions and Q&A

- Major research efforts are underway at DU to understand long-term behavior of PCCC conductors
- Our research progress will be greatly accelerated if we receive the NIST project
- You are invited to join the current group of sponsors (Western and Tri-State, NIST(?), etc)
- Q&A
- Mr. Brian Burks; a presentation on the effect of bending on one type of PCCC conductor (ACCC conductor).