2011 DOE Vehicle Technologies Program Review Presentation

AMD 405: Improved Automotive Suspension Components Cast with B206 Alloy

Principal Investigator: Dick Osborne (General Motors)

Presenter: Alan Luo

USAMP

May 12, 2011

LM040

Agenda

- **Overview**
- **Relevance**
- **Project Summary**

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Numbers DE-FC05-02OR22910 and DE-FC26-02OR22910.

OVERVIEW

Timeline

- Begin: October 1, 2004
- End: September 30, 2010
- 100% Complete

Budget

- Total project funding
  - DOE share - $519,570
  - Contractor share - $523,690
- Funding received in FY10
  - $100,162

Barriers

Barriers

A. Cost

B. Performance

C. Manufacturability

Targets

• Cast B206 automotive component with properties comparable to forged aluminum

Partners

- USAMP (Chrysler, Ford and General Motors)
- Rio Tinto Alcan
- GKS Engineering Services
- Alotech Ltd.
- Morel Industries
- NEMAK
- University of Windsor

Relevance

Objective: (Cost/Performance)

- Facilitate vehicle lightweighting by providing lower cost cast B206 aluminum alloy automotive suspension components with equivalent mechanical properties and performance as forged aluminum.

➢ Barriers

- Ferrous material solutions dominate suspension components due to strength, stiffness and cost benefits.
- Forged aluminum solutions are attractive with respect to strength but are at a disadvantage due to cost and diminished domestic supply base.
- Castings offer reduced cost and a larger domestic supply base but need improved mechanical and fatigue properties to be considered as an alternative to ferrous solutions.

➢ Target

- To cast automotive control arms with mechanical properties and fatigue equivalent to that of a baseline 6082-T6 forged control arm (See Table 1)

Table 1: Forged 6082-T6 Mechanical Properties		
YIELD STRENGTH	**ULTIMATE TENSILE STRENGTH**	**ELONGATION**
270 MPa	310 MPa	10%

Project Summary

- The B206 alloy is a suitable alloy for automotive components when heat treated to the T4 or T7 temper.
  - The project successfully made control arms with B206 that met the target mechanical and fatigue properties of the forged 6082-T6 control arms.
    - The T4 temper is preferred for low temperature applications and provides improved fatigue properties.
    - The T7 temper is preferred for applications which may be exposed to heat above 150 °F.
- Stress corrosion cracking susceptibility is sensitive to casting section size and the uniformity of the heat treatment process
- The Ablation casting process has potential to produce B206 components with superior properties versus traditional casting processes like semi-permanent mold.

2011 DOE Vehicle Technologies Program Review Presentation

AMD 704 Development of Steel Fastener Nano-Ceramic Coatings for Corrosion Protection of Magnesium Parts

Principal Investigator: Dick Osborne (General Motors)

Presenter: Alan Luo (General Motors)

USAMP

May 12, 2011

LM040

Agenda

- **Overview**
- **Relevance**
- **Approach**
- **Milestones**
- **Progress to Milestones**
- **Technical Accomplishments**
- **Next Steps**
- **Summary**
- **Collaboration**
- **Proposed Future Work**

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number No. DE-FC26-02OR22910.

OVERVIEW

Timeline

- July 14, 2010
- September 30, 2011
- 60% Complete

Budget

- Total project funding (Phase 2)
  - DOE share - $200,000
  - Contractor share - $210,000
- Funding received in FY10
  - (Phase 2) $41,545

Barriers

Barriers

A. Performance

B. Cost

C. Joining and Assembly

Targets

- Less than -1.2 mA/cm^2 galvanic current between nano-ceramic coated steel and magnesium

Partners

- USAMP (Chrysler, Ford and General Motors)
- Alfred University
- Visteon
- General Fasteners
- KAMAX

Relevance

Objective

- To facilitate the use of light weight magnesium in automotive applications by developing and validating nano-ceramic coatings for steel fasteners that will inhibit galvanic corrosion between the fasteners (cathode) and magnesium (Mg) components (anode).

Milestones/Targets

- Develop a nano-ceramic coating with equivalent or better performance than aluminum (1.2 mA/cm^2) when corrosion tested using the Galvanic Current Measurement Test.
- Determine if the Galvanic Current Measurement Test is a good predictor of galvanic corrosion performance.
- Determine if the nano-ceramic coated fasteners can perform equal to or better than aluminum when assembled against magnesium using mass-loss/gain measurements in modified VDA testing (galvanic corrosion).

Expected Result

- Successful development of nano-ceramic coatings will enable vehicle lightweighting using magnesium by providing a low cost solution for joining magnesium to steel with reduced likelihood of galvanic corrosion, which has inhibited the use of magnesium in automotive structures.

Approach

- The most common means of attaching magnesium components to automotive steel structures is to isolate the steel from magnesium through use of aluminum washers, spacers and/or fasteners
  - The difference in electrochemical potential is less between aluminum and magnesium than it is for steel and magnesium, thereby generating less galvanic corrosion.

- To be considered as an alternative to aluminum isolation, nano-ceramic coated steel fasteners must induce less (target is 0 mA/cm^2) galvanic corrosion than aluminum.

Approach

- The project established a two phase approach.
  - Task 1: Apply nano-ceramic coatings to steel coupons, evaluate the galvanic current between the coated steel coupon and magnesium and compare results against aluminum coupled with magnesium.
    - Decision Gate: If the nano-ceramic coated steel coupons exhibited less galvanic corrosion than aluminum then Task 2 can begin.
  - Task 2: Apply nano-ceramic coatings to steel fasteners, evaluate the galvanic and general corrosion of the coated steel fasteners against magnesium using a modified VDA test (salt-spray), and compare against aluminum fasteners mounted against magnesium.
    - The VDA test is a European corrosion test

Milestones

Month - Year	Milestone		Deliverable
Jan.-11	1	Design of Experiments to determine the nano-ceramic coating materials and parameters that best isolate steel from magnesium.	DOE Study
Mar.-11	2	Nano-ceramic coated steel substrates have a galvanic current equal to or less than aluminum when coupled with magnesium in salt water (Galvanic Current Measurement Test).	An effective Nano-ceramic coating (materials/thickness)
July-11	3	Nano-ceramic coated fasteners induce less galvanic corrosion than aluminum fasteners when tested using modified VDA testing (salt-spray w/ magnesium base) as determined by mass gain/loss measurements	An effective Nano-ceramic coating for fasteners

Progress to Milestones

Task	Approach	Status per Milestone
1.1	Conduct a Design of Experiments to determine the coating materials and parameters that best isolate steel from magnesium.	**Milestone 1: 100% Complete** Nano-ceramic SiN coating material was determined to be the most influential contributor in isolating steel from magnesium with respect to galvanic current.
1.2 – 1.5	Flat 1050 steel alloy specimens were coated with single and multi-layer nano-ceramic coatings of SiN, AlO and CeO. The coated specimens were then tested using a Galvanic Current Measurement Test and compared against the baseline aluminum.	**Milestone 2: 100% Complete** Multilayer coating with SiN as a basecoat followed by AlO and a UV curable topcoat performed better than aluminum with respect to galvanic current.
2.1 – 2.1	Steel M8x1.0x1.25 fasteners will be coated with the best coating established in Task 1. The fasteners will be mounted against magnesium and tested using a modified VDA test (salt-spray) and compared against the baseline aluminum fasteners.	**Milestone 3: 10% Complete** Initial salt spray testing begun.

Technical Accomplishments

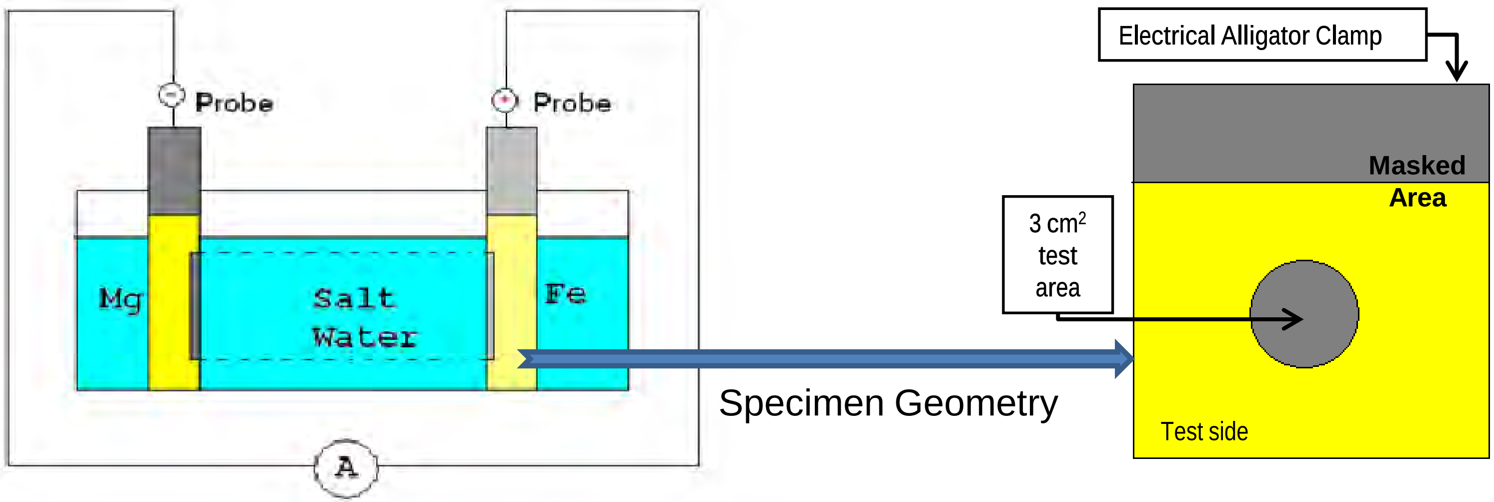
Task 1.1: Design of Experiments

- A DOE was performed using galvanic current measurements for single layer and multilayers of SiN, AlO and UV curable AlO in different combinations (A, B, C, AB, AC, BC, ABC)
  - The DOE revealed that the SiN nano-ceramic coating had the most impact on galvanic corrosion.
- Multilayer coatings could have an additional benefit on general corrosion.
- The team concluded that multilayer coatings using SiN as the base coat showed the most promise.

Technical Accomplishments

Task 1.2 – 1.5: Galvanic Current Measurement Testing

- The galvanic current measurement test measures the current between dissimilar metals placed into a fixture and selectively exposed to a 3.5% sodium chloride solution.
  - The samples are masked to expose an area of 1 cm^2 on each side of the galvanic couple.
  - A saturated calomel electrode (SCE) is utilized as the standard reference electrode (+0.241 V vs. standard hydrogen electrode (SHE).
  - The fixture holds the two samples at opposite ends of a 6.7 cm long PVC tube containing the salt solution.
  - Electrical contacts are connected to the samples and to a zero resistance ammeter.
  - Two measurements with nominally identical samples are conducted. Each measurement lasts for 30 minutes (1800 seconds).



Technical Accomplishments

Task 1.2 – 1.5: Galvanic Current Measurement Testing

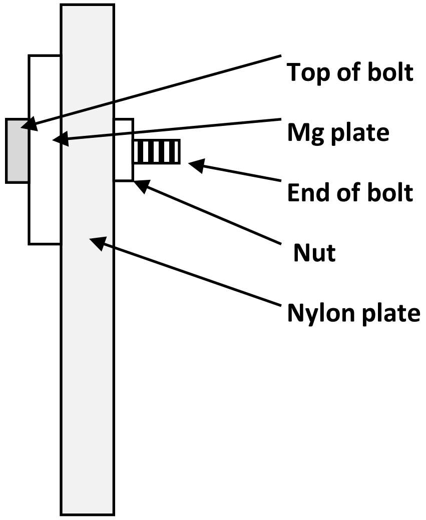
- 1050 Steel (control) had an average corrosion current of **8.83 mA/cm^2**
- 6061 Aluminum (Target) had an average corrosion current of **1.26 mA/cm^2**
- Single layer SiN nano-ceramic coating achieved the target with an average corrosion current of **0.79 mA/cm^2**
- Multilayer nano-ceramic coating of SiN-AlO-UVAlO improved upon the SiN single layer with an average corrosion current of **0.55 mA/cm^2**

Sample	Average Corrosion Current (mA/cm^2)
Control-1 (1050 steel)	8.83
SiN 1	0.79
AlO-1	8.12
UVAlO-1	8.05
AlO-UVAlO-1	6.95
SiN-UVAlO-1	1.10
SiN-AlO-UVAlO-2	0.55
Al-Mg-1 (Target)	1.26

Next Steps

Task 2.1 -2.2: VDA Testing

- The VDA is essentially salt spray testing using a fixturing as shown below.
- Fasteners are coated and assembled into fixtures.
  - A sterile cloth is used to hold the head of the bolt, so as not to damage the coating, while a torque wrench is applied to nut and tightened to 3 Nm.
- The sample is inclined during testing
- Samples are removed daily, photographed and measured for mass loss/gain.
- Testing has just started.



Side of substrate holder

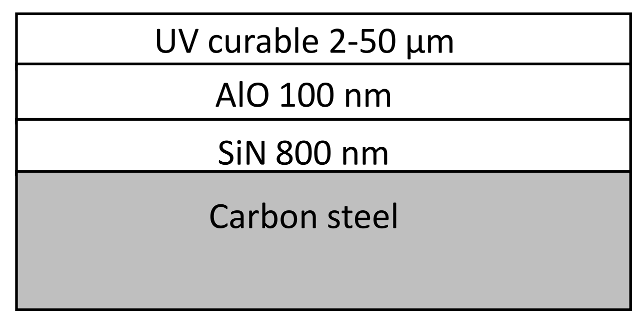
Summary

Project Summary:

- Design of Experiments was completed and showed that the SiN nano-ceramic coating has the most significant impact on galvanic current and was not overly sensitive to coating layer thickness. Tested multilayer coating thickness is shown below.
- Nano-ceramic coated steel using a multi-layer coating of silicon oxide, aluminum oxide and UV curable topcoat exhibited less average galvanic current (0.55 mA/cm^2) than 6061 aluminum (1.26 mA/cm^2) when coupled with magnesium in a salt water solution.
  - The project demonstrated the concept feasibility of nano-ceramic coatings to isolate steel from magnesium.
- Initial VDA testing shows less mass loss for multilayer SiN-AlO-UVAlO nano-ceramic coatings

Next Steps

- Complete VDA Testing
- Issue Final Report
- Technology Transfer



Multilayer Coating Thickness

Collaboration

Partners

- USAMP
- Alfred University
- KAMAX
- Visteon
- General Fasteners

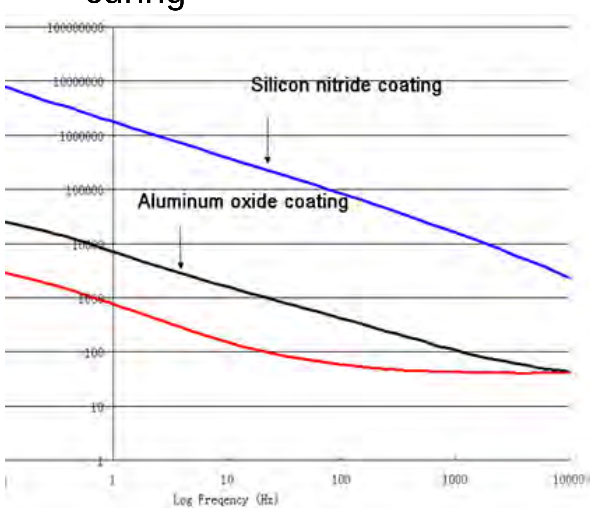
Proposed Future Work

- Successful conclusion of this work will demonstrate the concept feasibility of nano-ceramic coatings for use on steel fasteners as a means of mitigating galvanic corrosion between magnesium and steel.
- Future work would be to demonstrate the technical feasibility of using nano-ceramic coated steel fasteners on magnesium substructures.
  - Establish the ability of nano-ceramic coatings to achieve reliable torque/tension requirements.
  - Evaluate residual torque of assembled joints with nano-ceramic coated fasteners
  - Determine if nano-ceramic coatings have sufficient durability to resist damage induced by handling and assembly as well as assembly stress
  - Evaluate the general corrosion performance of nano-ceramic coated fasteners

Technical Back-Up Slides

Experiments - Thin film coatings

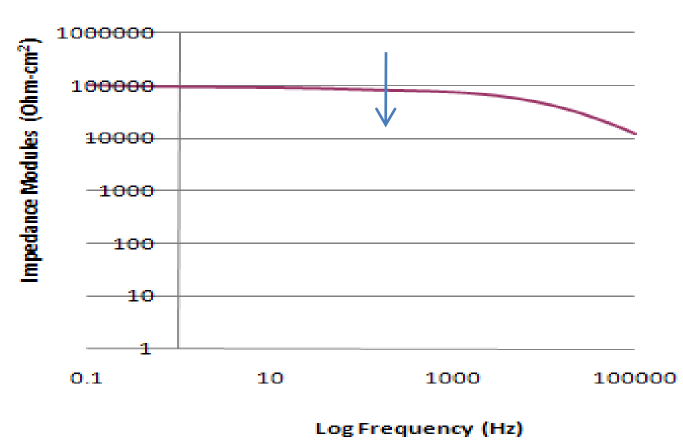
- Silicon Nitride
  - Techniques: PECVD / ALD
  - Thickness: 300 - 850 nm /20-60 nm
- Aluminum Oxide
  - Techniques: E-beam
  - Thickness: 100 - 700 nm
- UV-curable materials
  - Techniques: UV-light
  - Thickness: depending on the method of curing



- Back ground:
  Thin film coating materials on flat surface
  - Previous study (on a flat steel plate):

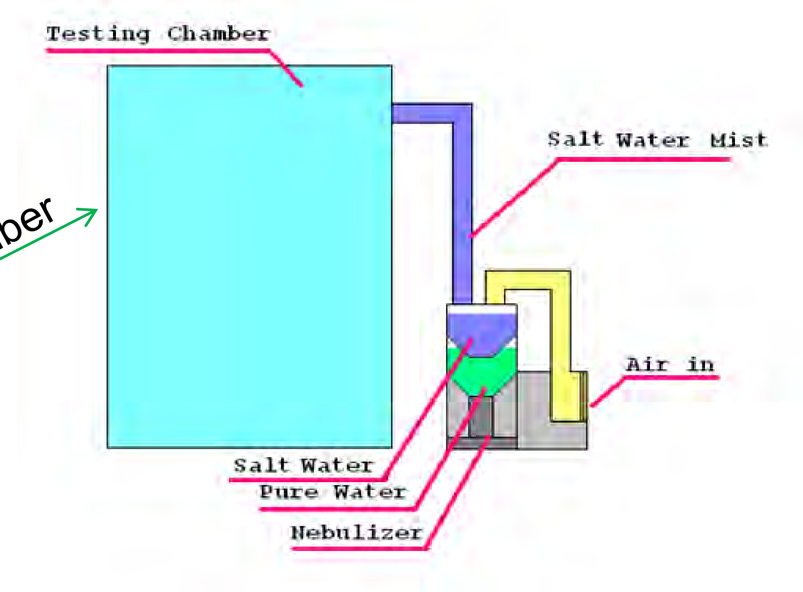
  Impedance module:
  SiN>UVCeO>AlO>control
  - Thin film coating applied on bolts (This work)

UV-curable Cerium Oxide

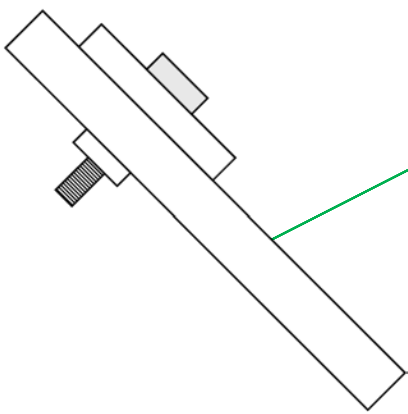


Corrosion test on bolt

- Weather chamber
  - Salt Water (50 g NaCl, 1000 g distilled water)
  - Feed salt mist 15 minutes every one hour



Place in the chamber



Sample

- Rotate every 24 hours
- Tilt 30-45 degree
- Testing duration:
  - 11~12 days
  - Corrosion product is built to its “maximum” stage for one of the samples
- Photo record everyday

Example Modified VDA Test Result:

- Under bolt head: area A
- Galvanic corrosion: area B
- General corrosion: area C
  - Estimated depth of corrosion ring: 2mm (area B)
  - Estimated width of corrosion ring: 2.5mm (area B)
  - 0.334g (Estimated from the galvanic corrosion ring)
  - 0.318g (from measurement)