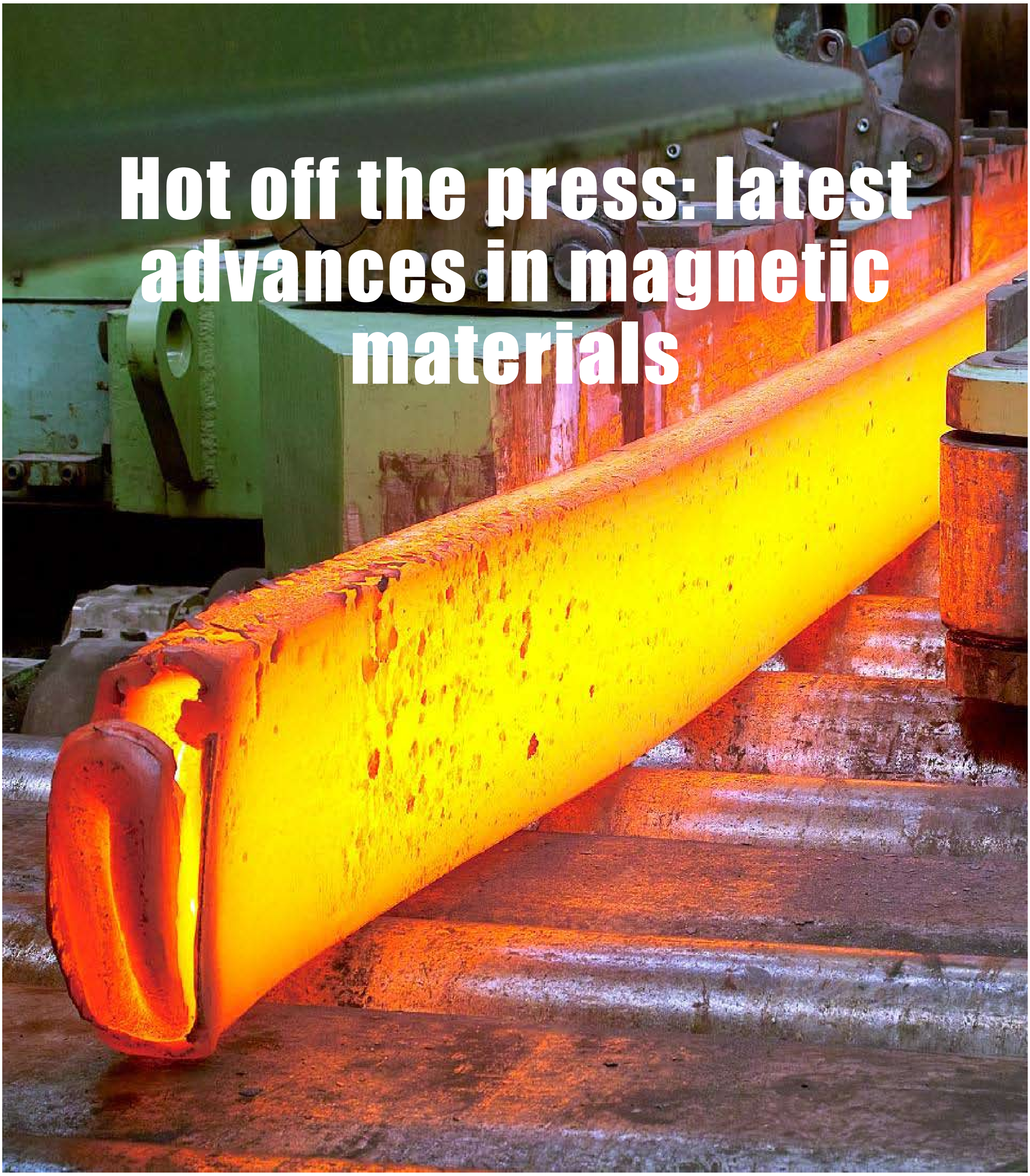
magnews

The international publication
of the UK Magnetics Society

Autumn 2009

Hot off the press: latest advances in magnetic materials



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From the chairman

Welcome to the Autumn edition of Magnews. The Society is pleased to report that its recent seminar *Advanced Magnetic Materials and Applications*, held in Hanau, Germany, was a great success, with a high turnout of academic and industry specialists and many excellent presentations. The factory tour was also a particular draw for the event. One of the aims of the Society is to represent and support industry and academia in all areas of magnetics, not just limited to the UK; indeed, around three quarters of the attendees of this seminar were based outside of the UK. The Society would like to thank Vacuumschmelze for their invaluable help and generosity in organising the event. We are now in the very early stages of planning for our next event in mainland Europe!

Another of the ways in which the UK Magnetics Society supports magnetism in the UK and abroad is by providing funding for students to travel to conferences of international standing. The value of the bursary has recently been reviewed and increased to better reflect the financial support that a student requires for attendance at such a conference. So if you are a post-graduate researcher of a member organisation you could apply for an additional £250 to support your trip. All we ask in return is a write-up of your experiences and the highlights of the conference and in addition your name will be put in the hat for the Dennis Hadfield Memorial Prize at the end of the year. These student bursaries are available to any member universities. Please contact the Secretariat for an application form.

You may also have noticed that the membership subscription costs and seminar fees have remained the same as last year. This is of course due in part to economic circumstances but also reflects the desire of the Society to keep costs as low as possible for its members. Additionally your organisation can now benefit from new deals on multiple seminar registrations: discounts for groups of three and above from the same organisation. Deals for larger groups can be negotiated – please contact the Society's Secretariat. It is our desire to draw as many interested parties to our seminars as possible. For those of you who will be attending a forthcoming seminar, your feedback is much appreciated – please fill out a delegate questionnaire on the day – we do actually read your comments!

As first announced in the last issue of Magnews, this year's 23rd Ewing Lecture will be given by Professor Geraint Jewell of Sheffield University, and the event will be held at Oriel College, Oxford, on 3 December – full programme details in this issue. The Ewing Event represents the social highlight of the UK Magnetics Society's seminar programme, where as well as providing the usual networking opportunities, old friends and colleagues meet to catch up and learn about one of the emerging areas in the field of magnetism. Being an afternoon to evening affair, the conversations will be helped along by wine and food from a warm buffet. Spaces are limited, so I suggest you register early!

Stuart Eaton, QinetiQ Ltd

Contents

If you have any comments on issues relating to magnetics in general, or any articles contained in Magnews, the Editor will be pleased to hear from you.

Front page graphic:

Hot rolled ingot on the hot rolling mill at Vacuumschmelze GmbH & Co KG, Germany

Bunting® Magnetics appoints European Sales Director

Charles Collier has been appointed Sales Director for the European operations for Bunting® Magnetics Co, which is headquartered in Newton, Kansas, USA. Charles will have dual responsibilities to drive the sales strategy for both Bunting® Magnetics and Magnet Applications Limited (MAL), which Bunting® purchased in April 2008 and is based in Berkhamsted, England.

"I am proud to be entrusted with the task of launching Bunting® Magnetics into Europe. By building on the 50 years of experience and history of the company, I believe that the Bunting® product range of magnetic detection, separation and material handling products will quickly find its rightful place in the rapidly developing European market," stated Charles. "In addition, the Magnet Applications product line, which has an impressive range of magnetic products along with new value added products, will continue to grow in the European market."

Mr Collier brings extensive sales experience to his new role primarily with a manufacturing background. This includes time spent in operational and consultancy positions. In the past, Charles has served as a consultant to MAL. During this time, he assisted MAL with the expansion and improvement of their supply chain partnerships. Charles will be based out of the MAL headquarters in Berkhamsted.

"The addition of Charles as our Sales Director for Europe is a natural progression stemming from our purchase last year of Magnet Applications," said Robert J Bunting, the Company's owner and Chief Executive Officer. "Charles has over 30 years of industrial sales experience including over 20 years with Magnetics. His background will be instrumental as we continue to expand our sales in the continent of Europe. Also, his leadership skills will help as we quickly add more personnel in this area."

Bunting® Magnetics Co is a major US-based manufacturer of magnetic assemblies and equipment. The company's product line serves global markets and includes a broad range of magnetic materials and components, magnetic separation systems, material handling equipment, magnetic printing cylinders, flexible dies and metal detection equipment. Magnet Applications Limited is a leader in the manufacturing and distribution of bonded magnets and assemblies.

For more information on Bunting® Magnetics Co, call 1-800-835-2526 (US & Canada) or 316-284-2020; or visit www.buntingmagnetics.com. For more information on Magnet Applications Limited, call +44 (0) 1442 875081 or visit www.magnetuk.com.

New Three-Axis Surveillance Magnetometer by Bartington Instruments

Bartington Instruments has released a new, very low-power, three-axis magnetometer.

The Mag648 incorporates innovative fluxgate technology to deliver noise performance previously only available in larger, more power-hungry devices.

Designed primarily for use in perimeter security and surveillance systems, it is especially suited to battery-powered applications. Its small size and competitive pricing make it an ideal candidate for integration into multi-sensor arrays.

The Mag648 is a three axis, analog output sensor with a range of ± 60μT. It is available in two noise versions: low noise (<10pTrms/√Hz @1Hz) and standard (10-20pTrms/√Hz @1Hz). The sensor operates from a single 4V power supply and consumes less than 15mW. Its compact enclosure (70 x 30 x 32 mm) offers a high level of environmental protection (IP67) and an MTBF of 12 years.

Bartington Instruments Ltd (UK) designs and manufactures a wide range of magnetic measuring instruments used in defence, geophysics and underwater applications. This includes single and three-axis fluxgate sensors, fluxgate gradiometers and magnetic susceptibility measuring equipment. Custom magnetometer design and manufacture is also available.

For further information visit www.bartington.com or email sales@bartington.com

UK Magnetics Society Student Bursary Scheme

The Society is pleased to announce that its Student Bursaries have increased from £100 to £250. These bursaries are to assist postgraduate students of member organisations to attend international conferences - see page 15 for further details.

NPL's Knowledge and Innovation Centre

The National Physical Laboratory (NPL) is one of the UK's leading science and research facilities. It is a world-leading centre of excellence in developing and applying the most accurate standards, science and technology available.

NPL has now opened its Knowledge and Innovation Centre aimed specifically at measurement intensive businesses that rely on measurement and characterisation for competitive advantage.

Potential tenants must have the ability to benefit technically from co-location with NPL and other measurement intensive businesses. We are looking to accommodate both smaller companies who might have the NPL site as their main premises or larger organisation who might co-locate specific activities or parts of their business.

The Centre will provide a fully serviced office in SouthWest London with access to the world class measurement facilities and expertise at NPL. Our aim is for tenants to have the opportunity to engage with the scientific community at NPL through specialist networks and meetings, managed access to 385 laboratories designed and equipped for measurement and characterisation, and participation in collaborative activities such as joint research and secondment projects.

Further information can be found at http://www.npl.co.uk/knowledge-innovation-centre. If you would like to see the facilities for yourself, please contact Glenis Tellett, the centre manager, tel: +44 (0)208 943 6005, email: glenis.tellett@npl.co.uk.

Welcome to new UKMAG members

Max Baermann GmbH, Germany

Why not advertise in Magnews?

Magnews's ever-growing, comprehensive and well targeted mailing list reaches magnetics specialists, including manufacturers, distributors and users, in industry, academia and government, worldwide, covering UK: 40%, Europe: 30% and North America/Japan/China/other: 30%. Magnews is the only publication targeted to such groups.

Graphics/artwork: High quality eps/tiff/jpeg, minimum of 300 dpi, preferably higher, high resolution print-ready pdf (Illustrator/Freehand/Photoshop/QuarkXpress)

2009 copy deadlines:

Spring 1 March (published early April)
Summer 1 June (published early July)
Autumn 1 September (published early Oct)
Winter 15 November (published mid-January)

Please contact jward@ukmagsoc.co.uk for advertising rates

Bunting® introduces next generation of RotoGrate magnet

Bunting® Magnetics Co has added a newly redesigned RotoGrate

Magnetic Separator to its Magnetic Separation product line. This product, which is ideal for products with poor flow characteristics, features a powerful motorised rotating grate magnet which processes material, such as cocoa, flour or starch, that would bridge traditional grate assemblies.

"The Bunting® RotoGrate will remove ferrous metals from powders and granular products with even the most difficult flow characteristics," stated Rick Bigham, the Bunting Product Manager for Magnetic Separation Products. "We have streamlined the design elements. Also, we based the construction standards on essentially the same design, and with the same superior magnetic separation capabilities, as the Bunting® HF Drawer Filter.

The RotoGrate is available in food grade and self-cleaning options as well as our standard design. These options include the ability to order Ceramic, Alnico, or Rare Earth magnets to get the holding force right for your application. Bunting® can custom design anything to fit your installation requirements. Optional features include the ability to transition your product flow into the grate housing and removable tube assemblies for easy cleaning. Bunting® construction standards and magnetic assembly are industry-leading and we feature CE Certification and USDA acceptance on many of our Drawer Magnet product line.

For more information on the RotoGrate Magnetic Separator and the rest of Bunting's extensive line of magnetic separation equipment, visit www.buntingmagnetics.com.

Bunting Magnetics Co, 500 S Spencer Avenue, PO Box 468, Newton, KS 67114-0468; call 1-800-835-2526 (US & Canada) or 1-316-284-2020; email: bmc@buntingmagnetics.com

Rex Harris's 70th birthday symposium

To celebrate Rex's birthday we held a meeting at Birmingham entitled *Symposium on Materials for a Sustainable Future* on 11 and 12

Enjoying a glass or two or three ...

September. The aim was to hold a meeting on a subject that is dear to Rex's heart and to have a good knees up and see old friends. We held the meeting directly after the Euromat conference in Glasgow so that people travelling from around the world could easily attend both meetings. The idea was to have a packed day of science on Friday with a more relaxed social event on Saturday.

It turned out that the meeting ended up as a bit of a CEAM reunion. For those of you who may be too young to have been around, CEAM was the Concerted European Action on Magnets that began in 1985. As Mike Coey said in his introduction to the symposium "CEAM was a pioneering experiment in Europe-wide cooperation on a topic that presented a serious technical challenge, the development of rare-earth iron permanent magnets. At its height, CEAM involved more than 80 industrial and academic groups, who pooled their expertise, and the latest knowledge, to advance the understanding of materials properties, processing and applications of these novel materials. Many exchanges between partners have led to lasting links between them, and the creation of a European permanent magnet community." The final CEAM meeting was held in Birmingham in 1994 and, to be honest, my recollection of that meeting is also that it was some good science but mostly about networking and enjoying meeting old friends.

I think that Rex had a very good time and I have tried to pick a couple of photos that capture the spirit of the meeting. There is more information and photos on the Birmingham Magnetic Materials Group website (www.magnets.bham.

One of the groups for a boat ride

ac.uk). We were very lucky with the weather and the boat rides and BBQ on Saturday, 12 September, were held in bright sunshine. We are looking forward to another get-together like this in Bled, Slovenia, next August, for the Rare Earth Permanent Magnet Workshop (nano.ijs.si/repm10.htm).

Dr Andy Williams, Dept of Metallurgy and Materials, University of Birmingham, a.j.williams@bham.ac.uk

Building quench protection into superconducting magnets

by John Simkin, Cobham Technical Services

Superconducting magnets nearly always became resistive (quenched) before they reach their expected operating current. The heat generated spreads and extends the resistive section until it fills the coil. Quenches start because the specific heat of materials is very small at 4.2K and rapid micro movements in the coil can release sufficient energy to raise the superconductor above its critical temperature. The small movements may be caused by imperfections in the coil's structure or by cracks in the material used to fill the coil. A well constructed magnet will reach a higher current after each quench, until it finally achieves its operating current (a process called training).

Although quenching is inconvenient, training cycles can be incorporated during manufacture; however this adds cost. Quenches happen even with the best manufacturing process control and magnets must be designed to withstand them without damage. Magnets are subject to a thermal shock during a quench, with high temperature gradients within the coil; high voltages are generated across the resistive section and large out of balance forces may be created by eddy currents or sections of coils discharging at different rates. In addition, actively shielded magnets that use reverse windings to minimise their external field, require specially designed protection to circuits to avoid a burst of high field leaking during quench.

Adiabatic approximations have been used to design safe magnets. However they have limited accuracy in multi-coil systems, especially if thermal connections between coils and formers spread the quench. A fully coupled thermal, electromagnetic and circuit simulation of the quench process has now been implemented in the Opera finite element package. To protect a magnet the superconducting coils may be electrically divided into smaller units that have individual protection resistors; heaters switched by the protection circuit may be incorporated into the winding; conducting contacts may be incorporated between separate coils and conducting formers may be included that are heated by eddy currents during a quench and thus raise a complete coil surface above the critical temperature. Opera's fully coupled simulation makes it easy to include all these options and perform What-if? investigations.

During a quench, when currents are changing rapidly, coil flux density also varies. Changing flux density causes losses in the filaments of the superconductor and eddy currents in the superconducting wire; these eddy currents produce higher losses than would be predicted for a simple resistive wire, because they flow partly in the superconducting filaments and then across the resistive matrix that separates filaments. Analytic models

Building quench protection into superconducting magnets contd...

can predict the rate-dependent loss in superconducting wires; in cables made from the wires the situation is made more complicated by eddy current flow between wires, leading to losses that depend on the orientation of the magnetic field to the cable cross section. Although models predict the observed characteristics of the loss, measurements are essential because the wire's complex metallurgy may result in resistive boundaries between filaments and matrix. The quench simulator can include these effects too.

The rate-dependent loss feature of the program means that it can also be used to study the heating of the coil structure during charging or ramping of current in the magnet. Magnets designed for static operation may have relatively high rate-dependent losses in their conductor and the current can therefore only be changed slowly if a quench, caused by these losses heating the coil, is to be avoided.

Although Opera can predict when a quench will occur if internal rate dependent losses cause the problem, other types of quench are initiated by random events. The magnet designer may guess that the quench is likely to occur in the coil's peak field region, but numerous simulations must be performed to make sure that quenches initiated in other magnet regions will not cause more severe hot spots or internal voltages.

www.cobham.com/technicalservices

UKMAG seminars: 2009/2010

High Speed Machines

Wednesday, 25 November 2009

Conference Centre, George Porter Building, University of Sheffield

High speed machines are finding their way into more and more real-world applications. This seminar will bring together engineers and academics working in this area to discuss the design challenges in detail.

High speed means reduced volume for the same power; this is an advantage where space is at a premium, for example in aerospace, oil and gas, automotive and domestic appliance applications. High speed, however, means high frequency; advances in power electronic drive technology has allowed for high switching frequencies, now making high speed drives an economic choice.

There are many challenges to designing high speed electrical machines. The mechanics (rotor construction, bearing design etc) must be able to withstand the large mechanical forces. The high switching speed and high electrical frequencies mean the efficiency of the electro-magnetic circuit must be carefully considered, in order to minimise the acoustic and EMC emissions and minimise energy losses.

from 0900 REGISTRATION/COFFEE

1000 WELCOME/INTRODUCTION

1015 *Ultra High-Speed Brushless DC Motors, Drives and Applications*, Professor Zi-Qiang Zhu, Dept of Electrical and Elec Engineering, University Sheffield

1045 *High Frequency Materials*, Lars Hultman, Hoganas AB, Sweden

1115 *Mechanical Design of High Speed Electrical Machines*, Professor Keith Pullen, Centre for Energy and the Environment, City University London

1145 *High Speed Vacuum Pumps*, Dr Ulrike Höfer, Edwards Ltd

1215 LUNCH/LABORATORY TOUR

1345 *Revving Up*, David Gerada, Cummins Generator Technologies

1415 *Experiences in the Design and Manufacture of a High Speed Traction Motor,* Dr Rajesh Deodhar, IMRA Europe SAS UK

1445 *Very High Speed Slotless Permanent Magnet Motors: Some Modelling Aspects*, Pierre-Daniel Pfister, Moving Magnet Technologies

1515 TEA/COFFEE

1545 *Simple Calculation of Retaining Sleeves for PM Sleeveless Machines*, Professor Tim Miller, SPEED Laboratory, University of Glasgow

1615 *High Speed Axial Flux Machines - Mechanical and Electrical Engineering Join Forces*, Dr Michael Lamperth, Evo Electric Limited

1645 END

For full details of the programme: www.ukmagsoc.org
To register for this event: jward@ukmagsoc.co.uk

Do you have an idea for a future UKMAG seminar?

The UK Magnetics Society endeavours to organise seminars that will appeal to our membership. If you have any ideas of future topics for seminars, have a subject, or your latest product or research developments that you want to present on, then please get in touch with the Secretariat. We would like to hear your suggestions. Please contact jward@ukmagsoc.co.uk

23rd Ewing Event

Thursday, 3 December 2009

at Oriel College, University of Oxford

Ewing Lecture: *High Temperature Electromagnetic Devices*

Professor Geraint Jewell, Dept of Elec & Elec Eng, University of Sheffield

There are many potential applications in sectors such aerospace, automotive and nuclear generation that require electromagnetic devices that are capable of operating reliably in high temperature environments. In the context of electrical machines and actuators, high temperatures environments can be regarded as being >250°C, which in turn can give rise to internal temperatures of up to 500°C in critical regions such as the excitation coils. Such elevated temperatures present many challenges since almost all aspects of electromagnetic performance tend to diminish with increasing temperature, some very markedly such as coil loss. Furthermore, the range of materials that can be deployed is considerably more limited, particularly in relation to electrical insulation materials, and there tends to be a dearth of reliable data on key elevated temperature properties and long-term behaviour. This lecture will discuss the nature of these challenges by reviewing key developments in materials and device design and construction. It will draw on several case studies which encompass magnetic and electrical material characterisation; the development of modelling techniques; and the design, construction and testing of prototype devices.

Afternoon programme: *High Temperature Magnetic Materials and Components*

from 1500 REGISTRATION/COFFEE
1530 WELCOME/INTRODUCTION
1540 *Permanent Magnets for High Temperature Applications*, Dr Andy Williams, Dept of Metallurgy and Materials, University of Birmingham
1610 *High Temperature Wires and Insulation*, Professor Simon Hodgson, School of Science and Technology, Teeside University
1640 *Soft Magnetic Cobalt-Iron Alloys at High Temperatures*, Dr Witold Pieper, Vacuumschmelze GmbH & Co KG, Germany
1710 *SiC Based Electronics for High Temperature Applications*, Dr Alton Horsfall, School of Elec, Elec & Computer Eng, University of Newcastle upon Tyne
1740 INTERVAL/TEA/COFFEE
1830 23RD EWING LECTURE: *High Temperature Electromagnetic Devices*, Professor Geraint Jewell, Dept of Elec and Elec Engineering, University of Sheffield
2000 BUFFET SUFFPPER
2200 END

February 2010 (Date TBC): Distributed Generation-Challenges and Innovations, at Areva T&D Technology Centre, Stafford

The consistent and reliable flow of power from a national to a local level within the UK has historically been an accepted norm. However, we are slowly moving from the traditional arrangement of a simple power flow from a small number of solid centralised power generations toward a system with an increasing reliance on multiple smaller generation sites; sites whose prime movers are typically driven by more transient power sources. This trend means that inevitably, the demands on our existing distribution infrastructure will become more and more exacting and complex.

This seminar sets out to highlight our present position as well as the challenges we face from our current move toward multiple standalone generation systems. The seminar will explore the paths and innovation required from the next generation of Transmission Systems, Generators, Transformers, Control, Monitoring and Conversion equipment to meet these challenges.

1015 *Distributed Generation: Overview of Current Position and Future Trends*, Dr Richard Cooke, AREVA T&D UK Limited
1045 *Smart Grids:What are They?*, Dr Patrick Favre-Perrod, AREVA T&D UK Limited
1115 *Organic Rankine Cycle Generators for the Conversion of Waste Heat to Electrical Energy in a Distribued Environment*, Martin Page, Freepower
1145 *Impact of Low Voltage Ride Through and the Need for CyberGen,* Dr Neil Brown, Cummins Generator Technologies
1215 LUNCH/POSTER SESSION
1345 *DC Transmission for Distributed Generation: From Low to High Voltages*, Dr Roger Critchley, AREVA T&D UK Limited
1415 *Inverters, Distributed Generation and MCS*, Dr Nigel Jakeman, GenDrive Limited
1445 *Future Green Electric Ships Utilising 2G High Temperature Superconducting Power Generation, Propulsion, Trans-*

24 February 2010: Magnetic Measurements, Instrumentation and Facilities for Innovations, at Cardiff University

As new applications of magnetic materials appear novel measurement techniques are required to enable the full realisation of their potential. In this seminar measurement methods ranging from the use of pulse field magnetometry to determine the full loop behaviour of permanent magnets for 100% quality control to achieving magnetic environments with a noise floor of less than 1 fT/ √ Hz for new sensor developments will be presented for discussion.

UKMAG seminars 2009/2010 contd...

April 2010: Electrical Field Protection and Insulation Systems - venue TBC

Almost all electrical machines, devices and systems have electric fields yet, for many, considerable effort must be expended in controlling and containing these fields - both those for which they were designed and those emanating from their external environment. One part of the seminar will be devoted to the specification and testing of insulation systems and dielectrics. Another strand of the event will be the detection of, and protection from, abnormal and unexpected electric fields. In this part of the seminar, the topics of EMC/EMI/EMP, shielding and lightning detection will be addressed. A third theme for the day will be the suppression of and protection against high electrical fields and the surges that they cause.

12 May 2010: Hybrid Vehicle Technologies at TRW Conekt, Solihull

2 March 2009 saw the 100th anniversary of the granting of the first US hybrid car patent or "Mixed Drive for Autovehicles" as it was described then, by a German inventor, Henri Pieper. Unfortunately for Pieper, the year before his patent was granted the assembly lines for the first "affordable" mass produced car based on the internal combustion engine, the Ford Model T were under construction. By the 1930's production of hybrids based on the Pieper system had all but stopped.

One hundred years later, Hybrid Electric Vehicles have re-emerged as a feasible alternative to the gas-only internal combustion vehicle, with more than 1.5million hybrids on the roads today. Apart from the worldwide environmental issues, this re-emergence has been driven by the many major advances in magnetic materials, electrical machine design, power electronics and battery/fuel cell technology. This seminar aims to give an overview of the current "state-of-the-art" and explore the technical achievements and issues surrounding the advancement of hybrids today.

June 2010: Non-Destructive and Accelerated Life Testing - date/venue TBC

Non-Destructive and Accelerated Life testing are concerned with methods of detecting and evaluating flaws in materials. The service life of a material or structure is dependant on such flaws and NDT is therefore needed in important aspects such as quality control, plant life and guaranteeing safe operation. Progress in sensor technology and data processing algorithms are making it possible to determine key material parameters using measurement techniques based on Eddy currents, magnetic particle inspection and Barkhausen noise. This seminar will include presentations from these and other key areas and will include examples of how such advances are extending the measurement knowledge involved with NDT and associated technologies.

For full details of the programme: www.ukmagsoc.org
To register for this event: jward@ukmagsoc.co.uk

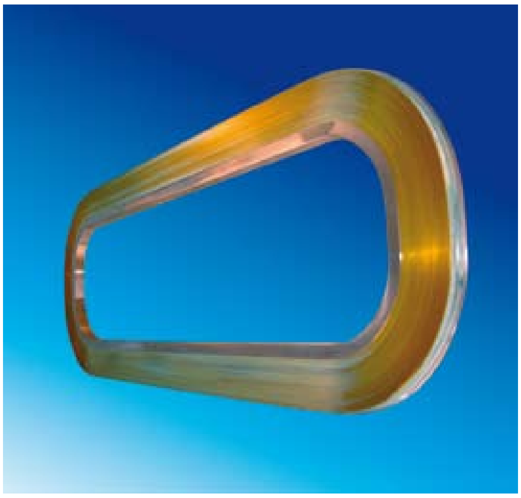
Coil delivery for superconducting renewable energy generator

Zenergy Power, the superconductor energy technology company, announced in August that it has successfully produced the first complete set of superconducting coils required for the construction of a full-scale superconducting electricity generator. This achievement has particular significance in not only demonstrating Zenergy Power's ability to scale production with a high degree of consistency, uniformity, quality and reliability, but also in enabling the completion of construction work on what is to be the world's first superconducting hydropower generator.

The groundbreaking machine is a 1.7MW hydro power generator, which will be installed into the commercial hydro power station of EON Wasserkraft GmbH in the early part of 2010. Once installed, the superconducting generator will be responsible for the supply of electricity to over 3,000 homes in the local area.

The timely and efficient production of the complete set of superconducting coils represents a significant technical milestone and all 28 full-scale electromagnetic coils required for the generator were manufactured with throughput and production yields matching the highest expectations. Following the completion of extensive testing, the Group shipped the set of superconducting coils to its collaborative development partner (and project leader responsible for overall generator design), Converteam UK Ltd, who are undertaking the final construction work on the full-scale machine. The ongoing collaborative project (initiated in late 2006 by the European Commission to accelerate the deployment of a superconducting hydropower generator) has now progressed through research and development to the final stages of physical assembly taking place at the world class manufacturing facilities of Converteam in the UK.

The groundbreaking project (named 'Hydrogenie') was originally part funded by the European Commission to bring about the installation of a 1.25MW superconducting generator into EON's commercial hydro power plant located in Bavaria, South-East Germany. EON subsequently requested an upgrade of the generator to an increased electrical capacity of 1.7MW. It is anticipated that EON will achieve a significant increase



in electrical output at its existing hydropower station as a result of the 36% increased capacity of the high efficiency superconducting machine.

These improvements in electrical performance not only underline the commercial attractiveness of superconducting generators, but also the incredible electrical properties of superconductor materials. In this application, the use of superconductors in place of traditional copper components is enabling the emergence of a revolutionary class of generators that are significantly smaller than conventional copper-based machines and also capable of delivering conversion efficiencies of greater than 98%.

As the development project of the world's first superconducting hydroelectric power generator progresses into its final stages of assembly, the company recognises the increasing importance that is now conferred upon the development of its proprietary low-cost production techniques for the mass manufacture of 2G superconducting wire. It is the intention of Zenergy Power to use its own supply of low-cost superconducting wire in the mass manufacture of renewable energy generators so as to complement their technical superiority with unbeatable economic value.

Since the beginning of this year, the Group has increasingly focused its resources on both improving the quality and consistency of its 2G wire, as well as deepening its working relationships with Honeywell and ThyssenKrupp VDM in order to qualify them as industrial scale suppliers of base materials.

As a result of this, the development of its 'all-chemical' production techniques continues well and is on schedule to support the anticipated large-scale production of superconducting generators.

info@zenergypower.com

World's largest magnet project powers up (again)

Magnews readers will recall last year's Autumn edition featured the latest milestone reached at CERN when protons had been circulated in the Large Hadron Collider for the first time. Unfortunately we then had to report in the next issue the magnet quench, in which a tonne of liquid helium leaked into the experiment's 27km-long tunnel.

However, a year later, we can report that protons are once again being injected into certain sections of this huge machine. All eight sectors of the LHC have been cooled to their operating temperature of 1.9K allowing the 1232 dipole magnets and 392 quadrupole magnets to be brought online. The intention is to circulate protons though the entire pipeline in the next few weeks.

First Announcement: 4th International Conference Magnetism and Metallurgy, WMM10, 9-11 June 2010, Freiberg, Germany

The 4th International Workshop - WMM10 - will, like previous WMM Workshops, provide a general overview of status, trends and recent developments in the field of Magnetism and Metallic Magnetic Materials and their Applications. Invited papers only will be presented by experts on magnetism and magnetic materials from industry and universities. The Workshop will be combined with a restricted number of exhibition or poster presentations. The aim of the Workshop is to bring together scientists from universities and research groups working on the development of magnetic materials, as well as electrical engineers from universities and industry who are engaged in applications of magnetic materials.

More than 130 participiants from 20 countries took part at the 3rd International Conference. At all of the Workshops, a large number of participants came from producers of magnetic materials, including ThyssenKrupp Stahl, US-Steel, ArcelorMittal, Novolipetsk, Wälzholz, Cogent, Posco, Tempel Steel, Duferco Steel, JFE, Nippon Steel, Voestalpine, Magnequench, China Steel Corporation, Hoeganaes, as well as from producers of electrical machines or electromagnetic components, including Cogent, Bourgeois, LCD Laser Cut, Wilo, ABB, Siemens, Voith, Siemens VDO, Alstom, VEM, Rotomatika, Eurotranciatura, Brockhaus Messtechnik, Danfoss, SEW and from universities, which are engaged in the development of materials and in their use in electro-magnetic machines. The same kind of audience is expected for the 4th Workshop.

The presentations and the discussion at the 3rd workshop demonstrated:

- the complexity of the topic
- the progress with respect to metallurgical aspects of the development of electrical steels
- the role of a deeper understanding of the evolution of structure and texture along the processing route on further developments of the metallurgical technique and the technology of fabrication of electrical steels
- the demand on improved electrical steel products in special application areas, especially for higher frequency applications
- the need for a more general discussion of the different aspects: material development, material fabrication on one hand and market, design aspects, optimum choice and optimum use of the material on the other hand
- the need for a more extensive cooperation of the different partners to reach a better understanding and a larger progress concerning materials and products.

The organisers hope that the 4th International Conference WMM10 will provide new contributions to these aspects.

International experts from Europe, Japan, China and the USA will again be invited to cover by their papers the aspects of the 4th International Workshop.

The 4th International Conference on Magnetism and Metallurgy, WMM10, is organised by the Technische Universität Bergakademie Freiberg (TU-BAF), Institute of Metal Forming in cooperation with Ghent University (UGent), Department of Material Science and Engineering, and is co-sponsored by the UK Magnetics Society.

Topics of the Workshop:

- Advances in process techniques: metallurgical routes
- Progresses in electrical steel grades
- Thin electrical steel grades
- Progress in modelling the evolution of microstructure and texture during the metallurgical process
- Progresses for NdFeB based hard magnetic materials
- Soft magnetic materials and their application: status and trend
- Magnetic materials for automotive application
- Electrical steels for high energy efficient electrical machines
- Electrical machines with increased power density; role of improved magnetic materials
- Optimum choice of magnetic materials: working conditions for the magnetic materials and optimum material characterisation
- Design-improved models for loss calculation
- Optimum use of magnetic materials in special application areas: optimum design and optimum fabrication methods of the magnetic parts.

Chairpersons:

Professor Y Houbaert, Gent, *yvan.houbaert@ugent.be*
Professor R Kawalla, Freiberg, *kawalla@imf.tu-freiberg.de*
Professor J Schneider, Freiberg and Gent, *schneider-bo@t-online.de*

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Oxford Yasa Motors secures new funding

An Oxford University spin-off company has secured £3.4m in private investment and government funding to take their design of lightweight electric motors developed at the University to market.

Valentine Ganin, University of Oxford (left) and Prof Malcolm McCulloch, head of Oxford's Electronic Power Group (right). In the foreground is the casing and outer wall of the stator and in the background pole pieces from the stator of the motor

Isis Innovation, the University's technology transfer company, has set up the new company, Oxford Yasa Motors Ltd. The design is a new type of axial flux motor; YASA stands for 'Yokeless And Segmented Armature'. It has no stator yoke, a high fill factor and short end windings which all increase torque density and efficiency (up to 97%) of the machine. Weight is reduced through use of less iron and copper. Torque ripple is reduced due to multi-phase windings, and the design exhibits improved cooling characteristics due to its segmented design. The peak torque is 500Nm from 23kg.

The motor was (originally) developed for the Morgan LIFEcar in 2008 and the new funding will adapt it for high-performance electric vehicles as well as aerospace, renewable and industrial applications where torque to low weight is important. The design is also scalable for large generators.

The company is aiming to sell a low volume of the motors in its first year, as well as scaling up production and developing new models. Part of the new funding is for a consortium to develop a higher volume version of the motor.

Prof Malcolm McCulloch, Head of Oxford's Electronic Power Group, said: "We're taking technology which has already been proven in a number of vehicles to a wider market. With Oxford Yasa Motors we'll be able to deliver a range of commercial products that will help the UK launch itself as a premier destination for electric vehicles development."

"We have optimised the materials and design so that the motor is much lighter and more effective, giving half the volume and twice the torque for the same power output. This electric motor technology will reduce fuel consumption and also help us move away from fossil fuels to alternative energies."

A spokesman from the investment company said: "This is a great opportunity to participate in world-leading technology at the forefront of a rapidly expanding multi-billion dollar market for electric motors."

The Oxford team has been collaborating with a motorsport engineering company to configure the motor for a new four-seat coupe, which is scheduled for track tests at the end of this year.

For further details contact Nick Farrant, CEO, Oxford YASA Motors, nick.farrant@oxfordyasamotors.com

IEC launches "Global Standards for Smart Grid" web portal

To satisfy global energy needs and protect our planet, we must become increasingly efficient in how we produce, distribute and use energy. The aim of Smart Grids is to optimise energy distribution and use, as well as integrate electricity from small and big producers and from renewable sources. To do so, Smart Grid projects depend on protocols and standards that ensure seamless interoperability of existing and new devices and systems.

With the launch of its web portal "IEC Global Standards for Smart Grid", the International Electrotechnical Commission (IEC) provides the basis for building safe and efficient Smart Grid projects. This unique, one-stop access point for anyone involved in Smart Grid projects provides a comprehensive catalogue of well focused standards.

The IEC is the world-leading international electrical standards development organisation. Together with leading experts on Smart Grid technology, it has developed a framework for standardisation that will help many countries to take the first step towards addressing their Energy Efficiency Challenge.

Richard Schomberg, Vice President Research, EDF, Chairman of the IEC Strategic Group in charge of Smart Grids says "There is now an urgent need to demonstrate how the electrical industry will be able to rely on the IEC as a 'beacon' in terms of smart grids, and to start providing a one-stop shop for the large number of smart grid projects that are being launched around the world."

The dedicated web zone, which is bound to expand as projects evolve, provides a single database of standards for anybody involved in Smart Grid projects. It clearly demonstrates the purpose of Smart Grid Standards in facing technical and interoperability challenges.

The site also provides a definition of the Smart Grid concept, a section regarding regional differences, context and needs and is a good starting point for anyone wishing to understand what a Smart Grid is all about.

To visit the IEC Smart Grid portal, please go to: http://www.iec.ch/zone/smartgrid/

STUDENT BURSARY SCHEME

As part of its role in securing the future vitality of the magnetics community, the UK Magnetics Society has introduced a competitive bursary scheme to assist postgraduate students to attend international conferences. £250 bursaries are available to support attendance at conferences of international standing in the UK or abroad, in subject areas which reflect the interests of the UK Magnetics Society membership. The award of a bursary is intended to acknowledge the student's contribution to the magnetics community and act as a catalyst for attracting additional support.

The following eligibility criteria will be applied in selecting students:

- restricted to full-time postgraduate students, ie not contract research staff;
- restricted to students from institutions which are members of the UK Magnetics Society;
- students should be presenting a paper, either poster or oral;
- applications from students presenting a paper on collaborative work between two or more members of the UK Magnetics Society (academic or industrial partners) will be particularly welcome;
- successful recipients of student bursaries are requested to provide a brief review of the conference to appear in a subsequent issue of Magnews.

DENNIS HADFIELD MEMORIAL AWARD

In addition to the Student Bursaries, the annual Dennis Hadfield Memorial Award will be made for the best Student Bursary conference report published in Magnews each year. The award will be announced at the annual Ewing Event, held each December, and the award winner will be invited to attend the Ewing Event free of charge and will receive a framed certificate.

Copy for Magnews

Members are invited to send technical articles, conference reviews, details of workshops or training courses, or general news for inclusion in forthcoming issues of Magnews to the Editor, jward@ukmagsoc.co.uk (see page 5 for copy deadline dates)

UKMAG seminar papers

UKMAG seminar papers are available to members free of charge; non-members may purchase sets of papers after the event has taken place. For further details contact: jward@ukmagsoc.co.uk

UKMAG members' training courses and workshops

Members: please let us have details of your training courses and workshops for free inclusion in Magnews. See copy deadlines for Magnews, page 5, or contact jward@ukmagsoc.co.uk

International Electrotechnical Commission Technical Committee TC68: Magnetic Alloys and Steels Plenary and Working Group meetings at The British Standards Institution, London, 26–28 October 2009

[by Dr Hugh Stanbury, Chairman IEC TC68]

Technical Committee 68 of the International Electrotechnical Commission is the committee which prepares international standards relating to magnetic alloys and steels. The committee works within the framework of the IEC and specialises in producing documents which standardise the specifications that apply to these materials and the measurement procedures for the relevant magnetic and physical properties. The published documents may then form the basis of the national standards of individual countries or a country may accept the IEC publication in its entirety when it is dual numbered as its own standard. In particular, the European (EN) standards for magnetic alloys and steels are derived from the IEC standards.

TC 68 meets biennially. The last meeting, in 2007, was held in Shanghai and in October 2009, at the invitation of the British Standards Institution, the three day event covering the plenary and working group meetings was held in Chiswick, London. There are six working/maintenance groups within TC68 and the delegates represented Belgium, P R China, France, Germany, Japan, Rep of Korea, Sweden, United Kingdom and the United States.

The Joint Working Group of IECTC68WG1 and ISOTC17WG16 is responsible for the production of the specification standards for the electrical steel industry. The current situation is that the specification documents for relay steels, grain oriented silicon steels and semi-processed silicon and non-silicon steels have recently been revised and published.

In recognition of developments in the electrical steel industry, it was agreed that proposals would be prepared for the addition of lower loss grades in the standard for non-oriented fully processed silicon steels.

The grading of grain oriented electrical steels through the single sheet test method (IEC 60404-3) is becoming more adopted throughout the world by the producers. It was agreed that it would now be appropriate to invite producers and users to comment on their current methods in response to a questionnaire which is being formulated by the working group. It is expected that this assessment will be carried out over the next twelve months.

The measurement working group, WG2, has been preparing a Technical Report on the methods of measurement of magnetostriction in electrical steels. The interest in magnetostriction is increasing due to the recognised connection between the magnetostriction of the transformer core material and emitted transformer noise. The report is now close to being presented for voting for acceptance by the international community.

A technical report on the application of digital procedures for the measurement of the magnetic properties of soft magnetic materials has also made considerable progress and will soon be available in final draft form.

The maintenance of the published measurement standards is a principal function of WG2 and it was agreed that IEC 60404-11 for the measurement of surface insulation resistance would be amended.

There are a number of round robin measurement comparison projects being undertaken by WG2 as preparatory work for the development of technical reports or, ultimately, standards in particular fields. Current work covers:

- Testing of permanent magnet materials by means of permeameters and pulse field magnetometers
- Measurement of the magnetic shielding factors of high and low permeability sheet materials
- The measurement of the magnetic moment of hard ferrites and magnetic tapes by the vibrating sample magnetometer method.

The measurement of the series inductance permeability of soft magnetic material will be considered further by Working Groups 2 and 4 as it has been recognised that this parameter is widely used in Asia. Also, a new standard is being developed for the measurement of low magnetic permeability.

Working Group 5 which deals with permanent magnet materials has recently brought to publication two Technical Reports:

- Magnetisation behaviour of permanent magnets
- Rare-earth sintered magnets – stability of the magnetic properties at elevated temperature.

Further work will consider the rectangularity of the J-H curves of rare-earth magnets, particularly for smaller magnets at higher temperatures. This work will be addressed, in consultation with the terminology maintenance team, when the permanent magnet classification document, IEC 60404-8-1 is due for maintenance.

International Standards are market driven and serve to remove the barriers to international trade and increase acceptance of products on the world market. The development of standards which apply to the extremely wide range of materials in the magnetics industry depends on the active participation of experts and support from the national organisations. A key part of the process is the commenting and voting on the draft documents by the national standards committees so that the final published standard is then truly a consensus of worldwide opinion.

I would like to register my appreciation of the efforts of the IEC TC68 Secretary, Dr Johannes Sievert, the Working Group Convenors, Michael Casson and Suzanne Yap of IEC Central Office, and all the international experts who support and contribute to the working groups.

I would also like to thank the British Standards Institution for their support and for the provision of excellent facilities for these meetings of TC68 at their Chiswick conference rooms.

The delegates and our guests were invited to an evening dinner, hosted by Cogent Power, at the Kew Bridge Steam Museum, where we had a very enjoyable and fascinating evening. The museum has the world's largest collection of steam pumping engines and we were given a very interesting tour of the exhibits before sitting down to dinner surrounded by these wonderful machines. I would like to thank Peter Slot of BSI and David Fox of Cogent Power for their efforts in making all this possible. On a personal note, I was greatly surprised to be presented by Peter with a Distinguished Service Certificate from the British Standards Institution. This was a wonderful surprise and something which I will truly value – again, my thanks to BSI.

Steaming up at the control mechanism of the 100 inch Cornish Beam Engine at the Kew Bridge Steam Museum, as part of the working exhibits for the IEC plenary meeting evening dinner

Dr Hugh Stanbury, left, receiving a Distinguished Service Certificate from the British Standards Instition, presented by Peter Slot

The next meeting of TC68 will be held in 2011 with meetings of the working groups in the meantime.

Officers of IEC TC68

Chairman: Dr H J Stanbury
Secretary: Dr J D Sievert
Central Office: Ms S Yap

Working Group Convenors

Joint Working Group, Electrical Steels Products Standards: Mr B Creton

Working Group 1, Classification:
Dr J Müller

Working Group 2, Methods of Measurement:
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Running the gauntlet: rare earths, specialty metals and turf wars inside the beltway

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Introduction

In recent years there has been considerable increased interest in rare earth elements (the fifteen lanthanoid elements plus scandium and yttrium) and their growing importance to the US economy and those of other Western nations. This is hardly surprising, given recent developments in hybrid vehicles, electric vehicles and the potential for innovative electrical generators for wind turbines. Such technologies rely extensively on permanent magnet motors, and batteries, both of which utilise rare earth elements.

Recently in the US, there have been calls to look at rare earths from a national security perspective, possibly in the same light as other materials whose procurement for US Department of Defense (DoD) contracts are subject to import restrictions - the so-called specialty metals.

To better understand the impact that classifying rare earth materials as strategic materials would have, in particular as specialty metals, we need to examine such a potential move in the context of existing strategic and critical materials, which are deemed to be of potential or actual national security interest to the US.

Strategic Materials and the Law

Late in June 2009, the US House of Representatives passed HR 2647, the National Defense Authorization Act (NDAA) for FY2010 [1].

Section 828 of the Act included language concerning "the availability of rare earth materials and components containing rare earth materials in the defense supply chain". The Findings of this Section noted that it was necessary to "ensure the uninterrupted supply of strategic materials critical to national security". "Strategic materials" in this case explicitly referred to "rare earth materials", in addition to the specialty metals [2]. Also listed was the requirement to "support the defense supply-chain, particularly when many of those materials are supplied by primary producers in unreliable foreign nations" - presumably a reference to the People's Republic of China.

The second part of Section 828 noted that "less common metals" such as the rare earths and thorium were "critical to modern technologies, including numerous defense critical technologies and these technologies cannot be built without the use of these metals and materials produced from them and therefore could qualify as strategic materials, critical to national security". The Findings went on to suggest that the DoD's Strategic Materials Protection Board (SMPB) would need to determine a strategy for ensuring the "domestic availability" of these materials, and to present such a strategy to the President for consideration.

The House and the SMPB historically have had an uneasy relationship. Set up as part of the FY2007 NDAA "in order to identify items that are critical to United States national security interests" [3], the SMPB consists of DoD representatives and got off to a rocky start by failing to convene and meet on schedule. It finally convened in July 2007 [4]. In its subsequent initial report to Congress, the SMPB simply noted that it had formed and met, and that it would look to focus its efforts on "determining the need to take action to ensure a long term domestic supply of specialty metals as designated in 10 USC 2533b" [5].

The SMPB's second meeting did not take place until the end of 2008, and then published a highly controversial second report in early 2009, detailing the meeting's outcome. The key finding of this report was that "[s]pecialty metals are not 'critical materials'", further concluding that "[t]here is no national security reason to ensure a long term domestic supply of specialty metals" [5] - an outcome that apparently took the HASC and others rather by surprise.

Amongst other tasks, The SMPB commissioned a report from the Institute for Defense Analyses [6], to meet the requirement of the NDAA for FY2008 that the SMPB "perform an assessment of the extent to which domestic producers of strategic materials are investing and planning to invest on a sustained basis in the processes, infrastructure, workforce training, and facilities required for the continued domestic production of such materials to meet national defense requirements" [7].

Over time, a number of definitions were introduced by the SMPB in order to maintain consistency of language across all reports. Two key definitions, at the heart of the subsequent controversy surrounding the report published in 2009, were:

a) Strategic Material - a material:

- which is essential for important defense systems;
- is unique in the function it performs;
- for which there are no viable alternatives.

b) Critical Material (aka "material critical to national security") - a Strategic Material for which:

- the DoD dominates the market for the material;
- the DoD's full and active involvement and support are necessary to sustain and shape the strategic direction of the market;
- there is significant and unacceptable risk of supply disruption due to vulnerable US or qualified non-US suppliers.

The problem here was that there was already a statutory definition of the term "strategic material" included in the FY2008 NDAA language by Congress – such a material specifically being defined as:

- a material designated as critical to national security by the SMPB in accordance with 10 USC §187; or
- a specialty metal as defined by 10 USC §2533b.

In the subsequent report on HR 2647 that accompanied the original bill, the HASC criticised the SMPB's re-definition of the term "strategic material", claiming that this new definition undermined the purpose of the SMPB's existence. The report was particularly scathing of the SMPB's omission of any reference in these definitions, to the "range of materials that Congress has designated as critical to national security and, as such, has provided significant protection or domestic preference in DoD policy and in statute" [8] ie the specialty metals defined at 10 USC §2533b.

The HASC was also irritated with the key finding of the second report, which was that "specialty metals, as defined in 10 USC 2533b, are not 'materials critical to national security' for which only a US source should be used; and there is no national security reason for the Department to take action to ensure a long term domestic supply of these specialty metals" [5].

To add insult to the HASC's injury, the SMPB report went on to state that the incorporation of specialty metals into a DoD system did not, by definition, make a material critical to national security. As the authors astutely noted,"[i]f incorporation alone was sufficient, every type of material from plastic, to rubber and glass, would be a critical material. More discriminating criteria are needed to distinguish critical materials from the larger set of strategic materials" [5].

Clearly then, these findings were not what the HASC had been expecting. In recent years, sourcing restrictions associated with specialty metals have become ever more complex, as competing lobbyists have successfully managed to introduce language into the annual NDAA bills. In this report from the DoD's SMPB, the HASC and associated special interests were now confronted with the DoD's considered opinion that, for all intents and purposes, these restrictions no longer made sense, despite best efforts to show otherwise. In a further footnote in the report, the authors cannily noted that "Congress has placed no domestic source restrictions on the ores and other basic materials that are the precursors to specialty metals. However, for truly critical materials, reliable sources of supply for such ores and other basic materials also may be necessary" [5].

It wasn't just the HASC that publicly took exception to the SMPB report. Laurence Lasoff, a lobbyist for the Specialty Steel Industry of North America, said that "[w]e believe there is no legal basis for the conclusion that strategic materials are not critical because DoD is not the pre-eminent customer. There is no legal basis whatsoever for a definition of 'critical' based upon the fact that DoD has to be the principal customer" [9].

Individuals working for congressional leaders who drove the creation of the SMPB were even more incredulous. Jess Green, a past Policy Counsel to the HASC, was among a number of staffers who played a key role in the creation of the SMPB and other legislation concerning specialty metals. According to Green, the conclusion in the SMPB report represented a "fundamental failure to comply with congressional intent". He went on to say that "[n]ot identifying the issue of rare earths in high performance magnets [coming from China] totally misses the mark. The technical inaccuracies in the report are astounding"[9].

Green's comments on high performance magnets related directly to language in the HASC's report that accompanied the NDAA for FY2008, in which the HASC urged the DoD and SMPB to "consider the critical contributions to national security made by the domestic high-performance magnet industry, especially during consideration of any past or future domestic non-availability determinations, and to ensure the continued availability of these items from domestic sources". The HASC further encouraged the DoD and SMPB to "consider protections for certain classes of high-performance magnets, such as rare earths and ferrites, which are commonly used in Department of Defense weapons systems, but are not currently protected in statute" [10].

Green now lobbies Congress from the private sector, with current clients including a handful of domestic permanent magnet material producers [11]. He recently noted that Congress put the DoD on notice of their concern about rare earths as early as May 2007, specifically requesting that the SMPB review the issue. Green stated that the "DoD's own definition of 'critical' materials includes a review of potential 'significant and unacceptable risk of supply disruption', yet the DoD did not review a market where China controls over 96% of rare earth resources. To me, that is a situation of great concern and the type of scenario the [SMPB] was designed to review. Rare earth components are found in all sorts of defense systems and until the [DoD] gets a handle on the usage of these materials and their availability, the intent of the [SMPB] won't be met" [12]. Green also noted that the DoD was making strides in their review of rare earths, but that a final analysis was not expected until at least 2010.

The final version of the NDAA for FY2008 included amendments to the specialty metals provision at 10 USC §2533b and its applicability to commercial items. It included specific language which restricted certain aspects of the procurement of high performance magnets for DoD projects [7]. The specialty metals provision is implemented via the Defense Federal commercial items. It included specific language which restricted certain aspects of the procurement of high performance magnets for DoD projects [7]. The specialty metals provision is implemented via the Defense Federal Acquisition Regulation Supplement (DFARS). In July 2009, the DoD issued a final ruling on the implementation of changes to the DFARS, pertaining to specialty metals [13].

The final ruling included commentary on the definition of "high performance magnet", noting that it meant magnets that derive the "majority of their magnetic properties from rare earth materials". By definition, this excludes ferrites and alnico magnet materials, although alnico magnets would still be considered specialty metals by virtue of their cobalt (Co) content. The definition of "high performance magnets" now includes neodymium-iron-boron (Nd-Fe-B) magnet materials, in addition to samarium-cobalt (Sm-Co) magnet materials which were already considered to be specialty metals due to their Co content. The DoD did note in this final ruling that Nd-Fe-B magnets do not normally contain specialty metals and would thus not be subject to the specialty metals clause.

It is important to reiterate that Sm-Co magnets are at present considered to be specialty metals for reasons other than their rare earth element content. However, definitions can change. As noted above, per the NDAA for FY2008 there are two ways to designate a metal or alloy as being a "strategic material", with the subsequent associated scrutiny on procurement: either the SMPB defines it as such, or the specific metal or alloy gets listed as a specialty metal in the specialty metals provision within 10 USC §2533b and DFARS. In the former case, ultimately the DoD makes the determination; in the latter case, simple language from Congress would do the trick.

Since at present, there is no large-scale production of rare earth materials in North America, a scenario where rare earths are added to the specialty metals list would seem unlikely as it would make little sense. In the case of safeguarding domestic rare earth magnet production, for example, there is a single North American producer of Sm-Co, and there is at present no production of Nd-Fe-B magnet material at all.

However, the past 12-18 months have seen significant activity and interest in the revival of a once-thriving North American rare earth mining sector. Molycorp Mineral's Mountain Pass mine in California is coming back into operation and there are significant deposits of rare earths elsewhere in the US and Canada, which are available for development, with the right investment and infrastructure strategy. Molycorp is promoting its "mine to magnet" strategy and in July 2009 announced its intention to create a joint venture with Arnold Magnetic Technologies, to produce rare earth magnets [14]. There have been numerous recent media stories on the proposed production of electric vehicles, and the significant quantities of rare earth-containing magnets and batteries 1.75 mm

ate in the summer of 2009, a report that China planned to restrict and in some cases ban the export of rare earth elements [16], leading to a lack of access to such materials within 3-5 years, ignited a media frenzy, and once again put US strategic materials policies in the spotlight with regard to both defense and non-defense applications. It is entirely possible that, once Molycorp has its "mine to magnet" strategy in place, the calls for rare earths to be put on the specialty metals list will grow stronger.

As to be expected, not everyone disagreed with the SMPB report. David Gallacher, a Washingon, DC attorney with the firm Sheppard Mullin, is a practitioner in government contracts and compliance with regulatory requirements. He wrote soon after the publication of the report that to his surprise, "the Board seems to have actually embraced some common sense, running counter to the implicit 'policy demands' that protectionists like Senator Evan Bayh (D-IN) seem to be pushing" [17]. This was a reference to a press release issued in May of 2008, by Senator Bayh and then-Senator Hillary Clinton (D-NY) during Clinton's presidential campaign, demanding that the DoD rigorously enforce laws pertaining to specialty metals [18].

In her March 2009 update to the ongoing Congressional Research Service report on specialty metals, Valerie Bailey Grasso reviewed the report of the SMPB in the context of the larger debate on specialty metal provisions, noting that "[s]ome policymakers believe that the specialty metal provision conflicts with free trade policies and that the presence and degree of such competition is the most effective tool for promoting efficiencies and improving quality. Others believe that domestic specialty metal suppliers need the protections afforded by domestic source provisions, and that keeping a robust, domestic specialty metal industry is a hedge against any future enemy threat" [19].

There are those then, within the DoD and outside of it, who, for a variety of reasons do not want to see any further specialty metals-related restrictions or other parameters. This resistance will be encountered by those who would like to see the formal definition of rare earth materials as strategic materials, from a US national security point of view - at least, via the specialty metals route. That said, such proponents do have something of an insurance policy. HR 2647 also included a requirement that the Government Accountability Office submit to the House and Senate Armed Services Committees, "a report on the usage of rare earth materials in the supply chain of the Department of Defense".

The purpose of the report was to "determine the availability of rare earth materials, including ores, semi-finished rare earth products, components containing rare-earth materials, and other uses of rare earths by the Department of Defense in its weapon systems" [1]. The requirements also include a requirement to determine which defense systems are currently dependent on rare earths supplied by non-domestic sources, particularly neodymium iron boron magnets.

As an aside, the US Senate version of the NDAA for FY2010 that passed in late July 2009, also contained language concerning rare earth materials [20] but it is likely that the House provision on this issue will prevail.

While issues pertaining to specialty metals are usually found further down the DoD supply chain, there is a risk that the existing procurement restrictions embodied in the specialty metals provisions, as they relate for example, to rare earth-containing high performance magnets, might lead to significantly higher costs to the DoD (and ultimately to the US taxpayer) for components that use such materials.

Other Perspectives

It is useful to look at other assessments relating to strategic materials, to see if there are pointers regarding rare earth materials and the potential consequences for placing future restrictions on their procurement, via the option of designating them as specialty metals.

The 2008 report on the National Defense Stockpile by the National Research Council (NRC) noted that "[o]ne simple method for mitigating the risks of dependence on vulnerable foreign supplies is to simply bar goods manufactured or sourced outside national boundaries from defense procurement " [21]. The report went on to note that "[r]estrictive measures of this sort have implications for procurement costs that may not be attractive. By nature, they are not very flexible tools for managing supply chain risks, although discretion for waiver almost always exists if officials are willing to invest significant political capital in exercising this discretion. Import restrictions, if exercised, may also create undesired obstacles to US exports when copied, or retaliated against, abroad. They can, however, reduce dependence on foreign supplies at reasonable cost, but only if they are imposed some time before a crisis" [21].

Finally, in its 2009 report to Congress on national industrial capabilities, the DoD noted that it "desires that the industrial base on which it draws be reliable, cost-effective, and sufficient to meet strategic objectives. However, an infinitely robust industrial base is not the ultimate objective of the [DoD]. Rather, reliable, cost-effective, and sufficient industrial capabilities are a means to the [DoD]'s ultimate objective: the development, production, and support of defense materiel necessary to provide for the nation's defense" [22].

Final Thoughts

On the basis of Congressionally-mandated reports by the DoD and independent third parties, there appears to be little evidence that either the national security or economic needs of the US would benefit from a future designation of rare earth materials as strategic materials via their addition to the specialty metals list - particularly in a sole source situation, albeit a domestic one. Certainly it is important for the US to secure access to rare earths for both defense and non-defense applications. It would make sense to do this through a more cooperative concerted effort, perhaps sponsored by Congress AND the DoD (if they can be persuaded to work more closely together) along with private enterprise, to accelerate the pace required to establish multiple North American sources of rare earth materials [23].

In addition to meeting national security objectives, such a plan could provide a competitive landscape for all those involved in the rare earth supply chain, by avoiding the replacement of one single source situation (ie procurement from China) with another. Such a plan might also go some way to alleviate fears of the potential future nationalisation of such resources, in the interests of national security - fears which perhaps inhibit further private investment into the rare earth supply chain, in the near term.

Perhaps there already exists a viable approach. The US Defense Production Act Title III Program is a DoD-wide initiative to "create assured, affordable, and commercially viable production capabilities and capacities for items essential for national defense" [24]. According to the Web site set up by the DoD's Office of Technology Transition for this program, "Title III promotes production capabilities that would otherwise be inadequate to support the material requirements of defense programs in a timely and affordable manner. Title III focuses on materials and components that could be used in a broad spectrum of defense systems" [24].

Perhaps this type of approach might be worth considering for a North American rare earth materials development program.

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Dr Gareth Hatch, ghatch@dextermag.com

Advanced Magnetic Materials and their Applications, Hanau, Germany, 12-13 October 2009

This seminar on *Advanced Magnetic Materials and their Applications* was held in Hanau, Germany, on 12 and 13 October, and was kindly hosted and co-sponsored by Vacuumschmelze GmbH & Co KG (VAC) who began life as a company in Hanau in 1914.

VAC assisted in the organisation of the seminar programme, the running of the event and also provided a conference dinner and a chance to tour their hard and soft magnetic production facilities in Hanau.

Dr Kurt Baderschneider, COO of Vacuumschmelze GmbH & Co KG, Germany, left, and Dr Michael Hall, UK Magnetics Society committee member

The seminar was the second excursion outside of the UK for the Society, who have many members across Europe and indeed around the globe. One of the aims of the Society is to represent and support industry and academia in all areas of magnetics and not limited to the UK; indeed, around three quarters of the attendees being based outside of the UK.

Proceedings were opened by Dr Kurt Baderschneider of Vacuumschmelze. Dr Baderschneider is the COO of Vacuumschmelze in Germany and welcomed to Hanau the UK Magnetics Society, as well as distinguished guests from Europe and various other countries. Dr Baderschneider gave an overview of the history of VAC, starting with the first patent applications back in 1914, and went on to explain the milestones in product development of the VAC products from 1973 through to the present day, including such well known trade names such as VACOMAX®, VITROVAC®, VACODYM® and VITROPERM®. The company is split into three discrete business units defined as Permanent Magnets, Materials and Parts, and Cores & Components.

Dr Michael Hall from the Materials Division at the National Physical Laboratory (NPL), based in the UK, gave an informative talk on the *Measurement of Soft Magnetic Materials for Operational Conditions*. This talk introduced the need for new measurement methods, in the first instance to develop standards for purchase and sale of magnetic materials, but also in the future to better simulate and quantify for real operating conditions – voltages, currents, PWM waveforms, mechanical and thermal stress. The methods for determining and measuring of the DC properties of soft magnetic materials under applied stress up to 600 MPa, as well as AC measurement requirements were described. The AC measurement method aims to better understand how the properties of the soft magnetic material can be modified to be better able to resist mechanical stress. Michael went on to define an open circuit measurement principle, which allows for obtaining material properties from open circuit data.

Dr Joachim Gerster from VAC presented a technical paper on *Advanced Soft Magnetic CoFe Materials and CoFe Lamination Stacks*. Joachim has been employed for the past 10 years at VAC and is currently the Director in charge of R&D in the Parts and Materials Division, based in Hanau. Joachim concentrated on the development of materials for the *Global Search for Better Energy Efficiency*, this being an holistic goal targeted at the ability of the world to reduce its use of fossil fuels and to help

Speakers from left: Dr Todor Filchev, Dr Denis Filistovich, Dr Julia Lyubina, Dr Michael Hall, Dr Sunny Zhang, Dr Joachim Gerster, Dr Roger Allcock, Dr Franz-Josef Borgermann, Prof Qiang Zhu, Dr Andy Williams, Dr Andreas Boettcher (delegate), Dr Gareth Hatch, Dr Oliver Gutfleisch reduce affects of global warming. The paper went on to describe factors that VAC can influence in the design of high performance motors, generators and actuators, to make them more efficient (low losses) and also lightweight.

to be established. VAC have developed a process they call VACSTACK® to help optimise each of these factors.

Lars Hultman of Höganäs AB, Sweden, gave an overview of the technology of Soft Magnetic Composite (SMC) materials, the Advances in SMC Technology, a look at various materials and applications, as well as the capability of Höganäs in this field. At Höganäs there is a relatively small, but dedicated team of 12 scientists and engineers working on the development of the SMC materials. The SMC material is a very pure iron and has no alloying process applied, as the soft mechanical properties are required for the later stage of compression. The material has a nano-coated insulation layer applied before the material is compressed into its net shape. The material reaches a very high density and thus can reach approximately 98% of the maximum Js of pure iron.

Some of the delegates at VAC prior to the factory tour

The first target for a soft material is to have a high saturation Polarisation Js, which can lead to components which can be smaller and reduced in weight, which is very important for efficient generators and motors. Materials with the highest Js is therefore a must.

Lars Hultman, Hoganas AB, Sweden, left, and Jim Nunn, Vacuumschmelze GmbH & Co KG, Germany

In high performance motor and generators a laminated stack which exhibits low losses and high power density is also required. Here even more parameters have to be considered, such as low Hc, high mechanical strength, high electrical resistivity, low strip thickness, low excess losses and low manufacturing losses. Many of these are contradictory and thus innovative manufacturing methods need

As well as the obvious benefits of material per-formance (lower losses and smaller physical size) at higher frequencies, the other distinct advantage is a large reduction in part count of the assembly and in some cases much more accurate. One example given was of a linear machine, where the normal lamination design consisted of approximately 1300 parts, whilst the comparative SMC design consisted of only five parts.

Other new developments which will be of interest are the development of a "machinable" SMC material for use in the development phase of a product and also a powder used in inductors, which will improve on standard polymer bonded iron powder cores.

Dr Stefan Hiebel and Dr Denis Filistovich from Sekels GmbH, Ober-Mörlen, Germany, presented on *Helmholtz Based Equipment with Spatial Resolution to Measure the Efficiency of Complex Magnetic Shielding Configurations* and their work in developing a practical measurement system.

Sekels concentrates on manufacture of complicated magnetic shielding of electric and magnetic fields, distributor of VAC materials and also R&D and measurement services. The application of magnetic shielding is used in such areas as highly sensitive scientific instruments (earth field), MR scanners (high fields), electromechanics, power conversion, etc.

Jane Ward, left, and Margaret Swadling, UKMAG seminar organisers

Whilst analytical and 2D FEM solutions can be used for simple geometry Sekels find experimental confirmation is often required, due to mechanical tolerance during manufacture of the shielding components, variability in magnetic properties of the materials, heat treatment/annealing of materials etc. The approach of Sekels has been to develop a highly sensitive and repeatable measurement system using Helmholtz coils. They have two coils of 1m and 2m in diameter, which have a frequency range of DC through to 2kHz. The 1m coil has an amplitude range of 7.74 mT (DC) – 0.08 mT (2000 Hz), whilst the 2m coil has a range of 3.34 mT (DC) – 0.05 mT (2000 Hz).

Design vs experimental data was presented and showed the need for experimental confirmation and showed discrepancies to FEM even at simple geometries. As well as being capable to measure large components (due to the coil size) it also allows for examination in multi-dimensional arrays

Todor Filchev from The University of Nottingham presented on work being conducted with its commercial partner e2V on the design, manufacture and optimisation of *Nano-Crystalline High Voltage High Frequency Power Transformers*. The presentation discussed the different topologies for multi-core nano-crystalline power transformers, highlighted the challenges in the manufacture of such devices and also the approach the University took in its development.

The transformer in question was rated at 150kV, with an output current of 1.5A. The switching time was 1mS, hence a frequency of 20kHz. At such high voltages it is advisable to break the design down in to smaller 50kV modules. This of course has distinct advantages in the design of the electrical insulation system. The aim of the process is to optimise the number of cores in the multi-core transformer configuration.

The resultant process flowchart resulted in the minimisation of the total power losses, an optimisation of the geometry of the primary winding and also the design of a custom designed plastic case able to resist the high voltage and with good mechanical strength.

Dr Ralf Koch from VAC explored the use of Vitroperm nano crystalline cores used in common mode choke assemblies for a harsh automotive environment.

Common mode chokes need to operate in a wide temperature band from -40°C through to +180°C, as well as being subject to other humidity and harsh environmental conditions. The common mode choke is an important part in the Electric Power Assist system (EPS). The EPS is a replacement for the more conventional hydraulic system used in the steering rack of a vehicle. It is being employed to help reduce CO_2 emissions, improve fuel efficiency, elimination of belt-driven engine accessory, avoidance of several high-pressure hydraulic hoses and give a simplified manufacturing and maintenance, which will lead to an overall system cost reduction.

Two different designs were described to show superior performance in comparison to typical high temperature ferrites. Excellent attenuation properties combined with a small component size and low number of turns using VITROPERM® nanocrystalline magnetic cores was shown to be ideal for the use in EMC critical automotive applications.

After the coffee break the second session began with a change of chairman and a start of the Sintered Hard Materials talks.

The first talk of the session was from Dr Julia Lyubina of IFW Dresden, who presented a paper about novel materials for solid state energy efficient magnetic cooling. She then began by explaining the principles of magnetic cooling and went on to talk about some of the issues and materials used. Dr Lyubina explained that magnetic cooling at present has a maximum aficionado efficiency of 60% whereas conventional gas compression liquid gas phase type cooling only has an efficiency of 45%. The magnetic cooling relies on the reversible magnetisation and de-magnetisation of a magnetic refrigerant. This is based on the so-called magneto cavalry effect (MCE). Conventional magnetic cooling systems utilise your gadolinium and the MCE involves a ferromagnetic to paramagnetic second-order phase transition. More recently several materials with a giant MCE have been discovered. These materials are based on gadolinium silicon germanium, manganese arsenic antimony, manganese arsenic phosphorus, lanthanum iron silicon and nickel manganese X (X = tin, indium, antimony). As materials undergo a first order transition induced by a change in magnetisation. Results were presented on the use of $La(Fe,Si)_{13}$-based compounds and how their transition can be modified with the addition of a hydrogen. Also work on the Heusler alloys (nickel manganese X (X = tin, indium, antimony)), possibly known more for the magnetic shape memory effect, was also presented.

The final talk of the afternoon was given by Dr Oliver Marle of Continental Automotive, SAS France. He presented work on a range of magnetic sensors used in automotive applications. Although the automotive industry uses large volumes of ferrites for permanent magnet applications there are an increasing number of rare earth magnets being utilised in a whole range of sensors, for example, for position sensing of camshafts, speed sensing of turbo charger fans and many other rotational position sensors. As well as the design of these sensors he also discussed some of the material requirements for magnets in these sensors. In order to get an accurate sense of position of a rotating shaft it is often necessary to have good control of the direction of magnetisation of the magnets. Also of great concern is the stability of the magnet which may have to have many thermal cycles in possibly harsh environments.

This concluded the first day of the meeting and the evening comprised a conference dinner kindly sponsored by Vacuumschmelze. Dr Kurt Baderschneider gave a speech at the conference dinner on behalf of Vacuumschmelze and Dr Micheal Hall responded for the UK Magnetics Society, thanking Vacuumschmelze for their generosity in hosting and co-sponsoring this most successful event. The conference dinner was a great opportunity to network and meet up with old friends and colleagues for a glass of fine German wine or a much larger glass of fine German beer.

The following morning began with a presentation from Prof Qiang Zhu of Sheffield University who presented work on hybrid machines. He explained to us the different geometries of magnetic machines and how the introduction of permanent magnets allowed much more flexibility in design and how different types of motors could be combined into the same machine. These hybrid designs are either achieved by simply embedding magnets into the rotor or stator of other machines or by having, for example, a rotor that has permanent magnets at one end but a switched reluctance type rotor at the other end. These hybrids allow optimisation of performance for particular applications yielding the greatest efficiencies over the lifetime of the machines. He referred to permanent magnets as "a strong gene", ie when put into a machine then that machine must be considered as a permanent magnet type machine.

The second talk of the day was from Dr Gareth Hatch of Dexter Magnetic Technologies Inc, USA. He presented an introduction to magnetic couplings and gears giving some examples of the devices made by Dexter. These devices were categorised into either asynchronous or synchronous couplings, ie they either move at different speeds or at the same speed. An example of an asynchronous coupling utilised alnico permanent magnets that are magnetised and de-magnetised as the coupling rotates such that the coupling works in an energy loss situation and allows a rotational coupling to apply a limited torque. This type of coupling has applications for example in the food industry for screwing on the tops of jars such that the consumer will be able to unscrew them. Gareth presented some gear designs and gave an illustration of a device used in a well bore drilling motor, such a device can be used to convert high speed to high torque for drilling oil wells.

After a coffee break Dr Sunny Zhang of Bakker Magnetics, the Netherlands, gave a presentation about the application of Halbach magnetic arrays for high-performance energy converting. He presented a range of applications utilising these type of magnetic arrays, for example in eddy current separators used to sort recycled scrap based on the electrical conductivity of the scrap. Dr Zhang also discussed some of the practical difficulties associated with assembling these systems.

Next up was Dr Oliver Gutfleisch of IFW Dresden. He gave a presentation about the processing of permanent magnets in particular the use of hydrogen in the processing showing a very interesting video of the hydrogen decrepitation (HD) process whereby alloy is broken into a powder by exposure to hydrogen gas. He spoke about the developments being made with an aim to produce magnets suitable for new applications and growing applications such as hybrid electric vehicles and wind turbines. One of the main driving forces for development of permanent magnets currently, is to use less dysprosium in the neodymium iron boron magnets as the current levels of dysprosium used exceeds those found in ores, relative to the amount of neodymium.

Finally, the program of presentations was concluded by Dr Franz-Josef Boergermann of Vacuumschmelze who presented a paper concerning the optimisation of permanent magnets for undulators. These are systems that produce oscillation in a beam of electrons which then produce photons of light which are used in complicated physics experiments. Some of these undulators are extremely large systems, for example, Vacuumschmelze are working on an undulator that is 200m long and requires 10 tonnes of neodymium iron boron permanent magnets. In order to get this free electron laser (FEL) from the electron beam there must be a consistent and reproducible oscillation of magnetic field as the beam passes along the undulator. Dr Boergermann presented work looking at improving the tolerances on magnetic properties including remanence, degree of alignment as well of the accuracy of the direction of alignment. The next step of this program is to see if the improvements in tolerances can be applied to a 10 tonne batch of magnets required for the 200m oscillator.

At the end of the seminar there was a very interesting tour of the Vacuumschmelze factory, which was a short walk from the seminar venue.

Roger Allcock, Cobham Technical Services, and Dr Andy Williams, Dept of Metallurgy & Materials, University of Birmingham

Advanced Soft Magnetic CoFe Materials and CoFe Lamination Stacks

Joachim Gerster, Witold Pieper, and Niklas Volbers, Vacuumschmelze GmbH & Co KG, Germany

[This paper was presented at the UKMAG seminar *Advanced Magnetic Materials and their Applications,* co-sponsored by Vacuumschmelze GmbH & Co KG, Germany, held in Hanau, Germany, 12-13 October 2009. UKMAG members may access the full presentation on the Society's website: www.ukmagsoc.org]

Abstract

High-performance motors and generators require soft magnetic 49 % Co 49 % Fe 2 % V (basic composition of the CoFe-alloy) material due to their high induction saturation. In many cases the rotational speed is increasing in order to improve further the power density of the motor or generator. When the rotational speed is extremely high, the material has to exhibit a combination of high strength and good soft magnetic properties.

However, the total power absorbed by the soft magnetic laminated rotor and stator stack should be as low as possible. The paper will cover a presentation of the whole range of 50%-CoFe alloys from the magnetically softest to the material with the highest strength. The physical aspects will be discussed as well. Furthermore data of a CoFe laminated stack which exhibits extremely low losses will be presented.

Introduction

The global search for better energy efficiency requires a conversion from electrical to mechanical power with minimal losses. Commonly electromagnetic devices like motors, generators and actuators are used for this conversion. One of the key factors is to reduce the losses originated by the soft magnetic material.

When considering the total system performance, there are additional requirements in many applications. Very often the size and weight of the electromagnetic device is an important issue. Soft magnetic CoFe-alloys exhibit the highest saturation flux density level. Therefore this material is very attractive for applications where very high power density or high forces are needed. Among others it is particularly the aircraft industry which requires highly sophisticated soft magnetic CoFe-alloys for their lightweight and high efficient generators.

New High Strength CoFe Alloy

Regarding a motor, a certain amount of energy can be converted from electrical to mechanical energy per turn. If the power of the machine shall be increased, the rotational speed has to be higher. So, in many motor and generator designs the speed of revolution is increasing in order to improve further the power density of the motor or generator. If the rotational speed is critically high, the material has to exhibit a combination of high strength and good soft magnetic properties. In aircraft applications the soft magnetic CoFe material shall show a combination of low losses and high strength.

According to [1] and [2] the total power absorbed by the soft magnetic material ptot can be expressed by

$$p_{tot} = p_{hyst} + p_{d} + p_{excess} \quad \text{, Eq (1)}$$

where p_{ed} are the eddy current losses and p_{excess} are the additional excess losses due to the domain structure of the ferromagnetic material [3]. For materials showing a nearly z-shape hysteresis loop the hysteresis losses p_{hyst} can be estimated by

$$p_{hyst} \approx 4 \cdot H_c \cdot B_r \cdot f \quad \text{, Eq (2)}$$

where H_c is the coercivity, Br is the remanent flux density and f the sinusoidal frequency of the applied electromagnetic field.

Unfortunately there is a trade-off between low H_c (low losses) and high strength. Both H_c and the yield strength $R_{p0.2}$, are material parameters and can not be optimised separately, because both parameters are influenced by the microstructure of the material.

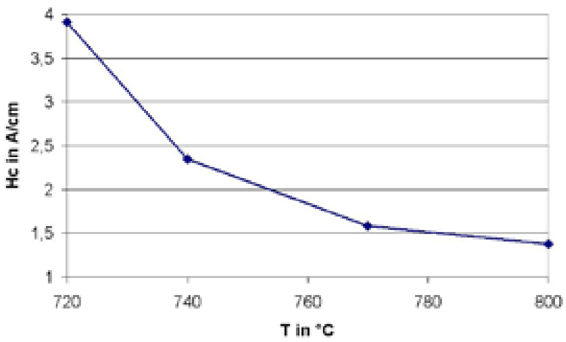
The Hall-Petch relation [4],[5]

$$R_{p0.2} = \sigma_0 + k \Big/ \sqrt{d_g} \quad \text{Eq (3)}$$

expresses that the yield strength is determined by the average grain size d_g and the equation by Mager [6]

$$H_c = k' \big/ d_g \quad \text{Eq (4)}$$

gives the relation between the coercivity and the microstructure of the ferromagnetic polycrystalline material.



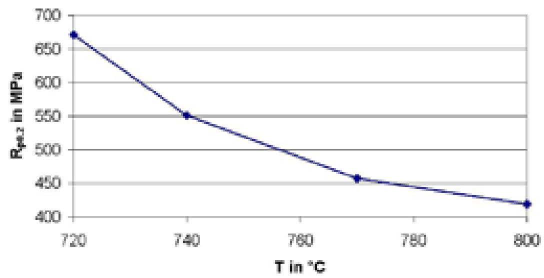


Figure 1 Typical coercivity and yield strength of the soft magnetic CoFe alloy VACODUR® S Plus after 4 h heat treatments

σ_0, k and k´ are material constants.

H_c and $R_{p0.2}$ can be adjusted by the magnetic final annealing of the soft magnetic material. Figure 1 shows H_c and $R_{p0.2}$ of the soft magnetic CoFe alloy VACODUR® S Plus after different heat treatments. Both parameters are decreasing with increasing annealing temperature.

Eq (3) and Eq (4) can be combined to

$$H_c = \frac{k'}{k^2} \cdot (R_{p0.2} - \sigma_0)^2 \quad . \quad \text{Eq (5)}$$

This quadratic equation illustrates the trade-off between low losses (low H_c) and high strength. The alloying additions of the high strength soft magnetic VACODUR® S Plus optimise the material constants σ_0, k and k´ in order to guarantee the best compromise between low losses and high strength. A further advantage of this alloy is the wide range of properties which can be adjusted by annealing, see Figures 2 and 3.

New Lamination Stacking Procedure

The focus of the worldwide research work was on the improvement of the material as well as on the motor and

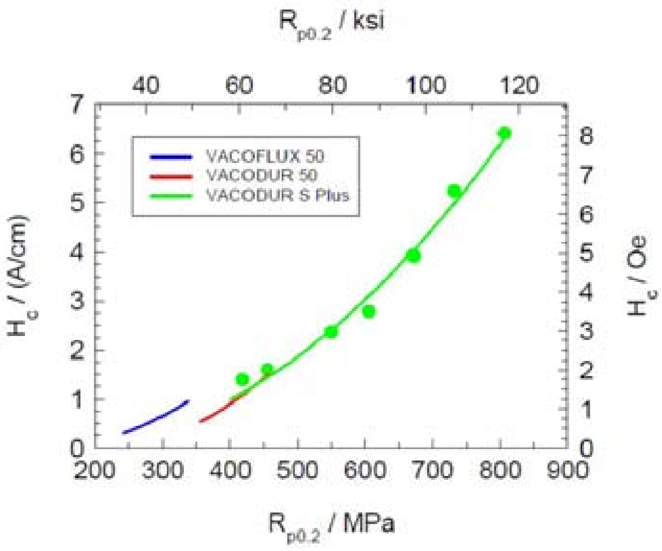


Figure 2 Coercivity versus yield strength of three different 50% CoFe alloys

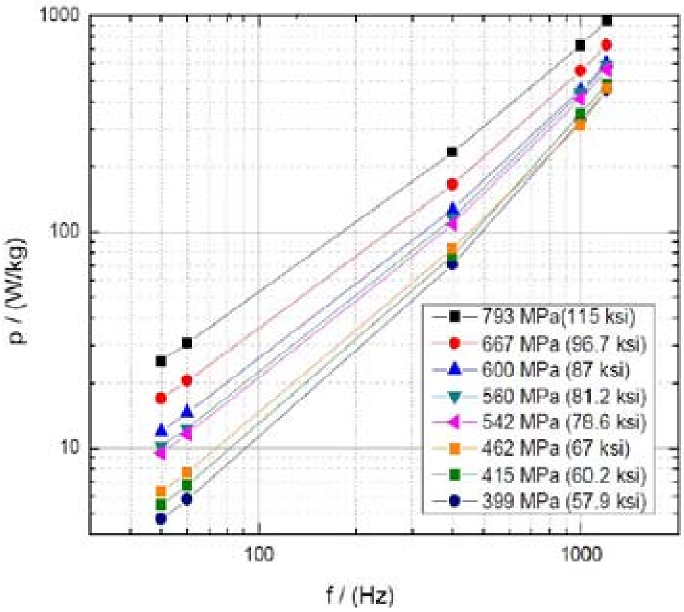


Figure 3 Typical total losses p_{tot} versus frequency of VACODUR® S Plus with 0.35 mm strip thickness (14 mil) for different strength levels adjusted by heat treatment

material as well as on the motor and generator design. But enhancements on the stacking procedure were neglected. Regarding Eq (1), the eddy current losses p_{ed} of a soft magnetic strip with the thickness d can be written as

$$p_{ed} = \frac{\pi^2}{6 \cdot \rho_{el}} \cdot d^2 \cdot B_{max}^2 \cdot f^2 \quad , \quad \text{Eq (6)}$$

where ρ_{el} is the specific electrical resistivity of the material [1]. To improve the losses significantly, the first step is to reduce the strip thickness. Because of the quadratic relation the eddy current losses can be reduced by the factor of 12, when reducing the strip thickness from conventionally used 0.35 mm to 0.1 mm. We developed an advanced production technology which provides an improvement of the soft magnetic properties and a significant reduction in losses compared to standard processes. Further, this technology guarantees low geometrical tolerances and very high filling factors ≥ 98 %. This is also valid for thin strip with 0.1 mm thickness.

Above all we dramatically reduced the so-called manufacturing losses, which describe the difference between measured material losses (losses of material samples, stacked as loose rings, see Figure 4) and the losses of the soft magnetic glued laminated stack, see Figure 4. VAC's technology VACSTACK® is very close to the theoretical optimum.

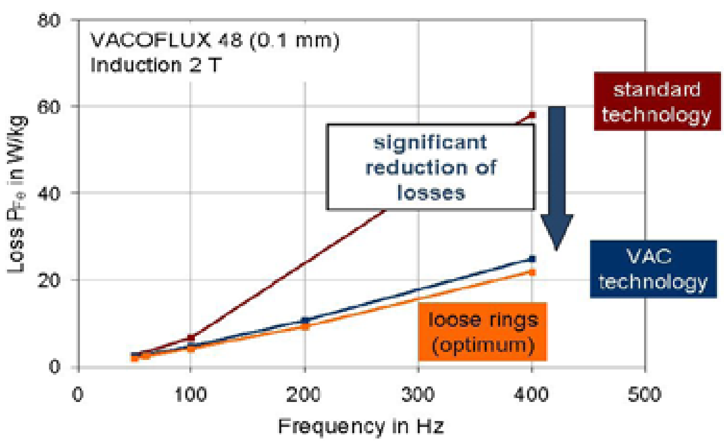


Figure 4 Total losses ρ_{tot} versus frequency influenced by different production technologies

Conclusion

Soft magnetic high strength CoFe can be optimised in the trade-off between low coercivity (low loss) and high yield strength. This material is needed for rotating electrical machines with the highest power density.

In order to reduce the total power absorbed by the soft magnetic stack, we developed a new production technology, which is very close to the theoretical optimum.

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Applications of Halbach Magnetic Arrays for High Performance Energy Converting

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Abstract

In this paper practical aspects of applying Halbach Magnet Array (HMA) are presented and discussed for mechanical-mechanical energy conversion, mechanical-thermal energy conversion and mechanical-electrical energy conversion or vice verse. It has been demonstrated that the Halbach array magnet technology provides an effective means to enhance the performance of various magnetic devices.

1 Introduction

Magnetic energy resulting from a deliberately designed magnetic circuit can be used to attract, lift, separate, levitate and actuate a ferromagnetic object or conducting media or current-carrying conductor. The whole process is realised by the energy conversion, during which the efficiency shall be maximised to perform a targeted task and function.

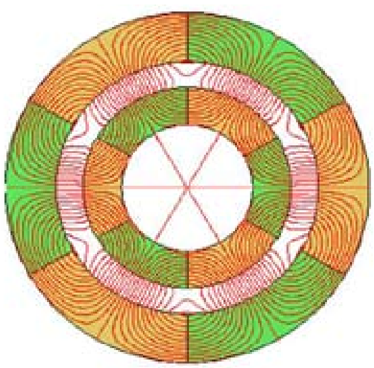


Figure 2 Two rotors made of Halbach arrays

Analysis and synthesis of a right magnetic profile, which could be sinusoidal, trapezoidal or spike-shaped for a high field gradient, is of great importance. Halbach magnet arrays and their variants provide unlimited options to achieve this. In this case a number of application fields are presented including high intensity magnetic separation, eddy current separation, synchronous coupling, magnetic refrigeration and electric machine.

2 Mechanical energy conversion

2.1 Permanent magnet coupling

Permanent magnet coupling provides a high efficiency contactless energy

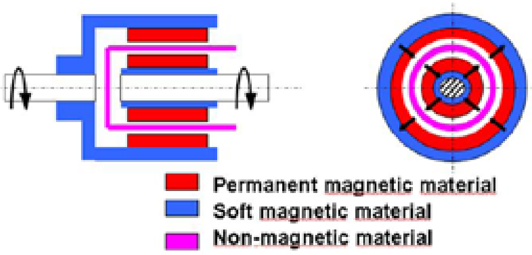


Figure 1 Schematic presentation of a radial flux type synchronous coupling

transmission technology, which is widely used in various pumps, flow meters and so forth. The magnetic coupling could be categorised into three types that include 1) synchronous coupling; 2) hysteresis

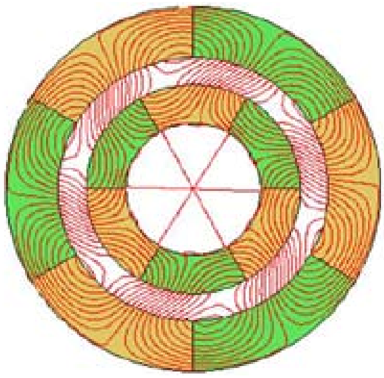


Figure 3 Torque produced due to Push-Pull

coupling; 3) eddy current coupling.

A schematic construction of a synchronous coupling, with a radial flux topology, is shown in Figure 1. As illustrated, a driving part or a driver is connected to a motor, serving normally as an external member, and a driven part, which is an internal member segregated by a separation cup from a driver, is connected to a pumping body.

In the case of need to remove the flux return path made of soft magnetic materials, the Halbach magnetic array is of great use to achieve the desired flux density in the airgap that is reponsible for the targeted torque production. Figure 2 shows the magnetic flux path, in which there exists no steel parts conducting the magnetic flux flow. A maximum torque to be transmitted is achieved when the maximum co-energy variation over the rotary angle is reached as shown in Figure 3. The static torque is computed and compared with the measured data shown in Figure 4 revealing a desired agreement.

2.2 High intensity and high gradient magnetic separation

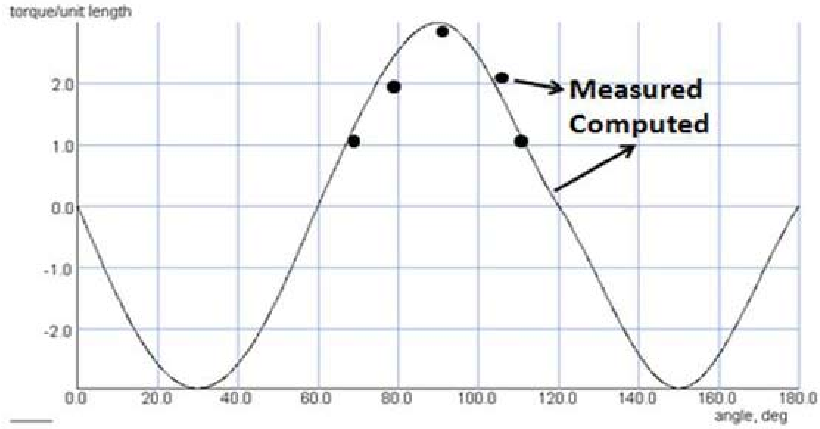
Recovery and recyling of valuable materials from obsolete electronics and other scrapped or discarded waste is becoming more and more important, not only because of the worldwide concerns over the depletion of raw materials, but also due to the need that the life cycle of the material shall be closed. In this article the expensive Cr-containing black sand used for the high temperature foundary casting is separated from a sand mixture and reused. The high efficiency separation is achived by a HMA circuit.

2.3 Eddy current separation

A thorough understanding of eddy current separation and approximation of eddy current forces can be made without using complicated differential equations for an engineering purpose, although electromagnetic theories are full of them. The author presented a way in which eddy current forces acting on a conducting particle can be much simplified. However a lumped analysis for assessing the magnetic deflecting force on a electrical conducting particle in the rotating eddy current separator might be presented as:

$$F_d = K_{mag} \bullet B_e^2 \bullet f \bullet m \bullet \frac{\sigma}{\rho} \bullet S_{particle}$$

where K_{mag} is the complex coefficient relating to the magnetic roll system design, B_e the effective magnetic induction, f the oscillation frequency of the magnetic field, m the mass of the conducting particle, σ the electrical conductivity of the particle, ρ the mass density of the particle, and $S_{particle}$ the complex factor relating to the dimension and shape as well as orientation of the particle in the magnetic field. For a given



particle and a fast-spinning magnetic roll system, the Halbach magnetic array can achieve a maximum magnetic induction at a defined air gap.

3 Thermal energy conversion – magnetic refrigeration

Magnetic refrigeration is an emerging market, which is able to compete the conventional vapour compression-based technology. In terms of less energy consumption typically by 20% and absence of the greenhouse gas emission, the magnetic refrigeration technology attracts worldwide attention both academically and industrially. Professor K A Gschneidner has published a large number of papers including the overviews of the past, present and future of this technology across the time.

The magnetic field source plays a key role in realising the commercialisation of this emerging magnetic cooling technology in an economically viable manner. The cooling capacity is proportional to the intensity and distribution of the magnetic field in an active magnetic field zone. The Halbach arrays are a proven technology which can achieve a desired high-intensity magnetic field.

4 Electrical energy conversion

In the motion world, energy efficiency is playing a pivotal role, due to on-growing worldwide concerns over energy security, resources depletion and global warming. It is reported that electrical machines consume approximately more than 80% of the total electricity in the major industrialised countries. Therefore energy-saving, energy-efficient and (electrical) energy-converting technologies are of paramount importance in developing a sustainable and more green human society. Under such a circumstance, the renewable energy including solar, wind, hydro-, and wave/tidal energy is under the intensive and extensive development and execution. Figure 5 shows a Finite Element Analysis (FEA) result of a Halbach magnet array that is manufactured as a modular component which can be easily assembled onto a large rotor circumferentially, as shown in Figure 6.

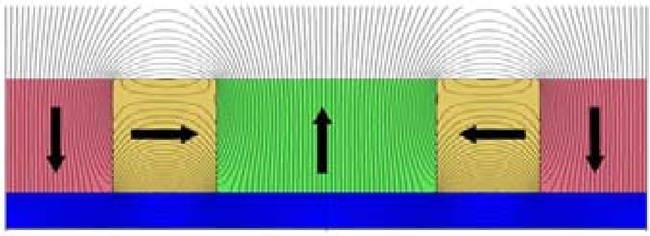


Figure 5 FEA analysis of a modular Halbach array

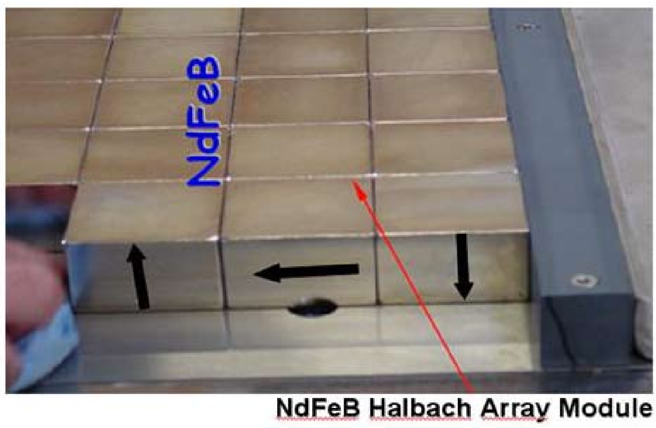


Figure 6 Modular Halbach arrays in real life

5 Discussions

Design of a high performance magnetic energy converting device is a complicated process which might involve a judicious selection of active materials, an optimised synthesis of magnetic circuits, and a cost-effective manufacturing of the assembly and device, not only for the functionality but also for the durability and reliability. Some key design issues are discussed in the following sections.

5.1 Magnetic material selection, specification and validation

A booming application of magnetic materials is in full swing as already discussed. However, an appropriate and cost-effective selection of magnetic materials is becoming a specialist area, due to the fact that there exists a large range of both permanent and soft magnetic materials of varying types and grades, to some great extent. Even within each type of magnetic material, the magnetic, electrical, mechanical and thermal properties and capabilities change to a great degree. In case of modern NdFeB permanent magnets, there are more than 100 types and grades available for a device design engineer, including both sintered and bonded types.

Selection and specification of the best magnetic material for a specific application is a joint effort of the cost consideration and the material performance over the device service time in a specific environment. Under such a circumstance, the continuous working temperature and the maximum transient temperature as well as the demagnetising field, resulting from permanent magnets and/or wound coils, are common issues that could have a tremendous impact on the magnetic materials to be used. Furthermore, an appropriate assortment of testing and measurement method and equipment must be chosen for the magnets specified to be validated for a targeted application.

5.2 Magnetic circuit synthesis, analysis and optimisation

A desired magnetic circuit structure, for a given magnetic material, delivers a specific magnetic field profile across a defined airgap, in order to meet or exceed a torque or force curve desired by a specific application. An optimal design of a magnetic circuit needs a wide range of expertises, experiences and design tools, analytical and/or numerical, in order to fulfil the defined functions both technically and economically.

5.3 Magnetisation, stabilisation and demagnetisation

Permanent magnets, in particular, high energy rare earth magnets, are troublesome or even dangerous to handle. It is preferred, in some cases, that the magnets are assembled in a non-magnetised state which will be magnetised after a final assembly. In this context, an appropriate magnetiser, which could be DC-electromagnetic field-, pulsed field-, or even permanent magnetic field-based, must be compared and selected. Quality of permanent magnet magnetisation, including level of saturation, magnetisation/orientation direction and its deviation, plays a key role in the device performance. It must be emphasised that a possible demagnetisation or an irreversible loss, both partially and completely, of a permanent magnetic component shall be considered with great care.

5.4 Assembly know-hows

Intensive care must be taken for assembling or mounting magnetised high energy rare earth permanent magnets due to a dangerous repulsion and attraction among the magnets themselves, and between the magnets and the soft magnetic steels as a flux return path. The flux return path is obviated completely or partially in case of Halbach magnet arrays being used. A significant magnetic interaction force must be controlled and guided, by means of innovative assembly tools and expertises, in an effort to avoid magnet damages/defects, surface protective coating damages/defects and localised (visible or invisible) mechanical stress causing magnet cracking.

Permanent magnets to be used could be glued, screwed, anchored or retained by various high strength sleeves or tapes. In this context, some dedicated assembly tools and methods could be developed in an attempt to suppress and/or make use of the magnetic interactive forces.

6 Conclusions

Advanced permanent magnet technology is a high value-added enabler that opens up many opportunities for device innovations and advancements. The continued price decrease of both rare earth permanent magnets and power electronics further boosts the rapid penetration into a number of important areas where recycling of valuable raw materials, energy efficient/saving motoring/driving, renewable energy production are all critical towards accomplishing low-carbon economy.

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Dates for your diary

2009

12-13 Oct	UKMAG seminar Advanced Magnetic Materials & their Applications, Hanau, Germany [hosted & co-sponsored by Vacuumschmelze GmbH, Germany]: www.ukmagsoc.org
12-14 Oct	Euro PM2009, Int Congress and Exhibition, Copenhagen, Denmark: www.epma.com/pm2009
13-14 Oct	EMCUK 2009, EMC Exhibition & Conference (partnered by IET), Newbury: www.emcuk.co.uk
13-15 Oct	CWIEME Chicago 2009, Chicago, USA: www.cwiemeuk@coilwindingexpo.com
25 Nov	UKMAG seminar High Speed Machines, at University of Sheffield: www.ukmagsoc.org
16-18 Nov	EHE09, Int Conf on Electromagnetic Fields, Health & Environment, Sao Paulo, Brazil: www.ehe09.usp.br
22-26 Nov	Compumag 2009, Florianopolis,Brazil: www.compumag2009.com
24-26 Nov	CWIEME Mumbai 2009, Mumbai, India: www.cwiemeuk@coilwindingexpo.com
3 Dec	UKMAG 23rd Ewing Event: Ewing Lecture: High Temperature Electromagnetic Devices/afternoon programme: High Temperature Magnetic Materials and Components, at University of Oxford: www.ukmagsoc.org

2010

18-22 Jan	11th Joint MMM/Intermag Conference, Washington, USA: www.magnetism.org
Feb (TBC)	UKMAG seminar Distributed Generation:Challenges and Innovations, at Areva T&D Technology Centre, Stafford: www.ukmagsoc.org
24 Feb	UKMAG seminar, Magnetic *Measurements, Instrumentation and Facilities for Innovations*, at Cardiff University: www.ukmagsoc.org
April (TBC)	UKMAG seminar, *Electrical Field Protection and Insulation Systems*, venue TBA: www.ukmagsoc.org
19-21 April	PEMD2010, Power Electronics, Machines and Drives, Brighton: www.theiet.org/pemd
9-12 May	CEFC2010, 14th Biennial IEEE Conf on Electromagnetic Fierld Computation, Chicago, USA: www.cefc2010.org
12 May	UKMAG seminar Hybrid Vehicle Technologies, at TRW Conekt, Solihull: www.ukmagsoc.org
June (TBC)	UKMAG seminar Non-Destructive and Accelerated Life Testing, venue TBC: www.ukmagsoc.org
9-11 June	WMM10, 4th Int Conf Magnetism and Metallurgy, Freiberg, Germany: schneider-bo@t-online.de
13-16 June	ENDE2010, XV Int Workshop on Electromagnetic Non-Destructive Evaluation, Szczecin, Poland: www.ende2010.zut.edu.pl
22-24 June	CWIEME Berlin 2010, Berlin, Germany: www.cwiemeuk@coilwindingexpo.com
29 June-2 July	EPNC2010, 21st Symposium on Electromagnetic Phenomena in NonLinear Circuits, Essen, Germany: www.ptetis.put.poznan.pl/xx1epnc
June	UKMAG seminar, *Non-Destructive and Accelerated Life Testing*, venue TBA: www.ukmagsoc.org
6-8 Sept	ICEM2010, 19th Int Conf on Electrical Machines, Rome, Italy: www.icem2010.ing.univaq.it/
10-14 Oct	PM2010, Power Metallurgy World Congress and Exhibition, Florence, Italy [**deadline for abstract submission 30 Nov 09]:** www.epma.com/pm2010
TBC	UKMAG seminar, *Hybrid Vehicle Technologies*, venue TBA: www.ukmagsoc.org
Sept	IGTE, 14th Int Symposium on Numerical Field Calculation in Electrical Engineering: www.igte.tugraz.at/
4-5 Nov	1&2DM, 11th Int Workshop on 1&2 Dimensional Magnetic Measurement of Testing, Oita, Japan: www.2-dm.com
14-18 Nov	55th Conf on Magnetism and Magnetic Materials, Atlanta, Georgia. USA: www.magnetism.org
Dec	UKMAG 24th Ewing Event: TBC, www.ukmagsoc.org

2011

25-29 April	Intermag, IEEE International Magnetics Conference, Taipei, Taiwan: www.intermagconference.com/intermag2011
12-15 July	Compumag 2011, Sydney, Australia
30 Oct-3 Nov	56th Conf on Magnetism and Magnetic Materials, Arizona, USA: www.magnetism.org
Dec	UKMAG 25th Ewing Event: TBC, www.ukmagsoc.org

2012

30 Oct-3 Nov	57th Conf on Magnetism and Magnetic Materials, Scottsdale, USA: www.magnetism.org
Dec	UKMAG 26th Ewing Event: TBC, www.ukmagsoc.org

2013

14-18 Jan	12th Joint MMM/Intermag Conference, Chicago, USA: www.magnetism.org
1-4 July	Compumag 2013, in Europe: TBC
December	27th Ewing Event: TBC, www.ukmagsoc.org

You are invited to send details of appropriate events for inclusion in Dates for your Diary in future issues of Magnews, for the interest and benefit of Magnews readers

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