3. PM in magnet applications

3.1 GENERAL SITUATION

3.1.1 A market overview

The world market for permanent magnets will continue to grow strongly at 10 - 15% annually. Powder technology is, and will remain, the preferred, and for some materials, the only method of hard (permanent) magnet manufacture, and already accounts for over 80% of the market.

For soft magnetic products, the market is larger than that for the permanent magnet materials, being estimated at USD 12 billion, but only 15-25% of production uses powder technology. The powder component global demand is estimated at USD 2 - 3 billion, with soft ferrite (Ni-Zn and Mn-Zn base material) accounting for over 80%.

Soft magnet applications are expected to show significant growth, predicted to be 5-10% annually overall and this probably masks a much stronger growth trend for the powder products within it: e.g. soft ferrite and iron based powder components. Soft ferrite already has the dominant share of the soft magnetic powder market and continuous annual growth has been estimated at 5-15%.

3.1.2 The UK position

The UK does not have producers of sintered Sr or Ba base ceramic hard ferrite (except for a small amount of isotropic material) or fully dense Nd-Fe-B components, but does have producers of other permanent magnets components to include plastic bonded products containing Nd-Fe-B and hard ferrite as well as Alnico and Sm-Co magnet powders. It also has manufacturers of magnet sub-assemblies and magnet distributors dealing in all types of permanent magnet materials; often performing secondary operations on them.

There are at least two manufacturers of sintered soft ferrite components remaining in the UK, but cheap imports of soft ferrite into Europe, coupled with present exchange rates, make it difficult for UK companies to compete globally in mainstream markets with standard products. The UK also produces soft iron based powder components.

The magnets industry is not insulated globally and most of the larger manufacturing units are located outside the UK, particularly in Asia, to take advantage of lower labour costs and overheads.

UK end users also face stiff competition from East Asian producers in some market segments. Selected niche markets may therefore be the best option for UK producers. Morgan Crucible (a UK owned company) has recently entered the magnetics-manufacturing sector through acquisition of Crumax and Vacuumschmelze.

Intense competition, mainly from the Far East, in the form of low price imports of magnets and assemblies using magnets, has impacted adversely on European sales, particularly of Nd-Fe-B parts, but also of hard and soft ferrite components. Even Sm-Co has been affected more recently. China is now believed to be the largest producer of permanent magnets in the world, though a significant proportion is from non-Chinese owned companies e.g. Japanese ownership or joint ventures.

Overall, the main concern is long term Chinese domination of rare earth raw material supply. This gives them a very real advantage in the growing magnet market. San Huan (Magnequench) effectively controls the supply of melt spun powder and is stepping up its own manufacture and sales of magnets made from this material; in some cases in competition with the component producers who buy raw material powder from them. This is a direct threat to UK and other component producers, though other potential suppliers are developing melt spun powder production capabilities.

3.1.3 Yet more competition

South East Asia countries, India, South Africa, Brazil are also exporting low priced magnetic materials to varying degrees and imports from Eastern Europe are said to be growing. A potential challenge from Middle Eastern countries in the future supply of low cost parts cannot be ignored. Global competition is expected to remain intense.

Though some Japanese companies have set up manufacturing operations in low labour cost countries, high levels of automation in factories in Japan, offsetting high labour costs, still enable low cost imports from Japan, and the technical performance of the materials is good. (The technical performance of Chinese material is reported to be inferior but is improving quickly, and labour and overheads costs are very low and reflected in much lower prices. At least one major UK user of Nd-Fe-B has chosen not to use Chinese material because of doubts over product quality and quality assurance systems, but is unable to source the material in the UK owing to the absence of manufacturers.)

3.1.4 Trends and possibilities

Thus, although global growth for magnetic materials is generally strong, profitability does not necessarily flow from the market growth opportunity and there has already been rationalisation and consolidation in the industry, characterised by company closure and acquisition.

A number of OEMs have formed joint ventures or set up operations in the Far East and expect their suppliers to provide product to global operations, effectively as the local supplier.

Single sourcing seems to be the trend among magnet consumers. This implies that suppliers of magnetic materials will have to be able to offer a full range. Such a scenario encourages the large companies and makes it difficult for single product suppliers to survive and prosper, except perhaps, once again, in niche markets.

Given this scenario, magnet producers could divide into two broad groups. The first would sell to markets with a huge, but low margin, demand for single magnetic components (e.g. automotive, computer industries). Manufacturing expertise and a high level of automation would be essential. The second would supply smaller quantities of high margin product in an assembled or part-assembled form to more specialised markets (e.g. medical, aerospace). Technical development and design expertise would be critical factors in this case and the UK is probably capable in this area.

Since UK manufacturers of components do not produce sintered hard ferrite (except for a small amount of isotropic material), or fully dense Nd-Fe-B, their development may best be focused on niche markets (existing and new) for current materials and adding value by vertical integration to produce magnetic systems.

Bonded magnets also present a significant opportunity for UK companies. Global growth is good, the price of the raw material powders is falling, capital requirements are less onerous than for the other longer established products, and several companies are already manufacturing in the UK.

It is highly unlikely that a completely new material or series of new materials will be developed in the near future, but the possibility cannot be entirely discounted.

One material under development is Sm-Fe-N (Nitromag) for bonded permanent magnets. Pr-Fe-B is also being developed and has improved temperature characteristics compared to Nd-Fe-B. Substitution of at least some of the Nd by Dy in Nd-B-Fe has been shown to improve the temperature characteristics of the Nd-Fe-B type of material by increasing coercivity. Powder blending has also received focused development effort and is promising as a commercial process. A significant amount of basic research has been directed towards nanocomposites in which a soft magnetic phase with high magnetisation and a hard magnetic phase with high anisotropy are exchange-coupled (e.g. Pr-Fe-B).

3.2 SOFT MAGNETIC COMPONENTS AND THEIR APPLICATIONS

Significant global growth of powder based soft magnetic products is likely. Soft ferrite will increase in use and iron based powder components are also expected to show some growth. Two growth industries for soft magnetic parts are thought to be **information technology, high frequency power electronics**. Examples of applications segments expected to grow are: personal digital assistants, smart phones, pagers, cellular phones, and laptop computers. Automotive uses will also expand, for example in electromechanical valve opening and closing, noise suppression, direct fuel injection, etc.

Iron based soft magnetic composites are believed to have major potential, particularly in **electric motors.**

Although resin coated iron powders are already well-established commercially in relatively small volumes in dc choke cores, transformers and ignition coils; the potential for the newer range of iron base composites materials is huge, particularly in motors. Unlike the many laminated steel soft magnetic products which dominant the soft magnetics market, they are isotropic in nature and open up new design possibilities. However, significant research on magnetic steels continues and may slow the predicted growth of the powder composite materials, though it will not stop it.

Although the main growth for these composite materials is likely to come from applications not currently using soft magnetic powder parts, it is also possible that these materials will substitute for some of the potential soft ferrite growth.

Iron based soft magnetic composites are often termed ferromagnetic composite iron (FCI) or soft magnetic composites (SMC). They are increasingly used for soft magnetic applications. In low frequency applications (up to 50 kHz), high purity, coarse iron powder will be used with a thermoset resin powder to compete with low carbon steel laminate constructions. These applications will include small motors, reluctance motors and brushless dc motors (which will also require hard magnetic components for efficient design).

FCI materials for high permeability applications will use high purity iron powder without a resin but with an internal lubricant, and will only be given a low temperature annealing treatment. Applications include inductors, flux carriers and relays.

FCI materials for high frequency ac applications will use fine high purity iron powder with a thermoset resin. Applications will include high frequency inductors, ballast, magnetic fluids, and transformer cores.

It should be understood that the composite materials are a range of materials whose properties can be varied through material and process changes in manufacture, and thus offer application design flexibility.

Designers will have to learn how best to use the inherent properties of the materials, coupled with ease of manufacture to capitalise on the technical and cost benefits offered by these materials. By redesign from a laminated structure, benefits include a reduction in the number of parts, reduced overall cost, and improved electrical performance. In part, the cost improvements can come from the use of less copper in the form of windings for an equivalent component using FCI materials.

Not only will new powders make possible more efficient devices using less copper for equivalent power output, but also recycling is dramatically improved, as the powder components will crush back to powder leaving the copper windings clean for re-use. This is in marked contrast to laminated structures, which make separation of copper from the laminations extremely difficult.

It seems probable that the existing structural components companies will enter the market for soft magnetic materials. This is primarily due to the shapes required - usually multilevel - which are more suited to structural components pressing technology than hard magnetic pressing technology, where shapes tend to be simple. The implication is that structural component companies intending to enter this field will need to recruit and train accordingly.

It could be argued that the traditional magnet makers would be at a disadvantage in that they have been used to producing simple shapes, whereas the producer of structural parts is well accustomed to dealing more the complex shapes associated with soft iron composites, but the importance of magnetics design knowledge in developing this market should not be underestimated.

Supply chain organisations could also vertically integrate by producing their own magnetic components as part of an integrated manufacturing operation.

Motors using the newer composite materials are already at the pilot production stage.

It should be noted that the flux carrying capacity and mechanical strength of SMC have been perceived by some as problematic, but latest pilot production studies indicate otherwise. Either way, more development work and proving trials are needed to remove doubts and allow the new range of materials to fulfil their true potential.

3.3 HARD MAGNETIC COMPONENTS

3.3.1 The market in general

Currently, the size of the global permanent magnet market is estimated at USD 4.5 - 5 billion with material breakdown of roughly:

54% hard ferrite
32% Nd-Fe-B
14% other

Annual growth rates are predicted to be: hard ferrite 5-10%, neodymium-iron-boron (Nd-Fe-B) 12-15%, and bonded magnets 15-25%. Alnico will continue to decline, but is expected to retain a niche position. Samarium-cobalt (Sm-Co) sales will probably be static or show some growth in the short to medium term, as new developments are pursued and the price of cobalt remains relatively stable after earlier falls, but is expected to decline in the longer term and remain a niche material.

The price and availability of cobalt will affect the relative market shares of the main permanent magnet materials. Any increases in cobalt price encourage a reduction in Alnico and Sm-Co sales, with Nd-Fe-B as the main beneficiary. The price and availability of cobalt is currently expected to remain relatively stable as more non-African material enters the market, and this will tend to slow the substitution of Sm-Co and Alnico materials.

The price and availability of rare earth raw materials are also important in determining market share by material type, and it should be remembered that one of the reasons for the development of Nd-Fe-B was that Nd is more plentiful in terms of global deposits than Sm. Another reason was the earlier high price of cobalt and the uncertainty of African supplies, though this is seen to be much less of a problem now that more non-African cobalt is available.

3.3.2 market and supply

The earlier reduction in price of cobalt and its probable relatively stable price and expected availability in the near to medium future offers some encouragement to UK components producers, since Alnico and Sm-Co account for a majority of their sales. In the case of Sm-Co, there are also believed to be some opportunities for UK component suppliers in Japan.

Of the main types of sintered permanent magnet material families, namely ferrite, Alnico, Sm-Co and Nd-Fe-B, only Sm-Co and Alnico (except for a small amount of isotropic hard ferrite) are now manufactured in the UK. However, plastic bonded versions of both ferrite and Nd-Fe-B are produced in the UK and there are a number of UK distributors dealing in the whole range of permanent magnet materials and often carrying out secondary operations (e.g. cutting). The UK also has limited manufacture of plastic bonded Alnico. Worldwide, sintered ferrite and fully dense Nd-Fe-B account for over 70% of sales turnover, leaving the UK manufactured product, with the exception of bonded materials, largely excluded from the market.

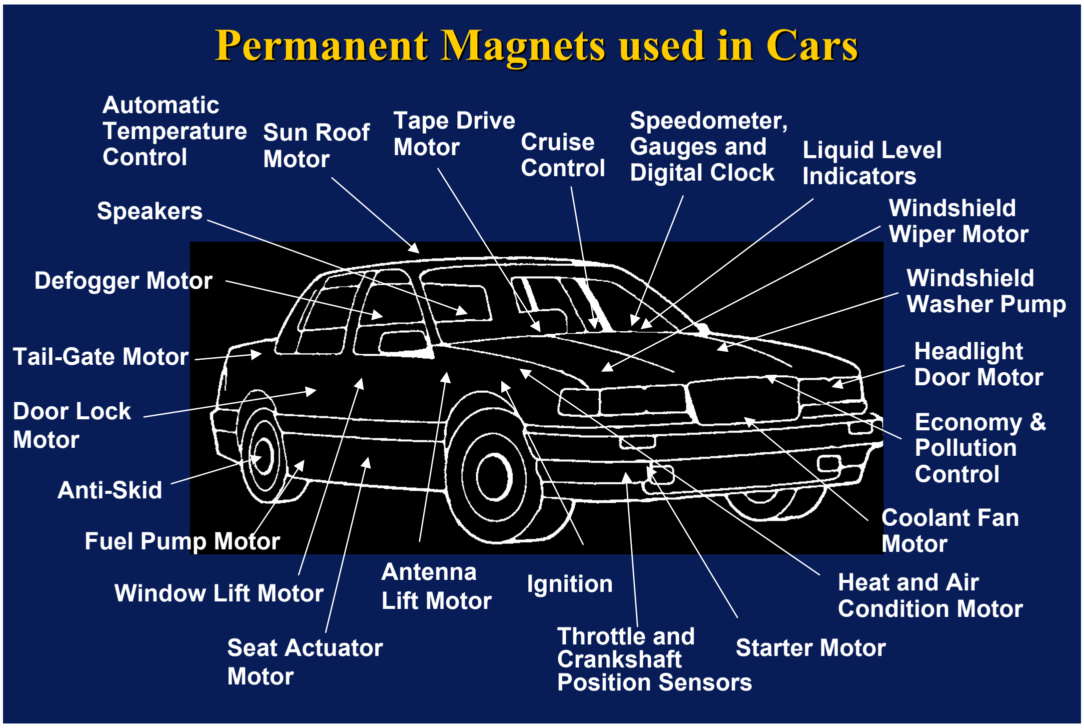

Fig. 4 Permanent magnets in passenger cars
(Courtesy EPMA)

3.3.3 Applications and new markets

The automotive, aerospace, computer, communications, power generation, electrical/electronic goods, medical and security industries all present growth opportunities for permanent magnets (and in many cases, also for soft magnetic materials).

Motors represent the largest single cross-sector market for permanent magnets and show good growth potential as an increasing number of motors employ permanent magnet systems. Even in motors not employing permanent magnets, there are significant opportunities for soft magnetic materials. Consideration of energy savings will force the trend in favour of permanent magnet systems and will be enabled by the availability of high performance magnet materials. Cost will remain a factor and some motor applications will require an improved temperature and corrosion performance from Nd-Fe-B. To some extent, temperature is less of a problem now that grades of Nd-Fe-B are available for operating up to 220 ^{o}C.

Motors currently employing electromagnetic systems probably present the greatest growth opportunity for substitution by permanent magnet systems.

The **automotive industry** will remain a very large and important market for permanent magnets, with strong growth potential. Growth areas for permanent magnets in this sector are (all of them present opportunities for powder magnets - Figure 4):

- propulsion motors for electric vehicles, hybrid electric vehicles and fuel cell electric vehicles
- sensors, gauges and loudspeakers
- small motors and actuators for auxiliary functions e.g. electric steering, electric braking, electric throttle actuation, auto-clutch and gearbox actuation, etc. (linear motors are a possible threat to the normal rotating variety and could offer real advantages, but are not considered cost effective at present; both types use magnets anyway, the former mainly ferrite and the latter mainly Nd-Fe-B; this segment is currently the largest group of automotive applications using permanent magnets and is said to be growing at 20% annually

Vehicle safety systems offer further opportunities for powder magnets (e.g. ABS, air bag actuators, fuel cut-off devices and, more recently, sensors that automatically alert the rescue services in the event of a crash).

More input to design work will be expected from suppliers, and in some cases the supplier will assume responsibility for everything from design through manufacture to installing the system in the vehicle.

Quality of components is taken as a given nowadays, so that price will be the main consideration in the choice of magnetic material for automotive components, once environmental and safety standards, and energy, size and weight considerations, are met.

Ferrite magnets will probably continue to dominate in the automotive sector (mainly in small motors), because of their low cost. There are over 100 motors in a luxury car and even standard models have an increasing number, as consumers demand better comfort and security levels in the vehicle package. Prices of the newer rare earth magnets (Nd-Fe-B) have fallen, and this material will increase its share of the automotive market as new applications are developed and emission and energy regulations bite. Some of this increase will be substitutional, but a significant proportion will be from new applications. Growth estimates for Nd-Fe-B in automotive are varied, up to 40% annually (from a low base). Automotive applications provide growth opportunities for both fully dense and plastic bonded Nd-Fe-B magnets, as well as for Sm-Co magnets.

A new family of Sm-Co materials has been developed, capable of operating up to 550^0 C, and this will encourage use of this type of material in automotive and other sectors such as aerospace, where good temperature performance is needed, though cost will remain a major consideration.

The most promising of the newer applications for sintered Nd-Fe-B in vehicles is in **electric power assisted steering** (EPAS) and this is expected to provide a large volume market, having now been commercialised. It has been said that EPAS will drive the future for Nd-Fe-B use in automobiles and EPAS production volumes are likely to more than double in the next 4-5 years. Hard ferrite is currently used in small volumes in this application, but the main thrust of the development is with Nd-Fe-B. Sm-Co has been largely discounted because of its cost, though cost overall is less significant now, as the need for lower weight and less volume, for energy and packaging reasons, assumes greater relative importance.

Some sources in the automotive industry have suggested that the highest potential for Nd-Fe-B is in sensor and miniature gauge applications, but there are also opportunities in small precision motors and for passenger compartment equipment. Temperature coefficient, maximum operating temperature, and corrosion have inhibited the more widespread use of Nd-Fe-B magnets in automotive applications, but newer grades of materials and design changes are providing answers (but under-hood use is still constrained by more stringent temperature and corrosion requirements). Temperature and corrosion performance also needs to be improved in some non-automotive applications, for example, in power generation. Other operating environments are not as harsh and therefore less demanding on temperature and corrosion performance, but low cost is still an important consideration (e.g. in computers/peripherals).

Increased noise and vibration are also said, by some, to be a concern with permanent magnet motors, and difficulties are encountered in the general handling and assembly of powerful magnets during the assembly process.

Longer term, the largest potential use for Nd-Fe-B is thought to be in the drive systems of electric vehicles.

The need for **sensors** will grow in both automotive and non-automotive sectors. Sensors are used to detect speed, position, acceleration, torque, fluid levels, etc. Samarium-cobalt (Sm-Co) components are now being used in automotive sensor applications because of their relatively good temperature performance and despite their higher cost. It should be noted that sensors often use small magnets weighing only a few grams and that the material cost is therefore less of an issue in material choice. Sensors, mainly for speed and position sensing, are expected to be predominantly magnetic in the automotive industry. The whole range of permanent magnet materials is used in sensor applications.

There are rival (i.e. non-magnet) sensor technologies and this matter needs evaluation, particularly beyond automotive applications. However, there is a significant opportunity for UK producers overall in this field.

Alnico magnets are used extensively in dashboard instrumentation (speedometers, tachometers, fuel and temperature gauges, etc.) mainly in the form of air-core gauge sub-assemblies. Although this may continue in the very short term, they will probably be replaced, at least partially, by plastic bonded Nd-Fe-B in the short to medium term. Ferrite bonded magnets are already used in some dashboard instruments to return the gauges to zero when the engine is switched off. Stepper motors are used in dashboard instruments to a small extent and the use of these is expected to grow, and they will probably replace the air-core system completely over the medium to long term. Either way, magnets are likely be at the heart of the systems.

The use of Alnico magnets is therefore expected to decline further, though the preferred manufacturing technology, because of its near net shape advantages and the progressive miniaturisation of applications, will remain powder based.

Plastic bonded magnets, predicted to continue growing rapidly at 15-25% annually, have global sales of about USD 800 million, though their use in automotive applications is constrained by the relatively poor temperature performance and the cost. A breakthrough in this sector would substantially increase Nd-Fe-B sales and replace some of the ferrite; even then, much of the growth would come from new applications. Comparatively recent commercialisation of anisotropic HDDR (hydrogenation disproportionation desorption recombination) Nd-Fe-B powder production (19-21 MGO) is expected to provide a boost to bonded products because of the better magnetic performance when compared with the normal isotropic bonded material. Bonded magnets are manufactured using compression, injection, extrusion, or calendering techniques, but the starting point for the magnet material is always a particulate. HDDR powder can also be used to make fully dense magnets by hot pressing and work has been carried out in the UK on this.

The use of motors is growing outside (as well as inside) the automotive segment (e.g. servomotors). The need for quiet operation and reliability will increase the demand for brushless dc motors. **Linear motors** also have significant potential.

The use of hard and soft magnets in the **communications** sector is showing substantial growth. Mobile phones represent a significant application for sintered Alnico and Nd-Fe-B and the volumes appear to be expanding rapidly, though design changes could impact growth. Car phones also use magnets.

The continuously expanding **entertainment/leisure** market uses magnetic materials extensively in loudspeakers, microphones, recording materials, game systems, vending machines, cameras, toys, models, etc.

Power generation is also seen to have good potential, as magnet based systems continue to be developed. Of particular interest is the large growth potential in portable power generation 'microturbines', which are particularly suitable for producing electric power in remote areas. This application has been commercialised and Sm-Co is used at present for its oxidation and hot corrosion resistance. An opportunity for UK manufacturers of this material is apparent. Nd-Fe-B may become the preferred material, as prices come down and temperature and corrosion performance is further enhanced (though Sm-Co is also improving). Given the continuous drive for environmental improvements, power generation using wind power provides another opportunity for powder magnet use. This method of electricity generation is predicted to become cost competitive with conventional sources over the next five years.

Aerospace is another significant growth sector for magnetic materials as the drive towards more ‘electric aircraft’ mirrors the automotive trend. The use of Sm-Co in aircraft represents an opportunity for UK producers. For example, aircraft will use electro-hydraulic flight control systems. The development of the A3XX Airbus represents one typical opportunity for UK Sm-Co producers. In this safety-sensitive sector, Sm-Co is the material of choice now, giving high performance in a lightweight, small volume package. The availability of recently developed Sm-Co materials with operating temperatures up to 550 ^{o}C will be of interest to designers of electrical machinery in aerospace applications. Nd-Fe-B is currently less favoured because of integrity doubts. Improved net-shape capability, electrical resistivity, higher operating temperatures, better corrosion resistance and mechanical robustness are all important in designing permanent magnet systems for aircraft. Electric jet engines with permanent magnet motor/generators are being worked on in the UK.

The **medical** field presents further opportunities for soft and permanent powder magnets. Examples are medical scanning devices and heart pacemakers; body scanners currently use approximately 15% of all Nd-Fe-B manufactured. Magnets are well established in orthodontics and finding more widespread use in orthopaedics. Work is also being carried out in the field of osteogenesis to promote bone growth. Use of magnets in medical applications has grown substantially on the basis of the newer rare earth magnet materials offering small size and much higher magnetic performance levels compared to earlier materials. In many medical applications, the magnets have to be protected by coatings against corrosion. So far, most magnets have been used in passive devices; recently, more complex active devices providing rotation or drive have been developed. These include ‘swimmers’ for catheter insertion into blood vessels, etc. Operating theatres and special care units are likely to require more applications using magnets (e.g. motors in robotics), and the drive to deliver diagnostics and treatment at the local patient interface will hasten growth (e.g. local GP surgeries with small portable scanning units).
This sector in particular demands a full evaluation of its potential, in view of population ageing, quality of life, and the consequent increased demand on medical services. Any major shift in the popular perception of ‘fringe medicine’ in the Western world would, incidentally, also have an effect: in East Asia, direct magnet therapy is often used to alleviate some medical problems and prevent others.

Crime prevention, safety, and the **security** industry in general are undeniably growing in importance and will almost certainly provide more magnet opportunities, and new applications arise continuously. A recent example is the launch of a magnet-powered torch, which is very robust and will never need batteries or bulbs. It uses a magnet in a coil to produce the power and an LED for illumination.

Computer and office automation applications are said to represent 70% of the market for bonded materials. The largest single market sector using Nd-Fe-B is the computer industry, where the main application is voice coil motors for hard disk drives (positioning the read/write head). Magnets are also an essential part of the brushless dc motor in disk drives. Data storage and data retrieval systems have motors driving the disk read/write heads. Peripherals such as printers also use motors in large numbers, as do fax machines and photocopiers. UK magnet component manufacturers have only a limited opportunity to supply the computer industry since there are no UK producers of fully dense Nd-Fe-B, but there are existing and potential raw material suppliers. Currently, the only opportunity for UK component makers is in supplying plastic bonded Nd-Fe-B, which, encouragingly, has shown particularly fast growth in this sector, and where small size and low cost are important, but temperature performance is less of a problem. Corrosion performance is, however, often important since major customers are storing and assembling parts in geographical areas where high humidity levels are the norm.

Other applications: Some magnet devices are being used to **prevent scale formation** in water pipes. It has also been suggested that magnets can directly **improve fuel consumption** in vehicles. Another example is the replacement of the chain drive alternator by a Nd-Fe-B magnet system in a Japanese motorcycle, to give a significant **weight reduction**. Motors, instead of hydraulic systems, are now controlling some **train doors** and linear motors are being developed for opening and closing **lift doors**. **Dewaxing** of oil in pipelines is the largest application for Nd-Fe-B in China. Electricity supply **meters** also use Nd-Fe-B magnets in China, thus replacing the more traditional Alnico systems still in common use in Europe. Older-established is magnetically controlled damping for vehicles, which uses an electromagnet in the damper piston.

3.3.4 The patents

The cause of serious and far-reaching concern is that China has around half of the raw materials deposits used in the manufacture of rare earth magnets and a much larger share in terms of shorter term availability. Main patents for Nd-Fe-B magnets are held by Chinese and Japanese companies, San Huan (Magnequench), Sumitomo and Mitsubishi, and licenses when obtainable have been costly and difficult. Although Magnequench, Sumitomo, and Mitsubishi have the main patents, others are held by Vacuumschmelze and Crumax (Morgan Crucible), the US Navy (Koon), etc. Magnequench and Sumitomo have 8-10 licensees each world-wide and the US Navy has five.

What are known as ‘Lean Neo’ patents are also held by the US Navy, Inland Steel, and Philips, and new producers of these materials are entering the market.

Licenses from one or more of the patent holders have to be obtained to produce Nd-Fe-B components, though an automatic licence is granted in the case of plastic bonded magnet producers who purchase their isotropic alloy powders from Magnequench. The materials are still said to be expensive but the price has fallen recently

Although key Nd-Fe-B patents expire in 2 - 3 years, there appears to be little readiness among UK suppliers to take advantage of the implied opportunity. Sumitomo has recently succeeded in patent infringement actions against 15 companies involved in imports into the USA. Meanwhile the sale of unlicensed material, mainly from China into Europe, continues.

Newer, but related, patents are expected to continue to make it difficult for new entrants to the market, but the present study has revealed some active interest. A detailed evaluation of the current Nd-Fe-B patent position is needed to determine the implications and opportunities for UK industry.

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The solution for UK companies wanting to take advantage of volume global growth of Nd-Fe-B materials (and other magnet materials perhaps) is likely to be the joint ventures route with Chinese partners.

3.4 NEED FOR PROGRESS IN MAGNET TECHNOLOGY

The foregoing market and applications review reveals many opportunities and a number of non-technical and technical inhibitors. It must be appreciated that many of the technical problems often apply quite narrowly to individual or small groups of companies - what is a problem for one company is not necessarily so for another; for example, corrosion protection through surface coating of Nd-Fe-B.

However, there are some common scientific, technological, and commercial threads of critical importance. These are discussed below.

3.4.1 Materials design and development

- Improvements to Nd-Fe-B need to be centered on temperature coefficient, maximum operating temperature, and corrosion resistance (and, to some extent, more powerful materials to enable weight and size reductions).
- A completely new range of materials may be desirable to reduce Western World dependence on Chinese raw materials, but is unlikely to emerge over the next decade, though the possibility cannot be discounted.
- Developments on new/improved materials must take account of existing patents.
- While energy savings and miniaturisation are increasingly important, the cost of Nd-Fe-B magnets (although falling), coupled with temperature constraints, is limiting their use.
- Improvements in the performance of Nd-Fe-B materials would not directly benefit existing UK component manufacturers, except in the case of plastic bonded magnets, because they do not manufacture fully dense Nd-Fe-B. However, work in this area would probably have spin-off benefits and help encourage UK producers to invest in the manufacture of these materials.
- In the case of soft magnetic materials, improvements seem to be required for motors and high frequency applications and there are interesting developments in soft iron magnetic composites that should be fully evaluated as an opportunity for UK industry.

3.4.2 Materials data

There is unfortunately at the moment little support for work on magnetic material standards but support is predicted to develop. Standards for permanent magnets already exist but may need collation and improvement. Work is already underway on soft magnetic material standards, at least at a European level.

3.4.3 Process technology

For the UK to compete, prices will have to be substantially lower and production costs (as well as overheads) will need to fall to counter the effect of low-priced imports.

- Nd-Fe-B raw materials prices must fall substantially (particularly for bonded products)
- Cobalt price and availability must be maintained/improved
- Processes will require a greater level of automation to minimise labour costs
- Batch-to-batch consistency and repeatability at the lowest possible cost is vital
- Long term availability (at reasonable cost) of magnet raw materials is needed

Of the specific process problems identified in this present investigation, **consistency of pressed parts** seems to be the main requirement, to include: **better die fill, raw material powder characteristics and flow, lubrication, pressing control and handling of green parts**. Process automation and batch-to-batch consistency, with emphasis on pressing, is seen to be essential for both hard and soft magnetic materials.

3.5 THE GENERAL TRENDS

Present knowledge suggests the following picture:

- Most permanent magnets and a growing number of soft magnetic components will be produced using powder technology.
- Permanent magnet markets will continue to grow at 10-15% annually from the USD 4.5 -5 billion baseline now. Fastest growth will be in Nd-Fe-B materials.
- Ferrite and Nd-Fe-B magnets will account for over 80% of global sales turnover with niche markets retained by Alnico and Sm-Co. Some growth in Sm-Co is probable, but Alnico will almost certainly continue in decline. The price of cobalt will be an important factor for Sm-Co and Alnico sales, and will influence the material mix in the market.
- Nd-Fe-B magnets will increase their market share by substitution in existing applications and development in new ones. Price, temperature and corrosion considerations, and government legislation on vehicles will determine growth rates (Figure 5).
- Bonded magnet usage will grow strongly, with predicted growth at 15-25% pa, though it is likely to be closer to the 15% figure as the market matures. This presents an opportunity for UK producers.
- Soft magnetic parts are also expected to grow and soft magnetic composites have exceptional growth potential. This presents an opportunity for UK producers.
- UK manufacturers will be excluded from the major market segments using sintered hard ferrite and fully dense Nd-Fe-B, since there is no current manufacturing capability (investment could change this).

- Growth of the soft magnetics market will be lower than for permanent magnets at 5-10% overall, but within this, components produced using powder technology will probably grow at 10-15% (e.g. soft ferrite and iron composite materials).

Fig. 5 Neodymium-iron-boron applications

Computers and office automation	**Appliances**
disk drives and voice coil motors	portable power tool motors
printer and fax stepper motors	household appliance motors
printer hammer	scales
copy machine rollers	
CD drive spindle and pickup motors	
Automotive	**Factory automation and industrial**
permanent magnet starter moors	robot motors
sensors	robot arms
electric fuel pumps	magnetic couplings
instrumentation gauges	pumps
brushless dc motors	servo motors
actuators	bearings
	generators (especially portable)
Consumer electronics/communications	**Medical/health**
VCRs and camcorders	MRI
DVD	surgical tools
cameras	water purifiers
watches	
speakers	
headsets	
microphones	**Security/safety**
pagers	sensors
mobile phones	illumination

- UK producers of soft magnetic powder components exist, but would need investment to take advantage of the predicted growth.
- The automotive industry will continue to dominate the market in hard ferrite with an increasing proportion of Nd-Fe-B and some Sm-Co being used, both in the fully dense and bonded forms. Automotive will also continue to provide good growth opportunities for both hard and soft magnetic materials and thus remain pivotal. There are, however, significant major growth opportunities other than automotive, but these have not been evaluated or quantified.
- Emission reductions will force vehicle producers towards alternative drives. Hybrid vehicles will show the strongest growth in share terms, predicted to be 20% of vehicle market in 2010. Magnet systems will benefit from this.
- The computer industry will remain the main user of Nd-Fe-B but its dominance will diminish as other applications adopt the material.

- Growth sectors/applications have been determined, but not quantified, as:
  - Sensors (automotive and other)
  - Computer/peripherals and office machinery
  - Motors (automotive and other)
  - Communications
  - Power generation (especially transportable/portable)
  - Electrical/electronic goods
  - Medical
  - Security, crime prevention, safety
  - Aerospace
  - Leisure/entertainment
- China will dominate the permanent magnet market through low manufacturing cost, raw material supply and to some extent, patents.
- Cheap imports from South America, the Far East, India, Eastern Europe and even the Middle East are likely to remain a fact of life. The industry will become increasingly global and competitive.
- Further global industry consolidation will occur, leaving a small number of UK manufacturing companies supplying niche products and markets. Few, if any UK manufacturers will remain in British ownership.
- OEMs will manufacture globally and source suppliers locally where possible, based on cost and performance. Suppliers will therefore be under pressure to manufacture globally and close to OEM production units.
- Suppliers will increasingly be expected to provide 'magnetic solutions' to customer problems and this will encourage vertical integration (e.g. manufacture of magnetic assemblies or sub-assemblies)
- Customers will show a preference for single sourcing all magnetic requirements. Large global magnet producers will thus have an advantage over smaller companies with a more restricted product range (unless niche markets can be developed by SMEs).
- No major permanent magnet applications are likely to be replaced by alternative technologies over the next decade.

3.6 SUMMARY OF THE UK POSITION

Looking now at the UK in light of all the above, the country has:

- producers of powders for component manufacture
- manufacturers of samarium cobalt and Alnico parts
- manufacturers of plastic bonded components (hard and soft)
- manufacturers of soft ferrite and other soft magnetic powder products
- manufacturers of magnetic assemblies
- distributors for the whole range of magnetic materials, many carrying out secondary operations on the product
- tooling manufacturers

- magnetic material end users in most market sectors (but the main demand is overseas)
- research and development facilities, programmes and experts

The UK does not have:
- producers of sintered hard ferrite (except for a small amount of isotropic material) or fully dense Nd-Fe-B components
- significant magnet-related ore deposits

3.7 THE MAIN OPPORTUNITIES

In summary, therefore, the following are important to the future development of the UK magnet industry:
- Nd-Fe-B (or an alternative system) with improved temperature and corrosion characteristics, coupled with lower manufacturing costs
- Consistency and repeatability of magnetic and dimensional properties at minimum cost
- Having UK producers with a market position where they can compete globally and profitably
- Exploiting the potential for the rapid growth of powder technology in soft magnetic materials

Ways in which these matters can be handled include:
- Developing improved materials based on the Nd-Fe-B system (or any new alternative system) against a performance and cost specification
- Improving pressing operations through improvements to powders, die fill, compaction and handling
- Identifying existing and developing niche markets with high added value potential for UK manufacturers
- Persuading UK companies to invest in the design and manufacture of magnetic components
- Facilitating the design and manufacture of soft magnetic composites in the UK

Such action would need to be underpinned by:
- Carrying out a full appraisal of the Nd-Fe-B patent position for UK producers.
- Carrying out a full market research study in both the automotive and non-automotive sectors, focused on emerging applications and added value opportunities.
- Setting up training and awareness sessions for users.
- Linking Foresight Vehicle to the PM supply chain in some way
- Providing a ‘centre of excellence’ in PM which would be the ‘first port of call’ for anyone requiring assistance in anything related to PM. It would contain links to Government initiatives such as funding and Foresight, and would also link with industry players, universities working on PM, and relevant trade associations and others interested.