Driving the Electric Revolution Industrialisation Centres

UK Research and Innovation

Building a UK PEMD Capability

8 June 2022

Accelerating Power Electronics, Machines and Drives Supply Chain Capability and Growth

Driving the Electric Revolution is a UKRI funded cross-sector challenge in transport, energy and industry

Power Electronics, Machines & Drives (PEMD) are essential to next generation technologies:

- All UK cars to be zero carbon by 2035 (no 100% internal combustion engine from 2030)
- New aircraft to be electric/hybrid to meet next phase emissions and noise legislation by 2040
- Renewables (Wind, Wave, Tidal) to form an increasing % of energy generation (80% CO_2 reduction by 2050)
- High speed rail network to grow, no new diesels after 2040
- Marine transport's target to be 50% CO_2 reduction by 2050
- PEMD supports the realisation of the industrial digital technology (IDT) revolution – Industry 4.0

DER Driving the Electric Revolution Industrialisation Centres
North East | South West & Wales | Midlands | Scotland

UKRI UK Research and Innovation

Driving the Electric Revolution: £80m total funding

- Driving the Electric Revolution Industrialisation Centres (DER-IC): £33m funding
  - To establish a UK-wide network of PEMD capability, led by Newcastle University
  - Four regional centres – Scotland, North-East, Midlands and South-West & Wales
  - To build supply chain capability, capacity and competitiveness
- Collaborative Research and Development (CR&D) programme, c£35m in total, more than 40 projects funded
- Skills activity, c£6m – Building Talent for the Future and Skills Hub

DER Driving the Electric Revolution Industrialisation Centres
North East | South West & Wales | Midlands | Scotland

UKRI UK Research and Innovation

DER-IC activities, first two years

- DER-IC is an industry led project – we have so far engaged with more than 400 industrial organisations
- Set up and managed the £28.5m capital equipment competition, equipment is being progressively commissioned during 2022
- Bringing industry to network partners, including industry and supply chain partners, across multiple sectors
- Demonstrating partner capability to the broader PEMD community
- Creating and developing more collaboration opportunities with the DER-IC business development team
- Attending conferences and hosting DER-IC webinars and knowledge transfer events

DER-IC network partners

National reach through regional centres

- Enhancing and providing open access to £300m+ of existing capability across more than 30 partner organisations
- Regional centres facilitate access to industry clusters and support from SME to large OEM
- To deploy recognised PEMD industrialisation expertise
- To leverage regional and devolved funding for industry
- A strong collaborative approach

Network partners

North East:
AMRC
CPI
Newcastle
Northumbria
OREC
Sheffield
Teesside
TWI

Scotland:
AFRC
Edinburgh
Glasgow
MSIP
NMIS
PNDC
Strathclyde
St Andrews

Midlands:
Coventry
Loughborough
Manchester
MTC
NAMRC
NCC
Nottingham
NPL
Southampton
Surrey
UCL
Warwick
WMG

SW & Wales:
Swansea
Birmingham
CSAC

Delivering benefits for UK plc

- **Investment in state-of-the-art equipment** for industrial partners to accelerate capability, capacity and competitiveness in PEMD technologies
- Supporting UK **transition from ICE** to electrification
- Delivering **long term industrial growth**
- Focused on the Government Net Zero agenda
- Developing UK supply chain essential to achieving **2050 climate commitments**
- Growing PEMD **engineering talent** to meet industry needs
- Securing UK's **current academic leadership**

Agenda for today

Perspectives….

Dr Yi Gao, Principal Engineer, Research & Development Tata Steel UK

- *Advanced Steel Solutions for Sustainable Electric Vehicles*

Andy Woods, Business Development Director, Advanced Electric Machines

- *Challenge and Opportunity Scaling Up New Technologies*

John Robins, Business Development Manager, Compound Semiconductor Applications Catapult

- *The Importance of Power Electronics*

Panel Q & A session

Driving the
Electric Revolution
Industrialisation Centres

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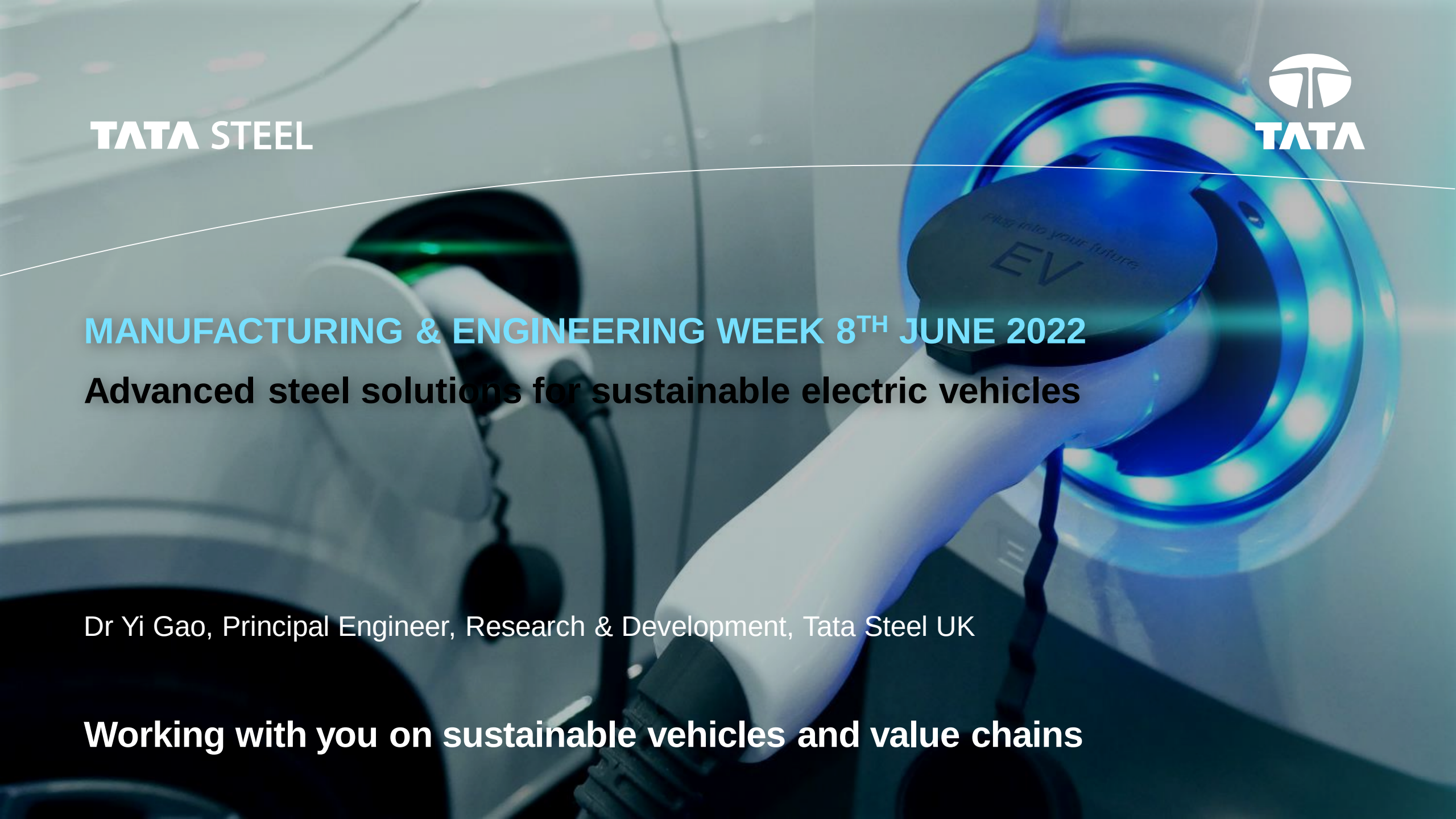
DER Industrialisation Centres



TATA STEEL

TATA

MANUFACTURING & ENGINEERING WEEK 8TH JUNE 2022

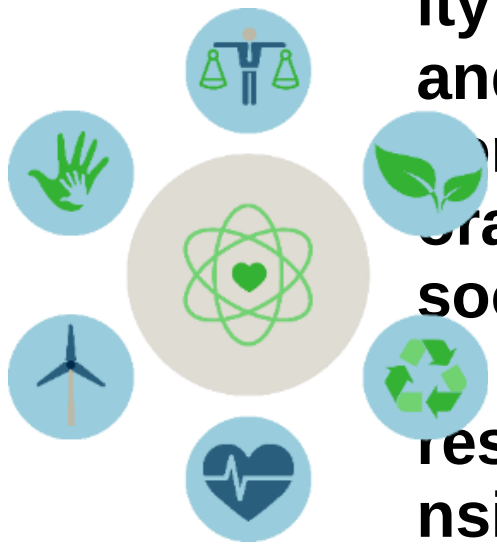
Advanced steel solutions for sustainable electric vehicles

Dr Yi Gao, Principal Engineer, Research & Development, Tata Steel UK

Working with you on sustainable vehicles and value chains

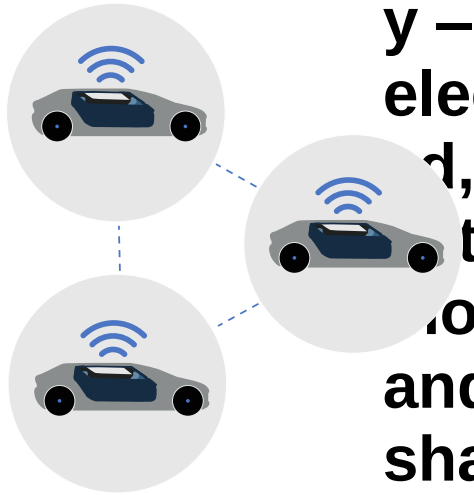
Working towards sustainable future supply chains

Sustainability and corporate social responsibility (CSR)



Digitalisat

Low-CO_2 mobility – electrified, autonomous and shared



Tata Steel | Advanced steel solutions for sustainable electric

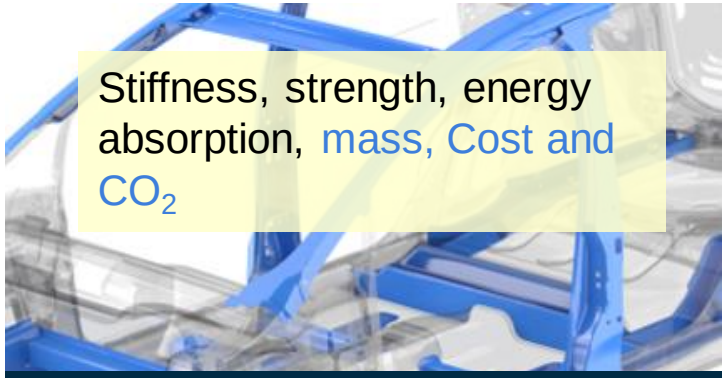
Tata Steel, a partner for strategic EV components

Power / torque density, efficiency, mass / volume, Cost and CO_2

Electric motors

Energy density, power, thermal stability, charging time, mass / volume, Cost and CO_2

Energy storage



Stiffness, strength, energy absorption, mass, Cost and CO_2

Battery protection & Passenger safety

Electrical steels

Thin-gauge non-grain-oriented strip steels for electric traction motors with the highest efficiency, power density and thermal performance.

Electro-plated steels

Nickel-plated diffusion-annealed strip, using ultra clean steel for high volume, high-speed production of quality

Steels for EV structures

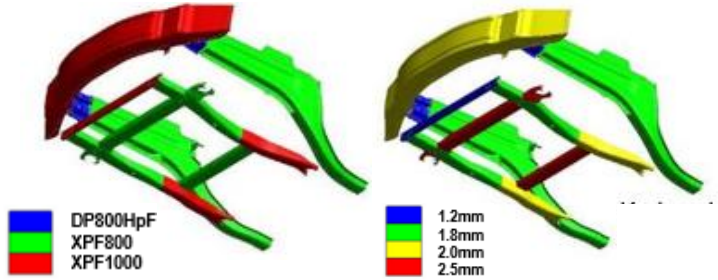
Advanced steels, available in coil, slit, blank, tube and tailor welded blanks with high strength & formability, and coatings for lightweight vehicle structures

HyperForm® and XPF®

Tata Steel | Advanced steel solutions for sustainable electric

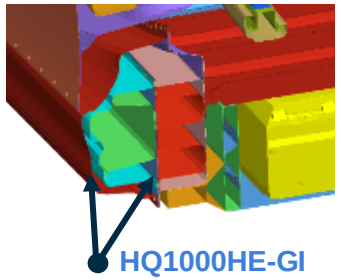
XPF® & HyperForm® extra-formable AHSS and hot-forming UHSS for lightweight crashworthy EVs

Compact and lightweight BEV front module using XPF and HyperForm

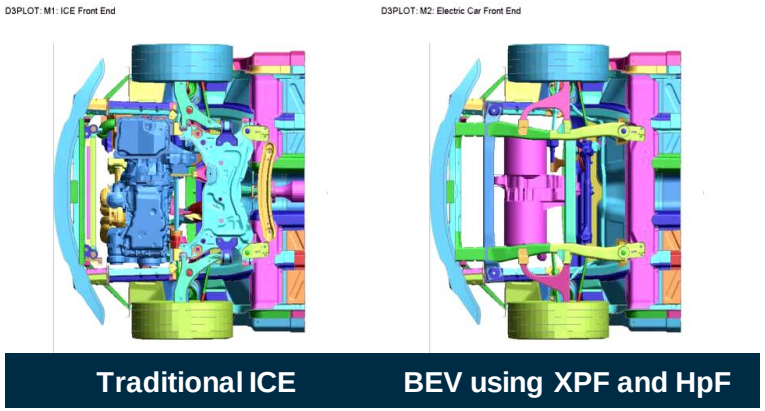


Safe and efficient side impact structure

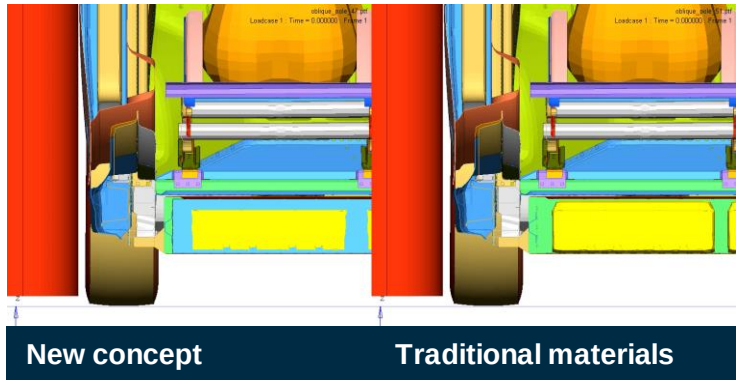
Energy absorption



Stiffness & strength



Traditional ICE | BEV using XPF and HpF



New concept | Traditional materials

XPF and HyperForm product range

Grade	t [mm]	YS [MPa]	TS [MPa]	A_{80} [%]	HEC [%]
CR DP800-GI HyperForm	0.8-1.9	≥440	≥780	≥18	-
XPF800-GI	1.8-2.4	≥680	≥780	≥16	≥60
XPF1000-GI*	1.8-2.4	≥850	≥960	≥11	≥40

*Development

Hot forming grades under development

Grade	t [mm]	YS [MPa]	TS [MPa]	A_{80} [%]
HQ1000HE-GI*	0.8-1.6	≥870	≥980	>15
HQ1900-UC*	0.8-1.6	≥1400	≥1900	~3

*Development

Tata Steel | Advanced steel solutions for sustainable electric

BEV = Battery Electric Vehicle
AHSS = Advanced High Strength Steel
ICE = Internal Combustion Engine
UHSS = Ultra-High Strength Steel

Tata Steel, a partner for strategic EV components

Electric motors

Energy storage

Battery protection & Passenger safety

Electrical steels

Thin-gauge non-grain-oriented strip steels for electric traction motors with the highest efficiency, power density and thermal performance.

Electro-plated steels

Nickel-plated diffusion-annealed strip, using ultra clean steel for high volume, high-speed production of quality

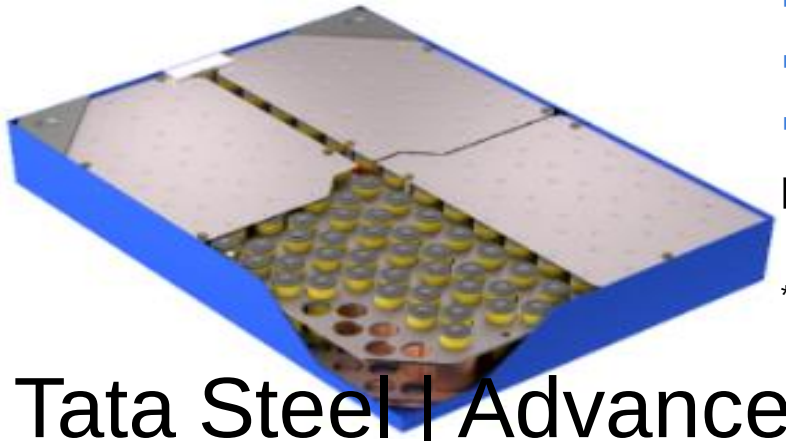
Structural steels

Advanced steels, available in coil, slit, blank, tube and tailor welded blanks with high strength & formability, and coatings for lightweight vehicle structures

HyperForm® and XPF®

Tata Steel | Advanced steel solutions for sustainable electric

Ultra-clean nickel-plated steel (NPS) for cylindrical cells in efficient EV battery systems



HILUMIN® for cylindrical battery cans enables higher energy density and more volume efficient battery packs

HILUMIN battery cans offer

- Low contact resistance
- Good corrosion resistance
- High strength - withstand higher pressure than pouch & prismatic cells*

*Compared to aluminium casings of battery cells

Hilumin product range	
Gauge [mm]	0.08 – 1.5
Coating gauge - differential [µm]	0.2 – 4.0

- *The only European and USA producer of battery quality NPS*
- *Development partner for next-generation battery cells*
- *IATF 16949 certified*

Tata Steel | Advanced steel solutions for sustainable electric

Tata Steel, a partner for strategic EV components

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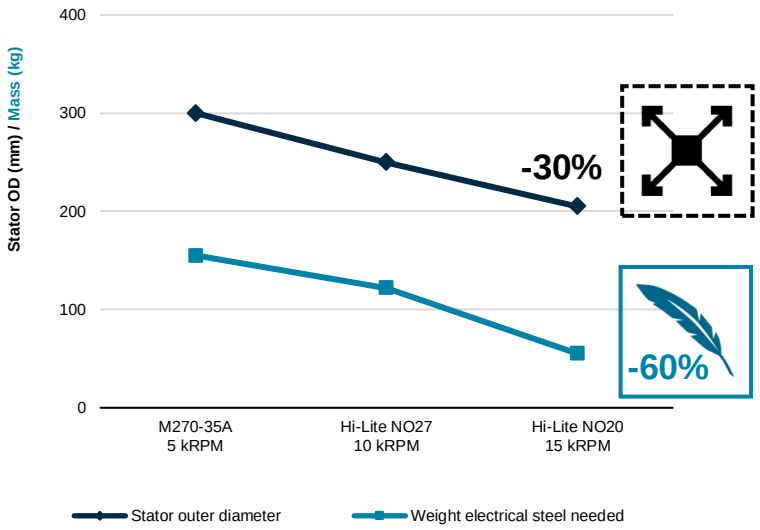
HyperForm® and XPF®

Tata Steel | Advanced steel solutions for sustainable electric

Optimising e-motor performance using thin-gauge non-grain-oriented electrical steel with low magnetic losses

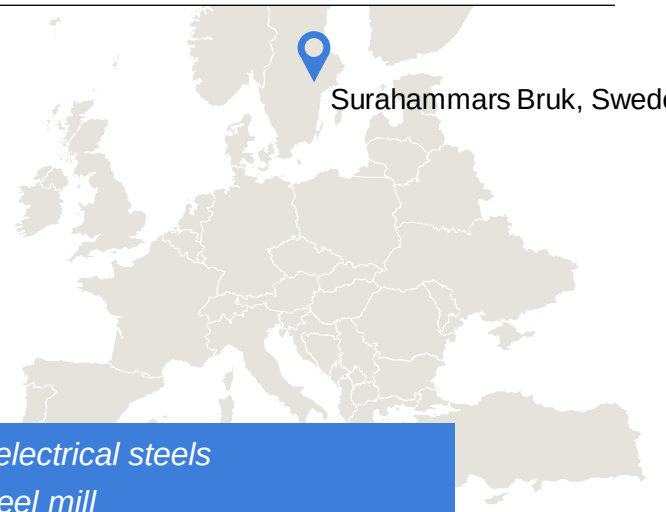


Hi-Lite enables the mass of the e-motor to be reduced by 60% while the size reduces by 30%*

Lower-loss stators and higher-speed rotors → Higher power, torque and efficiency, but smaller size

*Replacing M270-35A with Hi-Lite NO20

Hi-Lite product range	Gauge [mm]
NO10	0.10
NO12	0.12
NO15	0.15
NO18	0.18
NO20	0.20
NO20-1200H	0.20
NO25	0.25
NO27	0.27
NO30	0.30



Tata S ed steel solutions for sustainable electric

Agile producer of electrical steels
Integrated Tata Steel mill
IATF 16949 certified
Development partner for innovative e-machines

Summary

- Sustainability and legislation drive fast automotive electrification
- EV manufacturers overcoming structure, e-motor and battery design challenges
- Advanced steels help improve performance, efficiency, safety and costs for key EV components
- Tata Steel
  - offers advanced steels and services
  - collaborates with automotive, battery and e-machine partners

Tata Steel | Advanced steel solutions for sustainable electric

Working with you on sustainable vehicles and value chains

Thank you!

Tata Steel

Together we make the difference

ADVANCED ELECTRIC MACHINES LTD.

Advanced Electric Machines

ADVANCEDELECTRICMACHINES.COM

Electric Motor Supply Chain Challenge

Global automotive market demand of over 30m electric traction motors pa by 2030

Rare-earth PM: cost and supply security concerns → PM-free e-motor technologies

AEM's unique SSRD motor technology: PM-free & efficient

Manufacturing and assembly process challenges

High volume production of thin-gauge/electrical steels

Cutting of steel blanks

Joining blanks to form lamination

Coating with insulation for automated rotor/stator stack assembly

Electric Motor Supply Chain Structure

Steel, Coatings material supplier

Cost effective advanced high strength non-magnetic steels & Electrical Steels

Cost effective advanced insulation/adhesive coatings

Lamination supplier/AEM and Lamination blanking, joining, stacking equipment supplier

High volume manufacture of patented lamination designs

High volume production equipment using novel Laser technology for metal cutting and joining

High volume production equipment for automated lamination stacking

AEM

PM Free Traction Motors for applications in Commercial Vehicle, Passenger Car & Aerospace

OEMs, Automotive Tier 1's, Aerospace OEM's & Tier 1's

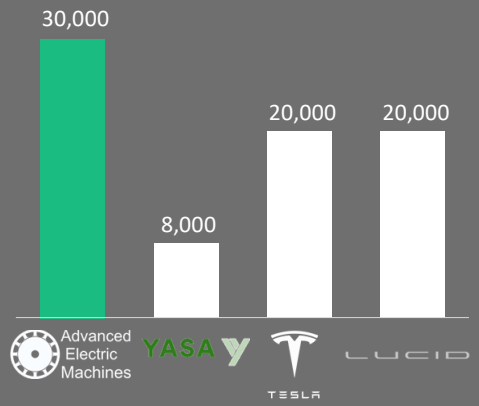
Differentiated Automotive EV powertrain and Aerospace drivetrain and ancillary system solutions which deliver market leading performance, reduce system complexity and overall cost

So What?

AEM vs. competitors

Faster

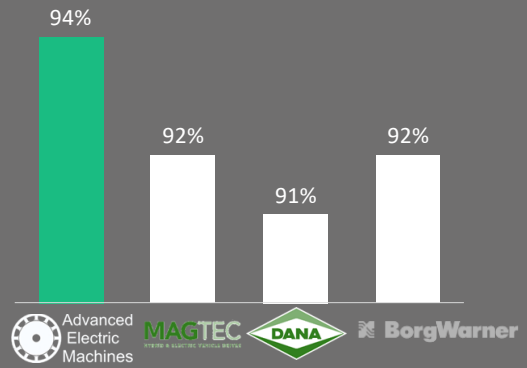
Rotational Speed (rpm) (1)



Higher Rotational Speed Means:
- Smaller, Lighter Motor
- Simpler, Less Expensive

Further

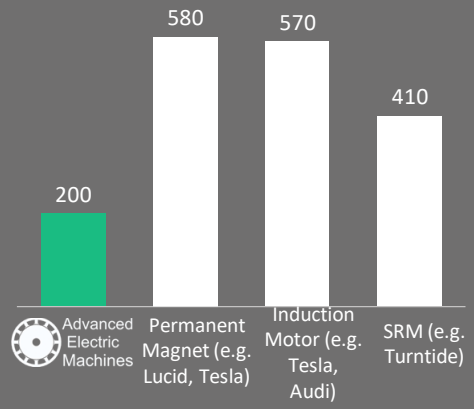
Average Efficiency over WLTP Cycle (2)



Customers report that AEM Motors improve vehicle real world range by up to 12%

Lower Cost

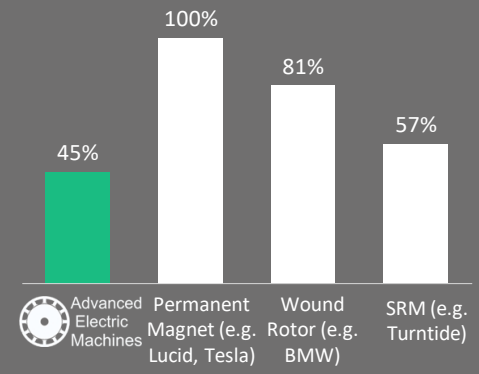
Relative Cost ($) (3)



AEM Motors significantly reduce customer system costs

Greener

Environmental Impact (%) (4)



AEM's motors are more sustainable than competitors

(1) AEM Internal Analysis based on competitors' published data.
(2) AEM Internal Analysis based on competitors' published data / customer feedback on their own analysis.
(3) Based on Newcastle University / Jaguar Land Rover / GKN / Sevcon / Tata Steel project findings (2016).
(4) AEM estimate based on Jaguar Land Rover Life Cycle Assessment of motor materials environmental impact.

Driving the Electric Revolution Industrialisation Centres

UK Research and Innovation

Importance of Power Electronics

8 June 2022

John Robins

Business Development Manager

Compound Semiconductor Applications Catapult

CSA Catapult

Key Areas

Power

- High Voltage GaN and SiC
- SiC Standardisation
- UWBG systems

Communications & Sensing

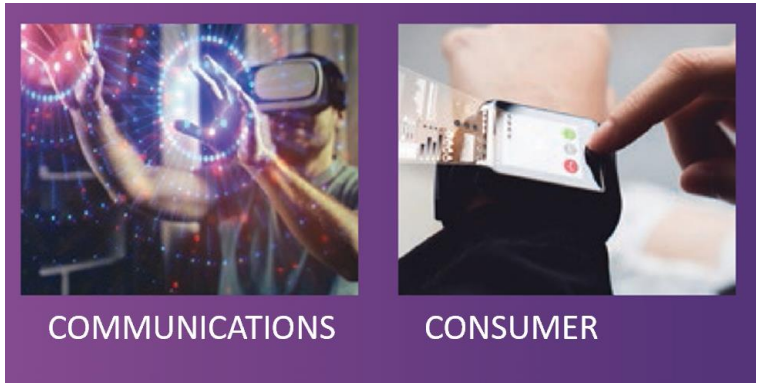
- Optical Comms
- High spec RF
- PICs
- Perception & Spectral Sensing
- High Reliability Photonics

Packaging

- Thermal Management
- Embedded Packaging
- Hybridisation

Cross-Cutting Capabilities

- MCIV
- Market Intelligence
- Skills
- Supply Chain convening



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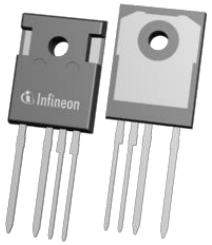
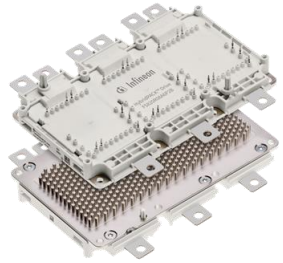
Power device market by application



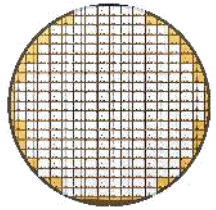


CATAPULT
Compound Semiconductor Applications

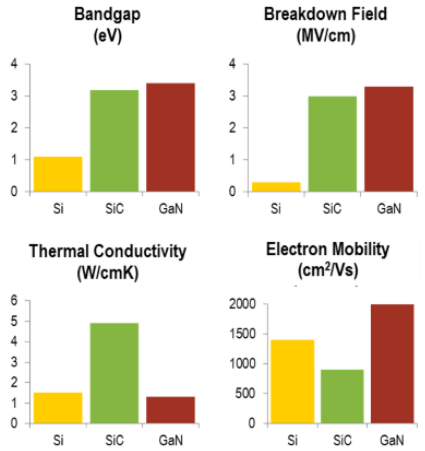
Power Electronics

Si vs SiC & GaN

Material



Benefits



Challenges

- Larger wafer size
- Yield
- SiC process steps

Power Device

Benefits

- Low on-resistance
- Smaller chip size
- Low capacitances
- High switching speed
- High operating temperature

Challenges

- Packaging – parasitics and temperature
- Integration of gate drivers
- High heat flux
- Qualification standards

Power Converter

Benefits

- Low power device losses
- High efficiency
- Thermal management
- High switching frequency
- Smaller magnetics and capacitors
- Higher power density

Challenges

- PCB/busbar – parasitics
- EMI
- Gate driving & protection
- Circuit topology
- Thermal management
- High frequency magnetics and capacitors

CATAPULT
Compound Semiconductor Applications

Application - EV

Benefits

- More range
- Smaller battery
- Lower cost
- Faster charging
- Lower weight

Challenges

- Supply chain
- Short technology track record
- Motor design

Trends in System Integration

Current:

- Traditional linear manufacturing and integration of components = **15-30kW/Kg**

Si Epilayer	Si Fabrication	Device Packaging	Module Integration	Module Packaging	Sub-system Integration	Sub-system Packaging	System Integration

Future:

- Highly flexible miniaturisation, integration and manufacturing breaking the concept of components = **30-100+kW/Kg**

WBG Epilayer	WBG Fabrication	Flexible Integrated Module and Sub-System Manufacturing	System Integration

CS Connected Cluster, South Wales

Swansea University Centre for Integrative Semiconductor Materials (Swansea Bay Campus) and Nexperia

Equipment

Synapse SiC deep etch tool

High Voltage Test Station

Back Contact Laser Anneal

CISM

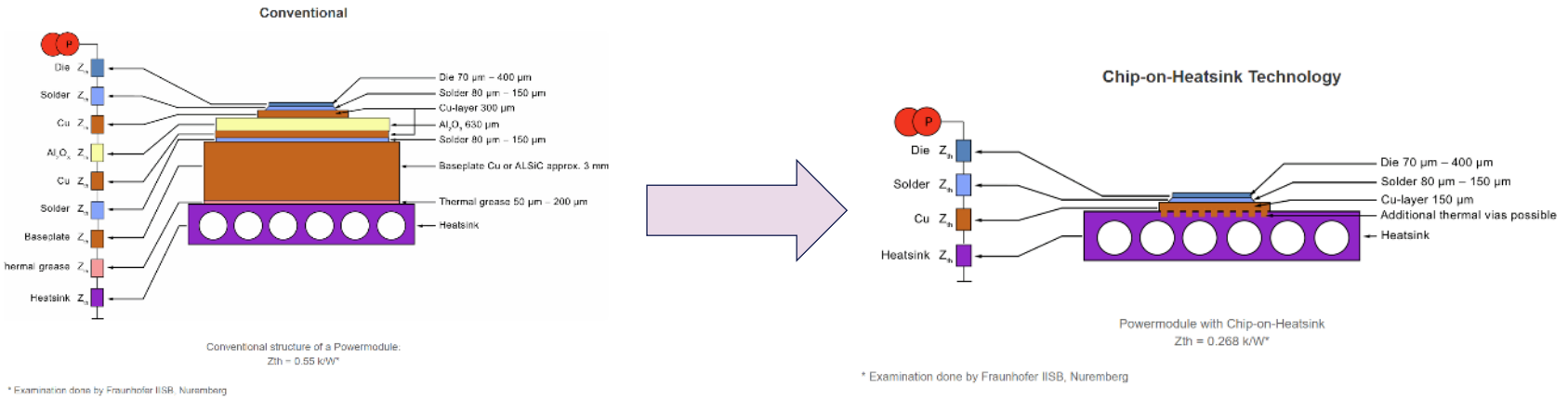
Wide Bandgap Semiconductor Power Electronics Component Industrial Pilot Line (Deposition, Etch, Contacting, Grind, Dice)

What gaps in supply chain are we addressing?

- Limited capability to process SiC materials and devices at an industrially relevant scale into components nationally
- No complete wafer-to-package process line currently available
- Deep etch for SiC vertical components not available on an open access basis
- Will enable wafer-to-component process development from early TRLs to de-risk industrial scale-up

Power Electronics

Ceramics Prototyping Lab



Proposed CSA Catapult DER centre investment into

Ceramics Prototyping Lab for Power Electronics Packaging

3D printer for printing ceramics
3D printer for printing copper and other metals
De-bind oven and infrastructure
Sintering furnace and infrastructure
Laser drilling and cutting machine and infrastructure
Polishing machine
Metrology equipment for measuring dimensions

Ceramic properties

- Matched CTE
- High thermal conductivity
- High electrical insulation
- High temperature capability
- High mechanical stability

Benefits

- Improved thermal management
- Higher power density

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UK Research and Innovation

Driving the
Electric Revolution
Industrialisation Centres

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DER Industrialisation Centres