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MARKET AND APPLICATIONS OF BONDED MAGNETS

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Abstract: *Bonded technology provide a possibility of applying various types of magnetic powder and polymer matrices in order to achieve optimal dynamic mechanical, magnetic, environmental and economical properties of final magnet. Primary applications of permanent magnets include automotive, personal computers, mobile phone, commercial motors and generators. The pricing and delivery for rare earth magnets, specifically neodymium-iron-boron (Nd-Fe-B) magnets are in crisis. The producers did not anticipate the dramatic increases and thus are not in a position to fully cover their demand. Although the USA represents the largest market for neodymium-iron-boron (Nd-Fe-B) magnets, all US suppliers of this material are either distributors or value-added resellers of product produced in Asia, predominantly in China. The price increases to the goal of the Chinese government to control its reserves of rare earths as well as to cleaning up existing environmental issues related to past mining practices and preventing new environmental issues.*

Keywords: *Bonded magnets, Nd-Fe-B, Market, Application*

1. INTRODUCTION

Permanent magnetic materials have been used for many years in various devices for converting electrical to mechanical energy and vice versa. [1-3]. They are a unique part of modern technical equipment and modern technologies. From many points of view requirement for applications is still growing. Although the materials used to produce permanent magnets are constantly being improved, the basic role of the magnet remains practically the same: generation and increase the magnetic flux.

In recent years, increasing in production and application of Nd-Fe-B magnets in spite of significant fluctuations in the world economic scene is present. It is anticipated that in the next five years the total market of Nd-Fe-B magnets will increase from the current $2 billion to about $4.8 billion [4]. This spectacular increase in production is predominantly influenced by increased production of personal computers (PCs) in the last 10 years, where the Nd-Fe-B magnets are used as components of hard drives. In current period, the demand for magnetic materials hardness and resistance to corrosion, have significantly contributed to the development of bonded magnetic materials.

Widely used bonded magnets have become an important part of various electrical devices essential for everyday life. Very good magnetic and mechanical performances are utilized in various apparatus such as: hard discs, scanners, DVD and CD drivers, different types of sensors [5], automatic office tools, automotive parts, spindle motors, magnetic bearings, and other applications. Bonded magnets produced by extrusion method can be used as reprographic magnetic rollers or brushes with set of required performances. Injected bonded magnets are used primarily in the automotive industry.

Ferrites are still dominant magnetic material in the market, but bonded magnets are becoming increasingly important and required due to their advanced magnetic properties. Flexible bonded magnets are often used for advertising purposes, for example as magnets for the fridge. Although this looks like a secondary application of bonded magnets, it shows their characteristics to be ultra thin and printable on a variety of images and text. Permanent magnetic materials have a wide range of applications due to large energy product and high volumetric efficiency. The largest progress in the development is found for magnets based on Nd-Fe-B with annually world production of around 39110 tones [6].

2. THE APPLICATION OF BONDED MAGNETS

On the basis of application areas, bonded magnets can be classified into [7]:

- Rubber or elastomeric bonded flexible ferrite magnets (BFFM),
- Plastic bonded ferrite magnets (PBFM),
- Polymeric bonded rare-earth magnets (PBRM).

Bonded flexible ferrite magnets can be ultra thin and very long strips. Their main application is to serving as: seals for doors and refrigerators, drive wheel for video recorders, the components of small motors for hard disk or floppy disk drivers, magnetic rollers for printers and scanners. The field of application of plastic bonded ferrite magnets are also magnetic rollers, magnetic deflector beams for color television sets, rotating magnets in motors for office equipment, magnets for rotational or frequency sensor, cooling fans, various motors in the automotive industry, etc. The application of polymer rare earth bonded magnets includes: fans, various miniature motors which are used in audio video technology or household appliances, but primarily, they are used as a miniature engine parts. The PBRM group includes a Nd-Fe-B bonded magnets. Permanent magnetic materials based on Nd-Fe-B have wide range of applications as presented in Fig. 1.

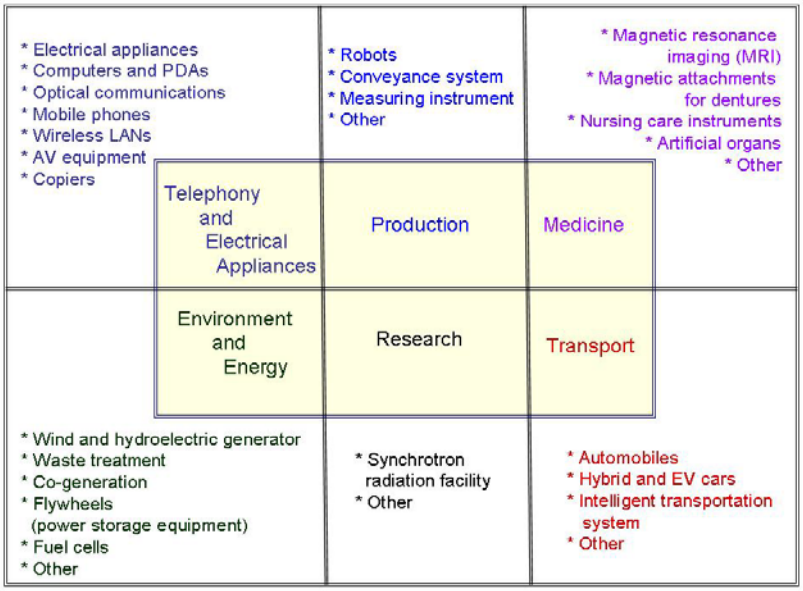

Fig. 1 – Schematic illustration of bonded magnets application

Bearing in mind that price of automotive fuel in the offing will rise, so the consumers will prefer a clean diesel fuel or hybrid electric vehicles. Bonded magnets are an important factor as an integral part in the production of hybrid cars. China became the most important country for trade of magnetic materials in general and unavoidable competitor in the production of bonded magnets. During 2006 China produced 51% of the total world production of ferrite magnets and 86% Nd-Fe-B magnetic materials. It is anticipated that total market value of world production of magnetic materials will be around $ 20 billion by 2020., and China will produce about 80% of total world production of magnets [8]. They are already the main manufacturers of bonded ferrite rollers for reprographic use, as well as magnets for disk drivers and their components.

Further development of bonded Nd-Fe-B magnets is directed on improving his mechanical properties. Fracture strength of this type of magnet increased by about 75% compared to a commercial Nd-Fe-B magnet. Also, very easy machining is one of the most important characteristics. .

For the bonded magnet manufacturers in Japan, as the leaders in this field, a very important fact is to undertake the price reduction of the products and maintain the existing quality. Otherwise, they will force to cede the leadership position in the global market. Price of final bonded magnets had to be between 30 and 40 $/kg to still be competitive manufacturers of parts for the automotive industry. Total world production of bonded magnets in 2005., divided by sector of application is shown schematically in Fig. 2.

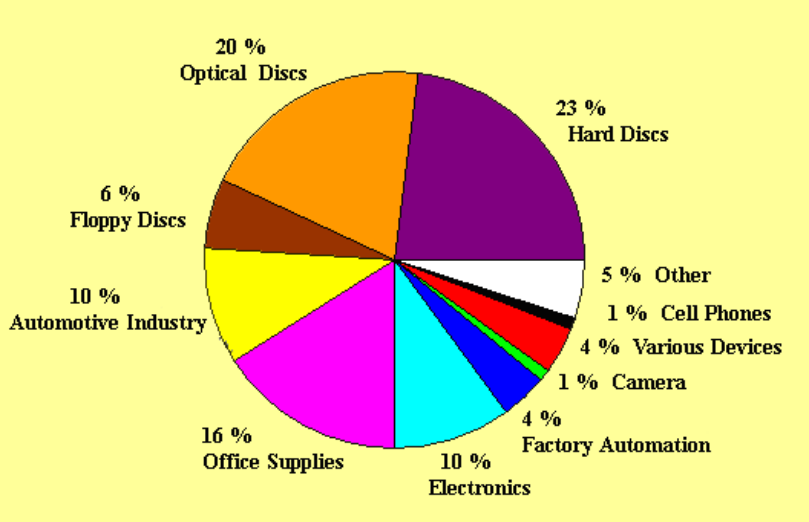

Fig. 2 - Production of bonded magnets in 2005. year

A very important discovery was Sm-Fe-N bonded magnets that can be used at temperatures up to 150 °C. Recent data indicate that Sm-Fe-N has high resistance to corrosion and superior flexural strength compared to Nd-Fe-B bonded magnets. This type of bonded magnet aspires in next decade to occupy a central place in the automotive industry, since high corrosion resistance and thermal stability are required [9]. One of the most advanced products is micro-pumps, [10] that work on the principle of electromagnetic energy. The main characteristic is a very small volume while the current strength and capacity of existing large pumps are retained. In the brushless DC motors (as a component of electromagnetic pumps) with an output between 40 to 70 W, physical contact with the engine is completely eliminated. As a consequence, there is no moving parts in the unit, which aims a very long life time ie. low wear of components. This type of unit contains injected bonded Nd-Fe-B magnet and an increased ability of heat dissipation.

These micro pumps have flow performances about 3.2 l/min with a maximum differential pressure of 7 bar.

The bonded magnets manufacturers should be use rare earth magnetic powder with lower concentration of main components neodymium, praseodymium and cobalt, because they are relatively expensive materials. Depending on the type and composition of magnetic powder, polymer, route and condition of bonded magnet production, material with desired properties can be pre selected. Depending on the mechanical and magnetic properties their price fluctuates, but it is only a few percent higher than the cost of production. It follows, if bonded magnets become more expensive on world market, many customers will accept new prices and will continue to use the many advantages of compression and injection molded bonded Nd-Fe-B magnets.

Further development of magnetic materials is focused on optimization and control of nanostructures. For example, miniaturization of MEMS requires materials having a large coercivity and remanence in order to maintain high values of magnetic energy with a reduced volume [11]. Thin films based on Nd-Fe-B permanent magnets are very important for the development of improved micro pumps, micro sensors and MEMS [12].

3. THE MARKET OF BONDED MAGNETS

Two facts lead to increases of the rare earth magnets amount in the market in recent years: increase in total energy product, as a basic standard of magnetic materials quality and cost efficiency. The main reason could be the high cost of ceramic ferrite magnets. The main topics of discussion in worldwide magnet meetings are related to rockets that could be launched into space, and raw rare earth materials cost necessary for that purpose. The price of rare earth neodymium, most commonly used material in the production of sintered and bonded Nd-Fe-B permanent magnets is most concerned. The low price of about 8 $/kg of neodymium have been stabilized at market. However, the price began to rise in late 2005. and has practically doubled in mid 2006. In late 2007, the price of Nd is beginning to stabilize in the range of 25 $/kg to 30 $/ kg. The fact is that on the worldwide market of permanent magnetic materials, ceramic ferrite is still dominant. This type of permanent magnet is still the most economical magnetic material. In Fig. 3 the growth of prices of neodymium per kilogram in 2005. and 2006.is illustrated.

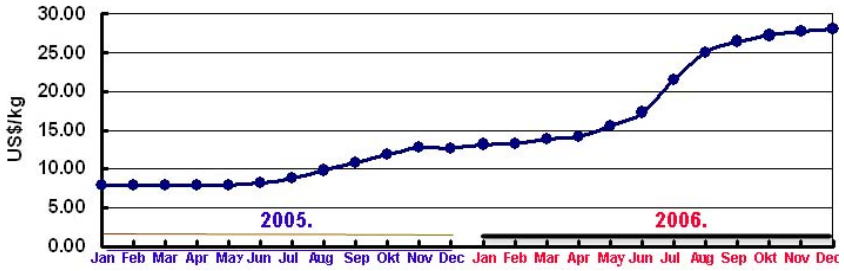

Fig. 3 – Trend of neodymium growth rates in 2005. and 2006.

A total sale of sintered Nd-Fe-B magnets is increased by about 6% compared to the ceramic ferrite, while bonded Nd-Fe-B magnets increased for only 1%. The main commercial application of Nd-Fe-B magnets begins with its innovation in 1983. Some of latest commercial Nd-Fe-B materials are still composed by cobalt, but iron mostly replaced cobalt due to much lower cost. This fact has led to the situation that neodymium became the basic element of Nd-Fe-B magnets composition. Neodymium's sensitivity growth rate can cause commercial capability applications growth, especially due to fact that

neodymium concentration typically makes 25-30mass% of the total weight of Nd-Fe-B magnets.

Neodymium is not always cost only 8 $/kg. In late 1980's. the rare earth magnets have been enabled a miniaturization of basic consumer products such as hard discs; sintered Nd-Fe-B magnet were produced for actuator head; bonded Nd-Fe-B magnet for motor shaft.

At present, disks size reduction makes significant advances in magnetic data storage properties Miniaturization and production of sintered and bonded Nd-Fe-B magnets are still in progress. However, the cost is controlled by final product more than cost of raw materials. Nevertheless, Nd-Fe-B magnets are commercially viable; although the price of neodymium in the market has increased dramatically while the price of hard drives and components continuing to decline [13]. Compared to ferrites, success in increasing participation in the global market will depend on reducing the cost of both raw rare earth material and final magnetic product.

Hard disc drives and other consumer electronic products are still the leading market for Nd-Fe-B magnets, but the new main application is in the automotive industry and the office automation equipment. Improving performance is provided only by Nd-Fe-B magnets. Price of miniature magnetic products depends mostly on the manufacturing process or technology, while the price of robust magnetic products depends mainly on raw rare earth materials price. This fact brings us back to the beginning of the story about the price of neodymium for spaceships and their impact on future opportunities where Nd-Fe-B magnets could repress ferrites from the world market [14].

The rapid growth rates of rare earth materials in recent years mainly derived from the actions of the Chinese government, due to fact that China is the main source of rare earth ores. They have introduced the newest measures related to improve the control environment pollution of smelters and abolished the tax on exports of both rare earth materials and important recent products of sintered Nd-Fe-B magnets that are very dependent on the neodymium. It appears that the growth rate of neodymium is stabilized in 2006, but the reasons for its rapid growth still occur. In 2011, driven by the enormously high market prices of major rare earth raw materials such as praseodymium and neodymium, Nd-Fe-B material price soared accordingly. Against such backdrop, the investment has increased substantially in Chinese Nd-Fe-B industry; in many key production areas of rare earth also have witnessed rapid growth in Nd-Fe-B capacity, with the scale of industry capacity reaching 300,000 tons, while a majority of new capacity projects still have not been put into production. In 2011, China’s Nd-Fe-B output reached 83,000 tons, nearly the same as that in previous year, and still giving priority to sintered Nd-Fe-B products. Under the price hiking of rare earth raw materials, major Nd-Fe-B manufacturers showed strong bargaining power by successfully transferring the cost pressure to downstream clients, thus achieving performance enhancement by a large margin [15]. This suggests that one should not be expected: the recent return to the low cost price from 2005.

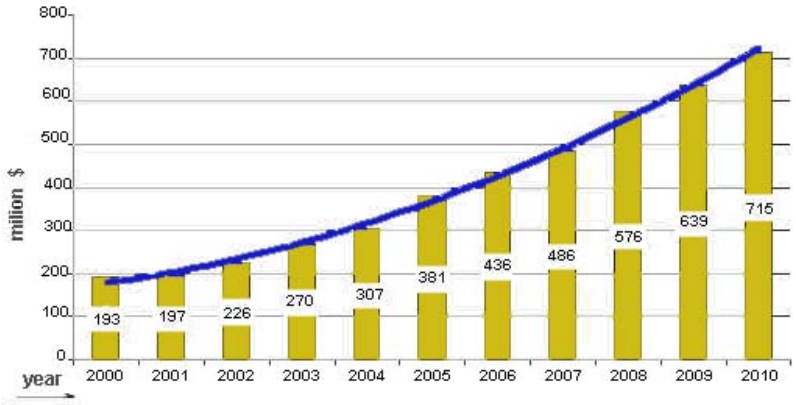

Fig. 4 – Production dynamics of hard disks since 2000.

Miniaturization is an important factor which enables the improvement of the product. The fact that the investment required to convert ferrite to Nd-Fe-B magnets will be justified, from the point of neodymium higher prices and stability of future long-term price. Possible application of Nd-Fe-B magnets (as a potential magnet that could replace ferrites) requires careful and comprehensive analysis of the technical possibilities and economic forecasting.

Around 50% of the total of Nd-Fe-B bonded magnets production has application for data storage. All manufactured hard disc drives use bonded Nd-Fe-B magnets as irreplaceable component of spindle motors. It is anticipated that the hard disks industry will continue with dynamic growth at least until 2010. (Fig. 4).

In recent years there has been the miniaturization of others. The products such as: electronic devices, memories, notebooks, smart phones and others contain also a small hard disc drives. For example, Apple iPod has a hard disk size of a coin. Therefore, the industrial requirements are aimed to produce small and very powerful hard disc drivers. Since 2006 up to date, world production of hard discs from 2.5" is increase for 10%, while the production of 3.5" hard discs dropped by the same percentage.

In China, mobile phones and PCs as consumer electronics for the Nd-Fe-B materials have traditional market demand. Among them, only the TDK Company has annual demand of Nd-Fe-B approximately 4000 tons. As the world's largest mobile phone production base, domestic demand for mobile high-performance Nd-Fe-B has steadily rising trend. In 2010 China's production of mobile phones was 998 million pieces, while the demand for high-performance Nd-Fe-B was 2500 tons. Including DVD players and CD-ROM drive high-performance Nd-Fe-B annual demand was more than 1500 tons [16].

Table 1 – Properties and advantages of most common magnetic materials

Type of magnet	Advantages			Properties	Application
	Price	Magnetic flux	Machining		
Ferrite	√			Good price, Low performances	Office tools, Large motors
Sintered Nd-Fe-B		√		Superior performances of basic form	VCM, MRI, Hybrid cars
Bonded Nd-Fe-B			√	Geometry accuracy, Medium performances	Spindle motors, Hard discs

Beside the basic purpose of Nd-Fe-B magnetic materials in the hard disks manufacture, they are increasingly appearing in all other applications where the ferrite magnet was used. Table 1 shows comparative advantages of different types of magnets and their specific application.

4. PERMANENT MAGNET CHARACTERISTICS AND COST

It is well known that the maximum energy product (BH)max is commonly used measure of the magnetic materials quality, because it shows the best combination of magnet features to produce magnetic flux and transfer it (flux) in the air gap. Product B x H is a direct measure of energy per unit volume of the magnet. Therefore, the final price depends on the value of the magnet $(BH)_{max}$.

Factors that directly affect the price of rare-earth permanent magnets are: the process of production, purchase of raw materials and the required performance of the final product. Sintered Nd-Fe-B magnet is anisotropic material with excellent magnetic properties obtained by compression molding process. This is the most widely used method for sintered Nd-Fe-B magnet production. Using the axially oriented fields much better magnetic orientation is obtained. Consequently, improved magnetic properties and lower price of final product is achieved (Fig. 5).

Sintered Nd-Fe-B can also be produced in the form of radially oriented ring providing the field alignment in the mold. This is a very complex process, and therefore, very expensive magnets are produced. The most of the bonded Nd-Fe-B magnets are produced from isotropic magnetic powder which magnetizes only after the production process. This is a much simpler and more economical manufacturing process that gives high density magnets ie. high magnetic remanence, resulting in a more suitable price. Anisotropic bonded Nd-Fe-B magnet has the highest cost price ($/kg) because the fine powders are highly unstable. This issue can be solved by batch process, which includes alignment in magnetic field. This orientation produces more superior magnetic properties compared to isotropic bonded magnets.

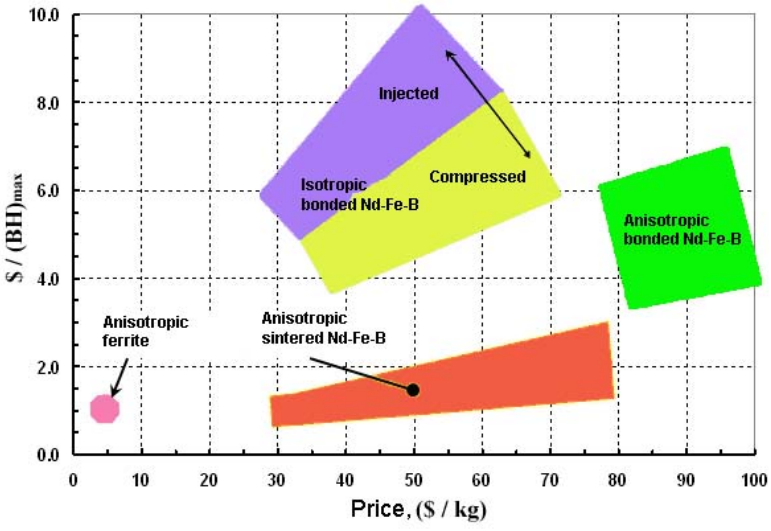

Fig. 5 - Permanent magnetic materials cost in relation to amount and the maximum energy product

The price diagram should be taken as a value tool in the process of understanding the magnetic materials. It can be represented as the ratio of the magnetic properties with

changing the prices. Simply, the diagram shows that if the higher density of magnetic materials and/or better orientation of magnetic powder exist, the cost is higher.

5. CONCLUSION

It could be concluded that Nd-Fe-B permanent magnets represents the materials for many future applications in various branches. Some indications of development and application in the near future show the potential purpose of these materials is in production of hybrid cars, elevators, air conditioning, etc. The hybrid vehicles are into the stage of rapid development. The high-performance hybrid car demand in 2014. will reach 7500 tons of Nd-Fe-B. China has become the world's largest elevator manufacturing base, the largest elevator market and the world's second largest elevator ownership countries. Use energy-saving permanent magnet synchronous traction machine elevator will lift the industry's future development direction. Also, there is a great demand for rare earth permanent magnet materials in the medical, robotics, machine tools and other areas.

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