Abstract: A lightweight eddy current rail brake 11 to be mounted on a bogie frame of a railway car comprises a magnet unit 12 which generates an electromagnetic attraction force with respect to a rail 5 and which comprises an elongated support member 15 and a plurality of permanent magnets 17. The support member 15 is ferromagnetic and extends generally parallel to the direction in which a side beam of a bogie frame extends, and it is rotatable about a shaft which is generally parallel to this direction. A plurality of permanent magnets 17 are arranged on the support member 15 in series and are spaced above a rail 5. At least two adjoining permanent magnets 17 of the plurality of permanent magnets 17 are arranged so as to have different polarities from each other.
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Description

Eddy Current Rail Brake

Technical Field

This invention relates to an eddy current rail brake of permanent magnet type for decelerating a moving railway vehicle without contacting a rail.

Background Art

Adhesion-type braking devices (referred to below as a adhesive brakes) which utilize the frictional force (referred to below as adhesion) between rails and wheels have been much used as braking devices for railway vehicles for high-speed rail lines such as the bullet trains in Japan called Shinkansen, railway vehicles on conventional (ordinary speed) railway lines, streetcars, and the like. The maximum braking force generated by an adhesive brake is determined by the strength of adhesion. If a large braking force exceeding the maximum braking force of a wheel is applied to the wheel, the wheel slides on a rail instead of rolling, and an adhesion is no longer obtained. This causes the braking distance of a railway vehicle to be greatly increased.

Under the laws of Japan, it was required by regulations governing construction that a bullet train had a prescribed deceleration. For a railway car for a conventional railway line, it was required that the car could be stopped within 600 meters after the operation of an emergency brake. In recent years, there have been plans for higher speeds for both bullet trains and trains on conventional railway lines. Therefore, it is necessary to further increase the braking force of both bullet train rail cars and rail cars for conventional railway lines.

A rail brake-type braking device (referred to below as a rail brake) has been proposed in the art. A rail brake is a braking device which is used in combination with an adhesive brake. It obtains a braking force for a rail car directly from the rails by applying brakes from a braking device mounted on a bogie (also called truck) to a rail. Rail brakes can be generally classified as (a) adsorption types, (b) eddy current types, and (c) adsorption/eddy current types which operate an eddy current type rail brake as an adsorption type rail brake.

Figure 8(a) is a perspective view showing one example of an
adsorption/eddy current rail brake, Figure 8(b) is a front view of one example of this rail brake, and Figure 8(c) is an explanatory view schematically showing the generation of eddy currents in the head of a rail at the time of braking with this rail brake.

As shown in Figures 8(a) and 8(b), with an adsorption/eddy current rail brake, a magnet unit 4 is suspended so as to be able to be raised and lowered by a raise and fall (up and down) device 3 (such as a hydraulic cylinder or a pneumatic cylinder) mounted on a side beam 2 of a bogie frame which supports wheels 1, 1. A plurality of electromagnets 4a are installed in the magnet unit 4 in a row extending in the same direction as the side beam 2 (to the left and right in Figure 8(b)). The pole face on the bottom of each electromagnet 4a is oriented toward the top surface of the head of the rail 5. Brake shoes 4b are mounted on the pole faces of the electromagnets.

At the time of braking of a rail car, the magnet unit 4 of this rail brake is lowered by the raise and fall device 3, and the brake shoes 4b are pressed against the top surface of the head of the rail 5. At the same time, electric current is passed through exciting coils wound around the poles of each electromagnet 4a so as to generate a magnetic flux in the pole cores of the electromagnets 4a, and eddy currents C shown in Figure 8(c) are generated in the rail 5 due to the relative speed of the bogie frame and the rail 5. A braking force which acts on the bogie frame is produced by the electromagnetic attraction force which is generated between the rail 5 and the cores of the electromagnets 4a.

Since an adsorption/eddy current rail brake also employs the braking force generated by friction between the rail 5 and the brake shoes 4b, it is difficult to obtain a stable braking force during rain or snow. In addition, an adsorption/eddy current rail brake converts kinetic energy into thermal energy caused by friction between the brake shoes 4b and the rail 5 in the same manner as an adsorption rail brake, and the thermal energy is dispersed into the rail 5. Therefore, this type of contacting rail brake is capable of damaging the rail 5.

In order to obtain the same braking force as an adsorption/eddy current rail brake, a non-contacting eddy current rail brake which does not use brake shoes must compensate for the braking force generated by friction with a rail in an adsorption/eddy current rail brake by employing alternative means, such as by increasing the number of windings of electromagnets. Therefore, the weight (mass)
of a non-contacting eddy current rail brake is unavoidably increased, and as its weight increases, the inertia of a bogie also increases, which may make it necessary to further increase the braking force.

An adsorption rail brake, an eddy current rail brake, and an adsorption/eddy current rail brake each use electromagnets to obtain a braking force. It is necessary to pass current through exciting coils in order for these rail brakes to generate a braking force. Normally, this current is provided by batteries which are mounted on a rail car as an emergency power supply. Therefore, the overall weight of these rail brakes increases since it is necessary to increase the capacity of the emergency power supply.

Thus, it is difficult to reduce the overall weight of a rail car using rail brakes of the adsorption type, the eddy current type, and the adsorption/eddy current type which have been proposed in the past.

Patent Document 1 discloses an eddy current rail brake which has a low probability of damaging rails and is not easily affected by the weather. In this rail brake permanent magnets are used instead of electromagnets.

Figure 9(a) is a front view of an eddy current rail brake using permanent magnets which is disclosed in Patent Document 1, Figure 9(b) is an enlarged view showing the main portions of this eddy current rail brake at the time of non-braking, and Figure 9(c) is an enlarged view showing the main portions of this eddy current rail brake at the time of braking.

As shown in Figures 9(a) - 9(c), a magnet unit 4 of an eddy current rail brake using permanent magnets disclosed in Patent Document 1 is suspended from a bogie frame 2. Permanent magnets 6 are rotatably mounted so as to be able to rotate about horizontal axes 7 which are perpendicular to the direction in which the side beam 2 of the bogie frame extends.

In the braking state shown in Figure 9(c), the pole faces of the south poles and the pole faces of the north poles of the permanent magnets 6 are parallel to the rail 5, and in non-braking state shown in Figure 9(b), the permanent magnets 6 are rotated by 90° with respect to the braking state shown in Figure 9(c). In the eddy current rail brake disclosed in Patent Document 1, the permanent magnets 6 are rotated by 90° in both directions by a rotating mechanism 8 through pole core 9. The rotating mechanism 8 comprises a crank 8a which pivots about an axis 7, and a link mechanism 8b which is connected to the crank 8a. As a result, switching is
performed between the braking state shown in Figure 9(c) and the non-braking state shown in Figure 9(b).

In the permanent magnet eddy current rail brake disclosed in Patent Document 1, it is purported that the size and capacity of an emergency battery on a rail car can be reduced because it is not necessary to supply current to coils of electromagnets from a battery and that the weight of an eddy current rail brake according to that invention can be decreased.


Summary of Invention

At the time of braking shown in Figure 9(c), the flux which emanates from the pole faces of the permanent magnets 6 passes from the pole core 9 through the gap 10 between the rail 5 and the pole core 9 and enters the rail 5, and it returns to the permanent magnets 6 from the rail 5 by passing through the gap 10 between the rail 5 and the pole core 9 and then through the pole core 9.

The flux from the permanent magnets 6 is in effect detoured through the gap 10 and the pole core 9, and as the flux passes through the pole core 9, the flux density decreases due to reluctance (magnetic resistance), resulting in a decrease in the braking efficiency. In addition, since the flux tries to pass along the shortest path, a magnetic short circuit is formed in portions of the magnets opposite from the surface opposing the rail 5, leading to a further decrease in the braking efficiency.

In the eddy current rail brake using permanent magnets 6 which is disclosed in Patent Document 1, it is necessary to have a pole core 9 which surrounds the permanent magnets 6. The pole core 9 produces an unavoidable increase in the overall weight of the rail brake. In addition, the eddy current rail brake disclosed in Patent Document 1 cannot control the magnitude of the braking force which it generates to a desired degree.

The present invention is an eddy current rail brake having a magnet unit which is mounted on a bogie frame of a railway car and which generates a magnetic attraction force with respect to a rail, characterized in that (a) the magnet unit comprises an elongated support member and a plurality of permanent magnets, (b) the support member is ferromagnetic and is installed such that it extends in a direction generally parallel to the direction in which a side beam of the bogie frame
extends and can rotate about an axis which is generally parallel to this direction, (c) the plurality of permanent magnets are installed on the support member in series in the above-described direction with their poles faces spaced above the rail, and (d) of the plurality of permanent magnets, at least two adjoining permanent magnets are arranged so as to have different (i.e., opposite) polarities from each other.

In a preferred embodiment of the present invention, (e) all the permanent magnets are disposed such that each permanent magnet has a different polarity from the adjoining permanent magnets, (f) in a braking state, the pole faces of the permanent magnets are disposed so as to face (or orient toward) the top surface of the head of the rail, and (g) in a non-braking state, the pole faces of the permanent magnets are disposed so as to not face (not orient toward) the top surface of the head of the rail. In this manner, a maximum braking force can be obtained.

In another preferred embodiment of the present invention, (h) in a cross section perpendicular to the above-described generally parallel direction, the pole faces of the permanent magnets have an outline constituted by a straight line portion positioned at the center of each pole face and two curved portions positioned on both sides of the straight line portion, and (i) in a cross section perpendicular to the above-described generally parallel direction, the shape of the two curved portions matches the shape of an arc drawn by the permanent magnets when the support member is rotated. As a result, a large braking force can be guaranteed at the time of braking, and the support member can be easily rotated at the time of braking.

In a further preferred embodiment of the present invention, (j) the rail brake further comprises a protective cover formed from a ferromagnetic material and positioned on the side of the magnet unit, and (k) the protective cover surrounds the pole faces of the permanent magnets at least in a non-braking state. The protective cover can prevent magnetic leakage and can prevent impact of the permanent magnets with objects and attraction of small falling magnetic objects to the permanent magnets.

In a still further preferred embodiment of the present invention, (l) the support member comprises a support plate having the shape of the letter L in a cross section perpendicular to the above-described generally parallel direction, and (m) in a non-braking state, the support plate faces the top surface of the head of the rail. As a result, the generation of a braking force due to magnetic leakage at the time of
non-braking can be prevented with certainty.

According to the present invention, as it is not necessary to have a pole core which surrounds permanent magnets, it is possible to provide an eddy current rail brake using permanent magnets which is lightweight and has excellent mountability and which has a braking force which can be easily controlled.

Brief Explanation of the Drawings

Figure 1(a) is a perspective view showing a magnet unit which is a component of an eddy current rail brake according to the present invention, Figure 1(b) is a perspective view of the magnet unit with a protective cover removed and with one bracket eliminated, and Figure 1(c) is a front view of the magnet unit with the protective cover removed.

Figures 2(a) - 2(d) are explanatory views showing two adjoining permanent magnets when switching from braking to non-braking with the passage of time in an eddy current rail brake according to the present invention.

Figure 3 is a cross-sectional view showing one example of the cross-sectional shape of a permanent magnet of the magnet unit of an eddy current rail brake using permanent magnets according to the present invention.

Figure 4 is a graph showing the braking force found by electromagnetic field analysis for an eddy current brake of the electromagnet disc-type, an electromagnet rail brake as shown in Figure 8, and an eddy current rail brake according to the present invention using permanent magnets.

Figure 5 is an explanatory view showing a model of an eddy current rail brake using permanent magnets according to the present invention which was used in the analysis shown in Figure 4.

Figure 6(a) is an explanatory view of a flat plate-shaped yoke, Figure 6(b) is an explanatory view of an L-shaped yoke, and Figure 6(c) is a graph showing the braking force accompanying magnetic leakage and the braking force at the time of braking for the yoke shown in Figure 6(a) and the yoke shown in Figure 6(b).

Figure 7 is a graph which compares the weight (mass) of parts constituting a magnetic circuit for an electromagnet disc-type eddy current brake, an electromagnet rail brake as shown in Figure 8, and an eddy current rail brake using permanent magnets according to the present invention.

Figure 8(a) is a perspective view showing one example of an
adsorption/eddy current rail brake, Figure 8(b) is a front view of one example of this rail brake, and Figure 8(c) is an explanatory view schematically showing the state of generation of an eddy current in the head of a rail at the time of braking with this rail brake.

Figure 9(a) is a front view showing an eddy current rail brake using permanent magnets which is disclosed in Patent Document 1, and Figure 9(b) is an enlarged view showing the main portions of this eddy current rail brake at the time of non-braking, and Figure 9(c) is an enlarged view of the main portions of this eddy current rail brake at the time of braking.

In the Drawings:


Detailed Description of Embodiments of the Invention

Below, the present invention will be explained with respect to preferred embodiments while referring to the attached drawings.

Figure 1(a) is a perspective view showing a magnet unit 12 which is a component of an eddy current rail brake 11 according to the present invention, Figure 1(b) is a perspective view showing the magnet unit 12 with a protective cover 13 removed and with one bracket 14b omitted, and Figure 1(c) is a front view showing the magnet unit 12 with the protective cover 13 removed.

As shown in Figures 1(a) - 1(c), a magnet unit 12 of this embodiment of an eddy current rail brake according to the present invention includes a yoke 15 which is a ferromagnetic support member, and two brackets 14a and 14b which rotatably support shafts 16 which are coaxially disposed at both lengthwise ends of the yoke 15.

The yoke 15 is a support plate made of a ferromagnetic material and supports a plurality of permanent magnets 17 which are arranged in series and secured to the yoke.
The plurality of permanent magnets 17 are disposed so that each permanent magnets 17 has a different (opposite) polarity from each of the adjoining permanent magnets 17.

The permanent magnets 17 are preferably rare earth magnets such as Nd-Fe-B magnets and most preferably Neomax-50 (trade name) magnets having a maximum energy product \((BH)_{\text{max}}\) of approximately 422 - 389 (kj-m\(^3\)).

The two brackets 14a and 14b are mounted and secured by welding or other suitable bonding method to an unillustrated bogie frame (such as the outer wall surface of a side beam of the frame) so that the pole faces 17a of the permanent magnets 17 can face the top surface of the head 5a of the rail 5 and so that the shafts 16 provided on the yoke 15 are aligned in the lengthwise direction of the rail 5. The spacing between the pole face of each magnet and the rail is preferably in the range of from 5 mm to 15 mm.

A rod 19 having a trunnion 18 provided thereon is provided at the lengthwise center of the yoke 15. The rod 19 supports the yoke 15 through a link 20 which is provided at its end.

The rod 19 can be rotated about the trunnion 18 by advancing and retracting an unillustrated pneumatic cylinder. As a result, the yoke 15 which is rotatably connected to the link 20 at the end of the rod 19 can be rotated by 90° in both directions about the shafts 16 to switch the eddy current rail brake 11 according to the present invention between a braking and non-braking state.

Figures 2(a) - 2(d) are explanatory views of two adjoining permanent magnets 17 showing the state of switching between braking and non-braking state with the passage of time in an eddy current rail brake 11 according to the present invention. The heavy arrows in Figures 2(a) - 2(d) indicate the direction of travel of a rail car.

As shown in Figure 2(a), at the time of braking, two permanent magnets 17 in a magnet unit 12 of an eddy current rail brake according to the present invention are disposed so that their pole faces 17a both face towards the top surface of the head 5a of the rail 5. This produces the largest braking force.

By operating the unillustrated air cylinder, the yoke 15 is gradually rotated around the two shafts 16 from the braking state shown in Figure 2(a). As the yoke 15 rotates, the two permanent magnets 17 supported by the yoke 15 also gradually rotate as shown in Figure 2(b) and Figure 2(c) so that the pole faces 17a of the two
permanent magnets 17 no longer face the top surface of the head 5a of the rail 5.

A braking force is produced even when the two permanent magnets 17 are in positions like those shown in Figures 2(b) and 2(c). Therefore, an eddy current rail brake 11 according to the present invention can adjust the magnitude of the braking force which is generated by suitably adjusting the rotational angle of the yoke 15 and adjusting the direction in which the pole faces 17a of the two permanent magnets 17 is directed.

As shown in Figure 2(d), by rotating the yoke 15 by 90° from the position shown in Figure 2(a) and making the pole faces 17a of the permanent magnets 17 face in a direction at 90° to the direction facing the top surface of the head 5a of the rail 5, a non-braking state can be achieved in which the braking force generated by an eddy current rail brake 11 according to the present invention is zero.

Thus, in an eddy current rail brake 11 according to the present invention, switching between braking and non-braking is performed by rotating the yoke 15 so as to rotate the permanent magnets 17. As a result, the magnetic path between the pole faces 17a of the permanent magnets 17 and the head 5a of the rail 5 can be minimized. Therefore, an eddy current rail brake 11 according to the present invention can increase magnetic efficiency and decrease the overall weight of the eddy current rail brake 11.

Figure 3 is a cross-sectional view showing one example of the cross-sectional shape of a permanent magnet 17 of the magnet unit 12 of an eddy current rail brake 11 according to the present invention.

Reference number 13 in Figure 3 indicates a protective cover of a magnetic material which surrounds the pole faces 17a of the permanent magnets 17 when the plurality of permanent magnets 17 arranged in series on the yoke 15 are in a non-braking state. In a non-braking state, the protective cover 13 can protect the pole faces 17a from being impacted by objects and from attracting small falling objects of a magnetic material. In addition, the protective cover 13 can prevent magnetic leakage at the time of non-braking.

As shown in Figure 3, the cross-sectional shape of the pole face 17a of each permanent magnet 17 facing the top surface of the head 5a of the rail 5 in a braking state as viewed in the direction of travel of a rail car preferably comprises a combination of a straight line portion Ls at the center of the cross section and two curved portions Lc on both sides of the straight line portion Ls. The two curved
portions Lc are preferably circular arcs matching a circular arc which is the path of rotation of the permanent magnet 17 at the time of switching between braking and non-braking.

In Figure 3, when the width of the rim of a wheel is 125 mm, the width of the head 5a of the rail 5 is 65 mm, and the spacing between the permanent magnet 17 and the rail 5 is 10 mm, the length of the straight line portion Ls of the pole face 17a of the permanent magnet 17 is preferably more than one-half of the width (65 mm) of the head 5a, such as 35 mm.

In Figure 3, the diameter of a circular arc (coinciding with the two curved portions Lc) which is the path of rotation of the permanent magnet 17 at the time of switching between braking and non-braking is preferably 96\% or somewhat smaller, for example, 120 mm, when the width of the rim of the wheel (such as 125 mm) is made an upper limit.

Furthermore, as shown in Figure 3, the center of the cross section of the pole face 17a of a permanent magnet 17 as viewed in the direction of travel of a rail car preferably coincides with the center of the rail 5 as viewed in the same direction.

In a system like the conventional eddy current rail brake using permanent magnets which was explained while referring to Figure 9 in which permanent magnets 6 are moved in the vertical direction of a rail car, a large force sufficient to overcome the attractive force of the permanent magnets 6 is necessary in order to separate the permanent magnets 6 from the rail by moving them in the vertical direction.

In contrast, in an eddy current rail brake 11 according to the present invention, it is sufficient to rotate the yoke 15 which supports the permanent magnets 17 about the shafts 16 functioning as an axis of rotation. Therefore, with an eddy current rail brake 11 according to the present invention, it is possible to move the permanent magnets 17 which generate a magnetic attraction force with respect to the rail 5 away from the rail 5 with a small force.

In addition, with an eddy current rail brake 11 according to the present invention, due to the repulsive force which accompanies an eddy current generated in a rail 5 during travel, it is possible to switch between braking and non-braking with a further decreased force.

According to the present invention, as it is not necessary to use a pole core surrounding permanent magnets 17, an eddy current rail brake 11 using permanent
magnets 17 can be provided which is lightweight, which has excellent mountability, and which can easily control the braking force.

Example 1

The present invention will be illustrated by the following example, which is solely intended for illustration.

In order to confirm the effects of the present invention, a conventional eddy current brake of the electromagnet disc-type (such as the eddy current brake proposed in Japanese Patent No. 2635573), an electromagnet rail brake as shown in Figure 8, and an eddy current rail brake according to the present invention were compared.

Figure 4 is a graph showing the relative braking force as a function of relative speed for each type of brake obtained by electromagnetic field analysis. The relative speed on the abscissa in the graph of Figure 4 uses 360 km/hr as a standard (speed value = 1.0 at 360 km/hr), and the relative braking force on the ordinate uses 6 kN as a standard (braking force value = 1.0 at 6 kN).

The following conditions were set for the magnetic field analysis.

Electromagnet disc-type eddy current brake
- disc material: same material as the rail
- disc diameter: 710 mm
- disc thickness: 36 mm
- maximum current: 770 A
- windings: 24 (T) electromagnets, 4 poles, 2 pairs
- gap between magnets and disc: 12 mm

Electromagnet rail brake
- yoke: overall length of 1000 mm, width of 60 mm, height of 120 mm
- electromagnets: electromagnets measuring 250 mm x 100 mm were mounted on the above-described yoke
- maximum current: 315 A
- winding: 104 (T), 8 poles
- gap between magnets and rail: 5 mm
Figure 5 is an explanatory view showing a model of an eddy current rail brake 11 according to the present invention used in the analysis of Figure 4.

In an eddy current rail brake 11 according to the present invention, 14 permanent magnets 17 having a cross-sectional shape like that shown in Figure 3 (width of 118 mm, height of 60 mm) were disposed on the yoke 15 shown in Figure 5 having an overall length of 1152 mm, a width of 118 mm, and a height of 20 mm so that the adjoining permanent magnets 17 had different polarities from each other. The gap between the permanent magnets 17 and the rail 5 was 10 mm.

Three-dimensional electromagnetic field analysis was employed in the investigation of the braking force of each braking device at the time of braking and of the braking force accompanying magnetic leakage, which is a characteristic problem of permanent magnets. The rail 5 was made of carbon steel for mechanical structural purposes (S50C), and structural members such as the yoke 15 and the protective cover 13 were made of rolled steel for general structural purposes (SS400).

The braking force for one bogie having two rail brake units is found by multiplying the maximum axial weight at the normal riding brake capacity (26 tons = 13 tons x 2) by the average rate of deceleration (0.416 m/s/s), and this value was approximately 10.8 kN per bogie or approximately 5.4 kN per rail brake unit.

As is clear from the graph shown in Figure 4, although a large braking force was obtained by the electromagnetic disc-type eddy current brake ("x" marks), the higher was the speed, the more marked was the decrease in braking force. The electromagnet rail brake ("o" or blank circle marks) had an increase in braking force as the speed increased, but in spite of the gap between the magnet and the rail being a small value of 5 mm, the braking force was small compared to the electromagnet disc-type eddy current brake.

In contrast, although an eddy current rail brake 11 according to the present invention (solid circle marks) maintained nearly the same gap of 10 mm between the permanent magnets 17 and the rail 5 as the electromagnet disc-type, an adequate braking force was obtained even at high speeds.

Figure 6(a) is an explanatory view of a yoke 15 having the shape of a flat plate as shown in Figures 1(a) - 1(b), Figures 2(a) -2(d) and Figure 3. Figure 6(b) is an explanatory view of an L-shaped yoke 15, and Figure 6(c) is a graph showing the braking force accompanying magnetic leakage and the braking force at the time
of braking for the flat yoke 15 shown in Figure 6(a) and the L-shaped yoke 15 shown in Figure 6(b).

The relative speed on the abscissa of the graph of Figure 6(c) uses 360 km/hr as a standard (speed value = 1.0 at 360 km/hr), the relative braking force on the left-hand ordinate uses 6 kN as a standard (braking force value = 1.0 at 6kN), and the relative braking force accompanying magnetic leakage on the right-hand ordinate uses 0.1 kN as a standard (braking force value = 1.0 at 0.1 kN).

In an eddy current rail brake 11 according to the present invention, instead of giving the yoke 15 the above-described flat plate shape shown in Figure 6(a), it may be formed with the L shape shown in Figure 6(b). In this case, at the time of braking, the pole faces 17a of the permanent magnets 17 are preferably made to face towards the top surface of the head 5a of the rail 5, and at the time of non-braking, the L-shaped yoke 15 is preferably made to face the top surface of the head 5a of the rail 5.

As shown by the graph in Figure 6(c), by forming the yoke 15 with an L shape, the braking force generated at the time of non-braking due to magnetic leakage can be greatly decreased compared to a flat plate-shaped yoke 15, and the decrease in the braking force due to magnetic leakage at the time of braking can also be decreased. In addition, it is possible to obtain a nearly constant braking force in a speed range in which the relative speed is 0.44 to 1.0.

Figure 7 is a graph comparing the weight (or mass) of various components constituting a magnetic circuit for an electromagnet disc-type eddy current brake, an electromagnet rail brake as shown in Figure 8, and an eddy current rail brake 11 according to the present invention.

As shown in the graph of Figure 7, an eddy current rail brake 11 according to the present invention can realize a decrease in weight of approximately 68% with respect to an electromagnet disc-type eddy current brake, and it can realize a decrease in weight of at least 29% with respect to an electromagnet rail brake since the electromagnet rail brake studied here has a small gap of 5 mm between the magnets and the rail 5 and has a low braking force.

Although the present invention has been described with respect to preferred embodiments, they are mere illustrative and not intended to limit the present invention. It should be understood by those skilled in the art that various modifications of the embodiments described above can be made without departing
from the scope of the present invention as set forth in the claims.

For example, a plurality of permanent magnets 17 are preferably arranged in series on a yoke 15 such that each permanent magnet 17 has a different polarity from the adjoining permanent magnets 17, but the present invention is not limited to this arrangement, and a plurality of permanent magnets 17 can be arranged so that at least two adjoining permanent magnets 17 have different polarities from each other.

In addition, in the above-mentioned embodiments, a protective cover 13 is installed on one side of the magnet unit 12 so as to cover the pole faces 17a of the permanent magnets 17 in a non-braking state, but a protective cover 13 may be provided on both sides of the magnet unit 12.
Claims

1. An eddy current rail brake which is mounted on a bogie frame of a railway car and which has a magnet unit which generates a magnetic attraction force with respect to a rail, characterized in that:

the magnet unit comprises an elongated support member and a plurality of permanent magnets,

the support member is ferromagnetic and is installed such that it extends in a direction generally parallel to the direction in which a side beam of the bogie frame extends and can rotate about an axis which is generally parallel to the direction in which the side beam extends,

the plurality of permanent magnets are installed on the support member in series in said generally parallel direction with their poles faces spaced above the rail, and

of the plurality of permanent magnets, at least two adjoining permanent magnets are arranged so as to have different polarities from each other.

2. An eddy current rail brake as set forth in claim 1, characterized in that:

the plurality of permanent magnets are arranged so that each of the permanent magnets has a different polarity from the adjoining permanent magnets,

at the time of braking, the pole faces of the permanent magnets are arranged so as to face the top surface of the head of the rail, and

at the time of non-braking, the pole faces of the permanent magnets are arranged in positions which do not face the top surface of the head of the rail.

3. An eddy current rail brake as set forth in claim 1 characterized in that:
in a cross section which is perpendicular to said generally parallel direction, the pole faces of the permanent magnets have an outline constituted by a straight line portion positioned in the center and two curved portions positioned on both sides of the straight line portion, and

in a cross section which is perpendicular to said generally parallel direction, the shape of the two curved portions coincides with the shape of a circular arc drawn by the permanent magnet when the support member is rotated.
4. An eddy current rail brake as set forth in claim 1 characterized in that:
it includes a protective cover of a ferromagnetic material which is disposed
on a side of the magnet unit, and
the protective cover covers the pole faces of the permanent magnets at least
in a non-braking state.

5. An eddy current rail brake as set forth in claim 1 characterized in that:
the support member comprises a support plate having an L shape in a cross
section which is perpendicular to said generally parallel direction, and
in a non-braking state, the support plate faces the top surface of the head of
the rail.
Fig. 5