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Numerical Analysis of Neodymium Magnet Influence in Relation Induction/Weight Structures of Sumo Robots

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Abstract: Since neodymium magnet possesses an extremely strong magnetic field, resulting from the combination of neodymium, iron and boron, it has become the most used in designing autonomous sumo robots. When it is mounted under the structure of this robot, the magnet produces a large amount of normal force resulting from the interaction between its field lines and the steel frame of the arena, reducing the risk of slipping its wheels. Thus, the heavier a robot, the greater the difficulty for the opponent to remove it from the arena. This article explains the properties of Nd-Fe-Br magnets and analyzes the influence of these characteristics in the relation induction/weight. Additionally, to a comparative analysis, this research analyzes the positioning, geometry and polarization of the magnets under study, based on numerical results obtained using Inventor and K & J Magnets Calculator software, given that these factors influence in their energetic product generation. Furthermore, more than just working with what we believe is a subject of great interest for sumo robot's teams, this study encourages their competitiveness, an essential factor for the competition.

Key words: Neodymium, induction, weight.

1. Introduction

In engineering, the word "robot" has become the target of intense study. To promote research and development of robots, several world championships recognized that students are urged to produce a smart competitor, are held. The idealization of the robot of this project refers to a standalone type, that is, able to perform commands without human interference and able to compete in the "autonomous sumo 3 kg" whose rules are defined to build an autonomous robot maximum 3 kg weight width and length of 20 cm and headroom. The robot was designed following a mechanical to allow their free movement, sensing reactive and efficient electronic able to allow communication of all robot devices.

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The robot sumo is the smart removal of the opponent's arena. Thus, an engine is essential that has high level of torque and with enough force to turn the wheels and beat the opponent. Allied to this criterion, an important device has become widespread in sumo competitions: the use of neodymium magnets in robot base structure in order to increase its normal force and consequently hinder its removal from the steel arena A32 ASTM covered with polyurethane. Numerical analyses through software were made through successive iterations proving that the proximity of a magnetic material with the arena of steel directly influences the mechanical robot skills. The paper is organized as follows: Section 2 discusses the methodology adopted for the classification of neodymium magnet as inductive potential; Section 3 presents results and discussions; Section 4 gives conclusions.

2. Methodology

Neodymium magnets can be magnetized axially and diametrically [3]. The possibility of two simultaneous magnetizations could be seen only magnets with ring format. This alternative influenced the choice of magnets in this format. Thus, when attached to the robot structure, and interact with the axially steel arena, it would be possible to visualize the interaction between the two rows of field magnets arranged side by side. For display of the field lines of each magnet and the identification of its poles, tests with iron filings were made. Iron is a ferromagnetic material and therefore its magnetic dipoles align themselves in the presence of a magnet (external magnetic field) [2]. In this case, the filings begin to behave as a natural magnet, while in the presence of a field. As the iron filings have little mass, this not only aligns its magnetic dipoles but also fits in the direction of the external field, “drawing”" so their distribution and direction around the magnet. It is interesting to do the mapping of magnetic field magnets with different formats, so you can understand that the spatial distribution of the magnetic field depends among other things magnet format [8].

Since the magnetic potential of the magnet influences directly on your energy product, the software chosen for the calculations was the K & J Magnet Calculator due to the computational nature of the analysis [1]. It is a well-known tool in the magnetic field. Their findings are based on extensive product testing, which through geometric parameters, we can predict traction suffered by each magnet, i.e., the force is able to pull him away from a ferromagnetic plan, and the intensity of the surface field for points along the route, assuming a single magnet in free space [5].

Magnets are not machinable materials: the incorrect method for fixing or drilling can oxidize it and affect its magnetic field. The best way to fix it in the robot structure is to use a special glue called professional Araldite: this glue is produced based on epoxy resin, a factor that justifies its high power setting, avoiding chemical reaction in the magnet.

The fairing robot, created containing 6061, and efforts suffered the same were developed using Inventor software, employed in the branch of Mechanical Engineering to conduct product simulations and 3D mechanical design.

3. Results and Discussions

The proposed magnet was based on research related to the magnetic properties most popular commercially. Each magnet has special characteristics that have been analyzed according to the need of inductive potential. To include the neodymium magnet in this project, the use of a comparative table was needed between the material of each magnet and its magnetic properties (Table 1) [4].

Paying attention to these particularities, a feasibility study was necessary. In comparative terms, the result of this analysis can be viewed below.

By reading the data, you can see that the neodymium magnets are those with greater intensity, but low

Table 1 Magnetic properties.

Material	Br (Gauss)	HcMax (Oersted)	BMax (MGO)
NdFeBo	14.600	12.300	26-51
SmCo	10.500	9.200	26-0.04
AlNiCo	12.500	1.500	5.5-0.02
Ceramic	3.900	3.900	1.0-4.4

Table 2 Study of the viability magnetic [6].

Material	Feasibility
NdFeBo	Extremely strong magnetic field, but little resistant to high temperatures. Note that is the most used in the competitions and the most modern. It has the best properties and the best value for induction/weight [6].
SmCo	Despite the excellent magnetic properties and temperature resistance (up to 250 °C), the high cost could limit their applications.
AlNiCo	Strong magnetic field and less than the neodymium magnets. Resistant to high temperatures. His Tcurie (temperature at which a magnet loses all its magnetism) is extremely high. However, the strength of demagnetization (HcMax), measured in Oersted, has low values.
Ceramic	Are those with lower cost and magnetic force. To achieve the magnetic strength of a neodymium magnet, 18 times the ceramic magnet volume is required.

resistance to high temperatures. In sumo competitions, no external material could damage the magnet structure, since the circuits are isolated from each robot to prevent any heat dispersion in its structure. Thus, the neodymium magnet presented itself as best material that satisfies the induction/weight ratio. The name of these magnets is given by N **, where ** is the energy density measured in MGOe. Taking use of K & J Magnet Calculator [1] software you can see in Fig. 1, the magnetic field of a magnet N42 category whose dimensions are:

- external diameter: 40mm;
- inside diameter: 6mm;
- thickness: 10mm.

The choice of these dimensions was based on several geometric iterations using as source a single magnet in space. Considering that the magnetic field decreases as the distance between the magnet and the surface increases from the arena, obtaining a uniform magnetic field is needed. Looking at the results of Fig. 1, the proposed method has the best magnet ratio distance/magnetic field which has developed a relatively uniform field of sufficient intensity, varying 5,200-3,600 gauss; Regarding the traction exerted by each magnet, the calculator has an artifice called "The Pull Force", which uses a meter to measure tensile behavior of the magnet and therefore the magnetic force thereof [5]. The results are shown in Fig. 2; those relate to the geometrical conditions shown above, considering the magnet at a distance of 0 mm of the ferromagnetic material and the traction received by this material lb.

The conversion to the greatness of strength, it appears that 46, 18 lb match 20, 94 kgf. Thus, disposing the magnets 2 on each side of the robot 2 and the central region, there is a satisfactory inductive potential, representing an increase of 40 times the weight of the robot, making it extremely competitive. The structure of the robot and the efforts sustained by the structure according to this arrangement are shown in Figs. 3 and 4, respectively.

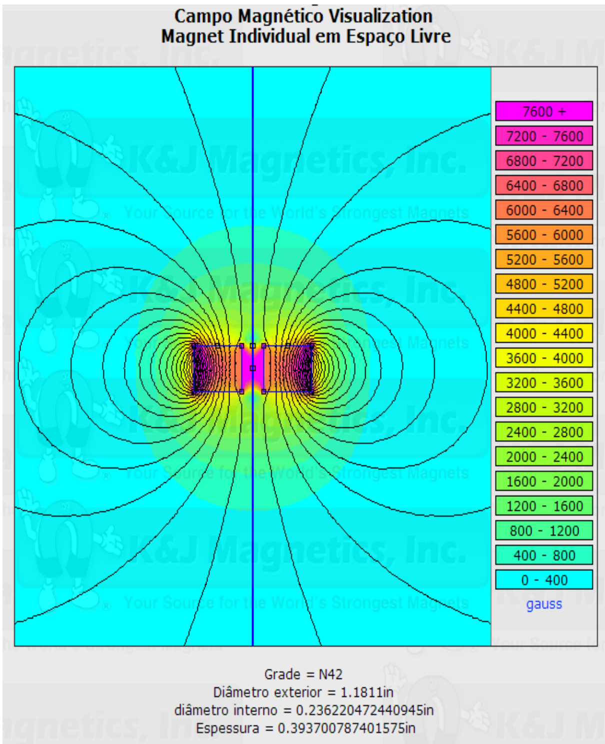

Fig. 1 Visualization of magnetic field strength.

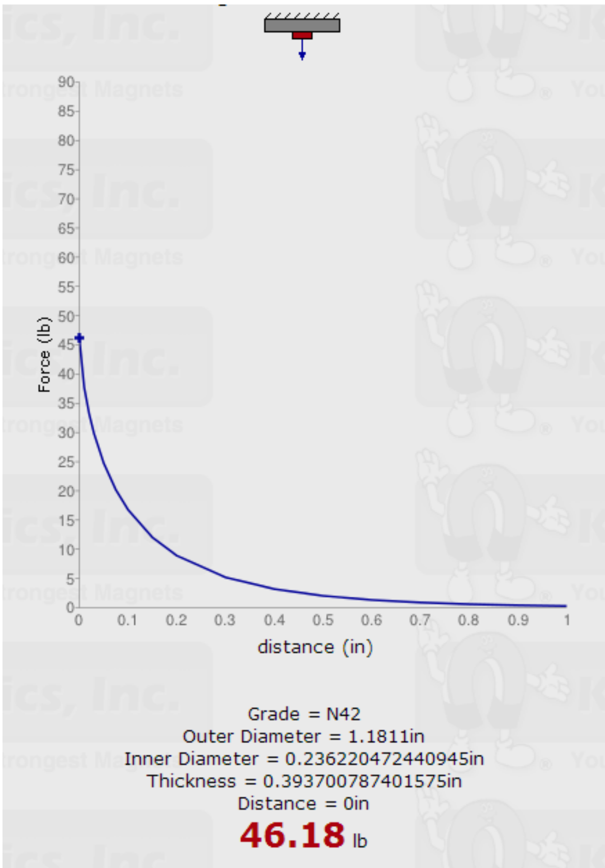

Fig. 2 Graph of "The pull force".

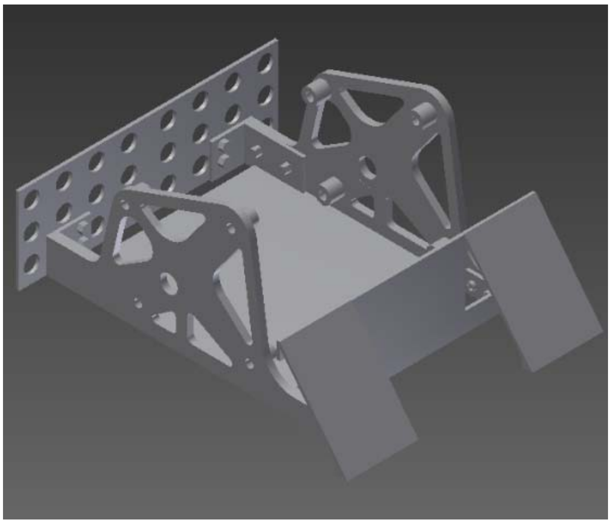

Fig. 3 Robot fairing design.

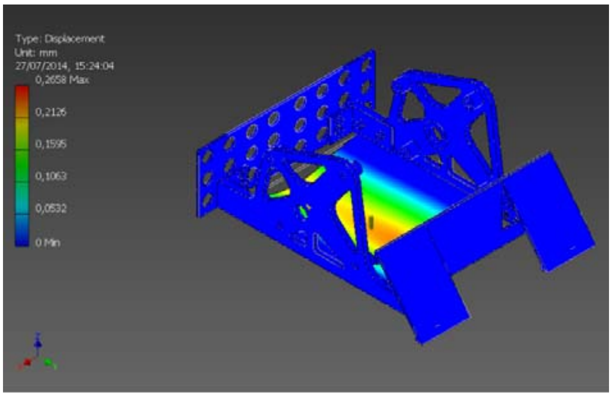

Fig. 4 Simulation of strain rate of aluminum sheet.

The color scheme bar shows that the apparent deformation of the structure obtained a maximum value of 0.2658 mm. In practical analysis, this value proved to be satisfactory, considering the strain rate within the acceptable limit for 6061 [7].

4. Conclusions

Through the analysis of the collected data, the proposed magnet profile has demonstrated that magnetic characteristics, combined with mechanical elements, presented results within the expected pattern. It is understood that the numerical analysis of the inductive potential of neodymium magnets is only the initial plan for more practical results. It was necessary the use of computational tools capable of lifting results considering the main data to be analyzed. The fact that profile adopted offer the best value for induction/weight and a uniform magnetic field along the free space makes the study an important tool for competing teams in category “sumo robots”.

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