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Rethinking electric motors – Interview with Advanced Electric Machines

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Q&A with Advanced Electric Machines

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As the global automotive industry accelerates its transition to electrification, concerns around the sustainability and security of electric motor supply chains are becoming increasingly urgent. One major point of focus is the use of rare earth elements — materials that are essential to traditional electric motors but are associated with environmental degradation, limited recyclability and geopolitical supply chain risks. In response, companies like Advanced Electric Machines (AEM) are developing rare-earth-free motor technologies that aim to address these challenges at the design level.

Founded in 2017 and based in the northeast of England, AEM originated from academic research at Newcastle University. The company specializes in electric traction motors that eliminate the need for both rare earth magnets and copper windings, replacing them with more abundant and recyclable materials like steel and aluminum. Its reluctance motor technology has been deployed in commercial applications worldwide and is now being adopted by original equipment manufacturers looking for more resilient and environmentally friendly alternatives.

To gain a deeper understanding of these innovations, S&P Global Mobility spoke with James Widmer, CEO of AEM. The conversation explored technical innovations, real-world applications, and the broader implications of rare-earth-free motor technology for the automotive industry and beyond.

The following is an edited transcript of the conversation:

S&P Global Mobility: How do you define "sustainable alternatives" in the context of electric motor manufacturing, and what specific metrics do you use to measure sustainability compared to traditional methods?

James Widmer: We define "sustainable alternatives" through a reimagining of motor design that addresses both environmental and supply chain sustainability. For instance, traditional electric vehicle motors rely on permanent magnets that contain rare earth elements, which pose environmental and geopolitical challenges.

Our approach focuses on eliminating rare earth materials from motor designs. While the industry often aims to make existing processes less harmful through incremental improvements, we explored a more fundamental question: what if motors could be designed to be sustainable from the outset? This led to the development of reluctance motor technology, which utilizes only abundant steel and aluminum instead of rare earth magnets and copper windings.

We assess sustainability using specific metrics that highlight advantages over traditional methods. A lifecycle assessment, conducted through the Advanced Propulsion Centre, indicates that our motors have a 55% lower environmental impact compared to equivalent permanent magnet motors. This assessment includes various environmental factors such as the potential for photochemical ozone creation, global warming, acidification and eutrophication.

The extraction metrics associated with traditional rare earth mining are significant. For every tonne of material produced, it generates approximately 1.4 tonnes of radioactive waste and 27.6 tonnes of CO_2. Our technology eliminates these impacts. If adopted on a global scale, the widespread use of our motors could prevent around 133 million tonnes of CO_2 equivalent, 300,000 tonnes of radioactive waste, and 5 million tonnes of landfill waste annually; notably, this represents a larger volume of radioactive waste than produced by the nuclear industry.

Can you provide concrete examples or case studies where your non-rare-earth motors have outperformed rare earth-based motors in specific applications?

Our HDRM300 motors have achieved over 4 million kilometers of operational service in urban buses and light trains with an [original equipment manufacturer] in Asia, demonstrating the reliability of rare earth-free technology in commercial applications.

A partnership with SAF Holland involved the development of an electric generator for an e-axle trailer refrigeration system, which replaced diesel generators. An assessment by the Zemo Partnership indicates that each e-axle has an environmental impact equivalent to removing nine diesel passenger cars from the road, highlighting the potential benefits of rare earth-free technology.

Speed capabilities are another notable aspect. Our SSRD traction motor operates at 30,000 revolutions per minute, significantly faster than any motor currently in volume automotive production. Work with Bentley has shown that SSRD motors allow high-performance electric vehicles to reach maximum speeds without the need for complex transmissions, thereby reducing mechanical complexity.

In what ways is your technology designed to be more recyclable than traditional electric motors, and what steps are you taking to ensure a circular economy in your manufacturing process?

Our motors are designed for complete recyclability without the need for disassembly, addressing a fundamental sustainability challenge in traditional electric motor manufacturing. Permanent magnet motors create recycling complications because they require careful dismantling to recover valuable materials, often resulting in value loss.

Our design approach eliminates those complications. The motors can be processed directly in electric arc furnaces, which are central to green steel production, allowing for complete recyclability without the need for material separation. Steel and aluminum separation is straightforward and contamination between materials is minimal, enabling both materials to be recycled indefinitely. This strategy was informed by insights from the steel industry, which expressed concerns about increased copper content in steel due to electrification, as copper levels above 3% can hinder the effectiveness of low carbon arc furnaces.

The removal of copper windings through compressed aluminum technology simplifies the recycling process. Traditional motors with permanent magnets and copper coils require energy-intensive mechanical separation and sorting before the individual components can be recycled. Our solution bypasses those steps.

Circular economy principles are integrated throughout the manufacturing process. The design aligns with existing industrial processes, leveraging established steel and aluminum supply chains to maximize resource efficiency while minimizing environmental impact.

Product longevity is another aspect of the circular economy. Our motors are designed without the risk of demagnetization, feature superior thermal management to extend operating life, and incorporate modular designs that allow for upgrades instead of replacements. This reduces the frequency of motor replacement and contributes to extending the service life of vehicles.

Can you elaborate on the technical aspects that allow for a 12% expansion in EV range, and how this might influence consumer adoption of electric vehicles?

These improvements are attributed to the reluctance motor design, which operates differently from permanent magnet motors. Instead of relying on fixed magnetic fields from rare earth magnets, these motors generate magnetic fields based on the stator's geometry and winding configuration. At higher motor speeds, permanent magnet motors can experience reduced efficiency due to the need for electrical current to be injected into the windings to maintain operation, which can become problematic. In contrast, reluctance motors maintain higher efficiency at maximum speed and torque levels.

The SSRD motor operates at 30,000 revolutions per minute, significantly exceeding the capabilities of current volume automotive production motors. This high rotational speed allows for compact motor designs that can deliver substantial power from smaller packages. The reduced size and weight can enhance overall vehicle efficiency and may eliminate the need for complex multispeed transmissions, thereby reducing mechanical losses.

Efficiency improvements are observed across various driving conditions. The motors maintain efficiency characteristics over a wider operating range, from urban driving at lower speeds to sustained motorway speeds. The specific efficiency gains depend on the vehicle application and drive cycle, which accounts for the variability in percentage improvements between commercial and passenger vehicle applications.

These documented range improvements address a significant barrier to electric vehicle adoption. Range anxiety is a common concern among potential buyers, with many seeking capabilities of over 300 miles. Additional range — whether achieved through a 10% improvement resulting in 25 miles or a 15% improvement yielding 37 miles — can help alleviate consumer concerns.

The range benefits also offer design flexibility for vehicle manufacturers. They can maintain current battery pack sizes while providing extended range or potentially reduce battery capacity for equivalent range, which can save weight and costs. This flexibility supports various market positioning strategies across different vehicle segments.

How does your compressed coil technology specifically improve the efficiency of electric motors, and what implications does this have for the overall design and performance of electric vehicles?

Traditional motors utilize copper in their windings. While copper is an excellent electrical conductor, it is heavy, expensive and poses challenges in terms of recycling within the context of electric motors.

Compressed aluminum windings offer solutions to these challenges through innovative material application and geometric optimization. When configured properly, aluminum can provide superior performance to copper in high-speed applications due to its conductivity characteristics. The compression process enhances winding density while preserving thermal management properties.

Efficiency improvements are observed in several ways. Reduced electrical resistance leads to decreased resistive winding losses, which are a primary source of energy waste in electric motors at lower speeds. At higher speeds, aluminum compressed coil technology can lower high-speed winding losses compared to conventional windings, thereby increasing efficiency. Enhanced thermal characteristics allow for sustained high-power operation without efficiency degradation from overheating.

Manufacturing efficiency improvements also contribute to scalability. The process reduces the weight of conductors by 50%, which can improve logistics, and decreases the material cost of the conductors by approximately 90%, leading to reduced manufacturing costs.

How do partnerships with companies like SAF Holland and Bentley influence your product development, and what trends are you seeing in the demand for rare-earth-free technologies from these OEMs?

The partnership with SAF Holland involved collaborative development to address specific industry challenges. Their specifications for trailer refrigeration applications led to refinements in the HDRM design, enhancing durability and reliability. This collaboration resulted in a unique e-axle solution that eliminates the need for diesel generators, showcasing the potential of rare earth-free technology in providing viable alternatives to traditional solutions.

Working with SAF Holland provided valuable insights into commercial vehicle requirements, such as the need for consistent operation under varying load conditions, maintenance accessibility in fleet environments, and integration with existing vehicle architectures. These insights informed the design philosophy, ensuring that the motors are equipped to meet real-world operational demands.

The collaboration with Bentley focused on performance vehicle applications, testing the technology's capabilities in high-performance scenarios. This partnership demonstrated that the SSRD motor allows high-performance electric vehicles to operate at maximum speeds without the need for complex transmissions, thereby reducing mechanical complexity while maintaining performance.

The involvement of Bentley illustrates the technology's applicability in luxury segments where performance and sustainability are both critical considerations.

With the UK government’s critical minerals strategy still in development, what immediate actions do you believe the industry should take to address supply chain vulnerabilities and promote innovation in electric motor technology?

Whilst the UK government's critical minerals strategy remains under development, immediate industry actions are essential to address supply chain vulnerabilities and accelerate innovation in electric motor technology.

Current supply chain vulnerabilities are severe and worsening. Export controls on medium and heavy rare earths have created immediate supply disruptions. These controls affect not just neodymium, dysprosium and samarium — the main rare earths in permanent magnets — but also gadolinium, terbium, lutetium, scandium and yttrium — materials essential for electronics, defence systems and renewable energy technologies.

The industry needs to diversify supply sources and develop alternative technologies. Technology innovation represents the most effective immediate response. Rather than competing directly with China's established rare earth supply chains, which at the same time will inevitably create massive environmental damage from new mining and refinement, developing rare earth-free alternatives eliminates dependence entirely. Our technology demonstrates this approach's viability, achieving performance parity whilst eliminating supply chain vulnerabilities.

Government support should focus on technologies that eliminate critical material dependencies rather than building competing supply chains. We’ve been here before with rare earth scarcities a few years ago, and the entire automotive sector will remember the post-COVID semiconductor shortages which caused several production issues globally. While globalization is beneficial, we do need to find new ways to make supply chains resilient and more sustainable.

Are you observing an uptick in interest in your technology this year, particularly in light of the challenges related to rare earth element supply chain licensing from China?

I guess the quick answer is yes. As a business we have now moved from a position of technology development to one where we can demonstrate — through real-life case studies — that our technology brings both sustainability and performance advantages. This has been critical to gaining the trust of larger customers.

Export controls on medium and heavy rare earths have created immediate urgency amongst OEMs and investors. Many exporters now require licences for many materials, and a number have told us that they had to stop EV electric motor production as a result of these changes. This supply disruption has generated interest in our rare earth-free technology. OEMs previously focused primarily on cost and performance are now prioritizing supply chain security. The conversation has shifted to how can we avoid supply chain disruption in the future whilst still improving our vehicles?

The technical validation our motors have achieved — over 4 million kilometers in commercial operations — provides crucial confidence during this period of supply chain uncertainty. OEMs require proven alternatives when considering supply chain restructuring, and our operational track record enables rapid adoption decisions.

The combination of supply disruption, price volatility and geopolitical uncertainty has created unprecedented market conditions favoring rare earth-free technologies. What began as a sustainability innovation has become a strategic necessity, positioning our technology at the center of global supply chain restructuring efforts across multiple industries.

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