Enhancement of Efficiency of the Magnetic Suspension of Belt Conveyor

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Abstract **- Transportation of large pieces of rock hauled on the belt conveyor causes fatigue wearness of the belt rollers. It has been proposed to upgrade the system of magnetic suspension using alteration of the direction of the magnetization vector of the permanent and levitating magnets in conveyor where there are no load-bearing rollers, and there is dual-magnetic suspension. Three layout schemes of the permanent and levitating magnets with axial placement of the magnetization vector, with a layout of the vector at forty-five degrees angle and a Halbach array of five segments have been reviewed. For each scheme, distribution of the magnetic field in plane at 0,5mm distance from the surface of the permanent magnets has been obtained. The repulsive force at parallel position of the permanent and levitating magnets at a distance of 1 mm has been obtained.**

Keywords - belt conveyor, magnetic suspension, change the direction of magnetization of the permanent magnets

I. Introduction

Roller-belt conveyors have a significant shortcoming, i.e. at transportation of lumpy rocks the operational life of the belts and rollers is greatly reduced due to the dynamic loads on the carrying idlers so the restrictions are imposed on the size of the rock pieces, besides economic indicators go down too. In this regard, nowadays active developments to create a belt conveyor without rollers with mechanical, pneumatic or magnetic suspension of belt capable to transport rock without secondary crushing are carried out. [1] Currently, the developed countries including the Russian Federation pay much attention to the development and construction of magnetic systems to create levitation for stationary devices, as well as in vehicles [2][3]. From the viewpoint of energy saving the preferred structure, comparing to the electromagnetic suspension and superconductivity systems, is the magnetic suspension assembly with powerful permanent magnets. Quite intense dynamics of the improvement of the magnets based on rare-earth elements should be noted [4]. At development of the magnetic suspension for the conveyor belt the most difficult issues are to ensure steadiness of the levitating system and minimization of the amount of hard magnetic materials due to their significant value [5][6][7].

II.METHODS

The Kuzbass State Technical University develops a conveyor with dual circuit magnetic suspension for a typical load-carrying belt [8]. The basis of the conveyor (Fig. 1) is the availability of the two symmetrically located hard-magnet-circuits of belt 4, which could be manufactured with embedded strips of rubber ferrite as well as embedded magnets of higher lift capacity and the design size. The operational belt circuits interact with magnetic supports 2. At such interaction (repulsion of like poles of magnets) a magnetic cushion is creating, as a result operating belts of the hard-magnet-circuit of the belts levitate above the magnetic supports and provide suspension for the load-carrying belt 1. Vertical side rollers provide centering of the hard-magnet circuit of belts 3. These circuits are connected in transverse directions by hinges 5 and traverse 6, on which an ordinary conveyor belt with a load is placed on 1. On the empty part of the belt the belt and the relevant parts of the hard-magnet circuits with traverses move by regular idlers 7. Optimization of the bent radius of traverse 6 as per the criteria of the maximum cross-sectional area of load on belt enables to minimize the width of the load-bearing belt.

Studies have shown that when the belt with the embedded magnets doesn’t have a direct interaction with the transported lump load, then the mechanical stress in magnets do not exceed the acceptable standards, and lack of shock and vibration loads in the loading / unloading points creates favorable conditions under which there is no alteration in the magnetization of the magnets [9-11].

Altering the number of rows of the permanent and accordingly levitating magnets, and embedded into the circuit belts magnets at the design stage it is possible to achieve the required load capacity for the main conveyor belt. Fig. 1 shows, as an example, a four-row suspension of the hard-magnet circuit of the belt. In addition, it should be noted that load capacity of the conveyor affects power consumption of the material of the permanent magnets.

In this conveyor the transmission of the drag force is possible by utilizing of the traditional drum drive on the load-carrying belt in combination with the intermediate drive on hard-magnet circuit, for example, known magnet friction and linear motors with permanent magnets of special design.

The task to provide synchronization of work of the double-drive circuits having intermediate drive has been successfully fulfilled for the cable belt conveyors, which are long time used in the mining industry; also currently an issue of synchronization of the end drive with intermediate drive has been resolved [12].

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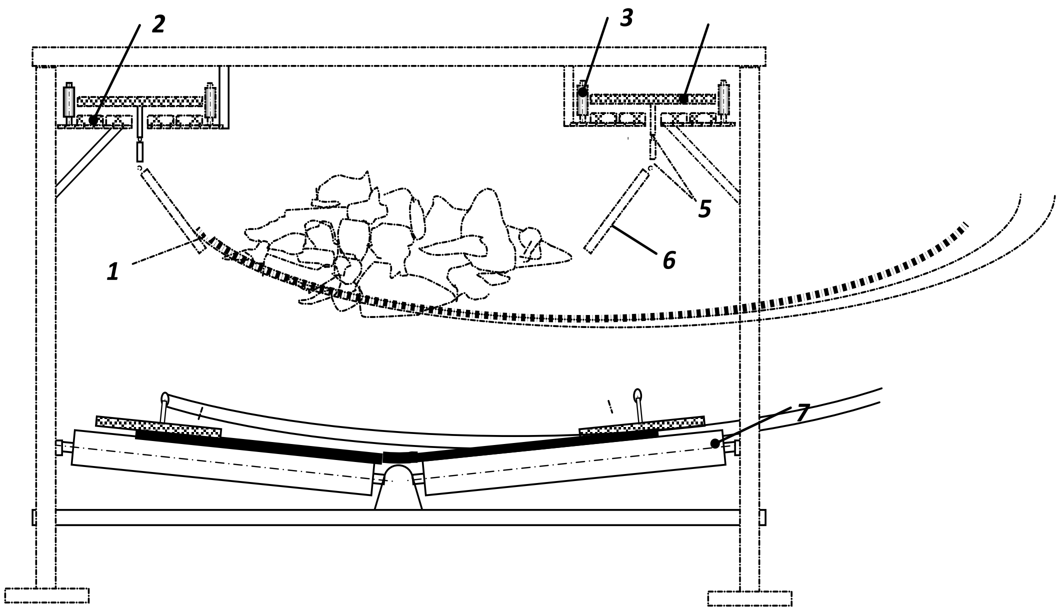

Fig. 1. Scheme of the conveyor cross-section with magnetic suspension for belt transportation of lump of rocks: 1 - load-carrying belt; 2 - magnetic supports; 3 – conveyer guide; 4 – hard-magnetic circuit; 5 – socket-joint; 6 - traverse; 7 - standard idler

As already mentioned the load-carrying capacity of the hard-magnet belt, at properly calculation of its data, generally depends on its width and element materials, by means of which the magnetization of the belt is provided. Modern magnetic materials allow provision of the very substantial load capacity, but they have significant value. The reduction of the amount of magnetic material can be done due to optimization of the direction of the magnetization vector.

Due to the different configuration and design features of the suspension, various magnetization directions of the magnets and levitating support systems can be used. Finding the optimum direction of magnetization makes it possible not only to minimize the weight of the permanent magnets, but also make it cheaper and therefore to gain profitability of the installation.

III.RESULTS AND DISCUSSION

A permanent magnet contains a fixed array of magnetic dipoles, each of which depends on the magnetic field. The total interacting force can be expressed as the sum of forces acting on the individual dipoles. We use general formula of the force applying to the magnetic dipole with magnetic moment m in an external field:

$$F = (m\nabla)B = m_x \frac{dB}{dx} + m_y \frac{dB}{dy} + m_z \frac{dB}{dz} \ ,$$

where m_x, m_y, m_z, - the date of the projection on the corresponding coordinate axis.

If the dipole in the point where there are no currents produced by the magnetic field, then we can write

$$F = grad\,(mB)\,.$$

Thus, the force of the magnetic interaction will be greatest when all the dipoles, i.e. the magnetization of the magnet, oriented along the force lines of the external field. At production of magnets sintering takes place during extrusion in strongest magnetic field, under the influence of which the magnetic dipole moment happens along the force lines. Therefore, altering configuration of the external field at the moment of sintering, it is possible to change the position of the magnetization vector.

To determine the maximum load-carrying capacity at interaction of the permanent magnets in shape of a cylinder and a ring, a number of suspensions of various magnetization has been considered as per the work of Arvi Kruusing, [13] where it was shown that if to consider load-carrying capacity as 100% at the axial magnetization, then the variable magnetization along the force lines will be better by 44.2%. But due to the complexity of manufacturing of the magnet another method has been selected with the angle of magnetization as of 45°; which allows improvement of the result by 38.7%. Moreover, there is a recognized principle of combination of magnets with various directions of the magnetization vector - Halbach assembly (Fig. 2). [14 - 17].

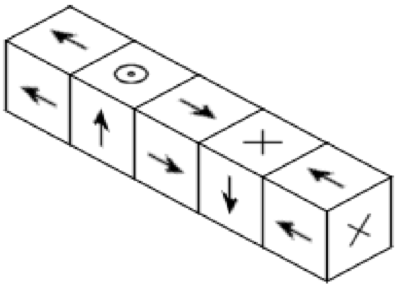

Fig. 2. A linear Halbach assembly consisting of five segments (arrows indicate the direction of magnetization of permanent magnets)

Let us consider three suspension systems: with axial magnetization, magnetization at 45° angle and Halbach assembly (Fig. 3.). For the adequate comparison of the results the magnets' dimensions were selected in such a way that the volume of the magnets in each system remained constant.

Parameters of magnetic systems:

1. 50mm × 50mm (4 pcs., volume V = 100 mm3) with magnetization angle of 45°;
2. 50mm × 50mm (4 pcs., volume V = 100 mm3) with axial magnetization;
3. 3.16mm × 3.16mm (10 pcs., Volume V = 99.85mm3) Halbach assembly.

The distance between the magnets of the supporting combination and levitating one is taken as of 1mm.

Applying the finite element method implemented in the software package ANSOFT Maxwell 3D, the intensity of magnetic field in every suspension system under consideration has been determined.

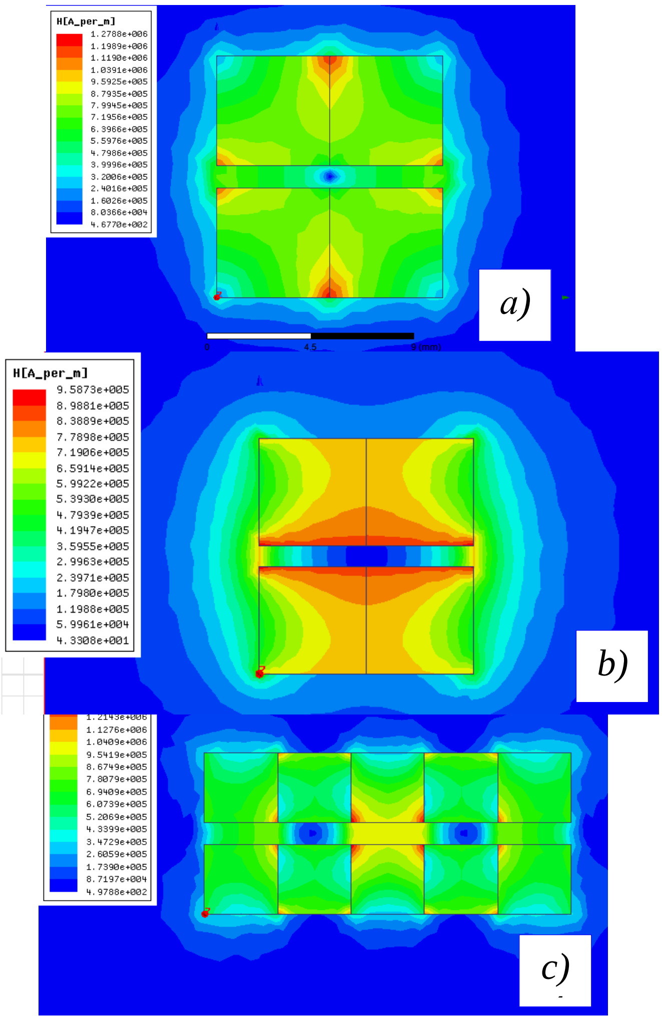

Fig. 3. Intensity of field is: a) with axial magnetization, b) at magnetization angle 45°, c) with Halbach assembly.

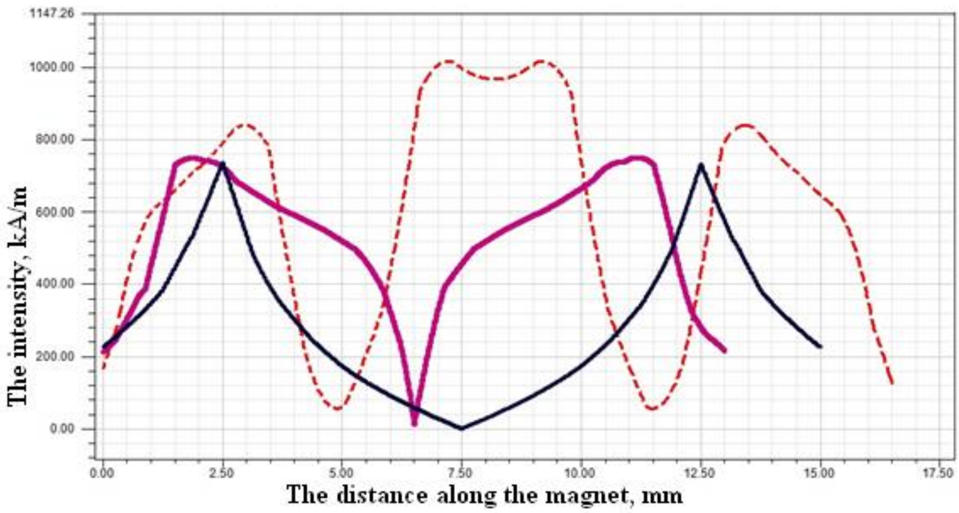

Fig. 4. Intensity of the magnetic field between the magnets (0.5mm from the surface of the magnet) at different magnetization (▬ magnetization angle of 45°, ▬ axial magnetization, and ▪ ▪ ▪ ▪ ▪ Halbach assembly)

As seen (Fig. 4), the intensity between the levitating and support magnets is higher and more homogeneous in Halbach assembly. The Halbach assembly has a maximum intensity 35% greater than the intensity of magnetization at angle of 45°. Suspension as per Halbach assembly has two local minimal values of intensity that can be used to stabilize sustainability of the magnetic suspension.

Utilizing the finite element method in the software package ANSOFT Maxwell 3D, the repulsive forces between the levitating and permanent magnet in various suspension systems have been defined:

1. At axial magnetization - 1228.1 H.
2. At magnetization angle of 45° - 2495.9 H.
3. At Halbach assembly - 4391.9 N.

IV.CONCLUSION

Thus, in the compared systems of magnetizing of the permanent magnets in the conveyor with double-suspension belt, the Halbach assembly consisting of axially magnetized magnets by interacting force exceeds the force of interaction by 1.75 times in the system with magnetization angle of 45°, and exceeds the force of interaction by 3.16 times in the system with axial magnetization with the same amount of magnetic material in the compared systems. Furthermore, it should be noted that the assembly of axially magnetized components of the permanent and levitating systems provides more favorable distribution of the magnetic field intensity to insure centering of the hard-magnet circuits. Therefore, applying the Halbach assembly principle at forming of permanent and levitating systems it is possible to significantly increase effectiveness of the magnetic suspension of the conveyor belt.

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Foreword

The 8th Russian-Chinese Symposium "Coal in the 21st Century: Mining, Processing and Safety" was organized jointly by T.F. Gorbachev Kuzbass State Technical University (Russia) and Shandong University of Science and Technology (China), which have had a long-term partnership of 25 years. The event was designed to promote the development of the Russian-Chinese scientific and technical cooperation in the field of mining including high-technology coal mining and deep coal processing, reduction of anthropogenic impact on the environment, production and operation of modern equipment, means and methods of industrial safety in the coal industry, as well as modern technologies of construction and modernization of the coal industry operations.

The symposium brought together the leading Russian and Chinese scientists working in the field of coal, heads of coal-mining companies, industrial safety professionals, managers and specialists of the government. The Symposium participants expanded their scientific and business contacts in the field of mining and defined new promising areas of research and engineering research aimed at the development of the coal industry.

We are confident that the 8th Russian-Chinese Symposium "Coal in the 21st century: Mining, Processing, Safety" will contribute to a new quality of relations between the scientists of Russia and China in the field of the mining science for the benefit of the two countries. We sincerely thank the local and foreign scholars who provided their support to the Symposium and all the authors who submitted their papers for publication.

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Table of Contents

Section 3. Industrial safety in coal industry

Section 4. Coal mining equipment. Production and operation

Section 5. Deep coal processing. Coal chemistry. Gasification. Ecology