ADVANCED HANDLING OF STEEL PRODUCTS IN SEAPORTS USING MAGNET SYSTEMS

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ABSTRACT

The intense growth of cargo traffic leads to a higher movement of goods in German seaports. Due to limited possibilities to upgrade existing infrastructure and the demand to ecologically extend the seaport's capacity, technological innovations are needed to fulfil these requirements.

Especially, the handling of steel products is dominated by classical, mechanical load handling attachments which usually consist of hooks, chains, ropes and belts. These attachments are comparatively heavy and unwieldy but are convincing regarding design, quality and reliability. However, this technology offers very little potential for innovation and process optimisation. Additionally, damage of the handled steel products cannot be excluded. But as an innovative alternative to mechanical load handling attachments different magnet systems are available. This article is focused on the basic conditions of the development of the handling technology and the development of an innovative logistics concept which is necessary because of the employment of the new technology.

Keywords: Seaport logistics, steel handling, magnet systems

1. INTRODUCTION

In the past years a trend towards a globalised economy was observed, resulting in the development of new strong economical centers in Eastern Europe or in Asia. Particularly in this context, logistics is facing ever larger challenges to ship the appropriate raw materials and products in the demanded time and quantities. The world-wide maritime traffic profited from this development strongly (Bloomberg, LeMay and Hanna 2001, Eversheim and Schuh 1996, Gudehus 1999).

However the capacities in the seaports are limited. Because of this fact a strong need for new, innovative technologies and concepts is given to transport and handle the quantities fairly, since a simple extension of the port area is often not possible or economically reasonable. The handling of steel products, which is analysed in this paper represents no exception, since the immense need of steel all over the world led to rising quantities which have to shipped (David 2004, Murphy and Wood, 2007, Rushton, Croucher, and Baker 2006).

The special characteristics of handling steel products in seaports arise from the variability of the products, which cover a range from coils to sheet metals of different forms and very high weights. Nowadays the handling of steel products is dominated by classical, mechanical load handling attachments which usually consist of hooks, chains, ropes and belts. Due to the high loads that can occur when steel products are handled a special protection of the handled load is strictly needed. This is realized by a complex and unhandy system using pole shoes.

The security requirements are optimally fulfilled by employing this system. But the handling process is enormously slowed down. Regarding the given situation, which is characterized by rising handling quantities, this is unfavorable. Therefore an innovative approach is chosen here to accelerate the steel handling processes accordingly by the development of a magnetic system, which will provide the same level of security as the common handling technologies.

A further central content of the work will be the development of an innovative logistics concept. This will be arranged in such a way that the rising quantities can be handled and at the same time the given port area will be not unnecessarily impaired by further traffic or repositories.

Following this introduction at first the technology itself, which is to be used in the context of this project and the technological requirements will be presented. Then a description of the typical steel products with its special characteristics as well as a description of the logistics concept which will be generated is given. The goals of the project presented here then finally lead to the results and a outlook.

2. MAGNET SYSTEMS

2.1. Electromagnet systems

An electromagnetic field is generated by the flow of an electric current through a conducting wire (Griffiths 2003). The electromagnet is then constructed by winding up long wires to a coil so that every turn counts for the magnetic field. Usually, a core of paramagnetic or ferromagnetic material (commonly soft iron) is placed inside the coil, which further concentrates and amplifies the magnetic field. The electromagnet can be switched on and off by simply regulating the current flowing through the coil.

An electromagnet can be operated with direct current as well as with alternating current. In the first case, the non-linear characteristic curve of force and displacement leads to a small force in the attracting phase when there is a large gap between the magnet and the target (Kallenbach, Eick, Quendt, Ströhla, Feindt and Kallenbach 2008). Therefore, this technique is generally inappropriate in cases where a strong force is needed immediately. One solution would be to raise the current in the attracting phase.

In contrast, electromagnets operated with alternating current yield large forces already in the beginning of the attracting phase. But the force has to be conserved also in zero crossings of the current flow, which increases the technological complexity of the system.

One big advantage of this technology is the fact that the force is controllable continuously. Thus, an adaption to different weights is easily possible. Furthermore, the magnetic force is no longer present when the system is switched off at the resting position. The magnetism is only produced by the electromagnet and cannot be destroyed by collisions (the magnet itself can certainly be damaged). But also certain disadvantages are obvious. The security of workers and equipment has to be guaranteed even in the case of an electrical power breakdown or cable breaks. This can only be achieved by redundant magnetic system and/or a mechanical backup. A point of economical interest are the operating costs. Due to the heavy load and the almost equal distances for empty and loaded runs the power consumption is an economic factor, which has to be regarded but in contrast, the acquisition costs are low.

2.2. A-stable permanent magnet systems

A permanent magnet is a piece of a magnetisable material, for example iron, cobalt or nickel. In contrast to electromagnets, this material keeps its static magnetic field without a current flow (Michalowski and Schneider 2006). So the magnetic field cannot be switched off, which is necessary for its application in handling systems. The solution is to use additionally an electromagnet here to generate a magnetic field that has the opposite orientation of the one produced by the permanent magnet. Both then compensate. Thus, in sum no magnetic field is present and the cargo is not attracted (see figure 1).

Permanent magnets can be made from different materials, which affect the characteristics like size or

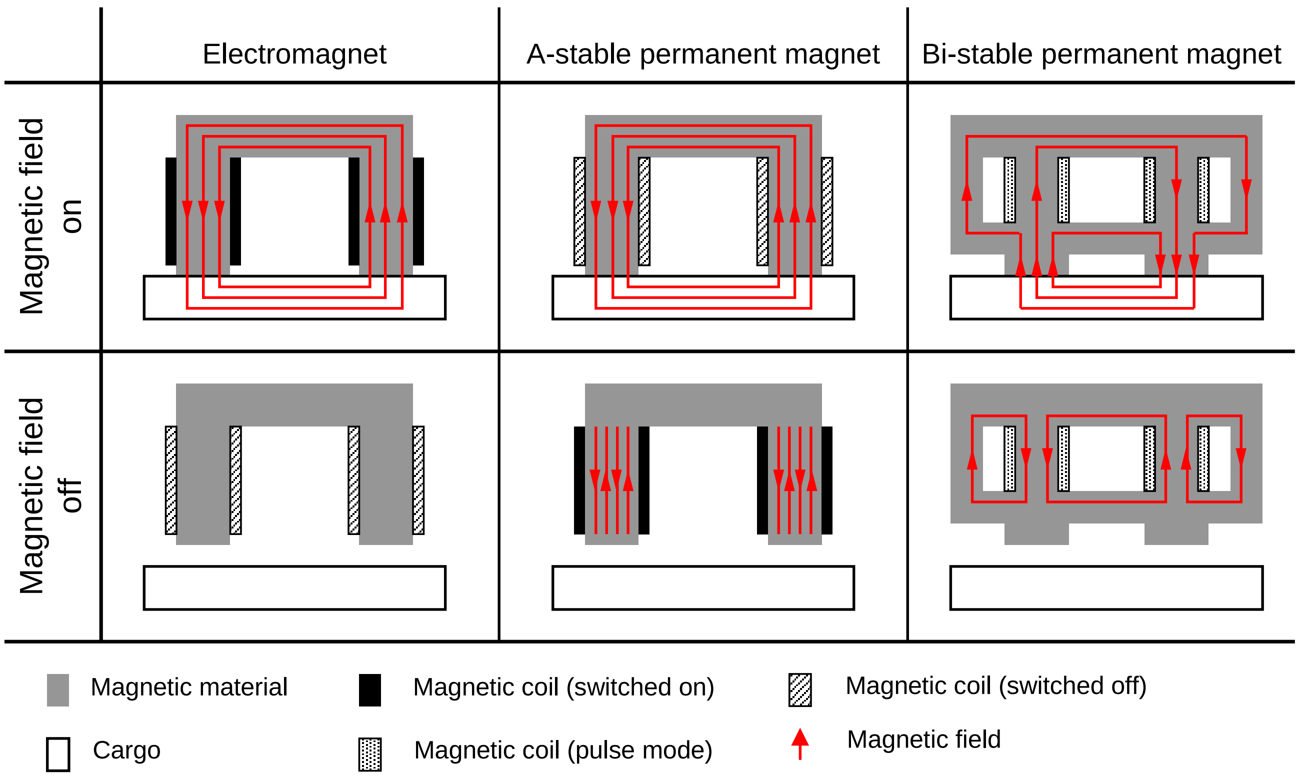

Figure 1:Visualisation of the Technology of the three different Magnet Systems.

strength of the magnetic field (Cassing and Seitz 2007). Cheap materials are ferrites. But magnets based on that substance are relatively weak and not sufficient for this kind of application.

Aluminium-nickel-cobalt (AlNiCo) based magnets are basically iron alloys with aluminium, nickel and cobalt as main elements. These materials can be employed up to temperatures of 500°C and are corrosion-resistant. But they are very hard and breakable. Neodymium-iron-boron (NdFeB) based permanent magnets provide very strong magnetic fields relative to their mass, are relatively cheap in production but are also mechanically fragile. For a long time, an application of this material was only possible in the range of temperatures up to 60-120°C. New developments allow temperatures up to 200°C.

One fact that has to be regarded in practice when operating the magnet systems is that permanent magnets can lose their magnetism due to various reasons:

- a decaying alternating magnetic field,
- exposure of the material above a critical temperature, known as the Curie point and
- especially in the regarded scenario of seaport handling occurring collisions.

One big advantage of this technology is the fact that the magnetic force is controllable continuously. Thus, an adaption to different weights is easily possible. Also security of workers and equipment can be guaranteed because the magnetic force will keep up even in cases of electrical power breakdown or cable breaks. Thus, a mechanical back up system is not needed. Nevertheless, this technique also reveals disadvantages. Due to the almost equal distances for empty and loaded runs the power consumption is an economic factor, which has to be regarded but like the electromagnet, its acquisition costs are low. A serious problem which is to be solved is the fact that the permanent magnet cannot be switched off, so that the magnetic force is present in the resting position when the electromagnet is not active.

2.3. Bi-stable permanent magnet systems

This new technology is a combination of two different kind of permanent magnets and electromagnets. The system is able to take two stable and permanent states: a magnetised and a demagnetised.

This is achieved by innovative configuration of the different single magnets. One kind of permanent magnet is used to establish a strong magnetic field. The electromagnets are used to reverse the polarity of the second kind of permanent magnets. The polarity of that magnet determines whether the magnet system has an external magnetic field and is attracting the cargo or the field is kept inside the magnet system (see figure 1 for illustration).

Like the other presented solutions, this system has several advantages as well as disadvantages. In contrast to the a-stable permanent magnet system, the bi-stable permanent magnet can be switched off, so that no magnetism is left. The magnet then is inactive in its resting position. Also security issues can be guaranteed because the magnetic force will keep up even in cases of electrical power breakdown or cable breaks since the electric power is only needed to switch the state between magnetised and demagnetised. Thus, a mechanical back up system is not needed.

The economic disadvantage of the other systems due to the power consumption of the electromagnets is not relevant here. There is only little power needed for switching the polarity of the permanent magnets. Thus, the heavy load and the almost equal distances for empty and loaded runs do not affect the power consumption.

Table 1: Summary of the Advantages and Disadvantages of the three regarded Magnet Systems

	Advantages	**Disadvantages**
Electromagnet	• Magnet inactive in resting position • Magnetic force controllable continuously • No loss of magnetism due to collisions • Low acquisition costs	• Security issues in case of electrical power breakdown or cable breaks • High operating costs due to power consumption
A-stable permanent magnet	• Magnetic force controllable continuously • In case of electrical power breakdown or cable break no loss of magnetic force • Low acquisition costs	• High operating costs due to power consumption • Magnet active in resting position • Possible loss of magnetism caused by collisions
Bi-stable permanent magnet	• Magnet inactive in resting position • Low operating costs • In case of electrical power breakdown or cable break no loss of magnetic force	• Possible loss of magnetism caused by collisions • High acquisition costs • Magnetic force not controllable continuously

But this new technology has high acquisition costs.

Like other permanent magnets the magnetism can be lost due to collisions especially when operating the system in seaport environments (and the reasons stated in 3.2). One major deficiency is the fact that the magnetic force is not controllable continuously since only two stable states, on and off, are possible. This will complicate the development of tandem strokes of steel sheets enormously.

3. TECHNOLOGICAL REQUIREMENTS

Magnetic systems for the handling of steel products are already in use in these days. Main focus is here in production environments. Also industrial trucks in port environments can be equipped with this technology.

But the steel handling with large cranes makes great demands to the applied magnet technology. A pilot installation in the inland port of Duisburg, Germany was installed and is operated by ThyssenKrupp AG (Preuss 2007). They use the new and innovative technology of bi-stable permanent magnets for the optimisation of the handling processes of steel slabs.

But the handling in seaports poses a certain challenge due to higher safety standards, which mainly result from the changed environmental conditions due to the vicinity of the sea. Thus, the existing technology does not yet fulfil the following requirements:

- larger lifting heights in combination with stronger winds,
- higher acceleration forces and
- longer traverse paths.

The safety of workers and material has to be guaranteed at all times. The different reasons for loss of magnetic force have to be eliminated or backup solutions have to be found. In detail that means in case of an electromagnet to install a redundant electromagnet system and / or install mechanical backup solutions to prevent the cargo from falling down. A further possibility is a battery pack, which ensures the current flow for at least 20 minutes. In case of the different permanent magnet systems collisions of the magnets have to be avoided and eventually, depending on the government safety organization, mechanical backup systems have likewise to be installed. A detailed summary of advantages and disadvantages of the different regarded technologies is given in table 1.

Furthermore, the technology is not yet able to handle other steel products like coils and stacks of sheets. Necessary for the development are solutions for

- tandem lifts and
- inhomogeneous masses (air gaps between the steel products).

4. RESEARCH

The research focuses on the development of innovative magnet systems regarding the above mentioned boundaries, restrictions and requirements. Typical handling problems will be solved and the necessity of permanent maintenance of the mechanical system will be reduced.

The process of the steel handling can be improved by the use of bi-stable permanent magnet systems significantly. The large number of electromagnet systems, which already led to impressive improvements in the landlateral handling, indicate this. The special challenge is the adjustment of the technology to the requirements in a seaport and to its high safety standards (the fulfillment of these safety standards is a condition for the certification of the technology by the responsible association).

At present bi-stable magnetic systems are used in a pilot project for unloading single slabs from ships at inland ports. However still no closing experiences and permissions exist. In principle this system is suitable for an advancement for the application in seaports. Therefore in addition solutions for tandem strokes, inhomogeneous bodies (gaps between the steel bodies and/or sheet metals or sheet metal layers), higher vertical lifts in combination with stronger wind influence, higher acceleration forces and larger traverse paths must be developed.

Innovative magnet cross beams will be developed, which will reduce typical handling problems and the necessity for constant maintenance of handling systems as well as to avoid damages of the steel products. Altogether the handling of steel products will become more material caring, fast and safe. This higher quality and the more economical processes will to lead to an improved competitiveness of the seaports.

The requirements to the bearing pressure for the handling of different product types of sheet metals, slabs and coils require differently laid out magnet cross beams. These will differ mainly in the arrangement of the magnets and their dimensioning. Logically in three modules three prototypes will be developed and tested. These modules and prototypes will be described in the following shortly:

- <u>Module Sheets</u>
  In the sector of sheet metal loading maximally two metal sheets per lift can be handled by a jib crane working at full capacity at present. An increase of the load quantity per lift will lead to an acceleration of the shipping process. The innovative approach is the further development of a magnetic system in such a way that several sheet metals can be handled at the same time. The special challenge consists of developing a sufficient adhesive force which corresponds to the safety standards for the seaport. To guarantee the operating licence of the government safety organisation the strength of the force has to be proven also in presence of gaps between the sheets.

- <u>Module Slabs</u>
  In case of the slab loading a versatile system has to be developed, which is suitable for the handling of two or more light or one heavy slab. Further the special requirements in a seaport must be considered, in order to be able to deal with e.g. higher lifting speeds and wind influences. For this application a special design of the magnetic system is necessary, which at present does not exist.

- <u>Module Coils</u>
  The transport of coils represents the largest challenge, since the weights and the outside diameters vary within a certain range. Thus, no optimal adjustment of the pole shoes to the circular geometry of a coil can be achieved. In comparison to the employment of other handling technologies the magnetic lift leads to a larger air gap between the single windings, which leads to a reduction of the adhesive forces. Besides, a coil is wound and depending on the rolling up tension different air gaps between the individual turns occur. That is in particular relevant for coated coils. It is here necessary to consider a large number of different parameters, like the mode of conveyance whether horizontal or vertical, whether additionally packed with a sheet-steel jacket or not. Furthermore, it must be examined whether the positions of the clips of the coil fit to the range of the pole shoe and which kind of coils have to be handled (cold rolled sheet or hot rolled sheets). In addition the range of the thickness of the sheet must be analysed. Especially, this case requires a thorough investigation of the individual parameters.

To allow the control of the magnetic force a special force measurement device (Cassing and Stanek, 2002) is used. This system must be further developed and adapted for all three modules. Furthermore the basic conditions for each application must be coordinated, in order to receive an operating permit.

Along with this technical development, a new integrated logistic concept will be developed which takes into account the advantages of this specific technology. This is primarily an optimisation of the handling processes of the transportation media by the employment of the new technology leading to a large amount of shipped materials. The logistics concept which must be developed has primarily to be designed in a way that the handling capacities can be used completely. So it must be particularly guaranteed that a sufficient amount of material is present on the land side at the right time in direct range of the crane.

In comparison to the existing situation this can be obtained on the one hand by improved storage capacities and on the other hand by an improved connection to the traffic infrastructure in combination with coordinated planning and control methods. An extension of the storage spaces for the different steel products is surely the simplest way to meet the quantitative requirements. But this is possible only rarely because today the work space is already strongly limited in the seaports. Thus, a first approach to meet the situation is to look for intelligent possibilities to store the material which will be shipped. However it becomes immediately clear that this makes necessary extensive investments in storage engineering, which will effect the cost balance of the technology altogether surely negatively.

Regarding this background it seems to be more success-promising to develop new innovative logistics concepts which are particularly adapted to the requirements of the regarded scenario. If no further storage spaces can be made accessible, the requirements on the rising transport of the often very large and heavy steel products into the seaport are of a major interest. Here in any case an improved synchronisation of the logistics chain from the manufacturer over the logistics service provider to the customer is strictly necessary.

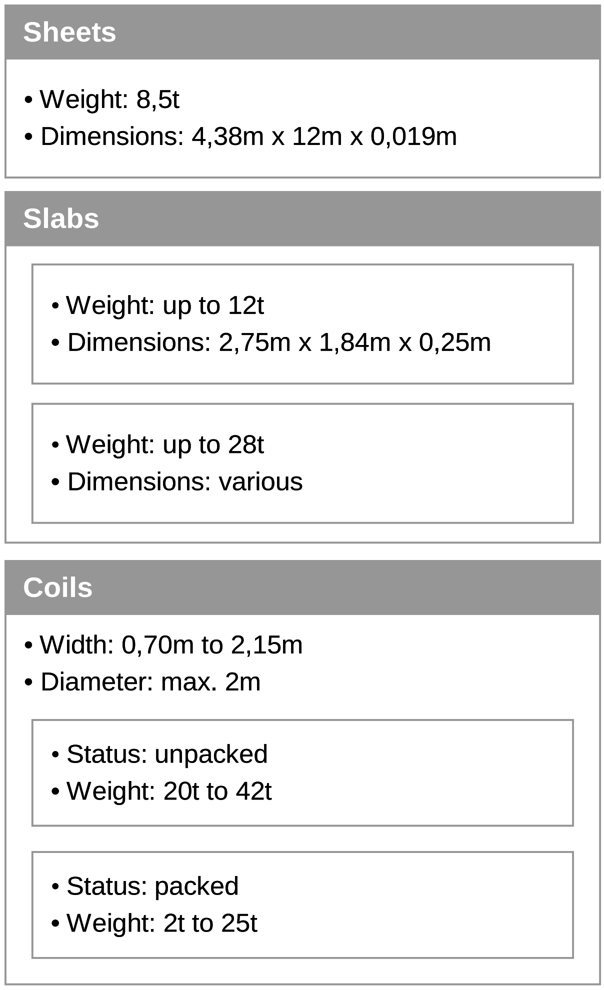

Figure 2: Steel Product Overview

Due to the very high dimensions and weights of the products especially the railway is applicable as transportation medium beside trucks. It must be examined in detail, to what extent the rising throughput can be transported by the different media. This will be analysed in detail in the progress of the project in order not to use up the economic advantages of the new technology by the costs of the upstream processes completely.

5. GOALS

The goal is to solve existing problems in handling as well as storage of steel products by the development of a magnetic handling system. This new and innovative handling technology will lead to a higher quality of processes and a significantly decreased handling time because load bearing will be reduced to some seconds, handling performance per shift will be increased and setting down of the load will be reduced to some seconds.

Additionally, the use of magnet systems and the automation of handling processes will help to avoid damage of steel products and significantly increase the operational safety. Altogether, the handling of steel products will be faster, safer and gentle to material.

Regarding the expected costs for purchasing and operating the new technology, the internal costs of the handling processes will be reduced in a range that this technology is supposed to amortise within about four years. This will be determined in detail. In particular the advantageous facts are:

- an acceleration of handling processes,
- an increase of operational safety and
- a minimisation of damage.

6. SUMMARY AND CONCLUSION

The steel handling processes not only in seaports become more and more complex because of the rising quantities. As shown in this article, an intelligent technological approach is necessary, in order to deal with this situation. Among other things it is the aim to relieve the available storage spaces and to increase the turnover rate at the same time.

In the opinion the authors the use of magnetic systems for the handling of steel products represents a concept, which is particularly suitable for the described requirements. Reasons lie here on the one hand in the high variability, which characterizes this technology. This is particularly favorable, since steel products of different form and weight must be handled. On the other hand a special focus of the development of the technology is drawn to the fulfillment of safety conditions of the government safety organisation, which have to be fulfilled in seaports, so that the systems can be used accordingly.

REFERENCES

Bloomberg, D.J., LeMay, S.B. and Hanna, J.B., 2001. *Logistics.*Upper Saddle River: Prentice Hall.

Cassing, W. and Seitz, D., 2007: *Dauermagnete*. Renningen: Expert-Verlag.

Cassing, W. and Stanek, W., 2002: *Elektromagnetische Wandler und Sensoren.* 2nd ed. Renningen: Expert-Verlag.

David, P.A., 2004: *International Logistics*, Atomic Dog Publishing.

Eversheim, W. and Schuh, G., 1996: *Produktion und Management, Band 2: Produktmanagement.* Berlin: Springer.

Griffiths, D.J., 2003: *Introduction to Electrodynamics*. 3rd ed. Prentice Hall International.

Gudehus, T., 1999: *Logistik: Grundlagen, Strategien, Anwendungen*. Berlin: Springer.

Kallenbach, E., Eick, R., Quendt, P., Ströhla, T., Feindt, K. and Kallenbach, M., 2008 : *Elektromagnete : Grundlagen, Berechnung, Entwurf und Anwendung.* 3rd ed. Wiesbaden: Vieweg + Teubner.

Michalowski, L. and Schneider, J., 2006: *Magnettechnik: Grundlagen, Werkstoffe, Anwendungen*. 3rd ed. Vulkan.

Murphy Jr., P.R. and Wood, D., 2007: *Contemporary Logistics*, 9th ed., Prentice Hall.

Preuss, A., 2007. In Zukunft mit Magneten, *ThyssenKrupp Inside*, 05/07, p. 11.

Rushton, A., Croucher, P. and Baker, P., 2006: *The Handbook of Logistics and Distribution Management*, 3rd ed., Kogan Page.

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