

VIBRATION DAMPING APPARATUS AND FERRIS WHEEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a vibration damping apparatus that suppresses vibrations of structures.

2. Description of the Related Art

A damper fixed to a fixing unit and a stockbridge damper are known as apparatuses for preventing vibrations of cables, and are widely put into practical use and commercially produced. However, because the dampers do not include a vibration frequency adjusting function, they cannot flexibly respond to the vibration frequency of an object whose vibrations are to be damped. For example, to use the damper fixed to a fixing unit, a cable fixing unit needs to be changed from the structure. Accordingly, a large-scale work needs to be done on the existing cable. Because the damper is installed on a cable fixing unit with a small mode, regardless of the vibration mode of the cable, which is an object whose vibrations are to be damped, the damping effect is small compared with the scale of the damper fixed to the fixing unit.

The stockbridge damper does not have any vibration suppressing function except to absorb vibration energy by

the element wire friction loss, due to bending or twisting of steel twisted wires. Accordingly, there is a limit to improving the vibration damping effect. The stockbridge damper depends largely on the damping effect caused by the vibration amplitude of a cable. If the vibration amplitude of the cable is increased, the weight swings in a large arc, and bends the steel twisted wires sharply. Consequently, when the stockbridge damper is used, the steel twisted wires tend to wear easily.

A cantilever-type dynamic absorber with leaf springs is known as a vibration damping apparatus including a vibration frequency adjusting function. For example, Japanese Patent Application Laid-open No. S59-110938 (lower left section to lower right section in p. 2) discloses a cantilever-type dynamic absorber with leaf springs in which one end of leaf springs equal to or more than two arranged in a predetermined interval on a surface perpendicular to the direction of vibrations that should be controlled is fixed with a fixing bracket, a weight is position-adjustably fixed on the other end of the leaf springs, and a viscoelastic body or a viscous damper is bonded between the two leaf springs.

SUMMARY OF THE INVENTION

It is an object of the present invention to at least

partially solve the problems in the conventional technology.

According to an aspect of the present invention, a vibration damping apparatus includes: a vibration damping body that includes a pair of spring members arranged opposite to each other and a viscoelastic body sandwiched by the spring members; a first connecting unit that connects the pair of spring members to each other at a side of one end of the vibration damping body; a second connecting unit that connects the pair of spring members to each other at a side of other end of the vibration damping body; and a vibration input member that is mounted on the vibration damping body by the first connecting unit, and transmits vibration from an object whose vibration is to be damped to the vibration damping body.

A vibration damping apparatus according to the present invention includes a vibration damping body that sandwiches a viscoelastic body by a pair of spring members and connects and fixes both ends of the pair of spring members, and mounts one end of the vibration damping body on an object whose vibrations are to be damped. Accordingly, the vibration damping apparatus according to the present invention can generate a vibration damping force larger than that of the dynamic absorber disclosed in the Japanese Patent Application Laid-open No. S59-110938, if the apparatus main bodies are made of the same material and

having the same size. Consequently, when the same material as that of the dynamic absorber disclosed in the Japanese Patent Application Laid-open No. S59-110938 is used, the vibration damping apparatus according to the present invention can provide required vibration damping capabilities, while further reducing the size of the apparatus main body.

Advantageously, the vibration damping apparatus further includes a weight at a side of another end of the vibration damping body. With this, the vibration damping apparatus can be easily adjusted to the frequency of the vibrations to be suppressed.

Advantageously, in the vibration damping apparatus, the weight is mounted on the vibration damping body by the second connecting unit. In this manner, the number of components of the vibration damping apparatus can be reduced, and the cost can be lowered, by mounting a weight on the vibration damping body by using a second connecting unit that connects the pair of spring members.

Advantageously, the vibration damping apparatus includes a plurality of such vibration damping bodies that has a different distance from the vibration input member to the weight. With this, each of the vibration damping bodies can be adjusted so as to suppress the vibrations of different frequencies. Accordingly, it is possible to

suppress a plurality of vibrations with different frequencies at the same time.

Advantageously, in the vibration damping apparatus, the vibration damping bodies are mounted on a same object whose vibration is to be damped, and receive vibration from a same position of the object. With this, the freedom to mount the vibration damping apparatus can be improved. Accordingly, even if the location at which the vibration damping apparatus can be mounted is limited by the restrictions of the size and the shape of an object whose vibrations are to be damped, the vibration damping apparatus can be easily mounted on the object whose vibrations are to be damped.

Advantageously, the vibration damping apparatus includes a plurality of such vibration damping bodies whose swinging direction is different from each other. With this, the vibrations in the different directions can be suppressed at the same time.

Advantageously, in the vibration damping apparatus, an object whose vibration is to be damped is a wire rope. Wire ropes are flexible and easy to bend compared with columnar-like and rod-like structures. Accordingly, vibrations are easily generated by the surrounding environment, and the amplitude of the generated vibrations tends to increase. The vibration damping apparatus

according to the present invention can generate a large vibration damping force, by including the vibration damping body that sandwiches a viscoelastic body by a pair of spring members, and connects and fixes the both ends of the pair of spring members. With this, the vibrations generated on the wire ropes can be advantageously suppressed. The vibration damping apparatus according to the present invention can also reduce the size of the apparatus main body, if the vibration suppression capability is the same as that of the conventional one. Consequently, it is possible to reduce the load applied to the wire ropes, which is an object whose vibrations are to be damped.

According to another aspect of the present invention, a Ferris wheel includes: a hub; an outer ring connected to the hub by a wire rope, and to which a gondola is mounted on a periphery; and the vibration damping apparatus described above. The vibration input member is mounted on the wire rope. With this, the vibrations of the wire ropes can be advantageously suppressed.

Advantageously, in the Ferris wheel, the vibration damping apparatus is mounted at a side of the outer ring. With this, the vibration damping apparatus can be mounted on the wire at the position closer to the ground. Accordingly, the work can be performed with ease.

Advantageously, in the Ferris wheel, the wire rope is mounted so as to swing in one direction with respect to the outer ring and the hub, and the vibration damping apparatus is mounted so as to swing in a direction perpendicular to a direction in which the wire rope swings. With this, only the vibrations in the direction in which the wire rope cannot swing are suppressed. Accordingly, the number of the vibration damping apparatus mounted on one wire rope can be reduced, thereby lowering the cost.

The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an overall view of a vibration damping apparatus according to an embodiment of the present invention;

Fig. 2 is a fragmentary view taken in the direction of arrows along a line Y-Y of Fig. 1;

Fig. 3 is a fragmentary view taken in the direction of arrows along a line X-X of Fig. 1;

Fig. 4A is a schematic of deflection of a cantilever

beam;

Fig. 4B is a schematic of deflection of a beam in which both ends are fixed and one of fixed supports is settled;

Fig. 5 is a schematic of vibration modes of an object whose vibrations are to be damped;

Fig. 6 is an overall view of a vibration damping apparatus according to a first modification of the present embodiment;

Fig. 7 is a fragmentary view taken in the direction of arrows along a line Y-Y of Fig. 6;

Fig. 8 is an overall view of a vibration damping apparatus according to a second modification of the present embodiment;

Fig. 9 is an overall view of a vibration damping apparatus according to a third modification of the present embodiment;

Fig. 10 is a schematic of the vibration damping apparatus according to the third modification of the present embodiment, viewed from a direction of an arrow Z of Fig. 9;

Fig. 11 is a front view of a Ferris wheel;

Fig. 12A is a schematic of a state when the vibration damping apparatus according to the present embodiment is mounted on the wire that forms the Ferris wheel; and

Fig. 12B is a schematic of another state when the vibration damping apparatus according to the present embodiment is mounted on the wire that forms the Ferris wheel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Exemplary embodiments of the present invention are described below in greater detail with reference to the accompanying drawings. However, the present invention is not limited to the preferred embodiments (hereinafter, embodiments) described below. The constituents of the embodiments described below include those that can be easily imagined by those skilled in the art, or those substantially the same, in other words, those that fall within the range of equivalents.

The features of the vibration damping apparatus according to an embodiment of the present invention are to include a vibration damping body that sandwiches a viscoelastic body or a viscous body by a pair of spring members (such as leaf springs), and connects and fixes both ends of the pair of spring members, and to mount one of the ends of the vibration damping body on an object whose vibrations are to be damped.

Fig. 1 is an overall view of the vibration damping apparatus according to the embodiment of the present

invention. Fig. 2 is a fragmentary view taken in the direction of arrows along a line Y-Y of Fig. 1. Fig. 3 is a fragmentary view taken in the direction of arrows along a line X-X of Fig. 1. A vibration damping apparatus 1 is suitable for suppressing vibrations of wire ropes (such as a wire, a rope, a single wire, twisted wires, and a cable), and in the present embodiment, an object whose vibrations are to be damped is a wire 100. The object whose vibrations are to be damped by the vibration damping apparatus 1 is not limited to the wire ropes, but may be for example, rod-like and columnar-like structures.

As shown in Fig. 1, the vibration damping apparatus 1 is mounted on the wire 100, which is an object whose vibrations are to be damped. The wire 100 is metal twisted wires, and for example, used to connect the hub and the outer ring of a Ferris wheel, or used as a hanger rope that connects between the main cable and the bridge girder of a suspension bridge. The vibration damping apparatus 1 is mounted on the wire 100, by sandwiching the wire 100 between a vibration input member 11 and a fixture 3 mounted on a vibration damping body 10. In this manner, the vibration damping body 10 and the wire 100 are connected to each other via the vibration input member 11. Accordingly, vibrations of the wire 100 are fed into the vibration damping body 10, via the vibration input member 11. The

vibration input member 11 and the vibration damping body 10 are connected by a safety rope 4, thereby preventing the vibration damping body 10 from falling out from the vibration input member 11.

As shown in Fig. 1, the vibration damping apparatus 1 provides the vibration damping bodies 10 at both sides of the wire 100, respectively. The vibration damping bodies 10 are arranged symmetric to the wire 100. In this manner, because the pair of vibration damping bodies 10 is arranged at both sides of the wire 100, the balance of the vibration damping apparatus 1 is improved. As a result, the bending force applied to a mounting unit of the vibration damping apparatus 1 on the wire 100 can be suppressed, thereby advantageously suppressing the durability of the wire 100 from being lowered.

As shown in Figs. 2 and 3, the vibration damping apparatus 1 includes the vibration damping bodies 10, bolts 12B and nuts 12N that are a first connecting unit, bolts 16B and nuts 16N that are a second connecting unit, and the vibration input member 11. The vibration damping bodies 10 are formed by a pair of spring members 13 arranged opposite to each other that sandwiches a viscoelastic body 14 therebetween. The pair of spring members 13 includes a first spring member 13A and a second spring member 13B. In the present embodiment, the first spring member 13A and the

second spring member 13B are both leaf springs, and are the same size, the same shape, and formed of the same material.

The viscoelastic body 14 held between the pair of spring members 13, which is the first spring member 13A and the second spring member 13B, is adhered on the pair of spring members 13. Accordingly, the pair of spring members 13 and the viscoelastic body 14 deform as a unit. The viscoelastic body 14 deforms because the vibration damping body 10 is swung by the vibrations of an object whose vibrations are to be damped. When the viscoelastic body 14 is deformed, kinetic energy of the vibrations is converted into heat energy. Consequently, the vibration damping body 10 generates a vibration damping force. Polymer materials such as resin, elastomer, and rubber may be used for the viscoelastic body 14. In the present embodiment, rubber is used. A viscous body may also be used instead of the viscoelastic body 14.

The pair of spring members 13 that forms the vibration damping body 10 is connected at a side T1, which is one end of the pair of spring members 13, by the bolts 12B and the nuts 12N, and connected at a side T2, which is the other end, by the bolts 16B and the nuts 16N. In the present embodiment, the bolts 12B and the nuts 12N, and the bolts 16B and the nuts 16N are used in plurality.

While the pair of spring members is connected by using

the bolts 12B and the nuts 12N, and the bolts 16B and the nuts 16N, in the present embodiment, a first spacer 17 and a second spacer 18 are arranged between the pair of spring members 13. More specifically, at the side T1, which is one end of the pair of spring members 13, the first spring member 13A, the first spacer 17, and the second spring member 13B are fastened by the bolts 12B and the nuts 12N. At the side T2, which is the other end of the pair of spring members 13, the first spring member 13A, the second spacer 18, and the second spring member 13B are fastened by the bolts 16B and the nuts 16N.

The first spacer 17 and the second spacer 18 are provided for preventing the viscoelastic body 14 sandwiched between the pair of spring members 13 from being deformed locally. The first spacer 17 and the second spacer 18 hold the viscoelastic body 14 at a predetermined position between the pair of spring members 13, and properly generate the vibration damping force on the viscoelastic body 14. The size of the first spacer 17 and the second spacer 18 in the direction from the first spring member 13A towards the second spring member 13B, in other words, the direction perpendicular to the surface of the first spring member 13A or the second spring member 13B, is set similar or slightly smaller to the size of the viscoelastic body 14 in the same direction. Accordingly, it is possible to

prevent the viscoelastic body 14 from being deformed locally, and the viscoelastic body 14 can be firmly held between the pair of spring members 13.

As described above, the vibration damping body 10 is mounted on the wire 100 via the vibration input member 11. As shown in Fig. 3, the vibration input member 11 and the fixture 3 are fastened by mounting bolts 4B and mounting nuts 4N, and the wire 100 is sandwiched between the vibration input member 11 and the fixture 3. The vibration input member 11 and the vibration damping body 10 are fastened by the bolts 12B and the nuts 12N, which are the first connecting unit. Accordingly, the vibration damping body 10 is mounted on the vibration input member 11, by the bolts 12B and the nuts 12N. With such a configuration, the vibration input member 11 transmits the vibrations of the wire 100 to the vibration damping body 10. The pair of spring members 13 is connected to each other by the bolts 12B and the nuts 12N at the side from which vibrations are received, and connected by the bolts 16B and the nuts 16N at the side opposite to the side from which vibrations are received.

In the present embodiment, a plate member 5 is provided between the bolts 12B and the first spring member 13A. The plate member 5 need not necessarily be provided, but the fastening force generated by the bolts 12B and the

nuts 12N are dispersed to the vibration damping body 10, by providing the plate member 5. Accordingly, the vibration damping body 10 and the vibration input member 11 can be fastened in a wide area.

In the present embodiment, the vibration damping body 10 swings in the direction parallel to (direction of an arrow F in Figs. 2 and 3) a surface (vibrating surface) perpendicular to a plate surface of the pair of spring members 13 formed by the leaf springs. Accordingly, the vibration damping apparatus 1 suppresses the vibrations in the direction parallel to the vibrating surface. The vibration damping apparatus 1 is mounted on the wire 100 so that the direction of the vibrations of the wire 100 to be suppressed becomes parallel to the vibrating surface.

At the side opposite to the side from which vibrations of the vibration damping body 10 are received, in other words, at the side T2, which is the other side of the vibration damping body 10, a weight 15 is provided. By adjusting the mass of the weight 15, the vibration frequency suppressed by the vibration damping body 10 can be adjusted. If the vibration frequency suppressed by the vibration damping body 10 can be adjusted without providing the weight 15, the weight 15 need not be provided. The weight 15 is mounted on the vibration damping body 10 by the bolts 16B and the nuts 16N. In this manner, the bolts

16B and the nuts 16N used for connecting the pair of spring members 13 are also used as a unit to mount the weight 15 on the vibration damping body 10. Accordingly, the number of components that form the vibration damping apparatus 1 can be suppressed, thereby lowering the cost and simplifying the structure.

Fig. 4A is a schematic of deflection of a cantilever beam. Fig. 4B is a schematic of deflection of a beam in which both ends are fixed, and one of the fixed supports is settled. As shown in Fig. 4A, if a beam B having a length L_b is supported by a cantilever, it is assumed that a load P is applied to a free end of the beam B, and the difference (deflections of the beam B at both ends) between a fixed end K and the free end is δ . In this case, the shearing force τ_1 of the beam B is calculated by formula (1). Alternatively, as shown in Fig. 4B, if both ends of a beam B (length is L_b) are fixed by fixed supports K1 and K2, and if the fixed support K2 at one end is settled, it is assumed that the difference (deflections of the beam B at both ends) between the fixed support K1 and the fixed support K2 is δ . In this case, the shearing force τ_2 of the beam B is calculated by formula (2). E in the formulae (1) and (2) is Young's modules of the beam B, and I is the second moment of the cross section of the beam B.

$$\tau_1 = 3 \times E \times I \times \delta / L b^3 \quad (1)$$

$$\tau_2 = 12 \times E \times I \times \delta / L b^3 \quad (2)$$

If it is assumed that the material, the size, and the shape of the beam B of the cantilever beam and the fixed ended beam are the same, and if the deflections of the beam B at the both ends are the same, the shearing force of the fixed ended beam becomes four times larger than that of the cantilever beam. In the vibration damping apparatus 1, the viscoelastic body 14 that forms the vibration damping body 10 deforms in proportion to the shearing force generated in the vibration damping body 10. Accordingly, the vibration damping apparatus 1 generates a damping force by converting kinetic energy to heat energy. The vibration damping body 10 sandwiches the viscoelastic body 14 between the pair of spring members 13, and connects and fixes both ends of the pair of spring members 13. Consequently, the deformation of the vibration damping body 10 becomes the same as when both ends of the beam B are fixed. Accordingly, the shearing force generated when the vibration damping body 10 is swung and deformed by the vibrations becomes the same as when the both ends of the beam B are fixed. As a result, the vibration damping apparatus 1 that includes the vibration damping body 10 can generate the damping force four times larger than that of the dynamic absorber

disclosed in the Japanese Patent Application Laid-open No. S59-110938, if the shape, the material, and the size of the apparatus main bodies are the same. This means that the size of the apparatus main body of the vibration damping apparatus 1 can be reduced than that of the dynamic absorber, if the vibration damping force is the same as that of the dynamic absorber disclosed in the Japanese Patent Application Laid-open No. S59-110938. In this manner, the vibration damping apparatus 1 can provide required vibration damping capabilities, while reducing the size of the apparatus main body. Because the size of the vibration damping apparatus 1 can be reduced than that of the dynamic absorber, if the vibration suppression capabilities are the same, it is possible to reduce the load applied to the object whose vibrations are to be damped.

The vibration damping apparatus 1 can change the frequency of the vibrations to be suppressed, by adjusting the mass of the weight 15 included in the vibration damping body 10, a length L (Fig. 2) of a portion in which the vibration damping body 10 swings, and the volume of the viscoelastic body 14. The vibration damping apparatus 1 can also change the damping force being applied. The configuration of the vibration damping apparatus 1 is simple, and the mass of the weight 15 and the length L of a

portion in which the vibration damping body 10 swings can easily be changed. In particular, because the weight 15 is fixed to the vibration damping body 10 by the bolts 16B and the nuts 16N, it can easily be exchanged even after the vibration damping apparatus 1 is mounted on an object whose vibrations are to be damped. In this manner, even after the vibration damping apparatus 1 is mounted on an object whose vibrations are to be damped, the frequency of the vibrations to be damped can be easily changed by the vibration damping apparatus 1. As a result, by using the vibration damping apparatus 1, a vibration problem can easily be solved, even after the problem comes up.

Fig. 5 is a schematic of vibration modes of an object whose vibrations are to be damped. The wire 100, which is an object whose vibrations are to be damped, is fixed at fixed ends FA and FB. A length between the fixed ends FA and FB, in other words, a portion in which the wire 100 vibrates is L_w . In Fig. 5, f_1 is a second vibration of the wire 100, f_2 is a third vibration of the wire 100, and f_3 is a fourth vibration of the wire 100. It is preferable that the vibration damping apparatus 1 is mounted on a portion where the wire 100 vibrates the most, in other words, at an antinode of the vibration. For example, it is preferable to mount the vibration damping apparatus 1 at a position of $L_w/2$, if the third vibration of the wire 100 is

to be suppressed. It is also preferable to mount the vibration damping apparatus 1 at a position of $Lw1$, if the fourth vibration of the wire 100 is to be suppressed. In this manner, the vibrations of the wire 100 can be advantageously suppressed.

Fig. 6 is an overall view of a vibration damping apparatus according to a first modification of the present embodiment. Fig. 7 is a fragmentary view taken in the direction of arrows along a line Y-Y of Fig. 6. A vibration damping apparatus 1a according to the present modification has the same configuration as that of the vibration damping apparatus 1 described above. However, the vibration damping apparatus 1a is different from the vibration damping apparatus 1, in including a plurality of vibration damping bodies (a first vibration damping body 10a1 and a second vibration damping body 10a2) in which the distances from the vibration input member 11 to weights 15a1 and 15a2 are different. As shown in Fig. 6, the vibration damping apparatus 1a is mounted on the wire 100, by sandwiching the wire 100 between the vibration input member 11 and the fixture 3. As shown in Figs. 6 and 7, the first vibration damping body 10a1 and the second vibration damping body 10a2 are mounted on the vibration input member 11, by the bolts 12B and the nuts 12N, which are the first connecting unit.

The first vibration damping body 10a1 is connected and fixed at the side T11, which is one end of a pair of spring members 13a1 (a first spring member 13A1 and a second spring member 13B1), that is, at the side of the vibration input member 11 (the side where vibrations are received), by the bolts 12B and the nuts 12N. The side T12, which is the other end of the first vibration damping body 10a1, is connected and fixed by the bolts 16B and nuts 16N, which are the second connecting unit. A first viscoelastic body 14a1 is sandwiched between the pair of spring members 13a1.

Similarly, the second vibration damping body 10a2 is connected and fixed at the side T21, which is one end of a pair of spring members 13a2 (a first spring member 13A2 and a second spring member 13B2), that is, at the side of the vibration input member 11 (the side where vibrations are received), by the bolts 12B and the nuts 12N. The side T22, which is the other end of the second vibration damping body 10a2, is connected and fixed by the bolts 16B and the nuts 16N, which are the second connecting unit. A second viscoelastic body 14a2 is sandwiched between the pair of spring members 13a2.

With such a configuration, the weight 15a1 provided at the side T12, which is the other end of the first vibration damping body 10a1, and the weight 15a2 provided at the side T22, which is the other end of the second vibration damping

body 10a2, are arranged on the opposite ends across the vibration input member 11. In a similar manner to the vibration damping apparatus 1 described above, in the vibration damping apparatus 1a, two first vibration damping bodies 10a1 and two second vibration damping bodies 10a2 are arranged at both sides of the wire 100. Accordingly, the balance of the vibration damping apparatus 1a is improved, thereby suppressing the bending force applied to the wire 100. Consequently, it is possible to advantageously suppress the durability of the wire 100 from being lowered.

In the present modification, the first spring member 13A1 that forms the first vibration damping body 10a1 and the first spring member 13A2 that forms the second vibration damping body 10a2 are integrally formed. Similarly, the second spring member 13B1 that forms the first vibration damping body 10a1 and the second spring member 13B2 that forms the second vibration damping body 10a2 are integrally formed. Accordingly, the number of components that form the vibration damping apparatus 1a can be reduced. The first vibration damping body 10a1 and the second vibration damping body 10a2 may also be formed separately. Because the first spring member 13A1 and the first spring member 13A2 are integrally formed, and the second spring member 13B1 and the second spring member 13B2

are integrally formed, the side T11, which is one end of the pair of spring members 13a1, and the side T21, which is one end of the pair of spring members 13a2, are virtual ends under the assumption that the second vibration damping body 10a2 and the first vibration damping body 10a1 are not present.

The distance from the vibration input member 11 to the weight 15a1 of the first vibration damping body 10a1, in other words, a length L1 of the portion in which the first vibration damping body 10a1 swings, and the distance from the vibration input member 11 to the weight 15a2 of the second vibration damping body 10a2, in other words, a length L2 of the portion in which the second vibration damping body 10a2 swings are different. Accordingly, the frequency of the vibrations suppressed by the first vibration damping body 10a1 and the frequency of the vibrations suppressed by the second vibration damping body 10a2 are different. Consequently, vibrations of different frequencies can be suppressed by one vibration damping apparatus 1a.

In the vibration damping apparatus 1a, the vibrations of the wire 100 are fed into the first vibration damping body 10a1 and the second vibration damping body 10a2, from the vibration input member 11 used in common. Accordingly, the vibration damping apparatus 1a is mounted on one

location of the wire 100. In other words, the first vibration damping body 10a1 and the second vibration damping body 10a2 are mounted on the same object whose vibrations are to be damped, respectively, and the vibrations are received from the same position as that of the object whose vibrations are to be damped. Consequently, even if the location where the vibration damping apparatus 1a is to be mounted is limited by the restriction such as the shape and the size of an object whose vibrations are to be damped, the vibration damping apparatus 1a can be relatively easily mounted on the object whose vibrations are to be damped.

For example, consider when the third vibration of the wire 100 shown in Fig. 5 is suppressed by the first vibration damping body 10a1 of the vibration damping apparatus 1a, and when the fourth vibration of the wire 100 is suppressed by the second vibration damping body 10a2. In this case, it is preferable that the vibration damping apparatus 1a is mounted at a portion close to the antinodes of both of the vibrations, which is between $Lw1$ and $Lw2$ in an example shown in Fig. 5. Accordingly, it is possible to advantageously suppress the vibrations of different frequencies by one vibration damping apparatus 1a.

Fig. 8 is an overall view of a vibration damping apparatus according to a second modification of the present

embodiment. A vibration damping apparatus 1b is similar to the first modification in including a plurality of first vibration damping bodies 10b1 and second vibration damping bodies 10b2 having the different lengths L_1 and L_2 from vibration input members 11b1 and 11b2 to weights 15b1 and 15b2. However, the present modification is different from the first modification in that the first vibration damping body 10b1 and the second vibration damping body 10b2 are separately formed. In other words, the first vibration damping body 10b1 and the second vibration damping body 10b2 include separate vibration input members 11b1 and 11b2, respectively.

For example, consider when the third vibration of the wire 100 shown in Fig. 5 is suppressed by the first vibration damping body 10b1 of the vibration damping apparatus 1b and the fourth vibration of the wire 100 is suppressed by the second vibration damping body 10b2. In this case, the first vibration damping body 10b1 is mounted on the antinode of the third vibration, which is at Lw_2 in the example shown in Fig. 5, and the second vibration damping body 10b2 is mounted on the antinode of the fourth vibration, which is at Lw_1 in the example shown in Fig. 5. Accordingly, it is possible to most advantageously exhibit the vibration damping capability of the first vibration damping body 10b1 and the vibration damping capability of

the second vibration damping body 10b2, for the vibration frequencies set respectively. Consequently, it is possible to advantageously suppress the vibrations of the different frequencies.

Fig. 9 is an overall view of a vibration damping apparatus according to a third modification of the present embodiment. Fig. 10 is a schematic of the vibration damping apparatus according to the third modification of the present embodiment, viewed from a direction of an arrow Z of Fig. 9. The features of a vibration damping apparatus 1c are the same as those of the vibration damping apparatus 1 described above. However, the vibration damping apparatus 1c is different from the vibration damping apparatus 1 in including a plurality of vibration damping bodies 10c1 and 10c2, and the directions to which the vibration damping bodies 10c1 and 10c2 swing are different, respectively.

As shown in Figs. 9 and 10, the vibration damping apparatus 1c includes a total of four vibration damping bodies including two vibration damping bodies (first vibration damping bodies) 10c1 and two vibration damping bodies (second vibration damping bodies) 10c2. The two first vibration damping bodies 10c1 are symmetrically arranged at the both sides of the wire 100. Similarly, the two second vibration damping bodies 10c2 are symmetrically

arranged at the both sides of the wire 100. The two first vibration damping bodies 10c1 and the two second vibration damping bodies 10c2 are mounted on the vibration input members 11c, respectively.

Two vibration input members 11c are mounted on arc-shaped mounting jigs 3c1 and 3c2, respectively. The mounting jigs 3c1 and 3c2, for example, are connected by bolts and nuts, which are connecting units. Because the wire 100 is sandwiched between the two mounting jigs 3c1 and 3c2, the two first vibration damping bodies 10c1 and the two second vibration damping bodies 10c2 are mounted on the wire, via the vibration input members 11c mounted on the mounting jigs 3c1 and 3c2. The vibrations of the wire 100 are fed into the two first vibration damping bodies 10c1 and the two second vibration damping bodies 10c2, via the mounting jigs 3c1 and 3c2 and the vibration input members 11c.

As shown in Fig. 10, in the vibration damping apparatus 1c, the swinging direction of the first vibration damping bodies 10c1 (direction of arrows F1 in Fig. 10) and the swinging direction of the second vibration damping bodies 10c2 (direction of arrows F2 in Fig. 10) are different. More specifically, the swinging direction of the first vibration damping bodies 10c1 and the swinging direction of the second vibration damping bodies 10c2 are

perpendicular to each other. In this manner, the vibration damping apparatus 1c can suppress the vibrations of the wire 100 whose vibrations are to be damped, in the different directions. An angle between the swinging direction of the first vibration damping bodies 10c1 and the swinging direction of the second vibration damping bodies 10c2 do not necessarily be 90 degrees, and it is preferable to appropriately set the angle depending on the direction of the vibration to be suppressed.

As shown in Fig. 9, in the vibration damping apparatus 1c, weights 15c1 mounted on the first vibration damping bodies 10c1 and weights 15c2 mounted on the second vibration damping bodies 10c2 are arranged in the same direction to the vibration input member 11c. However, arrangements of the first vibration damping bodies 10c1 and the second vibration damping bodies 10c2 are not limited thereto, and the first vibration damping bodies 10c1 and the second vibration damping bodies 10c2 may be arranged so that the weights 15c1 and the weights 15c2 are arranged in the opposite directions to the vibration input member 11c. In this manner, it is possible to prevent the first vibration damping bodies 10c1 and the second vibration damping bodies 10c2 from interfering with each other. Accordingly, even if the amplitude of the wire 100 is increased, it is possible to firmly suppress the wire 100

from being vibrated.

Application Examples

Fig. 11 is a front view of a Ferris wheel. Figs. 12A and 12B are schematics of states when the vibration damping apparatus according to the present embodiment is mounted on the wires that form the Ferris wheel. Fig. 12B is a schematic of a state when the vibration damping apparatus 1 and the like shown in Fig. 12A is viewed from the position rotated by 90 degrees around the wire 100 shown in Fig. 12A. In the following explanation, an example that the vibration damping apparatus 1 is applied on a Ferris wheel 200 is shown. However, other vibration damping apparatuses 1a, 1b, and the like may be applied thereto.

In the Ferris wheel 200 shown in Fig. 11, a rotating ring 201 is formed by a hub 203 that rotates around a rotation axis Z_r and an outer ring 202 connected to the hub 203 by the wires (wire ropes) 100 and on which gondolas 204 are mounted on the periphery. The vibration damping apparatus 1 is mounted on each of the wires 100. As shown in Fig. 12A, the vibration damping apparatus 1 is mounted on the wire 100, so that the two vibration damping bodies 10 are symmetrically arranged at the both sides of the wire 100.

In the present embodiment, a first bracket 101 is mounted at the side of the outer ring 202 and a second

bracket 102 is mounted at the side of the hub 203 on the wire 100. An outer ring side wire installation seat 202B is also provided at the outer ring 202, and a hub side wire installation seat 203B is provided at the hub 203. The first bracket 101 is pin-connected to the outer ring side wire installation seat 202B, thereby enabling to swing about a first axis Z1. The second bracket 102 is pin-connected to the hub side wire installation seat 203B, thereby enabling to swing about a second axis Z2.

With such a configuration, the wire 100 can swing in the direction parallel to a surface perpendicular to the first axis Z1 and the second axis Z2 (direction of an arrow Fw in Fig. 12A). Alternatively, the wire 100 cannot swing in the direction parallel to the first axis Z1 and the second axis Z2 (direction of an arrow Fd in Fig. 12B). In other words, the wire 100 is mounted so that it can swing in one direction with respect to the outer ring 202 and the hub 203.

With such a configuration, if the wire 100 is vibrated in the direction in which the wire 100 can be swung, the first bracket 101 swings about the first axis Z1 and the second bracket 102 swings about the second axis Z2, at the mounting units of the wire 100 and the outer ring 202, and of the wire 100 and the hub 203. Accordingly, even if the wire 100 is vibrated in the direction in which the wire 100

can be swung, the movement is allowed by the mounting units of the wire 100 and the outer ring 202, and of the wire 100 and the hub 203. Consequently, an excessive force is not applied to the mounting units, thereby suppressing the durability of the mounting units from being lowered.

However, if the wire 100 is vibrated in the direction in which the wire 100 cannot be swung, swing is not allowed between the first bracket 101 and the outer ring side wire installation seat 202B, and between the second bracket 102 and the hub side wire installation seat 203B. Accordingly, if the wire 100 is swung in the direction in which the wire 100 cannot be swung, an excessive force may be applied to the mounting units of the wire 100 and the outer ring 202, and of the wire 100 and the hub 203.

Accordingly, in the present embodiment, the vibration damping apparatus 1 suppresses the vibrations in the direction in which the wire 100 cannot be swung. More specifically, the vibration damping apparatus 1 is mounted on the wire 100, so that the vibration damping bodies 10 included in the vibration damping apparatus 1 are swung in the direction perpendicular to the direction in which the wire 100 can be swung. In this manner, the vibration damping apparatus 1 suppresses the vibrations in the direction in which the wire 100 cannot be swung, thereby suppressing the force applied to the mounting units of the

wire 100 and the outer ring 202, and of the wire 100 and the hub 203. Accordingly, it is possible to suppress the durability of the mounting units from being lowered.

Because only the vibrations in the direction in which the wire 100 cannot be swung is suppressed, the number of the vibration damping apparatus 1 mounted on one wire 100 can be reduced. Consequently, it is possible to lower the cost. It is preferable that the vibration damping apparatus 1 is mounted at the side of the outer ring 202 of the wire 100. Because the vibration damping apparatus 1 can be mounted on the wire at the position closer to the ground, the work can be performed with ease.

In the Ferris wheel 200 applied with the vibration damping apparatus 1, the hub 203 and the outer ring 202 are connected by the wire 100. However, the vibration damping apparatus 1 can be applied to a Ferris wheel in which an inner ring and an outer ring are connected by spokes that act as compression/tension units, and wires that act as tension units. The vibration damping apparatus 1 and the like can also be applied on an illumination pole, a traffic sign pole, an electric cable, and the like, in addition to the Ferris wheel.

In particular, because the configuration of the vibration damping apparatus 1 and the like is simple, it can easily be designed according to the frequency and the

direction of the vibrations to be suppressed. Accordingly, even if a vibration problem comes up after the structures such as a Ferris wheel, a bridge, a traffic sign and the like are built, individual measures can be easily and speedily realized, by using the vibration damping apparatus 1 and the like. Because the vibration damping apparatus 1 and the like use the vibration damping bodies 10 and the like formed so that a viscoelastic body is sandwiched between the pair of spring members and both ends are fixed, the vibration damping apparatus 1 has a large vibration damping capability. Accordingly, a large deformation hardly occurs in the vibration damping body 10 and the like. Consequently, the risk that the steel twisted wires are worn because the damper cannot follow the large deformation, as seen in the stockbridge damper, can be reduced.

The present invention can provide required vibration damping capabilities, while reducing the size of the main body of the vibration damping apparatus.

Although the invention has been described with respect to specific embodiments for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art that fairly fall within the basic teaching herein set forth.

What is claimed is:

1. A vibration damping apparatus comprising:

a vibration damping body that includes a pair of spring members arranged opposite to each other and a viscoelastic body sandwiched by the spring members;

a first connecting unit that connects the pair of spring members to each other at a side of one end of the vibration damping body;

a second connecting unit that connects the pair of spring members to each other at a side of other end of the vibration damping body; and

a vibration input member that is mounted on the vibration damping body by the first connecting unit, and transmits vibration from an object whose vibration is to be damped to the vibration damping body.

2. The vibration damping apparatus according to claim 1, further comprising a weight at a side of another end of the vibration damping body.

3. The vibration damping apparatus according to claim 2, wherein the weight is mounted on the vibration damping body by the second connecting unit.

4. The vibration damping apparatus according to claim 2

or 3, comprising a plurality of such vibration damping bodies that has a different distance from the vibration input member to the weight.

5. The vibration damping apparatus according to claim 4, wherein the vibration damping bodies are mounted on a same object whose vibration is to be damped, and receive vibration from a same position of the object.

6. The vibration damping apparatus according to any one of claims 1 to 5, comprising a plurality of such vibration damping bodies whose swinging direction is different from each other.

7. The vibration damping apparatus according to any one of claims 1 to 6, wherein an object whose vibration is to be damped is a wire rope.

8. A Ferris wheel comprising:

a hub;

an outer ring connected to the hub by a wire rope, and to which a gondola is mounted on a periphery; and

the vibration damping apparatus according to any one of claims 1 to 6, wherein the vibration input member is mounted on the wire rope.

9. The Ferris wheel according to claim 8, wherein the vibration damping apparatus is mounted at a side of the outer ring.

10. The Ferris wheel according to claim 8 or 9, wherein the wire rope is mounted so as to swing in one direction with respect to the outer ring and the hub, and the vibration damping apparatus is mounted so as to swing in a direction perpendicular to a direction in which the wire rope swings.