United States Patent

Sasaki et al.

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[54] **ELECTROMAGNETIC TRACTION INCREASING ASSEMBLY**

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[52] **U.S. Cl.**.................................**105/77,** 105/184, 188/165, 303/21 CE, 303/21 CF, 310/93, 310/95

[51] **Int. Cl.**.................**B61c 15/04,** H02k 49/04, H02p 15/00

[58] **Field of Search** ....105/77, 78, 76, 184; 188/165; 246/DIG. 9, DIG. 10; 303/3; 310/93, 95

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Assistant Examiner—Howard Beltran
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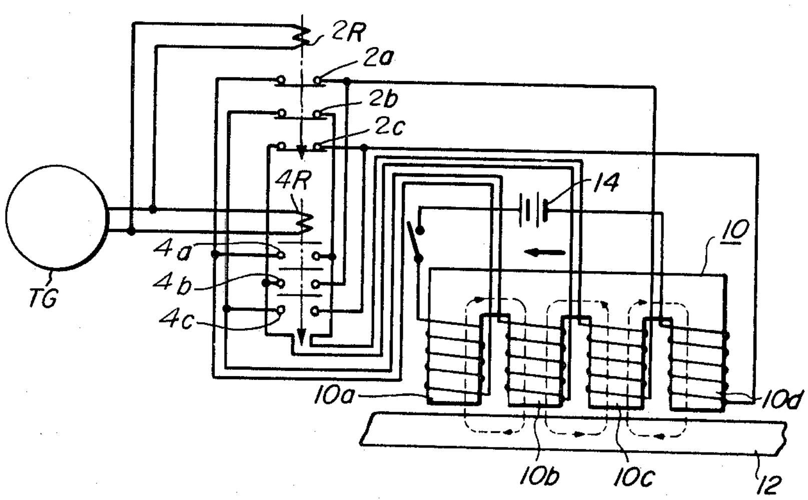
[57] **ABSTRACT**

In railway transportation facilities and the like having a rail track system and a running system running on the rail track by means of running wheels, a system for increasing the axle load having a plurality of magnetic poles disposed in one of the two systems for producing magnetic flux, and a magnetic material disposed in the other system for producing an attractive force between the two systems by the action of the magnetic flux and a braking effort by the transfer movement of the magnetic flux, wherein the magnetic poles are energized within a speed range in which the product of the attractive force and the coefficient of adhesion is greater than the braking effort.

3 Claims, 8 Drawing Figures



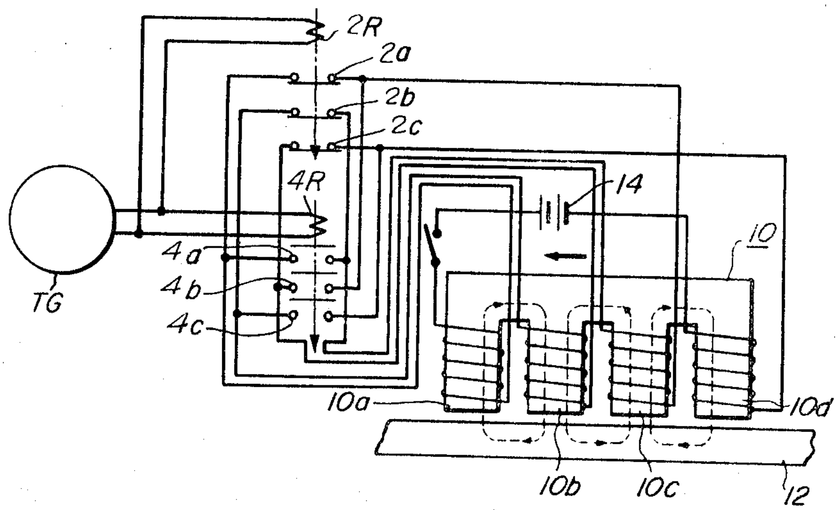


FIG. 1

FIG. 4a

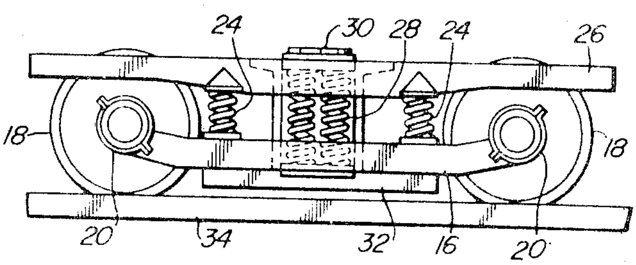
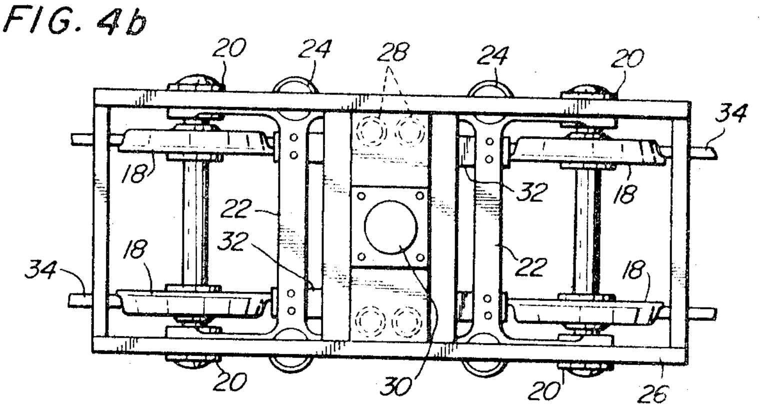


FIG. 4b



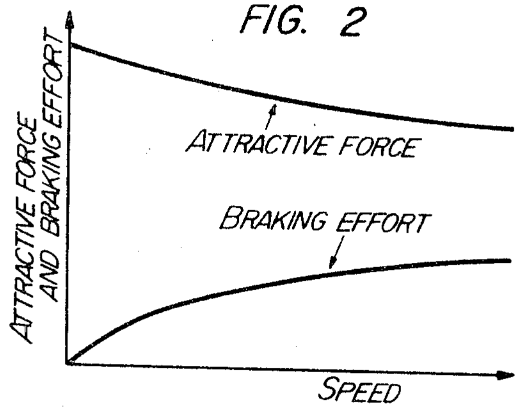

ATTRACTIVE FORCE AND BRAKING EFFORT
ATTRACTIVE FORCE
BRAKING EFFORT
SPEED

FIG. 2

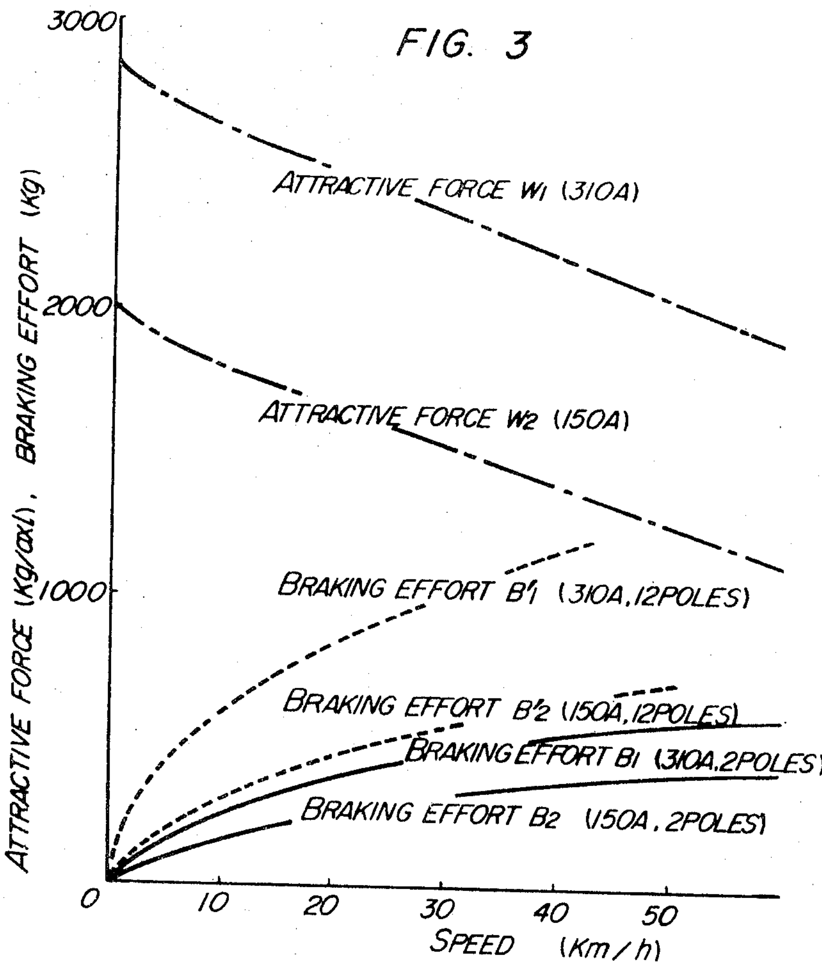

3000
2000
1000
0
ATTRACTIVE FORCE (Kg/axl), BRAKING EFFORT (Kg)
ATTRACTIVE FORCE W1 (310A)
ATTRACTIVE FORCE W2 (150A)
BRAKING EFFORT B'1 (310A, 12POLES)
BRAKING EFFORT B'2 (150A, 12POLES)
BRAKING EFFORT B1 (310A, 2POLES)
BRAKING EFFORT B2 (150A, 2POLES)
10
20
30
40
50
SPEED (Km/h)

FIG. 3

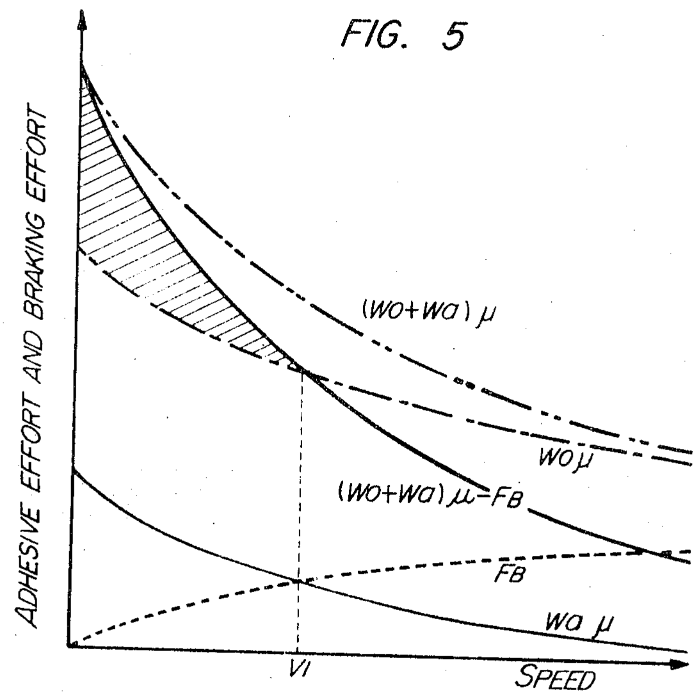


FIG. 5

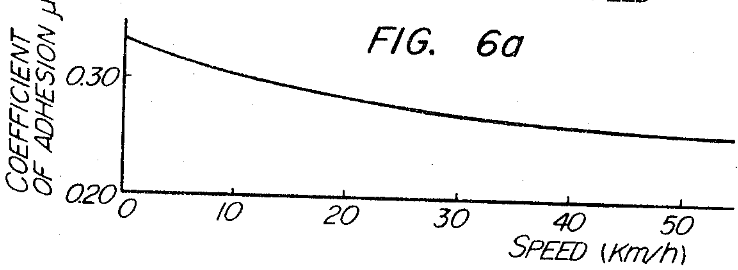


FIG. 6a

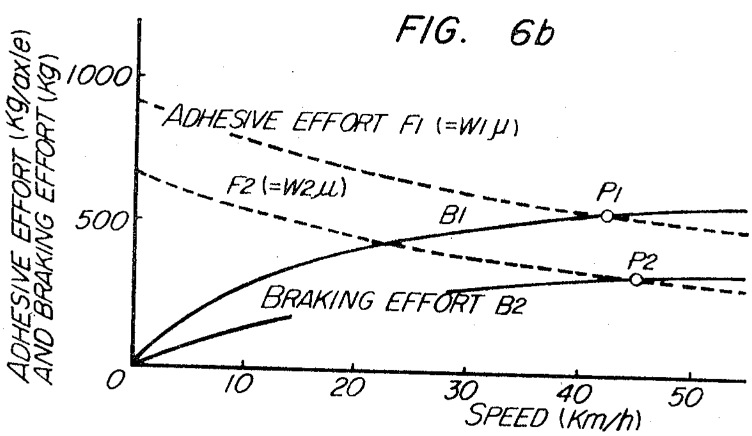


FIG. 6b

ELECTROMAGNETIC TRACTION INCREASING ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a system for improving the adhesive performance by increasing the axle load of the driving wheels of railway rolling stock and the like.

2. Description of the Prior Art

Employment of an intermediate truck represents one of the means adopted heretofore for the improvement of the adhesive performance of locomotives and the like. According to this method, a truck which does not contribute to the tractive effort of a locomotive or the like is fitted to a substantially central portion of the car body by means of air springs. In starting the locomotive, air is exhausted from the air springs and the body weight is substantially borne by the driving wheels so as to thereby augment the axle load of the driving wheels and increase the adhesive effort.

According to one of prior art examples, the axle load of the driving wheels at the time of starting is set at 16.8 tons per axle. After starting, air pressure fed into the air springs is gradually increased. This increases the share of the body weight by the intermediate truck and the axle load of the driving wheels is reduced to a normal working value of 16.0 tons per axle.

According to the means described above, a truck which does not contribute to the tractive effort must be provided in addition to the driving trucks, and yet there is a limitation to the maximum value of the axle load obtained at the driving wheels. This limit is determined primarily by the body weight. Accordingly, a heavy body weight is required when a large axle load is required. It is disadvantageous that these weights should be entirely imparted to the rails.

Various resolutions for these problems were suggested so as to increase the maximum adhesive effort by means of the attractive force exerted between an electromagnet and the rail. However, no success could be obtained for a practical application from these suggestions, even though various designs and structures were tried on the basis of these suggestions.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system capable of increasing the axle load without in any way imposing a heavy burden upon the rails.

Another object of the present invention is to provide a system capable of obtaining an axle load as desired which is more than that determined by the body weight.

The present invention is essentially featured by the fact that a force of attraction is produced between the rail track system and the running system of railway rolling stock or the like, and more particularly, by generating the force of attraction merely within a predetermined speed range.

Other objects, features and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view for illustrating the basic principle of the present invention and includes a schematic connection diagram showing the control circuit of the embodiment shown in FIGS. 4*a* and 4*b*;

FIG. 2 is a graph for showing typical speed characteristics of the system shown in FIG. 1

FIG. 3 is a graph showing the data from an experiment performed on the basis of the basic principle shown in FIGS. 1 and 2;

FIG. 4*a* is an elevational view of an embodiment of the system in accordance with the present invention;

FIG. 4*b* is a plan view of the embodiment shown in FIG. 4*a;*

FIG. 5 is a graph illustrating the operating principle of the system shown in FIGS. 4*a* and 4*b;*

FIG. 6*a* is a graph showing one example of an actual measured coefficient of adhesion in relation to speed; and

FIG. 6*b* is a graph showing the experimental speed characteristics of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a core **10** having a plurality of magnetic poles **10***a*, **10***b*, **10***c* and **10***d* is disposed opposite to a magnetic material **12** in such a manner as to define a very small air gap therebetween. An excitation coil is wound around each of the magnetic poles **10***a*, **10***b*, **10***c* and **10***d*. It is commonly known that, when such excitation coils are energized by a DC source **14**, magnetic flux is produced as shown by the dotted lines and an attractive force W attracting the core **10** and the magnetic material **12** toward each other is produced between the core **10** and the magnetic material **12**.

On the other hand, when the core **10** is moved in the direction of the arrow, the magnetic flux is transferred and an eddy current is generated in the magnetic material **12**. Due to the mutual action between the eddy current and the magnetic flux, a force directed in a direction to obstruct the movement of the core **10** is produced in the core **10**, that is, a braking effort B is produced in the core **10**. This arrangement is called an eddy current brake. Alternatively, the core **10** may be held stationary and the magnetic material **12** may be moved to similarly produce an eddy current braking effort since the braking effort is produced by the relative movement between the core **10** and the magnetic material **12**.

The attractive force W and braking effort B acting between the core **10** and the magnetic material **12** vary relative to the speed of movement in a manner as shown in FIG. **2**.

More precisely, the attractive force W decreases with an increase in the speed and the braking effort B increases with an increase in the speed. The reason therefor will be briefly described hereunder. The eddy current generated in the magnetic material **12** by the movement of the magnetic flux increases with the increasing speed. Further, a counter magnetomotive force which will cancel the magnetic flux is produced in the magnetic material **12** by the eddy current. Since an increase in the eddy current is followed by a corresponding increase in the counter magnetomotive force, the flux density in the air gap between the core **10** and the magnetic material **12** decreases with an increase in the speed. Thus, the attractive force W decreases with an increase in the speed.

Further, the product of the braking effort B produced by the eddy current and the speed, that is, the energy consumed at that time is equal to the eddy current loss occurring in the rails. Accordingly, neglecting the saturation of the flux density in the rails, the eddy current loss described above is approximately proportional to the square of the speed and hence the braking effort B increases with an increase in the speed.

Data of an experiment performed by the inventors will be shown by way of example. An apparatus used in the experiment had the following specifications:

Number of coils (number of poles)		12
Number of turns per coil		95
External dimensions	−59.055×5,9055×5.9055 inches 1,500×150×150 mm.	
Airgap between pole and rail	0.255905 inch (6.5 mm.)	

Data were obtained in two cases, that is, a case in which 12 coils are divided into two coil assemblies each consisting of six coils to provide two poles, and a case in which each of the 12 coils serves as a pole to provide 12 poles.

In a stationary state of the apparatus, an 6,160 pounds (2,800 kg.) of 310 amperes is supplied to the excitation coils, while an attractive force of 4,4000 pounds (2,000 kg.) is produced when a current of 150 amperes is supplied to the excitation coils. These attractive forces decrease with an increase in the speed as shown by the one-dot chain lines W_1 and W_2 in FIG. 3. The attractive force is not influenced by the number of poles.

Regarding braking effort, there is a great variation between the braking effort in the case of two poles and that in the case of 12 poles. The braking efforts in the case of two poles are represented by the solid lines B_1 and B_2, while those in the case of 12 poles are represented by the dotted lines B_1' and B_2'. Where, B_1 and B_1' correspond to an excitation current of 310 amperes, while B_2 and B_2' correspond to an excitation current of 150 amperes.

FIGS. 4*a* and 4*b* show a preferred embodiment of the present invention based on the principle described above. A rigid frame 16 is provided with axle boxes 20 and beams 22. The axle boxes 20 support driving wheels 18 whose driving mechanism is not shown. The rigid frame 16 is connected to a truck frame 26 through axle springs 24. The truck frame 26 is connected to a car body (not shown) through bolster springs 28 and a center plate 30.

A set of electromagnetic devices 32 each comprising a core and excitation coils are mounted on the beams 22. In this case, the magnetic poles of each electromagnetic device 32 must be opposite to a rail 34 with a predetermined air gap defined therebetween. The excitation coils are energized by a suitable power source. The armature current of the driving motor may for example be utilized as the power source. This is advantageous in that the axle load of the wheels 18 can be varied depending on the torque produced by the driving motor in a manner as will be described later.

Referring to FIG. 5, the operation of the apparatus shown in FIGS. 4*a* and 4*b* having a structure as described above will be described.

In a deenergized state of the electromagnetic devices 32, an axle load W_o due to the body weight is imparted to the wheels 18. $W_o\mu$ which is the product of the axle load W_o and coefficient of adhesion μ gives the limit of adhesion at this specific instant. This is represented by the one-dot chain line in FIG. 5.

Then when the electromagnetic devices 32 are excited, an attractive force is produced between them and the rails 34. This force is transmitted to the axles through the beams 22, rigid frame 16 and axle boxes 20 with the result that the axle load of each axle is increased by Wa. The increment Wa of the axle load multiplied by the coefficient of adhesion μ, that is $Wa\mu$ can be utilized as adhesion effort. This is represented by the thin solid line in FIG. 5. As is commonly known, the coefficient of adhesion μ between the wheel 18 and the rail 34 decreases with an increase in the speed of the wheel 18.

Here, it is supposed that a braking effort F_B produced concurrently becomes equal to the adhesive effort $Wa\mu$ at a speed V_1. Addition of the increment $Wa\mu$ to the limit of adhesion $Wo\mu$ gives $(W_o + Wa)\mu$ which is represented by the two-dot chain line in FIG. 5. The sum $(Wo + Wa)\mu$ can be utilized as an adhesive tractive effort during acceleration. However, the breaking effort F_B produced concurrently acts as a reverse component against the effort $(Wo + Wa)\mu$. Accordingly, $(Wo + Wa)\mu - F_B$ can actually be utilized as the adhesive tractive effort. Thus, the apparatus shown in FIGS. 4*a* and 4*b* exhibits its marked effect in a range in which $(Wo + Wa)\mu - F_B$ is greater than $Wo\mu$, that is, in a speed range in which the speed is lower than V_1.

FIG. 6*b* shows an adhesive effort and braking effort relative to speed in the apparatus shown in FIGS. 4*a* and 4*b*. In this case, however, it is supposed that the coefficient of adhesion μ varies in a manner as shown in FIG. 6*a*.

As seen from FIG. 6*b*, the adhesive effort $F = W\mu$) becomes greater with an increase in the excitation current, but the braking effort B produced concurrently is also increased with the result that the speed at which their magnitudes are equal to each other is gradually reduced. It will be noted, however, that the adhesive effort which can be utilized at the time of starting becomes greater with an increase in the excitation current. Therefore, when the armature current of the driving motor is utilized to energize the excitation coils as previously described, the speed at which the adhesive effort and braking effort become equal to each other is raised since the armature current decreases with an increase in the speed after starting. It will thus be understood that the available speed range of the apparatus can be widened with an increase in the speed.

Further, as can be noted from the data shown in FIG. 3, the apparatus described above can be utilized as a braking device. That is to say, the number of poles may be increased so as to positively utilize the braking effort. And, this is more effective at higher speeds.

The braking effort in a high speed range of the order of 62 miles per hour (100 km.p.h. is considerably great when the electromagnetic device 32 includes 12 poles. Therefore, means may be provided to switch over the number of poles of the electromagnetic device 32 in the apparatus so that the apparatus can be operated as a means for increasing the axle load during starting and as a braking device during braking.

A circuit for accomplishing the above operation is shown in FIG. 1, in which there is provided a tachometer generator TG for producing a voltage proportional to the wheel speed, a relay 2R having normally closed switches 2*a*, 2*b* and 2*c*, and a relay 4R having normally opened switches 4*a*, 4*b* and 4*c*. The relay 2R is operative when the wheel speed is higher than a predetermined value within a speed range lower than the speed V_1 in FIG. 5, but the relay 4R is operative when the wheel speed is higher than another predetermined value within a speed range higher than the speed V_1.

If a switch is closed when starting the wheel, the relays 2R and 4R are not effected or operative since the wheel speed is lower than the predetermined value. Hence, the magnetic poles 10*a* and 10*b* are each energized with a current passed through from the upper terminal to the lower terminal thereof to produce magnetic flux in the same direction with each other, while the magnetic poles 10*c* and 10*d* are each energized with the current passed through from the lower terminal to the upper terminal to produce magnetic flux in the same direction with each other but opposite to the magnetic poles 10*a* and 10*b*. Thus, the magnetic poles 10*a*, 10*b*, 10*c* and 10*d* act as a two-pole magnetic device and, as a result, the brake effort produced is minimum at this state.

If the switch is closed when the wheel speed exceeds the predetermined value, the relays 2R and 4R become operative, and the structures 4*a*, 4*b* and 4*c* are closed while the switches 2*a*, 2*b* and 2*c* are opened. Consequently, the magnetic poles 10*a* and 10*c* produce magnetic flux in the same direction with each other but opposite to that of the magnetic poles 10*b* and 10*d*. Thus, the magnetic poles 10*a*, 10*b*, 10*c* and 10*d* act as a four-pole magnetic device and, as a result, the braking effort becomes large at this state.

While a specific embodiment of the present invention has been described in the above, it will be apparent for those skilled in the art that the present invention is in no way limited to such a specific embodiment, and various changes and modifications may be made therein without departing from the scope of the appended claims.

We claim:

1. In railway transportation facilities and the like having a rail track system and a running system running on the rail track by means of funning wheels, a system for increasing the axle load comprising an electromagnetic device disposed in one of said two systems for producing magnetic flux, and a magnetic material disposed in the other said system for producing an attractive force between said two systems by the action of said magnetic flux and a braking effort by the transfer movement of said magnetic flux, the improvement comprising means for detecting the speed of said running system, means for comparing the detected means with a predetermined speed, at which the product of the attractive force produced by said electromagnetic device and the coefficient of adhesion is greater than the braking effort produced concurrently, and means for energizing said electromagnetic device when the speed of said running system is lower than said predetermined speed.

2. A system for increasing the axle load as claimed in claim 1, further comprising means for changing the number of magnetic poles of said electromagnetic device, said changing

means including a first relay operated over a first predetermined speed and a second relay operated over a second predetermined speed higher than said first predetermined speed, the number of the magnetic poles being minimum when said first relay is operated and being maximum when said second relay is operated.

3. A system for increasing the axle load as claimed in claim 1 further comprising at least one electric motor for driving said running system, in which said electromagnetic device is disposed in said running system and said magnetic poles are energized by a current which is proportional to the current of said electric motor.

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