

# MAGNESIUM FOR FUTURE AUTOS

*Magnesium-intensive vehicles and enabling technologies are under development through an international collaboration.*

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**M**agnesium is the lightest structural metal, yet its high strength-to-weight ratio makes it more attractive than steel in many applications. The world's automakers already use magnesium for individual components. However, new alloys and processing methods are needed before it can become economically and technologically feasible as a major automotive structural material.

This article explores the initial results of an international collaboration that is leveraging the expertise and resources of Canada, China, and the United States. Called the Magnesium Front End Research and Development (MFERD) project, its goal is to advance the manufacture of magnesium-intensive vehicles.

The MFERD project aims to develop the enabling technologies and knowledge base that will lead to a vehicle front end body structure that is 50 to 60% lighter, equally affordable, more recyclable, and of equal or better quality than today's vehicles. Toward this end, databases are to be developed that will enable further alloy and manufacturing process optimization, and a life-cycle analysis of the magnesium alloys will be conducted.

## **Why a magnesium front end?**

The magnesium front-end design was established under a separate project of the U.S. Automotive Materials Partnership. Called Magnesium Front End Design and Development (MFEDD), the vehicle design is based on a steel rear-wheel-drive unibody and a body-on-frame architecture.

*\*Member of ASM International*



*Fig. 1 — New alloys and processing methods for an economically feasible magnesium front end in magnesium-intensive vehicles are under development by engineering teams from Canada, China, and the United States.*

A magnesium front end consists of castings, extrusions, and sheet components (Fig. 1). It is an ideal target and test-bed for the magnesium alloys and manufacturing processes being developed in this project. When considered as a complete structure, the front end can be evaluated for overall functional improvements. Therefore, in this project not only are technologies being developed to create the individual components, but also the parts and structures of the entire system are being consolidated and re-engineered. Thus, additional benefits accrue in terms of mass distribution and performance — all while developing ways to maintain or reduce the cost of components.

## **Extruding and forming**

Development of magnesium extrusions with improved properties, crash performance, and corrosion resistance is essential to meet the goals of the MFEDD design for critical front-end applications. Current extruded magnesium products are expensive because they cannot be produced quickly. Most extrusions are made of wrought magnesium alloy AZ31, which can only be produced at a rate half that of its counterpart in aluminum extrusions, such as alloy 6063. This drives the comparative cost of magnesium up to levels that make it noncompetitive.

Therefore, extrusion speeds must be raised to achieve cost-effective magnesium parts. A new extrusion alloy, AM30, and modifications to existing

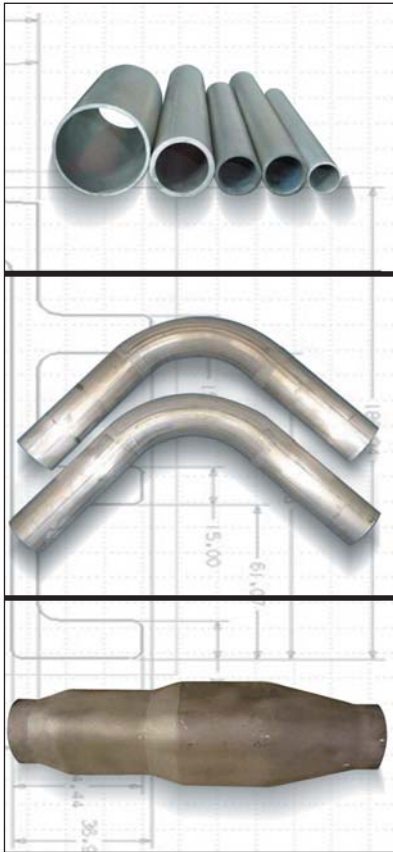


Fig. 2 — Extruded tubes from China are being tested in all three countries.

extrusion alloys (AZ31, AZ61), and new techniques for grain refinement may yield higher extrusion speeds and improved mechanical properties. This should drive the cost down and result in better function through improved microstructure.

To test these technologies, extruded magnesium tubes produced in China and solid extrusions produced in the United States are being evaluated in terms of their microstructure and formability. Techniques include traditional tube bending in the United States and warm-gas-forming in Canada. Magnesium's hexagonal close-packed crystallography makes it difficult to form at room temperature. Therefore, moderately warm-temperature bending may be necessary, and is being investigated. Figure 2 illustrates the examples of magnesium tubing supplied by China to the United States for bending and

forming. To support the integrated computational materials engineering task, others are developing the simulation capability for magnesium extrusion and process-structure-property relationships.

#### Progress in crashworthiness

Diecast instrument-panel beams, radiator support structures, and other magnesium components are functioning today in the front end of vehicles.

### A model for collaborative success

The Magnesium Front End Research and Development project may be a first-of-its-kind international collaboration to develop the enabling technologies and knowledge base necessary to build a lightweight vehicle that focuses on magnesium for the front-end of the automobile. U.S. DOE and USCAR, China's Ministry of Science and Technology (MOST), and Canada's Natural Resources Canada (NRCan) have demonstrated that this common objective can be achieved, while still ensuring that important intellectual property rights remain within the respective country. Comments from leaders of the funding agencies testify to the success and progress of MFERD.

According to Qi'an Wang, director of High-Tech Development for MOST, "The MFERD project is the best example of how good communication, efficient work, and friendly exchange of technical information have resulted in our common goal, to conduct R&D that promotes the use of magnesium."

"The multi-country approach has sparked a lot of interest from the researchers. It is stimulating their motivation and creativity," says Jennifer Jackman, director of CANMET, Canada's materials technology laboratory.

Joseph Carpenter, Development Manager for the DOE-OVT Materials Technologies Team, commented on how such progress will inevitably have economic benefit for each country involved. He referenced the J.F. Kennedy quote, "... a rising tide lifts all boats."

Although these components meet the five-star crash rating, an entire front end structure of magnesium has not been designed or evaluated for vehicle crash and energy management. Very limited data is available to engineers who need this information for component design and crash simulation. Therefore, validated finite element material models for the crashworthiness of magnesium alloys of interest are being developed, based on materials evaluations conducted in each country.

Crashworthiness research includes material testing to determine anisotropic mechanical properties, energy absorption capability, failure characterization, computer-aided engineering analyses, and selected tests of prototype sections in crush (low loading rate) and crash (high loading rate). Strain rates range from quasi-static at  $10^{-3}$ /sec, through the mid rates of 10/sec, up to  $10^3$ /sec in the high-deformation areas resulting from a high-speed crash. Crash performance is being modeled by the U.S. team for a design of cast AM60 and extruded AM30 (Fig. 3).

Labs in Canada, China, and the United States are conducting strain-rate tension and compression tests. The high strain-rate Split Hopkinson Bar tests are being conducted in China (Fig. 4).

#### Fatigue and durability

The fatigue and durability of magnesium structures are extremely critical. Unfortunately, very limited data is available in the literature, especially regarding wrought alloys. Therefore, the objectives of one task are to study, compare, and improve the ability to predict fatigue properties through analyzing magnesium components. To accomplish this goal, it is essential to better understand the critical interactions between design, material, and processing parameters that influence component microstructure and subsequent properties. Characterization of casting, extrusion, and sheet products is expected to establish links between microstructural features and fatigue behavior.

To produce an extensive amount of data in as little time as possible, the team has dispersed activities among the international partners. For example, extruded tube samples were produced in China, while ribbed profile sections came from the United States. Crack propagation being evaluated in China will relate the chemical composition to the microstructural properties and the micro-mechanisms of fatigue.

In addition, extruded samples have been tested in a round-robin series at five laboratories in the three countries. The results are being analyzed for more detailed tests (Fig. 5)

Collaboration with the other MFERD tasks is crit-

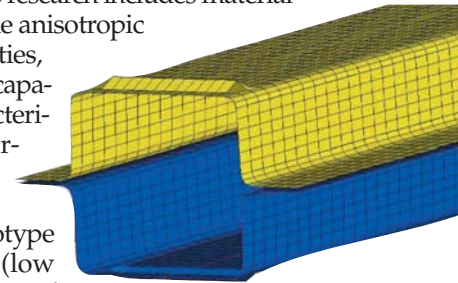


Fig. 3 — The crashworthiness team decided on a double top-hat beam as the component for verification testing. Initial designs could be produced by extrusion, sheet, and die-cast processes.

ical for the fatigue and durability team. For example, the welding and joining team is evaluating preferred joining methods and analysis parameters that allow accurate simulations of joints. The team also will analyze magnesium front end components and sub-systems with both multi-scale and traditional methods. They will compare results, and make recommendations that ensure component designs and subassemblies meet vehicle durability requirements. Functional durability of magnesium samples and typical magnesium joints eventually will be tested to validate the fatigue test and simulation results.

During the next 12 months, the MFERD members expect to demonstrate that a complex multi-national project, encompassing nine tasks and two related U.S. projects, can be successful in strengthening each country's competency in the design, application, and processing of magnesium. Furthermore, it is expected that the MFERD strategy of leveraged R&D funding and collaborative research will demonstrate its benefits to the entire supply chain — from the primary magnesium producers and component manufacturers to the automakers.

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**Additional information**

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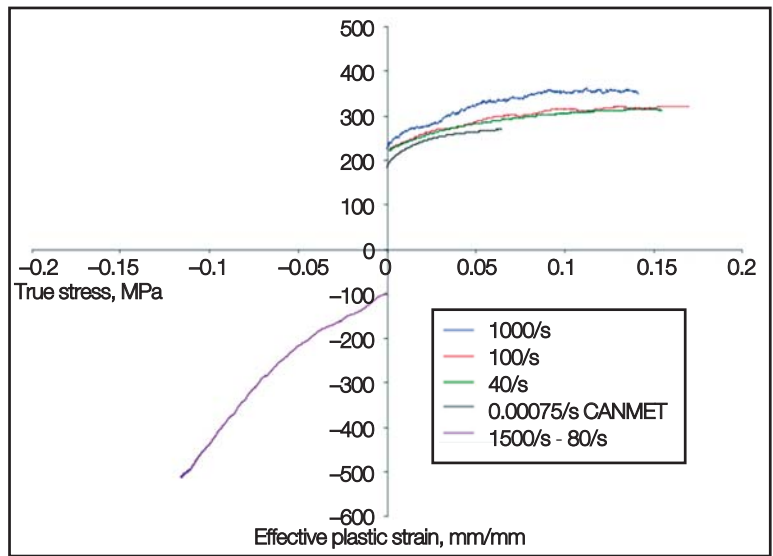


Fig. 4 — High strain-rate testing shows material performance under high-speed crash conditions for a magnesium AM30 extrusion.

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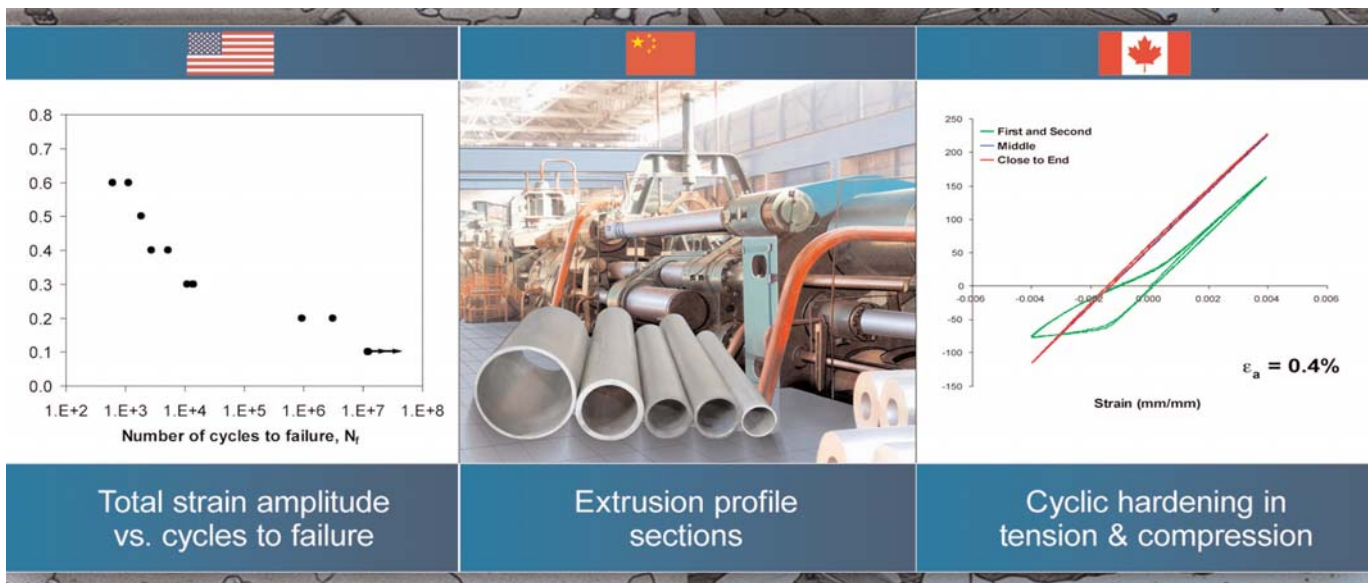


Fig. 5 — All three nations are contributing to the acquisition of fatigue data that helps define the useful life of magnesium components over the long term.