

Annual Report for the International Energy Agency
Of the Implementing Agreement for a Programme of Research and Development
on
Advance Materials for Transportation Applications

Calendar Year 2015

AMT Executive Committee

August 1, 2016

INTRODUCTION

The International Energy Agency (IEA) is an autonomous agency established in 1974. The IEA carries out a comprehensive programme of energy co-operation among 34 participating countries. The aims of the IEA are to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

To attain these goals, increased co-operation between industries, businesses and government energy technology research is indispensable. The public and private sectors must work together, share burdens and resources, while at the same time multiplying results and outcomes.

The Technology Collaborative Programs (TCPs) supported by the IEA are a flexible and effective framework for IEA member and non-member countries, businesses, industries, international organisations and non-government organisations to research breakthrough technologies, to fill existing research gaps, to build pilot plants, to carry out deployment or demonstration programmes – in short to encourage technology-related activities that support energy security, economic growth and environmental protection. More than 6,000 specialists carry out a vast body of research through these various initiatives. To date, more than 1,000 projects have been completed. There are currently 39 TCPs working in the areas of:

- Cross-Cutting Activities (information exchange, modelling, technology transfer)
- End-Use (buildings, electricity, industry, transport)
- Fossil Fuels (greenhouse-gas mitigation, supply, transformation)
- Fusion Power (international experiments)
- Renewable Energies and Hydrogen (technologies and deployment)

The TCPs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties and two experts' groups. For further information on the IEA, the CERT and the IAs, please consult www.iea.org/aboutus/standing_groupsandcommittees.

Under the End-Use Working Party, the Technology Collaborative Program on Advance Materials for Transportation Applications (AMT TCP) resides. AMT TCP conducts research on materials technologies for the development of fuel efficient, environmentally friendly cars and trucks for transportation applications. The views, findings, and publications of the (AMT TCP) do not necessarily represent the views or policies of the IEA or of all of its individual member countries. For more information about the AMT TCP please consult www.iea-ia-amt.org.

CHAIR'S REPORT

TCP 2015 highlights: With the heightened sense of urgency of the need to take action in curbing carbon emission to halt the global climate change, carbon emissions from the 1.2B+ legacy vehicles around the world need attention. Assuming an average 14 years of vehicle replacement rate, fuel economy and carbon emission of current and future models will have a profound impact on reducing global emissions. Transportation related carbon emission for the world is about 16% but in the US, it is 31%. With the Paris Accord, the world community has pledged to keep the temperature warming to 2°C or below. Current cooperative research focuses on friction surface, lightweighting, and waste heat recovery to improve fuel economy hence reduce carbon emission. The new Annex on multi-materials joining is up and running, paving the way for optimum lightweighting design for future generation of fuel efficient vehicles.

Technical highlights and milestones: We have successfully reached the planned milestones.

- The friction surface technology (Annex IV) has shown to be effective to protect engine wear when using ultra-low viscosity lubricants. The subtask on fuel efficient lubricants has demonstrated a fuel efficient low viscosity lubricant was able to achieve 2.4% compared with the 2014 commonly used lubricant. The Annex is proceeding to evaluate engine durability.
- Annex VIII on thermoelectric materials has completed three robin studies on bulk thermoelectric materials from room temperature to high temperatures. Various measurement methods have been tightened to give a 26% more precise ZT (figure of merit). The study is moving on device testing round robin study.
- Annex IX on model-based coatings has completed the characterization and testing of diamond like carbon (DLC) coating. Results are being fed into the computational models to provide insights into the test results. This may lead to improved coating design for higher performance and longer durability.
- Annex X on multimaterials joining has embarked on joining technology research

Impact and significance

Materials technology is the foundation of fuel efficient technologies. The friction surface technology has demonstrated that it is feasible to harvest fuel economy benefits, thus providing a technology option. The lightweighting of vehicle is inevitable and the joining of multimaterials will accelerate the design guidelines for optimum light weight vehicles. The improvement of thermoelectric materials measurement will enable the development of high thermal efficient materials for waste heat recovery.

Executive Committee Meetings

The Executive committee met twice in 2014: June 3 in Lanzhou Institute of Chemical Physics, Lanzhou, China; Dec. 2 in Saarland University, Saarbrucken, Germany. The ExCo leadership also visited BAM in Berlin on Dec. 3 to meet with the President of BAM to discuss closer ties. The meetings focused on emerging fuel economy technologies and realign AMT activities to achieve impact.

MEMBERSHIP

AMT membership in 2014 has 9 countries (US, Canada, UK, Germany, Finland, China, Australia, Korea, and Israel). A total of 15 Institutes and cooperating partners now participate in the technical activities.

Country	Contracting Party
US	US Department of Energy
Finland	Finnish Funding Agency for innovation (TEKES)
Canada	CanmetMATERIALS, Natural Resources Canada
Germany	BAM (Bundesanstalt fuer Materialforschung und-pruefung)
China	Lanzhou Institute of Chemical Physics, Chinese Academy of Science
	Shanghai Institutes of Ceramics, Chinese Academy of Science
Australia	Western Australia University to be transferred to Curtin University
UK	University of Sunderland
Israel	Israel Institute of Technology (Technion)
Korea	Korean Energy Technology Evaluation and Planning (KATEP)

ACTIVITIES

Annex IV Integrated surface technology for friction reduction in engines

Covering activities from Jan 1, 2014 to Dec. 31, 2014.

1. Overview of Scope: Within the moving parts of an engine, frictional losses consume significant amount of the input energy, depending on engine design. While some frictional resistance is needed for the operation, the parasitic energy losses can be reduced to increase fuel efficiency. The Annex focuses on research activities to develop surface textures, coatings, and ultralow viscosity lubricants to reduce friction and enhance durability.

2. Annex Participants

US: Led by Dr. Stephen Hsu, George Washington University, USA (Chair)
 China: Led by Dr. Junyan Zhang, Lanzhou Institute of Chemical physics, CAS, China
 Australia: Led by Dr. Gwidon Stachowiak, Curtin University, Australia

Israel: Led by Dr. Izhak Etsion, Technion, Israel
Finland: Led by Dr. Kenneth Holmberg, VTT, Finland
UK: Led by Dr. Mark Gee, NPL, UK
Germany: Led by Dr. Carsten Gachot, Saarland University, Germany

3. Activities/accomplishments

Surface textures, including surface topography designs, discrete dimples, grooves, and other geometrical shapes, if properly designed, can create or accelerate the fluid pressure buildup between two sliding surfaces, thus providing additional lift force to allow robust lubricant film to continue to support the load, hence reduce friction and wear.

In 2014, some original equipment manufacturers (OEMs) have reported significant fuel economy increase (2-4%) by using ultra-low viscosity lubricants in vehicle driving tests. While some OEMs have employed material technology to fortify their engines to be more wear resistant, this is not the case for all OEMs. A new ultra-low viscosity lubricant classification of the Society of Automotive Engineers (SAE) has been established in 2013 (SAE 0W-16) and a new lubricant classification GF-6 has been created to allow the use of ultra-low viscosity oils, pending the development and issuance of new engine sequence dynamometer tests to certify this class of oils. Because of the low viscosity, wear emerge as the key challenge.

A new subtask on developing robust low viscosity lubricants was established in 2014 to explore novel base oils (ionic liquid, polyglycols, and liquid crystals, etc.) and more robust friction modifiers and lubricant film enhancers as a means to achieve the fuel economy gains without wear. We have collected over 60 additives and base oils for study.

At the same time, the Annex began working with a major US OEM to identify a specific engine where friction surface technology can be fabricated to test the effect of ultralow viscosity lubricants on long term durability.

With surface texture design methodology developed, there is a need to address the issue of how textured surfaces can be specified for qualify control. Australia leads the effort on this aspect in the Annex. The aim is to develop a mathematical description of the textured surface which has directionality and multiple length scales. This can be described by using fractal mathematics. The method will be tested on computer images of different surfaces.

Significance and impacts

With 1.2B vehicles in the world today, and 86M vehicle annual production rate, the combined emission and oil consumption constitute one of the largest energy sectors. Reducing oil consumption by fuel economy improvement is one of the key strategies to reduce oil consumption and carbon emission in the near term. Friction surface technology and ultralow viscosity lubricants can have a significant impact on world energy consumption.

Annex VIII: Development of thermoelectric materials for waste heat recovery

Covering the period: Jan 1, 2013 to Dec. 31, 2013

1. Overview of Scope: the objective of the Annex is to develop standard test methods and precision data for the accurate measurement of thermoelectric materials and devices enabling the development of more effective thermoelectric materials.

2. Annex Participants:

USA: Led by Dr. Hsin Wang, ORNL, USA

Canada: Led by Dr. Yu-Chih Tseng, CanmetMATERIALS, Canada

China: Led by Prof. Lidong Chen, Shanghai Institute of Ceramics, CAS, China

Germany: Led by Dr. Jan Konig, Fraunhofer Institute for Phys. Meas, Germany

UK: Led by Dr. Alexandre Cuenat, National Physical Laboratory, UK

3. Activities/Accomplishments

International round-robin studies on bulk thermoelectric materials have been conducted.

Results showed significant data scatter on thermal conductivity and other properties associated with the determination of ZT [$ZT = \sigma S^2 T / \lambda$], the figure of merit commonly used to gauge the performance of thermoelectric materials (where S is the Seebeck Coefficient, λ is the thermal conductivity, σ is the electrical conductivity, and T is the temperature).

Annex VIII has completed three international round-robin (RR) studies on bulk thermal electric materials. The final report on commercially available bismuth telluride (RR1 and RR2) and its figure of merit, ZT found the errors (measurement scatters) for ZT varied from $\pm 11.7\%$ to $\pm 20.9\%$. The third round-robin (RR3) among 11 laboratories using n-type half-Hausser material was started in 2012. The temperature range of RR3 is 20-500°C covering the automotive exhaust temperatures. The final statistical analysis was completed. Overall, the electrical resistivity measurement was found to have an uncertainty of $\pm 6.5\%$ to $\pm 7.4\%$ for the entire temperature range. The Seebeck coefficient measurement was found to have an uncertainty $\pm 5.7\%$ to $\pm 7.9\%$. The thermal diffusivity measurement has an uncertainty is $\pm 1.9\%$ to $\pm 3.7\%$. The combined figure of merit of the study is shown in Fig. 1. The inter-laboratory uncertainty for ZT is $\pm 11.6\%$ to $\pm 16.4\%$. This is a significant improvement over the first round robin study results.

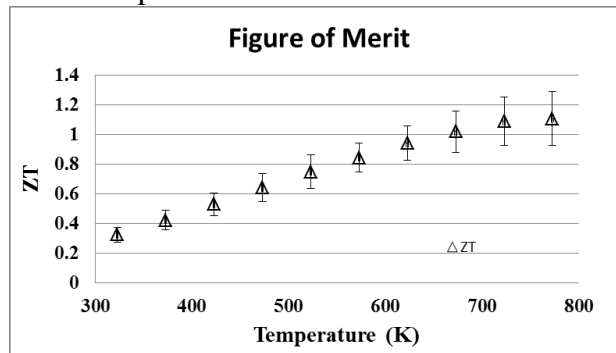


Fig. 1. Final figure of merit of 9 labs over the temperatures

A thermoelectric module efficiency measurement round robin is being organized and planned. There is an increasing demand for the development of standard method to assess the efficiency of thermoelectric module since ZT of the material may not reflect the system efficiency. A general survey of efficiency testing devices and their performance has been conducted including current commercial and homemade systems from the USA, Germany and Japan. The survey results indicated the lack of industry standards and test procedures. Fig. 2 shows a proposed measurement system being considered.

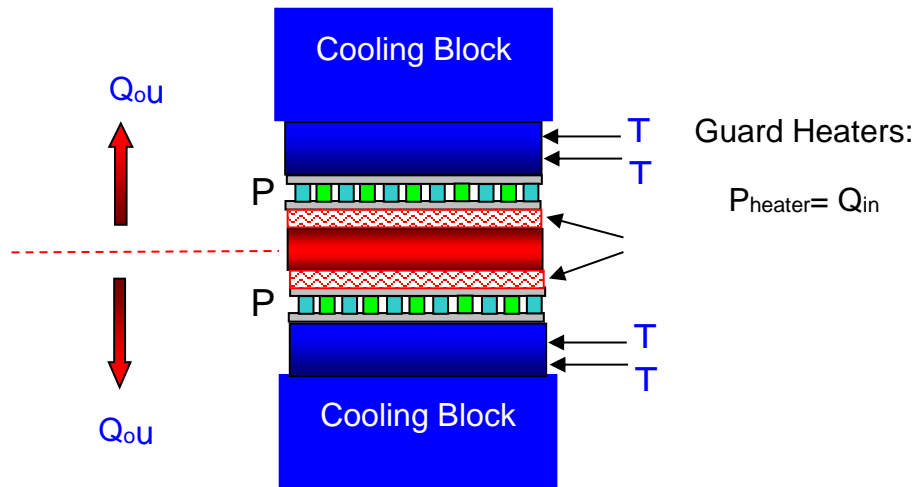


Figure 2. A proposed TE module efficiency testing system after the Annex VIII survey

4. Significance and Impacts

Thermoelectric material is a class of materials that captures waste heat from engine operations and can contribute significantly to the energy efficiency of cars and trucks. For engine waste heat recovery, much higher efficiency materials are needed. Creation of a standard test procedure coupled with standard reference materials issued by a National labs will lead to verifiable high efficiency thermoelectric materials, which have the potential to recover a portion of the roughly 40% of energy lost as heat through the exhaust systems of a normal internal combustion engine. It has broad applicability to the current annual production of 84M of internal combustion engine driven vehicles, and even greater potential for hybrid electrified vehicles due to the presence of onboard battery energy storage.

Annex IX Model based design of tribological coating systems

Covering the period: Jan 1, 2014 to Dec. 31, 2014

1. Overview of Scope: the objective is to integrate modeling and coating testing to guide the development of next generation of advanced coatings for energy efficiency and durability in engines.

2. Annex Participants

Finland: Led by Dr. Kenneth Holmberg, VTT, Finland (Chair)
Australia: Led by Dr. Gwidon Stachowiak, Curtin University, Australia
US: Led by Dr. Stephen Hsu, George Washington University, USA
Israel: Led by Dr. Izhak Etsion, Technion, Israel
China: Led by Dr. Junyan Zhang, State Key Lab of Solid Lubrication, Lanzhou, China
UK: Led by Dr. Mark Gee, National Physical Laboratory, UK
Germany: Led by Dr. Carsten Gachot, Saarland University, Germany
Hong Kong: Led by Dr. Lawrence Li, City University of Hong Kong, Hong Kong

3. Activities/Accomplishments

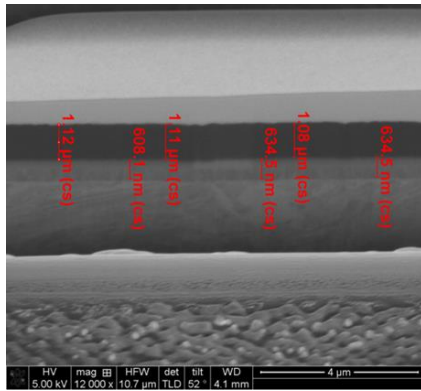
The work was carried out in three work packages focusing on three scale levels in a sliding contact with coated surfaces:

WP1: Integrated surface and microstructural modelling in a DLC coated tribological contact: study covering topographical and microstructural material modelling on macro and micro level.

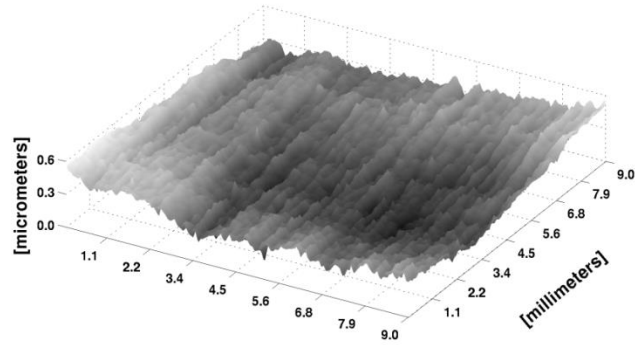
WP2: Optimization of thin film coated surfaces in tribological sliding contacts: a study focusing on asperity level micro scale modelling.

WP3: Phase transformation (sp^3 to sp^2) in DLC coatings caused by friction: a study on nano scale by molecular dynamic modelling.

Diamond-like carbon (DLC) coatings were chosen to be studied because of their excellent low friction and low wear properties and great potential for extensive use in transportation. In WP1 a very detailed DLC (diamond-like carbon) coated surface material characterization at the microstructural level was carried out (Fig. 3a). The surface roughness was characterized by determination of topographical parameters and orientations by 3D profilometry (Fig. 3b) and variance orientation transformation on several fractal scales from 30 – 840 μm (Fig. 4a).



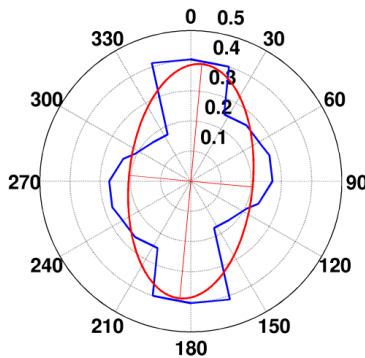
a)



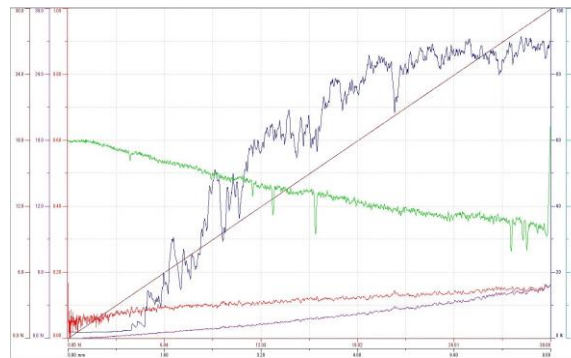
b)

Fig. 3. (a) Focused ion beam cross-section of a DLC coating with three layers from top: the DLC layer, the CrCx gradient layer, the Cr buffer layer and the substrate. (b) A 3D topography image by chromatic confocal surface profilometer of and average roughness DLC coated surface.

The surfaces studied had three levels of roughness (R_a 0.004, 0.012 and 0.1 μm) and three orientations (0° , 45° , 90°) in relation to the grinding grooving marks. The topographical effects on surface failure by fracture was studied by scratch test (Fig. 4b) and five failure mechanisms were identified, two on macro level and three on micro level (Fig. 5a).



a)



b)

Fig. 4. (a) Rose Hurst plots showing topographical heights and orientations on 360 μm fractal scale of an average roughness DLC coated surface. (b) Scratch test load, friction, acoustic emission and residual deformation measurements of an average roughness DLC coated surface.

The topographical effects on friction and wear were measured both for rotational and reciprocal movements (Fig. 5b). New interesting surface strengthening, surface weakening, frictional as well as wear effects of topographical orientation were identified, analyzed and reported in a journal paper. The multiscale analysis brought new insight to the basic contact mechanisms that control the friction and wear behavior and offers a platform for computational modelling based coated surface optimization with regard to reliability and effective lifetime.

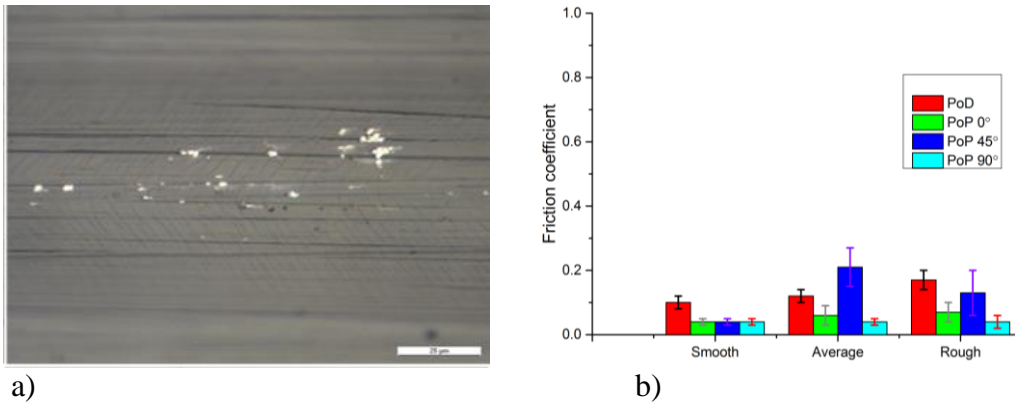


Fig. 5. (a) Scratch test image from above after tip sliding contact showing surface failure pattern with angular cracks and delamination of an average roughness DLC coated surface. (b) Coefficient of friction for DLC vs DLC coated surfaces in rotational pin-on-disc and reciprocating pin-on-plate tribotesting with three different roughness levels and three orientations.

In WP2 a universal model for the load-displacement relation in an elastic coated spherical contact was developed. These contact conditions correlates with the conditions found on asperity tips of coated surfaces. The model provides a universal expression for the effective modulus of elasticity that is based only on mechanical properties of the coating and the substrate.

In WP3 both the growth mechanisms (Fig. 6a) of hydrogenated DLC coatings and the interactions and degradation behavior in DLC a-C/a-C self-mated contacts (Fig. 6b) were modelled and simulated on atomistic level by molecular dynamic simulation technique. These nano level studies gives an explanation of the transformation of molecular structure from a diamond-like crystalline to a more graphite-like amorphous sliding interface, which is one of the key elements giving the DLC surfaces extremely low friction in automotive and other applications.

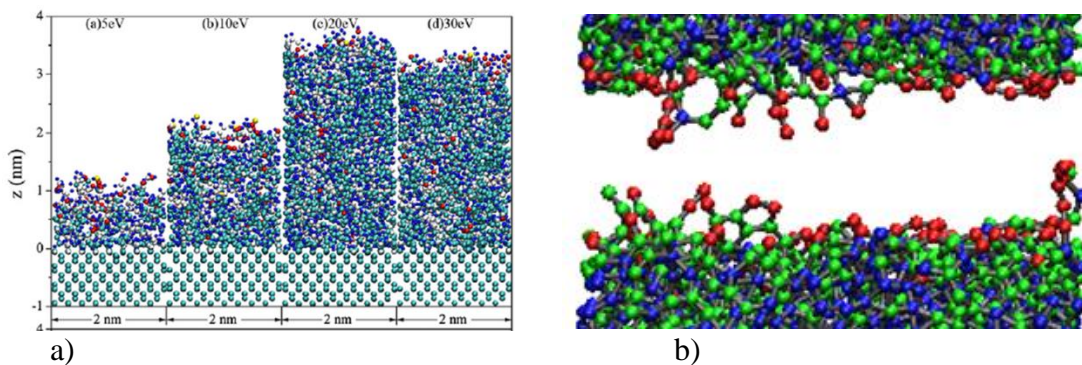


Fig. 6. Molecular dynamic simulation images of (a) growth of a hydrogenated DLC film and (b) molecular dynamics of a self-mated DLC a-C/a-C contact (blue is sp^3 , green is sp^2 and red is sp^1).

4. Significance and Impact

The combination of modeling and testing will yield important insights into the material behavior. The study is its initial stages and theoretical analysis of data is to be followed in 2015. Undoubtedly, this will lead to more durable coatings.

Annex X Multi-Material Vehicle Lightweight Structures, Materials Joining Technology Covering the period: Jan 1, 2014 – Dec 31, 2014

1. Overview of scope

This Annex was approved by the IEA AMT Executive Committee meeting in London, UK on June 4 2013. The objective of this Annex is to develop joining methods of various lightweight materials to enable the assembly of an optimum light weight vehicle with high energy efficiency

2. Annex Participants

Canada: Led by Dr. James Chen, CANMET Materials, Canada (Chair)
US: Led by Dr. David Warren, ORNL, USA

3. Activity/Accomplishments

An assessment on the feasibility of re-fill friction stir spot welding (RFSSW) on joining of Mg alloy (ZEK 100, 1.53 mm thick) and high strength steel sheets (DP 600, 1.0 mm thick) was carried out in 2014.

A schematic of refill friction stir welding process is shown in Fig. 7. Strategy for joining of non-ferrous alloys to steel was employed by controlling penetration depth to 0.03 mm on the lower sheet.

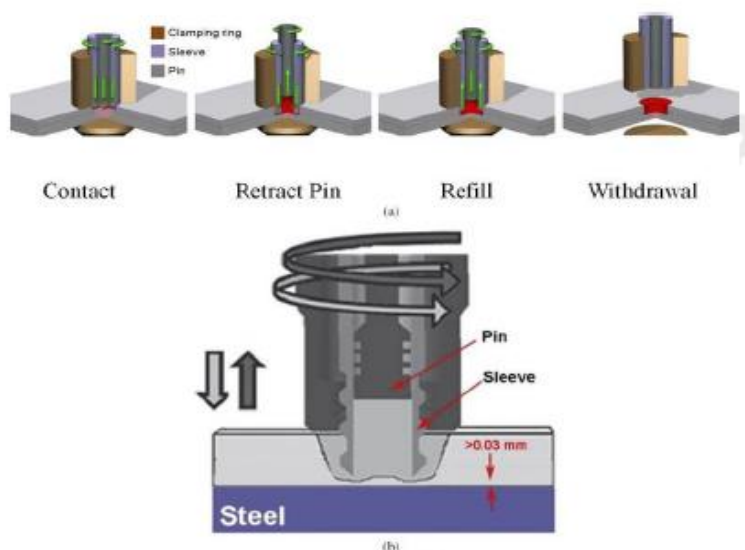


Fig. 7. Schematic of refill friction stir welding process, for joining two similar sheets (a) and strategy for joining of non-ferrous alloys to steel by controlling penetration depth to 0.03 mm above the sheet (b)

During welding, the steel sheet placed below, and the plunging depth of the tool into the upper Mg sheet varied from 1.3 to 1.5 mm. The tool operated under a rotation speed of 1600 to 2100 rev/min for 2.5–3.5s welding time. Owing to the severe mechanical deformation imposed by the tool during the refill process, significant grain refinement occurred within the Mg alloy (from 10mm grain size to 1.6 to 6.5 mm in the stir zone). The variation in grain size was symmetrical across the stir zone; with finer grain sizes observed towards the location below the tool sleeve at the outer periphery, while the coarser grains were observed near the centreline of the tool below the pin (see Fig. 8).

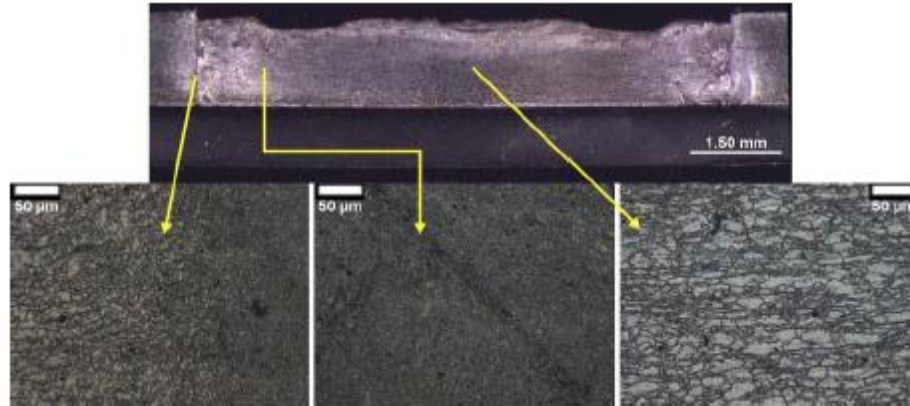


Fig. 8 Grain structures in ZEK100 stir zone produced using 1800 rev/min and 3 s (a) 1800 rev/min and 3.5 s (b) and 2100 rev/min and 3 s (c)

High concentrations of Zn are dispersed throughout the stir zone and typically at the periphery of the joint directly under the tool sleeve. The Zn coating appears to be displaced from the DP600 steel sheet surface and moved upwards as well as towards the periphery edges of the weld; such movement is consistent with the material flow.

There was evidence that some residual Zn coating on the steel sheet surface remained at the interface of the weld and was not completely displaced by the material flow imposed by the refill welding tool. Some of the Zn has also reacted with the Mg alloy and appears to form a very fine scale Mg–Zn eutectic structure. The presence of a Zn coating on the steel appears to provide a mechanism for bonding. A TEM image of the interface at the centre of the weld is shown in Fig. 9, along with the element mapping. No voids or pores were present at the interface; however, a discontinuous film of oxides could be observed, which likely originated from the original Mg alloy sheet since the surfaces were not brush finished before joining (as expected for a manufacturing scenario). The presence of Zn is only observed in the Mg alloy side, with an increased concentration within 250 nm of the steel interface. However, the most striking observation is the presence of an Al rich film with a thickness of ~100 nm at the interface within the Mg alloy sheet.

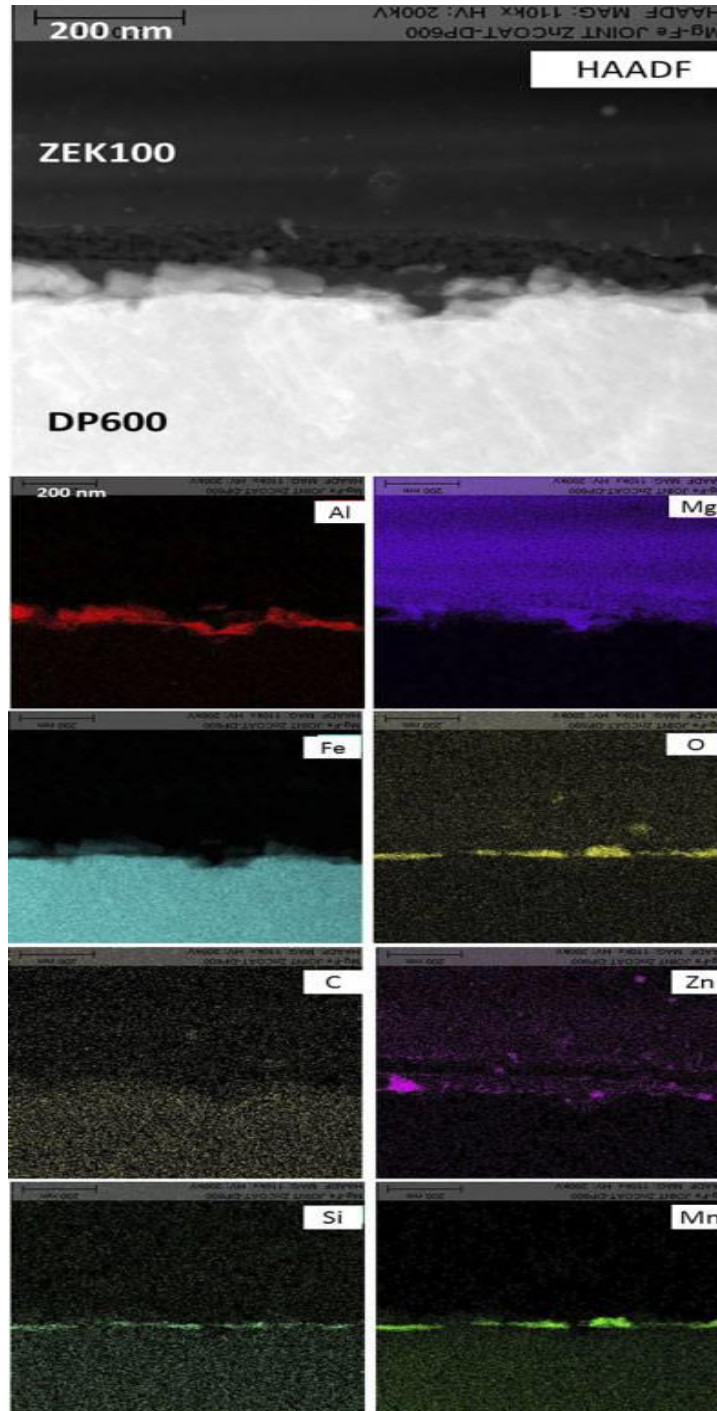


Fig. 9. High angular annular dark field image (TEM) of interface with element maps for Al, Mg, Fe, O, C, Zn, Si and Mn

The overlap shear strengths of individual joints reached over 4.9 kN for the Mg ZEK100/HS steel DP600 joints; however, the highest average load was 4.7 kN when using 1800 rev/min, a 3 s welding time and 1.5 mm of tool penetration as shown in Fig. 10. This compares well with the requirements of AWS D8.9M, which recommends an average of 3.8 kN for the equivalent resistance spot welds between the weaker material (ZEK100, which had a tensile strength of 275 MPa). The fracture loads drastically increased when the plunge depth increased above 1.3 mm, which indicates that a critical threshold distance between the tool and steel sheet must be reached in order provide bonding. When the welding time increased to 3.5 s using 1800 rev/min, the loads decreased, to an average of 3.45 kN, and when the tool rotation speed increased to 2100 rev/min, the average fracture load decreased to 3.29 kN. These results suggest that the quality of the bond deteriorates when excess heat is applied during welding. All the fractures during overlap shear testing occurred through the interface.

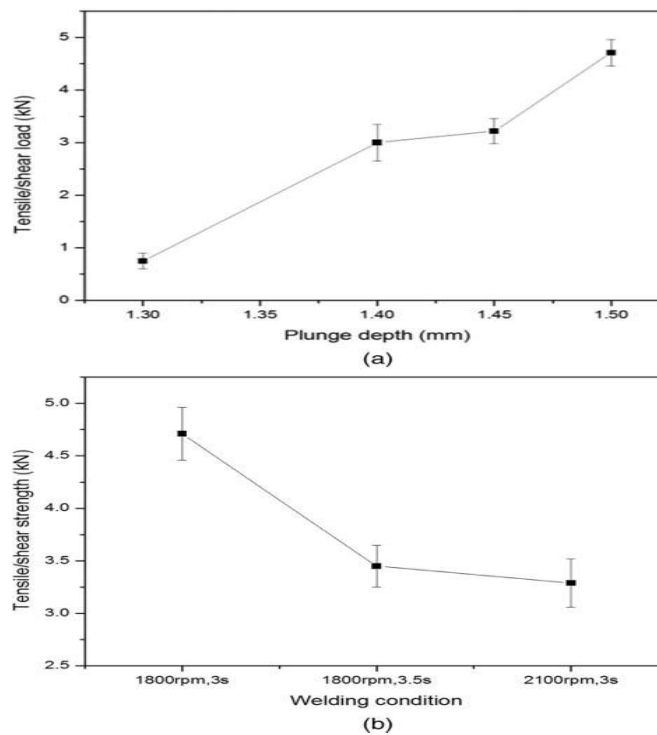


Fig. 10. Comparison of ZEK100/DP600 joint overlap shear fracture loads a versus plunge depth when using 1800 rev/min and 3.0 s welding time (a) and when revolutions per minute and welding time is varied (b)

These results suggested that re-fill fraction stir spot welding is feasible in joining Mg sheet to high strength steel.

4. Significance and impacts

Automobile fuel economy regulations vary across the globe but there is a unified effort to increase vehicle fuel efficiency using a range of technologies since no single technology will

achieve regulated targets. It is, however, known that structural lightweighting can increase fuel economy by 6-10% with a 10% vehicle weight reduction which affects its energy profile throughout the use phase of the vehicle. Use of light metals in vehicles is increasing and indications suggest that the optimum vehicle will include a range of alloys in a multi-material structure. Key technology enablers to achieve multi-material structures include development of both joining and corrosion mitigation strategies. As an increasing number of new platforms launch from the original equipment manufacturers, with ever increasing annual production on the order of 84M per year, there is an increasing opportunity to implement new alloys and the necessary joining technologies. The joining of steel to magnesium sheet in this project is one of numerous joining methods needed in order to be successful in reaching regulated targets and making an impact on GHG emissions and climate change.

AMT PLAN FOR NEXT YEAR

AMT ExCo committee continues to evaluate existing activities as the transportation sector transforms itself towards more fuel efficient, carbon neutral future. The link between technology options and policy mandates has been increasing. AMT has set up a technology assessment and policy implication working group to monitor the evolving trends. For 2015, we plan to:

- 1) Sharpen AMT's policy message and issue a short policy brochure.
- 2) On the friction surfaces activity (Annex IV), with the creation of two subtasks (shear resistant DLC and ultra-low viscosity lubricants), the Annex plans to work with an OEM to jointly develop the friction surface technology for implementation into practice in three years' time.
- 3) Annex VIII on thermoelectric materials will enter into device testing and measurement of system efficiency. There is no standard test for this and the Annex will work with industry to jointly develop such measurement systems.
- 4) Annex IX on model based coatings will continue with generating an integrated multiscale topographical and sub-coating microstructural model, simulations of friction and wear performance in industrially relevant contact conditions and linking the computational mesoscale model insights with testing.
- 5) For the multimaterials joining, Annex X, additional subtasks will be organized to have more countries participating.
- 6) Recruiting new member countries remains as one of the priority items.

COMMUNICATION

External communication

AMT participates in the transport contact group meetings organized by the EUWP Vice Chair and interacts with other transport IAs via email exchanges and circulate newsletters from AMF and HEV to our participants.

We have revamped our website to be more communicative and plan to publish Special Topical Reports as appropriate.

As we have been practicing over the past years, every ExCo meeting has a full day open technical symposium to introduce AMT activities to local technical community.

Publications:

1. Hsin Wang, Robin McCarty, James R. Salvador, Atsushi Yamamoto, and Jan Konig, “Determination of Thermoelectric Module Efficiency – A Survey”, *Journal of Electronic Materials*, Vol. 43, No. 6, pp2274-2286, June 2014
2. K. Holmberg, A. Laukkanen, H. Ronkainen, R. Waudby, G. Stahowiak, M. Wolski, P. Podsiadlo, M. Gee, J. Nunn, C. Gachot, L. Li, “Topographical orientation effects on friction and wear in sliding DLC and steel contacts: Part 1: Experimental”, accepted for publication in *Wear* 02/2015
3. R. Goltsberg, I. Etsion, “A universal model for the load-displacement relation in an elastic coated spherical contact”, *Wear* 322-323(2015)126-132.

FINANCING

AMT is a task-shared Implementing Agreement. Every participant in each country receives funding from the government agencies, universities, and industries on specific Annex activities or related projects. AMT does not have a common fund.

EXECUTIVE COMMITTEE MEMBERS

Mr. Jerry Gibbs, Department of Energy, Forrestal Building, Washington DC, USA (Chair)

Dr. Stephen Hsu, George Washington University, Washington DC, USA (Vice Chair)

Dr. Juergen Lexow, BAM, Berlin, Germany (Secretary)

Dr. Alan Wheatley, University of Sunderland, UK

Dr. Mark S. Kozdras, CanmetMATERIALS, Hamilton, Ontario, Canada

Dr. Hsin Wang, Oak Ridge National Lab, Oak Ridge Tennessee, USA

Dr. Pasi Viitanen, Tekes, Finland

Dr. Gwidon Stachowiak, Curtin University, Australia

Dr. Kenneth Holmberg, VTT, Finland

Dr. Junyan Zhang, Lanzhou Institute of Chemical Physics, CAS, China

Dr. Lidong Chen, Shanghai Institute of Ceramics, CAS, China

Dr. Mark Gee, NPL, UK

Dr. Izhak Etsion, Technion, Haifa 32000, Israel

Dr. Jae Seol Lee, Korea Institute of Energy Technology Evaluation and Planning (KETEP)

Dr. Hee Woong Lee, Korea Electrotechnology Research Institute (KERI)

CONTACT INFORMATION

Further details on AMT activities can be found on www.iea-ia-amt.org. For more information please contact Dr. Juergen Lexow at juergen.lexow@bam.de and/or Dr. Stephen Hsu at Stephen.hsu@erols.com