The International Energy Agency
Implementing Agreement on Advance Materials for Transportation Applications

Annual Report to IEA Secretariat

For Calendar Year 2009

AMT Executive Committee

April 13, 2010

Summary

Management and organization

During the calendar year 2009, the International Energy Agency (IEA) Implementing Agreement on Advanced Materials for Transportation Applications (AMT) was granted a three-year extension to continue its work on providing advanced materials technologies to the rapidly changing land-based transportation sector world-wide.

The AMT Executive Committee (Exco) undertook a detailed examination of its operational procedures, strategy, and potential impact of its work on energy and environmental issues. This examination led to the revision of the Agreement and the research projects (annexes) as well as development of a new operating plan to provide operational details.

Membership

One of the weaknesses identified during the examination was lack of critical mass in some of the technical activities. The Exco decided to expand our membership in two ways: add new member countries and add new institutes from existing member countries. During 2009, Japan, Finland, Israel, were invited to join as Contracting Parties and additional institutions in Canada and China were invited to join as additional contracting Parties. One of the Exco members visited Japan and discussed the IA with AIST officials in September. At year end, Finland indicated that they will join and Australia is finalizing the formal steps to join. Shanghai Institute of Ceramics applied for permission from the Chinese Academy of Sciences and was approved to join AMT. The original approval letter was sent to the IEA Legal Office for action.

Technical activities

Significant progress was made during 2009 on various technology fronts by the three existing annexes. These are detailed in the attached annex reports. Two new annexes were approved to proceed during the June 2009 Exco meeting in Paris. Annex VII focuses on the development of measurement techniques for nanomaterials, which are increasingly being utilized in automobiles to lower the cost and the weight of the vehicles. Annex VIII on thermoelectric materials will examine the characterization and performance measurements of new materials that convert waste heat to electricity more efficiently and at lower temperature than current materials. Both annexes have attracted significant interest among the member countries.

Annex IV: Integrated surface technology for friction reduction in engines
Covering the period: Jan 1, 2009 to Dec. 31, 2009

Annex Participants: USA, China
China: Dr. Junyan Zhang, Lanzhou Institute of Chemical physics
US: Dr. Stephen Hsu, George Washington University with industrial collaborators

Annex Objectives
The objectives are: to conduct cooperative research and development on the friction reduction surface technology; exchange information among participants; test method development; develop surface descriptors and specifications for surfaces with this technology; standardization of diamond like carbon (DLC) films; standardization of friction reducing chemically bonded films.

Technical Progress and accomplishments for the reporting period:
To prolong texture life, a protective film over the textured surface is sought. Adding a film to a complicated textured surface may alter the dimension and shape of the textured dimple; which in turn may alter the friction reducing characteristics of the textures, so the thickness of the film is a critical parameter. If the film is too thin, then the durability may be limited. If the thickness is to too large, the residual stresses would lead to rapid spalling. Thin films have the ability to conform to the textured surface with minimum residual stresses. There are no known films today capable of meeting all these requirements

A collection of high hardness, wear-resistant films were deposited on textured surfaces, these include chromium nitride, titanium nitride, carbides, and diamond-like carbon films. The film thickness ranges from 90 nm to 2 μm thick. Some coating were in the several micrometer thick. As a rule, thick hard films failed quickly.

Contact mechanics analysis of a dimple suggests that the edges of a dimple under high load, low speed conditions induce very high contact stresses, as shown in Fig. 1. Under such stresses, the film covering the dimple will tend to crack or spall under tensile stresses as shown in Fig. 2. Once the film spalls, the debris acted as an abrasive, causing more film wear and high friction. .

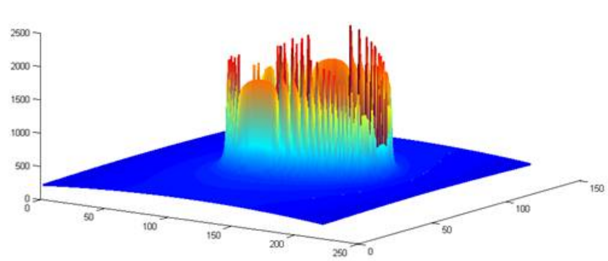


Fig. 1. Contact stress around the edge of the dimple

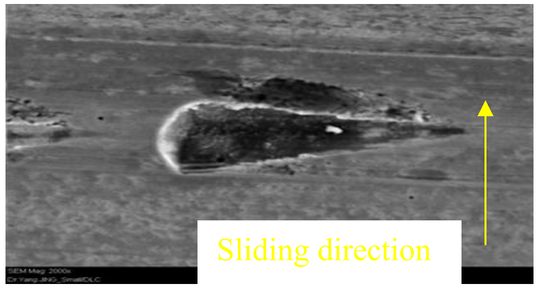
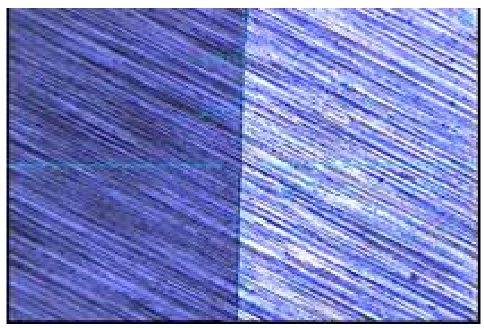


Fig. 2. Delamination of hard film at the edge perpendicular to the direction of sliding

Final selection of wear protective film
After many film failures, a diamond-like carbon (DLC) thin film was selected. The film thickness is below 200nm. An interlayer was used to increase adhesion between the steel substrate and the DLC film.



Coated side Uncoated side

Fig. 3. SEM image of DLC thin film on steel sample

With this thin film, the wear protection increases three times. When a reactive chemistry is added, the durability increases 8 to 10 times, meeting the project goal of five times.

Based on these findings, we developed multiscale designs for each engine component contact types. Preliminary tests on simulated test-beds were successful. A design guideline was developed for critical engine components.

Publications:

No paper was submitted for publication since IP filings were underway.

Annex V: Advanced Corrosion Protection Technologies for Structural Magnesium Alloys Used in Transportation Industry

Covering the period: 1/1/2009 to: 12/31/2009

Annex Participants:
MTL, Canada, Wenyue Zheng (LI), Derushie, Clinton; Roy, George; Bibby, Cathy
McMaster University, Canada, Joey Kish
Centre-Line Ltd, Canada, J. Villafeurte
Meridian technologies Ltd, Canada, J. Jeckle
GM Research, Canada, USA, G. Song
COSMA Engineering, USA, Tim Skszek
Xian Univ. of Tech, China, B. Jiang
IMR-CAS, China, En-hou Han
GKSS, Germany, W. Dietzel/C. Blawert

Objectives:

The objective of this Annex is to develop advanced coating technologies that can prevent stress corrosion cracking (SCC) and galvanic corrosion; and to establish the threshold loading (stressing) conditions for representative wrought products (AZ31, AM30, ZK alloy), which are used as structural components. The project aims to advance our understanding of the micro-mechanisms governing SCC of Mg alloys in a typical automotive in-service environment. Such understanding is necessary for technology development in this area.

Technical Progress and accomplishments for the reporting period:

Two subtasks were conducted in 2009:

- X Subtask I. Selection and initial characterization of test alloys for structural applications.

  Wrought products (sheet, extrusion) was chosen to be the focus of this study. At this stage, Mg alloys AZ31, AM30 are selected as the test alloy for the first batch of testing.

  Planned task achievements (PTA)**:** A database of microstructural characteristics of candidate alloys (texture, impurities, compositions, surface vs bulk properties). This task has started in the first part of 2010.

- X Subtask II: Test specimen machining and surface coating
  Technical achievement: AZ31 samples machined; AM30 alloy supplier source identified.

Other highlights of 2009 included:

(1) Completion of a comprehensive book chapter on Mg corrosion for publication by American Foundry Society,
(2) Launching of a joint SCC test program between Materials Technology Laboratory and McMaster and
(3) Initiation of first series of SCC and CF (corrosion fatigue) tests on AZ31 Mg sheet alloy.

Results from the study on the effects of stress on Mg alloy failure life suggest that a reduction of the net stress intensity at crack initiation sites may prolong the life of the alloy under cycling stresses.

The corrosion fatigue work on AZ31 in a GM9540P solution, on both as-received samples and shot-blasted samples indicate a high degree of sensitivity to surface contamination. Figure 1 shows an example of the SCC morphology in AZ31 alloys as immersed in GM9540P solution.

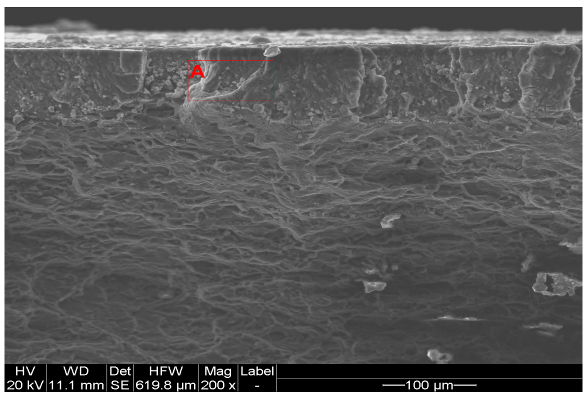


Figure 1. SEM photograph of SCC cracks developed at the surface of AZ31

Publications:

1. A book chapter entitled "Corrosion of Mg alloys: methods of assessment", Wenyue Zheng, in Print at AFS.
2. "Galvanic corrosion of Mg alloys", draft chapter for a book on Mg technologies (by Woodland Publishing Ltd.).

Annex VI on Low Cost Carbon Fibre Composites for Transportation Applications

Covering the period: January 1, 2009 to December 31, 2009

Participants: UK, USA

- Alan Wheatley University of Sunderland, UK
- David Warren, ORNL, USA

Objectives:

The objective of this task is to exchange information on testing and characterization of carbon fibre composite materials. Non-commercial, non-sensitive information/data will be shared. Activities will include:

X Exchange of reports, studies, and test samples as agreed upon in advance by the participating members on a semi-annual basis.
X Joint technical workshops and meetings.
X Reciprocal invitations to workshops and conferences.
X Reciprocal visits to research facilities.

Technical Progress and Accomplishments for the Reporting Period:

The combination of comprehensive characterization data and reliable predictive modeling tools will result in a bank of design data – thereby helping to alleviate one of the constraints on the adoption of CFRP (*spell out acronym – carbon-fibre reinforced polymers?)* , namely lack of confidence or comfort on behalf of the automotive industry in the material. Reliable materials data and predictive modeling tools are vital to engender confidence among potential users. In a similar manner, standard uniform test procedures must be employed to generate such design data – otherwise diverse sets of data will not be directly comparable. For novel materials such as low cost CFRP, the development and acceptance of standard test techniques are a vital step in its adoption. The aim of this task is therefore to formulate a set of relevant test methods and achieve consensus on the formulation.

- Establish a database of various relevant test methods currently used for evaluating carbon fibre composites.
- Liaise with industrial and government stakeholders (e.g. standards institutions) to identify any critical "gaps" in standard test provisions which currently constrain development and/or adoption of CFRP's.
- Develop relevant test techniques and standards via international round robin testing, evaluation and information exchange.

Publications: *Low Cost Carbon Fibre for Automotive Applications*: Energy Technologies at the Cutting Edge, IEA, 2009.

Annex VII – A cooperative program on development, evaluation and standardization of methods for testing mechanical properties of nanomaterials for application in automotive industries

Covering the period: 12 June 2009 to 31 December 2009

Annex Participants: USA, Germany, China, Canada

- Dr. Michael Griepentrog, BAM, Germany
- Dr. Stephen Hsu, GWU, USA
- Dr. Chanmin Su, VEECO, USA
- Dr. Gregory F. Meyers, The Dow Chemical Company, USA
- Dr Alan Brewin, NPL, UK
- Dr. Guanglu, National Center for Nanoscience and Technology, China
- Florence Perrin-Sarazin, Institute Industrial Materials, Canada

Objectives:

Nanomaterials have great potential for the topics of AMT (e.g. polymer/clay nanocomposites for automotive parts, carbon nanotubes in magnesium alloys). Even though the test methods for mechanical properties in the Macro-, Micro- and Nano-range exist, the linkage among them is lacking. To push for the wide-spread use of nanomaterials in transportation, the development of new test methods and the standardization of useful existing methods are needed.

The general objective of this Annex is to conduct cooperative research involving the development, evaluation and standardization of methods for testing mechanical properties of nanomaterials for application in automotive industries; and to establish nanoscale measurement methodology that correlates with the measured global property.

Technical Progress and accomplishments for the reporting period:

Period: 12 June 2009 to 31 December 2009
Revised the draft of the Annex
Draft was discussed and approved on 12 June 2009
Preparation of the final Annex
Final Annex was discussed and approved on 4 December 2009

Annex VIII on Thermoelectric Materials for Waste Heat Recovery: An International Collaboration for Transportation Applications

Covering the period: 01-10-2009 to: 31-12-2009

Annex Participants:

- Dr. Hsin Wang, ORNL, USA
- Prof. Terry Tritt, Clemson University, USA
- Dr. Jason Lo, CANMET, Canada
- Professor Holger Kieinke, University of Waterloo, Canada
- Professor Lidong Chen, Shanghai Institute of Ceramics, CAS, China
- Dr. Harold Bottner, Fraunhofer Institute for Phys. Meas, Germany

Objectives:
The annex aims to develop test methods for the evaluation of thermoelectric materials and to develop precision statements for the standardization of these methods.

Specifically, we aim to:

- Develop standard testing methods and procedures for thermoelectrics (bulk and nano-composite materials)
- Assess the state-of-the-art for thermoelectric materials and identify critical issues to improve performance
- Conduct international round-robin tests of standard thermoelectric materials (20-500ºC)
- Exchange technical information
- Characterize key properties (transport properties and others, using advanced tools such as STEM and neutron scattering) of potential thermoelectrics for transportation applications.

Technical Progress and accomplishments for the reporting period:

An exchange of technical information among participating countries started in June 2009 Exco meeting in Paris. A survey e-mail was sent to all participating countries to determine the testing capabilities of each laboratory. The information was used to design the round-robin test of thermoelectrics. Materials geometries were specified and the special batch Bismuth telluride (Bi_2Te_3) material was made by Marlow Industries using a known process which produces very homogeneous materials. The specimens have been purchased and are being sent to participating laboratories.

Round-robin study planning: The objective of the initial round-robin test is to assess the state-of-the-art of current measurement technologies. Based on this, the procedure will be tightened to establish a standard procedure and practice for the determination of ZT. N-type and P-type bismuth telluride specimens from the Marlow Industries were prepared for thermal diffusivity, Seebeck coefficient, electrical resistivity, and specific heat measurements. The aim is to establish current measurement methods and their variances. The round robin test will be conducted in sequence, i.e. the samples will be rotated among the participating labs after measurement.