MAGNETIC ACCELERATION
PROOF-OF-CONCEPT FOR AN EXPERIMENTAL PROPULSION SYSTEM

FINAL PROJECT REPORT

by

Billy Connor, PE
David Barnes
London Dunham
University of Alaska Fairbanks

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Pacific Northwest Transportation Consortium (PacTrans)

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USDOT University Transportation Center for Federal Region 10
University of Washington
More Hall 112, Box 352700
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16. Abstract

The Magnetic Acceleration (MagAcc) system is a new concept for magnetic levitation and propulsion that uses a specialized configuration of permanent magnets to achieve acceleration without the use of additional electricity or fuel. A bench-level demonstration, a seven-foot straight track system of permanent magnets with a related load cart, was constructed at the Arctic Infrastructure Development Center (AIDC) High Bay on the University of Alaska Fairbanks campus.

The demonstration track achieved acceleration using the MagAcc's passive magnetic propulsion system as predicted. The MagAcc system accelerated the cart from a resting position onto the drive section of the track using solely permanent magnets. This demonstrated the actions of the linear polarity switching series of the magnetic fields and polarity orientation, as well as the effectiveness of the London Assemblage configuration for achieving acceleration.

Iterative improvements were made to the initial design to reduce drag and improve acceleration and speed. Our research with the prototype provided concept validation and initial data for the potential applications and scale of the MagAcc system, and it suggested the potential for streamlined retrofitting of existing tracks. Additional possible implementations include smaller industrial applications, such as on a factory floor, and reductions to the complexity, expense, and emissions in regional and national transit systems. The system could also reduce operational costs associated with maglev systems currently in use.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in'	square inches	645.2	square millimeters	mm'
ft2	square feet	0.093	square meters	m'
yd'	square yard	0.836	square meters	m'
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft'	cubic feet	0.028	cubic meters	m3
yd'	cubic yards	0.765	cubic meters	m'
	NOTE: volumes greater than 1000 l shall be shown in m³			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	shorttons(2000lb)	0.907	megagrams (or "metric ton")	Mg (or"t")
		TEMPERATURE (exact degrees)		
OF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	•C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/irf	poundforce per square inch	6.89	kilopascals	kPa

APPROXNATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m'	square meters	10.764	square feet	11'
m'	square meters	1.195	square yards	yd'
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m'	cubic meters	35.314	cubic feet	ft'
m'	cubic meters	1.307	cubic yards	yd,
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or"t")	megagrams (or "metric ton")	1.103	shorttons(2000lb)	T
		TEMPERATURE (exact degrees)		
•C	Celsius	1.8C+32	Fahrenheit	OF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	le
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbl
kPa	kilopascals	0.145	poundforce per square inch	lbl/in²

•sI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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LIST OF ABBREVIATIONS

AC	Alternating current
AIDC	Arctic Infrastructure Development Center
CFS	Central force system
DC	Direct current
DCF	Dominant central force
DS	Demarcation surface
LA	London Assemblage
LIM	Linear induction motor
LPS	Linear polarity switching
LSM	Linear switching motor
MagAcc	Magnetic Acceleration
SISARA	Swift internal switching actions of repulsion and attraction
TBZ	Translation balanced zone
TZ	Translation zone
UAF	University of Alaska Fairbanks

EXECUTIVE SUMMARY

The Magnetic Acceleration (or MagAcc) system is a concept for magnetic levitation and propulsion that uses permanent magnets to achieve acceleration without the use of additional electricity or fuel.

MagAcc is a passive magnetic propulsion system that employs special arrays of high-field permanent magnets, called the London Assemblage (LA) configuration. Located on the load cart, LAs are aligned in a "track" consisting of a second series of permanent magnet arrangements (linear polarity switching (LPS) magnets), which are interleaved with special staggering alignment configurations.

The MagAcc system utilizes the properties of a permanent magnet, which allow their forces to be focused, resulting in swift internal switching actions of repulsion and attraction (SISARA) wave forces between the LAs and LPSs. The SISARA wave forces accelerate the cart along the straight track, thereby producing an initial acceleration. The encountering force values that produce the acceleration are the products of the internal actions of repulsion and attraction. The demonstration track proved the MagAcc system to function on a small scale in the laboratory, at a Technology Readiness Level 6 or 7.

1. INTRODUCTION

1.1. About the MagAcc System

Traditional Maglev systems use direct current (DC) and alternating current (AC) linear motors to generate thrust for their trains. Both require a polarity switching mechanism that is complex to build. For instance, a brushed DC motor uses a commutator and brushes for current switching in the windings. This condition gives rise to excessive wear and tear at the brush contacts, which makes the DC motor unsuitable for high-speed applications. Meanwhile, an AC motor requires a costly, external, high-precision switching computer algorithm. External switching of the polarities back and forth is the current way that propulsion systems operate on all existing Maglev systems. Timing must be precise, and the gate must be positioned accurately for effective propulsion.

The Magnetic Acceleration (MagAcc) project was designed to perform the polarity orientation switching actions automatically without the use of external circuitry and without the actions of any motor with permanent magnets. Because the polarity orientation switching component is performed internally, it is simpler, more reliable, more robust, lower maintenance, and more cost-efficient than any other Maglev system in existence.

Therefore, we investigated the effectiveness of the actions of the linear polarity switching (LPS) series of the force of the magnetic fields and polarity orientation by building a prototype to demonstrate the effectiveness of producing acceleration solely with permanent magnets arranged in the London Assemblage (LA) configuration and the LPS series.

2. PROTOTYPE

2.1 Construction

The MagAcc prototype was constructed as a seven-foot straight track system of permanent magnets, with a related load cart, at the Arctic Infrastructure Development Center (AIDC) High Bay on the University of Alaska Fairbanks campus. The track was designed for compatibility with existing track systems, as the retrofitting of existing tracks is a significant potential application.

First, permanent magnets were arranged in the London Assemblage (LA) and inspected for consistent force measures, and then each LA was housed in a case (three permanent magnets in an aluminum case). The LAs were then combined, the force measures were once again inspected for consistency, and then the LAs were attached to the load cart. Seven independent permanent magnets were then positioned in an LPS series tube. Each LPS tube was then inspected to confirm that its antithetical ends emanated the forces of the magnetic fields and primary polarity orientation from one end, and the forces of the magnetic fields and inverse polarity orientation from the opposite end. Last, we confirmed that the antithetical ends performed the actions of attraction and repulsion according to their respective isolated dominant polarity orientation. The LPS tubes were then connected in a seven-foot straight track.

At this point, the load cart was applied to the track, and the track was iteratively adjusted to achieve acceleration for the load cart (which was designed as a generic base for potential retrofit situations). The track was shorter than initially designed. The track length and shape were limited by the adjustments needed for the LPS tube design and the layout in the initial construction and force measure verification phases (see Lessons Learned).

2.2. Acceleration

The MagAcc system utilizes the properties of a permanent magnet, which allow their forces to be focused, resulting in swift internal switching actions of repulsion and attraction (SISARA) wave forces between the LAs and LPSs. Our goal was to demonstrate that the mode of propelling a cart using the SISARA wave was viable and that stable and continuous acceleration produced solely with the forces of magnetic fields and polarity orientation was viable. We found that the SISARA waves overcame initial and continuous drag forces between the cart and the straight track, thereby allowing continuous and controllable force vectors down the straight track. We also determined some simple design improvements based on our observations that would allow the cart to reach higher speeds.

The MagAcc system also eliminates the complex synchronization between the traveling cart and each external switch gate. For the MagAcc system, after initial velocity has been achieved, the interactions between the LA configurations and the LPS series continue to generate SISARA waves throughout the length of the straight track. Stable SISARA waves and continuous momentum in both the vertical and lateral aerodynamic forces are generated by the LA configuration's continuous interaction with both antithetical ends of the LPS series; that is, continual actions of repulsion and attraction.

2.3. Lessons Learned

Early in the construction phase of the project, a design flaw caused the SISARA waves to initiate a higher drag force at the initial launching than expected. Consequently, the cart stopped before reaching the end of the LPS series. After investigation, we discovered that an early design had assumed that use of the entire length of the LPS series would be needed to make a smooth, controlled handshake between series. By testing multiple design changes, we discovered that at each LPS series handshake, the measured force value ring of the previous LPS series had to be equal to or less than that of the next LPS series. The handoff from one LPS series to the next LPS series had a greater chance of being in sync if it occurred mid-LPS-translation between the two. In early iterations, our model showed that we were operating on the downslope side of the drag force curve, slowing the cart down at every handshake. To achieve increased speeds, we needed to narrow all handshakes solely to the place where the SISARA wave peak regions were equivalent to the preceding SISARA wave peak.

We could overcome the ever-present drag force with two approaches that would accelerate the cart with the existing straight track length. First, if we used the MagAcc system's existing launcher arrangement, then we could increase cart velocity after launch by having LPS series sections of straight track operate on the drive-up slope side of the SISARA wave. Hence, the initial velocity of the cart would operate at the very peak of the SISARA wave. Second, doubling the number of one LPS series alongside each other could greatly boost the acceleration force. This would increase the peak velocity and SISARA wave width of the forces of magnetic fields and polarity orientations by factors yet to be measured. With this improvement and an additional LPS series with the drive only, the cart could reach any desired acute to the SISARA wave.

These improvements could be achieved without changing any electronic bus work or drive circuit of any design because the safe limits on the circuit components are not present on the MagAcc system.

3. TECHNICAL DISCUSSION

3.1. Present Systems

Present maglev systems use external components, such as the switching components from linear motors, to generate thrust for their trains. Direct current (DC) or alternating current (AC) motors require an external polarity switching mechanism that is complex to build. Where a linear induction motor (LIM) or linear switching motor (LSM) is used for propulsion, these engines encounter complex problems with polarity switching mechanisms (Shieh and Tung, 2002). For instance, a brushed DC motor uses a commutator and brushes for current switching in the windings. As the polarity of the active part of the motor alternates with the motor translation, arcing takes place at the brushes, connecting the active and passive parts of the motor. This condition gives rise to excessive wear and tear at the brush contacts, which makes the DC motor unsuitable for high-speed applications (Rivera, 2007). Similarly, an AC motor requires a costly, external, high-precision switching computer algorithm. Externally switching the polarities back and forth is the way propulsion operates on all existing Maglev systems. Timing must be precise, and the gate must be positioned accurately for effective propulsion.

The working principle of an LIM is similar to its rotary counterpart. Stator windings, when excited, produce a traveling magnetic field, which induces eddy currents in the translator. The interaction of magnetic fields produced by the stator currents and translator eddy currents produce the necessary propulsion force (Boldea, 2013). This drive has higher complexity because of its large number of power stages and system components, which may lead to improper controlling, short circuiting, and other such damage. Along with these drawbacks, this motor also has higher force ripples and low reliability (Rivera, 2007). These limitations of the traditional maglev system are all eliminated with the propulsion component of the new MagAcc system.

3.2. Improvements to the MagAcc System

The switching component performs automatically without the use of external circuitry and without the actions of any motor. Because the polarity orientation switching component performs internally, it is simpler, more reliable, more robust, lower maintenance, and more cost-efficient than any other maglev system. Our preliminary research suggested that the MagAcc system features inherent advantages. These include cheap and simplified construction because windings and electricity are eliminated, less stress due to high force ripples, less vibration and acoustic noise, and less complex polarity switching control units. As expected, the demonstration track confirmed that, once developed and scaled up, this alternative propulsion system could outperform the efficiency and cost of present maglev systems.

The demonstration track proved the MagAcc system to function on a small scale in the laboratory, at a Technology Readiness Level 6 or 7. Our research with the prototype demonstrated the viability of moving away from multiple components in the traditional train or maglev system, which has complex, grid-dependent, and power-intensive components. Systems that use external switching controls for polarity switching are not simpler than just internally switching them. Permanent magnet internal switching that occurs as a normal function of the permanent magnet configurations is less grid-dependent and the preferable method of polarity switching.

3.3. Applications

There are many potential applications for the MagAcc system, including energy generation systems, transportation payload launches, and complex environments. Proximate potential applications include serving smaller industrial applications (for instance, on a factory floor or as part of a seaport goods system). These could also be scaled up to a regional or national level for transportation of freight and people over a longer timeline. They could also be installed or retrofitted into current maglev systems. This would eliminate the high cost of electricity needed for traditional electromagnetic systems, decrease the cost of wheels and bearings at load rest and slow down, and lessen the overall costs for maintenance and operation. Using them to retrofit existing operations would reduce the expense and delay of introducing a whole new propulsion system industry to the U.S.

Using the propulsion portion of the MagAcc as a retrofit for a traditional maglev system or other existing train systems would make implementation of the MagAcc system less expensive and more appealing. The MagAcc system would present another advantage for the infrastructure industries in that it yields no local emissions and is environmentally friendly. The MagAcc system would introduce new flexibility in energy sources and storage. For example, when a launch order is given, no power is pulled from the generators in two- to three-second pulse rates because the force of the LA configuration stands constant and consistently ready to be used.

4. THEORY

4.1. Premise

The MagAcc system is based on Michael Faraday's conceptualization of two central force systems existing in a single permanent magnet. In addition to the two central force systems (CFSs), there is a mid-way section where the respective forces of magnetic fields and polarity orientation are balanced. Both CFSs translate a portion of their independent force of magnetic fields and respective polarity orientations toward the other's CFS, thereby creating a balanced zone between them: the translation balanced zone (TBZ). Our theory is that although the permanent magnet has two separate CFSs, the two antithetical ends balance to produce a single direction of force. One is an encapsulation of an isolated primary force of magnetic fields and polarity orientation and the other is an encapsulation of an isolated inverse force of magnetic fields and polarity orientation.

4.2. Formulae

The Demarcation Force Value formula is ($|\varpi| = F - rR_n$). This formula shows how each condition of a spherical ring can be interpreted for the central force system spherical radius and the adjusted force value at a particular translation away or toward the surface of the central force system.

The following conditions are defined:

- (F) represents the surface of the origin of the central force system.
- (r) represents the radius between the surface of the origin of the central force system and the demarcation.
- R_n represents the adjusted force value at any particular demarcation as translation is away or toward the surface of the origin of the central force system.
- Ringfunction ($|\varpi|$) (the absolute value of omega-hat) represents the final magnitude for the force value of that particular demarcation to be the difference that the F has to the product of r and R_n.

The equation for R_n is the proportion of the origin of the central force system (F) and the total demarcations (T_d) set between the translation between the surface of the origin of the central force system and its furthest demarcation.

$R_n = FT_d$

The equation of the final strength of a force value of a particular demarcation consists of a difference of F to the product of r and R_n:

$$|\varpi| = F - rR_n$$

It must be emphasized that the equation focuses only on defining the force of the magnetic fields confined within the boundary of its encapsulating spherical polarity orientation without defining the primary or inverse of the polarity orientation.

4.3. Demarcation Surface Model

The demarcation surface (DS) model helps demonstrate Faraday's theory of a permanent magnet as having two CFSs at antithetical ends, and it explains how their respective CFSs orbit one another. The DS model is patterned after the Gaussian Surface model, but with the objective of observing and calculating the force value of the demarcation that is nearest to the surface of its particular CFS. Both the LA configuration and the LPS series use the findings of the DS model to determine the location of the demarcation points orbiting around the CFS in a spherical shape.

In Figure 4.1, an isolated demarcation point of a CFS is emanating at its surface a force value of 500 lbs. This DS model describes how to measure the force value translation by using the $|\varpi|$ concept. The force value of the magnetic fields inhabiting their own particular encapsulate demarcation spherical ring references all demarcation points corresponding to maximum inward or outward displacements that translate at intervals of 50 lbs. toward its own CFS is considered to be an increase of its force value and to translate at intervals of 50 lbs. away from its own CFS is considered to be a decrease of its force value.

Although it is not possible to specify with certainty the exact physical properties and locations of a demarcation emanating from the CFS, it's possible to assign probabilities for observing it at any given position in its orbit. There is no examination of the polarity orientation in the DS model. Only the magnetic fields and their force value at measured translations are taken under consideration; the assumption is that the magnetic field is an entity separate from that of the polarity orientation.

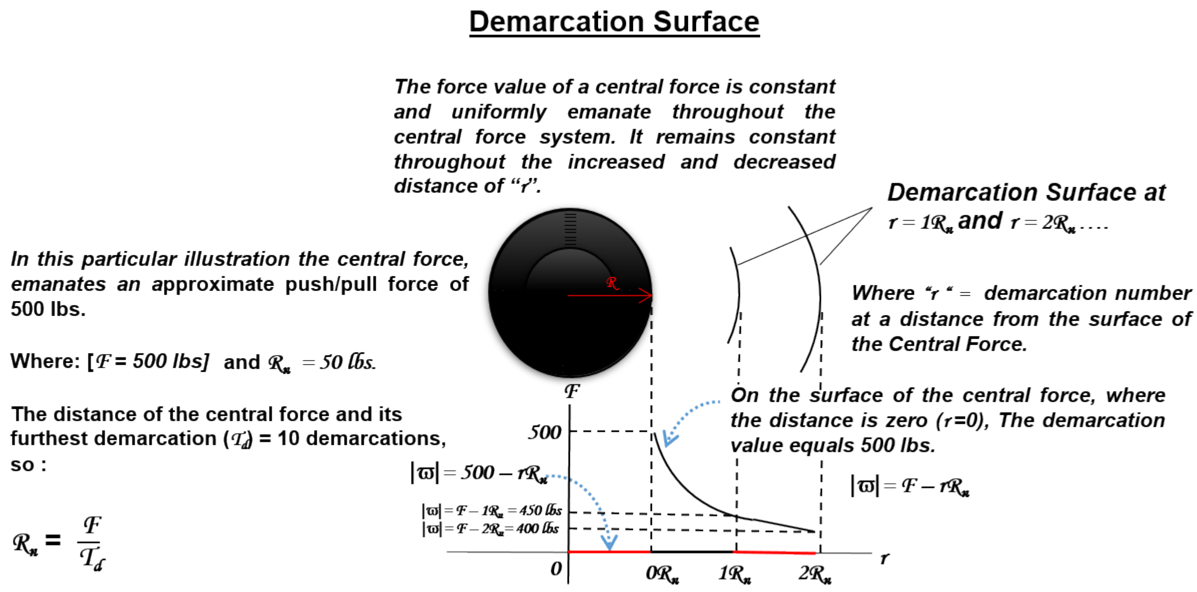


Figure 4.1. Demarcation surface.

In any region within its respective CFS are force value measures of an approximate force amount in the respective spherical coordinate system. The system described in Figure 4.1 simply specifies the determination of a coordinate of a single CFS in terms of degrees of freedom of a spherical shape. It can be used to determine a single event at a specific location in space at a certain time dilation. It's just one coordinate system explaining how the force of magnetic fields and polarity orientations propagate from or toward the origin of a respective CFS.

The two CFSs are combined to show the properties of a single permanent magnet. This illustrates how the translations emanating from each dominant central force (DCF_1 and DCF_2) of a single permanent magnet could be theorized. In Figure 4.2 we have added labels for the force of the magnetic fields and polarity orientations, A_β and -A_β. A_β [A-Sub-Beta] arbitrarily labels the DCF_1 side of the permanent magnet and is arbitrarily chosen to represent the primary central force system of a single permanent magnet. -A_β [inverse-A-Sub-Beta] arbitrarily labels the DCF_2 side to represent the inverse central force system of the same single permanent magnet. The rings of A_β and -A_β approach one another and emanate a dual point of interest of their independent DCF systems at infinite points.

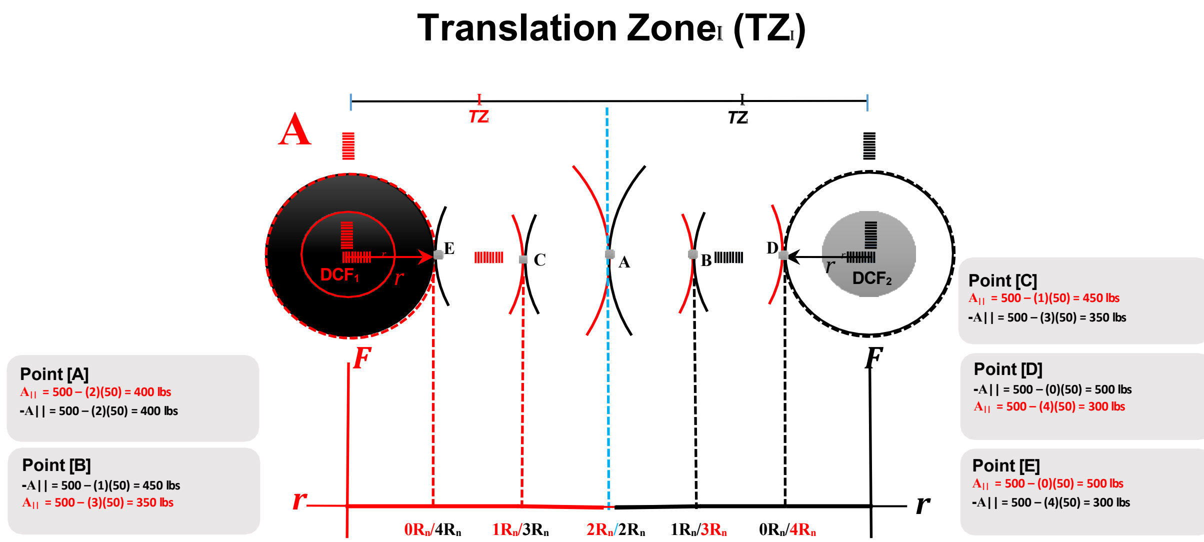


Figure 4.2. Translation zone.

In Figure 4.2, when the Aβ spherical rings are measured at an angle perpendicular to the -Aβ spherical rings in the regions of the translation zone (TZ_I) then the Aβ spherical rings join one to another in the inverse direction of the -Aβ spherical rings. When the -Aβ rings are measured at an angle perpendicular to the Aβ spherical rings in the regions of the TZ_I then the -Aβ spherical rings join one to another in the opposite direction of the Aβ spherical rings.

All demarcation points observed emanating from the surface of each DCF system to the translation balanced zone (TBZ) are said to fall into the TZ_I , where the DCF system closest dominates. In Figure 4.1, demarcation points C and E are found on the side closest to the DCF_1 and are located in the TZ_I, while demarcation points B and D are found on the side closest to the DCF_2 system and are located in TZ_I. Demarcation point A is in the TBZ, where the two coordinates emanating from the DCF_1 and DCF_2 systems are balanced in all ways except for direction.

The TBZ for a single permanent magnet is located at coordinates 2R/2R. When two or more permanent magnets are joined together at their points of attraction, then an expansion occurs between the TBZ and either side of the DCF systems. With every additional permanent magnet in the array, there are TBZ advancements to a new midpoint between the two DCF systems.

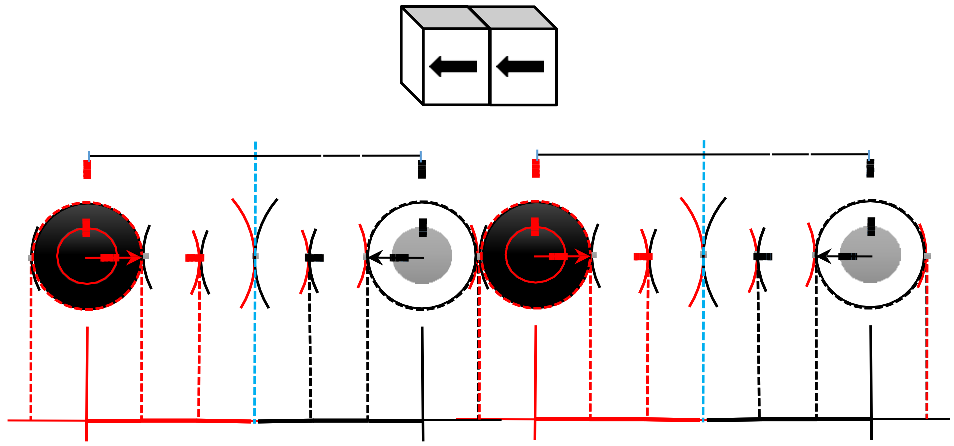
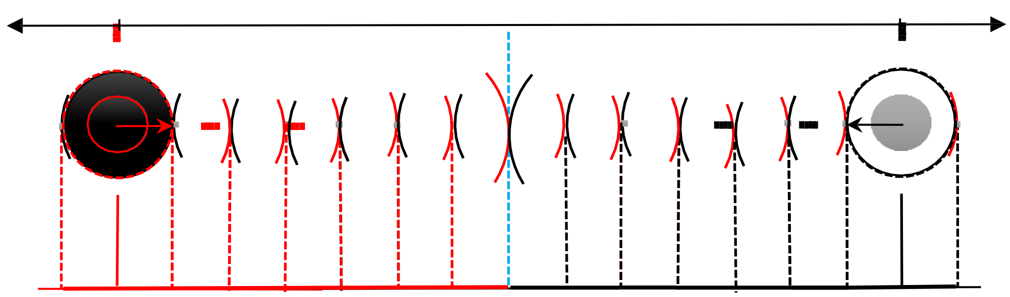


Figure 4.3. Two magnets.

Figure 4.3 shows two permanent magnets joined together at their point of attraction, and it shows how their translation automatically adjusts itself. Thus, the new TBZ for the joining of two permanent magnets at their points of attraction is 6R/6R.

4.4. In the LPS Model

For the straight track built at UAF, Figure 4.4 shows how nine individual permanent magnets are evaluated when they are connected at their points of attraction. This produces a



DCF_1 system at the antithetical end emanating forces of magnetic fields and a primary polarity orientation on one antithetical end and a DCF_2 system at the other antithetical end emanating forces of magnetic fields and its inverse polarity orientation on the other antithetical end. Both dominant polarity orientations at each antithetical end of their respective CFS approaches the other end's CFS, where they reach a midpoint at which neither polarity orientation dominates.

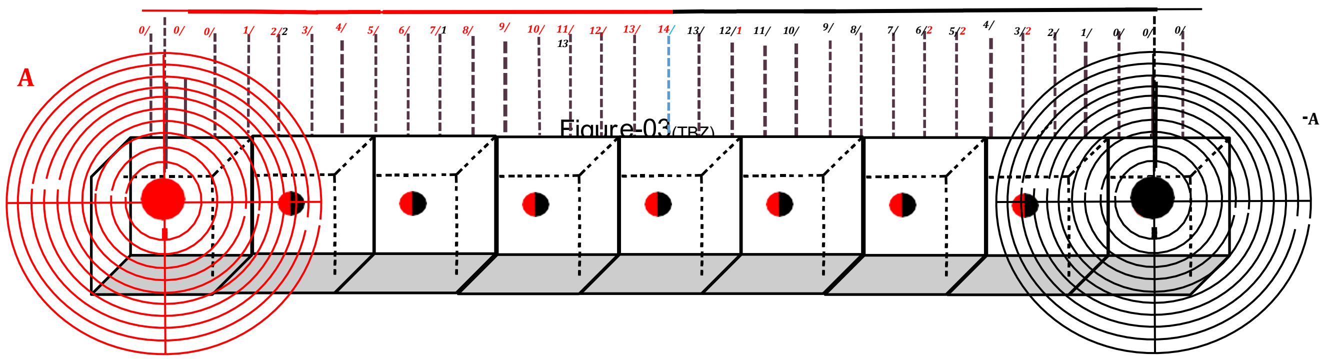


Figure 4.4. Nine permanent magnet array.

Before this midpoint/TBZ is reached and before the two DCF systems' spherical rings cross over into the regions of their inverse DCF system, they are unbalanced in force value and direction of force. As their translation crosses over the TBZ, their encounter of the dominant force of magnetic fields and polarity orientation translate from being a dominant status to a minor status. For either DCF system, all points before and after the TBZ are demarcation points of dominance, respective to their TZ_I location, but at the TBZ, neither DCF system is dominant. Their forces of magnetic fields and polarity orientations are in balance. We applied this principle to produce the prototype track.

Because the two DCF systems are on antithetical ends of each other, we can treat each antithetical end as an independent DCF system. The TBZ is a point where neither DCF system dominates when either is introduced to a single force of magnetic fields and polarity orientation. The LPS system responds like an internal polarity switch mechanism when encountered by the external force of the magnetic fields and polarity orientations. The internal polarity switching mechanism produces the actions of repulsion and attraction on every encounter with the external force of the magnetic fields and polarity orientations.

Figure 4.5 illustrates how an added isolated DCF system placed at a distance from the LPS series can produce an internal translation of attraction and repulsion, thereby producing the MagAcc propulsion field called the SISARA wave. When the second DCF system interacts with the DCF_1 system of the LPS series' antithetical end that produces the repulsive action on the SISARA waves, it produces an initial acceleration toward the DCF_2.

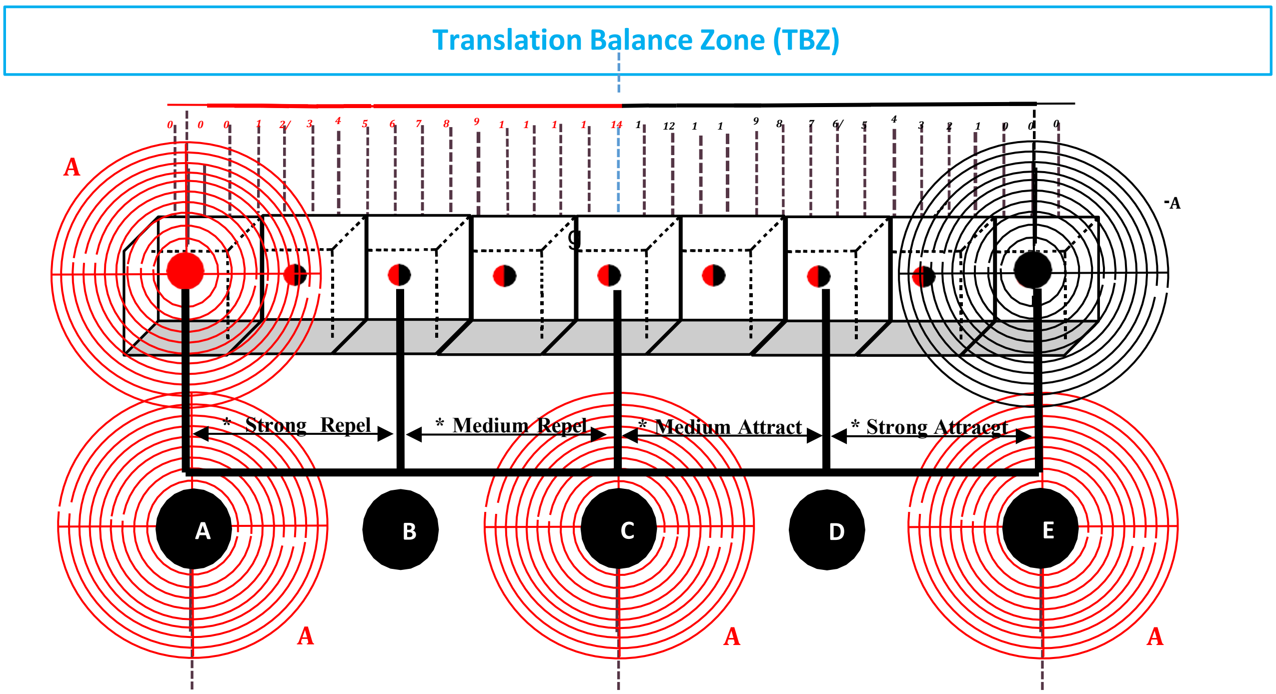


Figure 4.5. Translation balance zone.

Note: In Figure 4.5, the second isolated DCF system is the primary DCF system Aβ.

At all points A, B, C, D, and E, the interacting DCF systems have a SISARA wave that produces both an attraction action and a repulsive action.

At point A, because the antithetical end encountered along the LPS series is of a primary DCF_1 system to the encountering second primary DCF_1 system, their action at the SISARA wave produces an unbalanced strong repulsion with a weak attraction.

At point B, because the antithetical end encountered along the LPS series is of a primary DCF_1 system, but the encounter is at a distance from/toward the primary DCF_1 system of the LPS series, the second DCF_1 system's action at the SISARA wave produces an unbalanced strong/medium repulsion with a weak attraction.

At point C, because the TBZ is encountered along the LPS series, the encountering second DCF_1 system produces actions at the SISARA wave that are equivalent repulsion and attraction. This makes the TBZ zone balanced in producing equivalent actions of attraction and repulsion.

At point D, because the antithetical end encountered along the LPS series is of an inverse DCF_2 system, but the encounter is at a distance from/toward the primary DCF_2 system of the

LPS series, the second DCF_1 system's action at the SISARA wave produces an unbalanced strong/medium attraction with a weak repulsion.

At point E, because the antithetical end encountered along the LPS series is of an inverse DCF_2 system to the encountering second primary DCF_1 system, their action at the SISARA wave produces an unbalanced strong attraction with a weak repulsion.

In the LPS series, the force of the magnetic fields and polarity orientation of the permanent magnets in connection between the independent dominant polarity orientations have a continuing toggling action of both independent dominant polarity orientations. On either side of the TBZ, both independent dominant polarity orientation translations toggle polarity orientation dominance back and forth on their respective TBZ side until they reach a point between them of equal dominance at the TBZ. Occurring on either side of the TBZ are multiple subsidiary actions that work in sync to interweave rapidly internal polarity switching of translations of attraction and repulsion when a single force of magnetic fields and polarity orientation is encountered. Throughout the approach of either CFS, the force of the magnetic fields and polarity orientation toward the TBZ produces multiple polarity switching of the dominance of the CFSs until they reach the TBZ.

REFERENCES

Boldea, I. Linear electric machines, drives and MAGLEVs handbook. Boca Raton: CRC Press, 2013.

Rivera, NN. “Permanent Magnet DC traction motor with reconfigurable winding control.” Transportation Research Board of the National Academies: August 2007. http://onlinepubs.trb.org/onlinepubs/archive/studies/idea/finalreports/highspeedrail/hsr- 44final_report.pdf.

Shieh, NC, and PC Tung. “Robust position regulation control of a transportation carriage directly driven by linear brushless DC motor.” Electric Power Component Systems 30(7):661–677: 2002.

BIBLIOGRAPHY

Boldea, I; LN Tutelea; W Xu; and Pucci, M. “Linear electric machines, drives, and MAGLEVs: An Overview.” IEEE Transactions on Industrial Electronics, vol. 65, no. 9, pp. 7504-7515: Sept. 2018. doi: 10.1109/TIE.2017.2733492.

Halbach, Klaus. "Magnetically levitated train takes flight.” US Department of Energy Science News EurekAlert! Science News. https://www.eurekalert.org/features/doe/2004-11/ddoe-mlt111104.php.

Post, Richard F. "Toward More Efficient Transport: The Inductrack Maglev System." Lawrence Livermore National Laboratory: 10 October 2005. Retrieved 1 December 2017. https://gcep.stanford.edu/pdfs/ChEHeXOTnf3dHH5qjYRXMA/09_Post_10_11_trans.pdf

Post, Richard F., and Ryutov, D. The Inductrack concept: A new approach to magnetic levitation. United States: n.p., 1996. Web. doi:10.2172/237425.

Tung, L.S.; R. F. Post; and J. Martinez-Frias." Final progress report for the NASA Inductrack model rocket launcher at the Lawrence Livermore National Laboratory.” 27 June 2001. Web. https://web.archive.org/web/20160305122350/http:/www.askmar.com/Inductrack/2001-6- 27%20Inductrack%20NASA.pdf