

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 627 031 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

12.06.1996 Bulletin 1996/24

(21) Application number: **93905216.3**

(22) Date of filing: **17.02.1993**

(51) Int Cl.⁶: **E01D 11/00, E01D 21/00**

(86) International application number:
PCT/DK93/00058

(87) International publication number:
WO 93/16232 (19.08.1993 Gazette 1993/20)

(54) **A SYSTEM AND A METHOD OF COUNTERACTING WIND INDUCED OSCILLATIONS IN A
BRIDGE GIRDER**

SYSTEM UND VERFAHREN ZUR KOMPENSIERUNG WINDINDUZIERTER SCHWINGUNGEN IN
EINEM BRÜCKENTRÄGER

SYSTEME ET PROCEDE POUR CONTRECARRER LES OSCILLATIONS INDUITES PAR LE VENT
DANS UNE TRAVÉE DE PONT

(84) Designated Contracting States:
DE ES FR GB GR IT

(30) Priority: **18.02.1992 DK 209/92**

(43) Date of publication of application:
07.12.1994 Bulletin 1994/49

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Description

The invention concerns a system and a method of counteracting wind induced oscillations in bridge girders on long cable supported bridges, wherein a plurality of control faces arranged substantially symmetrically about the longitudinal axis of the bridge utilize the energy of the wind for automatically reducing said oscillations in response to the movement of the bridge girder.

In connection with long-span bridges having insufficient stiffness and damping, oscillations may occur because of aerodynamic instability. At worst, these oscillations may be fatal and cause the bridges to collapse. The oscillations may also be termed flutter. They may be torsional oscillations or vertical oscillations or a combination of these. For example, it was torsional oscillations which caused the Tacoma bridge in the USA to fail in 1940, which was the longest suspension bridge in the world at that time.

Aerodynamic instability occurs when the aerodynamic forces reduce the torsional stiffness of the bridge girder, or the total damping (structural as well as aerodynamic) becomes negative, which means that the bridge receives more energy than is absorbed in the oscillatory motion. The wind velocity at which aerodynamic instability occurs is called the flutter wind velocity or the critical wind velocity, and it decreases with decreasing structural stiffness and damping.

Traditionally, the problem is solved by e.g. increasing the stiffness of the bridge girder or by mounting mechanical damper devices. For a given cross-section of the bridge girder its torsional stiffness decreases with increasing span. When the span is increased, it is therefore necessary also to increase the bridge cross-section to establish the sufficient torsional stiffness. However, the increased bridge cross-section gives rise to greater wind loads, which in turn involves increased demands on the structural strength of the bridge girder and thus adds to the costs of construction. Furthermore, owing to the desired appearance of the bridge there is of course a limit to the increase in the bridge girder cross-section. These circumstances have thus set an upper limit to the spans that can be achieved.

From US-A-4 741 063 a system is known that uses control faces for counteracting the wind induced oscillations in a bridge girder utilizing the energy of the wind. A face is placed on each side of the longitudinal axis of the bridge. The faces are preferably firmly fixed, but they may be adjustable in position, even automatically.

An article by H. Kobayashi, et al. "Active control of Flutter of a suspension Bridge" (Preprint from the eighth International Conference on Wind Engineering, London, Canada, July 1991) describes a system in which two control wings are mounted above the bridge girder at their respective sides of the bridge. The wings are suspended pivotally and can be moved harmonically in step with the movements of the bridge girder. The wind load on the wings hereby generates forces that can be trans-

ferred to the bridge girder and counteract its movement. This system entails that the mechanical dimensions of the bridge girder can be diminished and possible oscillations be damped instead by means of the control wings. However, this system is vitiated by drawbacks.

The described system is a harmonic control attached to a specific oscillation frequency. This is inexpedient, because the oscillations in a cable supported bridge preceding an instability situation are a superposition of several modes of oscillations each having its own oscillation frequency. The combination of these oscillations are not of a harmonic nature, and the described control thus has no general utility.

The control wings are mounted above the bridge, and this means that they will be positioned in an area where the air flow is frequently rather turbulent. One reason is that this is where the elements are mounted which partly carry the bridge, e.g. cables, hangers, etc., partly protect and guide traffic, e.g. guard rails, crash fences, windscreens and the pylons. The traffic on the bridge also contributes to making the air flow on the top side of the bridge turbulent. It is thus difficult to adjust the movements of the bridge precisely when the control wings are mounted in this area. Furthermore, control wings mounted in this manner above the bridge considerably affect the aesthetic appearance of the bridge.

Furthermore, the system described in the article does not take it into consideration that the control of the control faces depends on the direction of the wind with respect to the bridge girder. Reversing of the wind direction requires the opposite movement of the control faces for the intended effect to be achieved.

The invention provides a system which makes it possible to utilize the energy of the wind much better than the system described in the above-mentioned article for creating stabilizing aerodynamic forces on very long bridges, thereby counteracting the forces which cause the bridge to oscillate. The system is not affected by the turbulent air flows which are present on the top side of such a bridge, and it is also capable of allowing for changing wind directions and velocities as well as combinations of several modes of oscillations. Thus, the flutter wind velocity can be increased considerably without using a large, inexpedient and expensive torsionally stiff bridge girder.

This is achieved according to the invention by using control faces which are divided into sections in the longitudinal direction of the bridge. Furthermore, a plurality of detectors are provided for measuring the movements of the bridge girder, and each control face section is associated with a local control unit adapted to control the control face section concerned in response to information from one or more detectors.

By dividing the control faces into sections in this manner it is possible to give the system a quite long extent in the longitudinal direction of the bridge, and the division into sections makes it possible to adjust the separate sections individually, thus allowing for the oscilla-

tion tendencies which can be observed at the point in question on the bridge, even though the oscillations are not of a harmonic nature.

When, as stated in claim 2, the detectors are distributed in the longitudinal direction of the bridge while each local control unit controls the associated control face section in response to information from the nearest detector or detectors, the ability of the system to allow for local oscillation conditions is additionally improved.

In a special embodiment, which is described in claim 3, the detectors as well as the control faces are arranged substantially symmetrically about the longitudinal axis of the bridge so that there is a detector for each local control unit, and said unit controls the associated control face section in response to information from the associated detector.

When, as stated in claim 4, the system is provided with a main control unit capable of receiving information from several detectors distributed in the longitudinal direction of the bridge and transmitting control signals back to the local control units, the system can moreover allow for the total oscillation picture for the entire bridge.

In a special embodiment, which is defined in claim 5, the local control units control the associated control face section in response to the control signal received from the main control unit.

An embodiment, which is described in claim 6, includes at least two main control units. When each main control unit receives information from some of the detectors and correspondingly transmits control signals to some of the local control units distributed in the longitudinal direction of the bridge, additional security is obtained in case of errors on one of the control units. In that case, the detectors and the local control units belonging to the other control units can still operate. Thus, the control face sections are divided into groups, each of which is distributed over the length of the bridge, and an error in a control unit will only make the associated group inoperative, thus significantly improving the security for the entire bridge.

When, as stated in claim 7, the system is moreover provided with a plurality of sensors capable of measuring the direction of the wind, and the local control units or main control units, respectively, utilize the resulting information on the wind direction, a system capable of adjusting the control faces in consideration of the wind direction is obtained.

When, as stated in claim 8, use is moreover made of sensors capable of measuring the velocity of the wind, the system can also take this into consideration.

In an embodiment, which is described in claim 9, the control faces are arranged below the bridge girder and at a distance from it where the air flow is almost undisturbed by the bridge girder. This provides a system which is not affected by the turbulent air flows which are present in particular on the top side of the bridge. Claim 10 describes a special embodiment where the control faces are secured to the bridge girder by means of py-

lons on the underside of the bridge girder.

In an alternative embodiment, which is defined in claim 11, the control faces are formed by segments of the surface of the actual bridge girder, the outermost portions of the bridge girder in the transverse direction of the bridge being capable of moving in a manner such that the cross-section of the bridge girder and thus its aerodynamic properties are changed. This provides an aesthetically nicer appearance of the bridge girder, since the control faces are not readily visible.

In the method of the invention the control faces are divided into sections in the longitudinal direction of the bridge. A plurality of detectors measures the movements of the bridge girder, and then a local control unit at each control face section controls it in response to information from one or more detectors.

An improved method is achieved, as described in claim 13, when one or more main control units receive information from a plurality of detectors and transmit control signals to a plurality of local control units, it being thus possible to take the total oscillation picture of the bridge into consideration.

An additional improvement of the method is achieved, as mentioned in claim 14, by measuring the direction of the wind by a plurality of sensors and transmitting signals on this to the local control units or main control units and utilizing these signals in the control of the control faces.

The invention will be described more fully below with reference to the drawing, in which

fig. 1 shows a section of a suspension bridge to which the invention can be applied,

fig. 2 shows a section of a cable-stayed bridge having central inclined stays to which the invention can be applied,

fig. 3 shows a section of a bridge having a first embodiment of controlled control faces positioned in the free flow below the bridge girder,

fig. 4 is a detailed view of a cross-section of the bridge of fig. 3,

fig. 5 is a cross-section of the bridge from fig. 3,

fig. 6 shows how detectors and local control units can be connected with a main control unit,

fig. 7 shows an alternative mode of connection which incorporates two main control units,

fig. 8 shows a section of a bridge having a second embodiment of controlled control faces integrated in the edge of the bridge girder, and

fig. 9 is a detailed view of a cross-section of the

bridge of fig. 8.

Figs. 1 and 2 show examples of bridges to which the invention can be applied.

Fig. 1 shows a suspension bridge. A bridge girder 1 is carried by cables 2 and vertical or inclined hangers 3 secured thereto. The carrying cables 2 are in turn carried by a bridge tower 4. Bridges of this type typically have two towers, and the spacing between these towers is called the span of the bridge. The bridge girder 1 is thus carried by the carrying cables 2 and the hangers 3 over the entire extent between the two towers 4.

It will be appreciated that in case of strong wind loads such a bridge girder will be subjected to considerable forces, which may mean that oscillations may occur in the bridge girder. The oscillations may be of various types. In case of vertical oscillations the deflection of the bridge girder will take place in a vertical direction, while, correspondingly in case of horizontal oscillations, deflection will occur in the horizontal direction. The oscillations may also be torsional oscillations, the entire bridge girder "twisting" about the longitudinal axis of the bridge. Furthermore, combinations of these types of oscillations may occur. It may e.g. be mentioned that the longest suspension bridge in the world at that time, the Tacoma bridge in the USA, was destroyed in 1940 because of torsional oscillations.

To counteract these oscillations, it was necessary in the past to increase the stiffness of the bridge girder or to mount mechanical damper devices. It will be appreciated that the greater the span of the bridge, the stiffer the construction of the bridge girder if these oscillations are to be avoided. Since, however, there is a limit to the dimensions of the cross-section of the bridge girder and thus to its stiffness, this also sets an upper limit to the width of spans that can be built safely. The invention has been found to make it possible to increase this limit considerably.

Fig. 2 shows another bridge type, viz. a so-called cable-stayed bridge, in which the oscillation phenomenon can occur, and the invention thus be applied. Here a bridge girder 5 is carried by a plurality of so-called inclined stays 6 which are in turn carried by a bridge tower 7. One or two bridge towers are also used in this bridge type, and the span of the bridge is the distance between two supports of the bridge girder. The oscillation conditions described for the suspension bridge of fig. 1 also apply to this bridge type. There are also combinations of the two bridge types, just as other variants are conceivable. These bridges are frequently called by the collective name cable supported bridges.

Fig. 3 is a perspective view of a section of a suspension bridge of the same type as shown in fig. 1. This figure too shows carrying cables 8, 9 to which a plurality of hangers 10 carrying the bridge girder 11 are secured. The top side of the bridge girder is provided with roadways 12, and various guard rails and crash fences 13 are provided. As will be seen, the bridge is here provided

with a plurality of control face sections 14, 15, 16, 17. Each section is mounted on two aerodynamically shaped pylons 18, and, as will be described more fully below, they can be controlled individually. Control face sections are provided on both sides of the bridge girder.

When these control face sections are subjected to the impacts of the wind, they will affect the bridge girder with a force in an upward or downward direction depending upon their positions. Both the direction of the force and its size can be changed by changing the position of the control face section. In case of a wind direction toward the sections 14, 15, 16 the control face section 14 will thus apply an upward force to the bridge girder, while correspondingly the section 16 provides a downward force. In this manner it is thus possible to counteract oscillations that might be about to be generated in the bridge. If at a given point the bridge girder is thus about to oscillate upwardly, the bridge girder can be affected at this point by a downwardly directed force by adjusting the corresponding control face section, thus damping the oscillation.

The control faces are mounted on the underside of the bridge, because the air flow here is relatively undisturbed by the presence of the bridge. The flow is more turbulent on the top side, e.g. because of cables, hangers, guard rails, crash fences and windscreens as well as the traffic on the bridge.

A plurality of detectors are arranged in the bridge girder in order to measure the movements occurring in the bridge. These detectors are e.g. accelerometers. The control face sections are controlled on the basis of the measurements from these detectors in a manner such that oscillations are counteracted.

Fig. 4 shows a detailed segment of a cross-section of a cable supported bridge. The figure shows the bridge girder 11 on which a roadway 12 and a guard rail/crash fence 13 are provided. As described before, the bridge girder is suspended from hangers or inclined stays 10, and a control face section 17 is mounted on a pylon 18. A detector 19 measures the movements or accelerations of the bridge at the point concerned and transmits a signal to a control unit 20. This control unit may e.g. be a computer. On the basis of a control algorithm the control unit 20 then applies a signal to a servo pump 21 which controls a hydraulic cylinder 22. The hydraulic cylinder 22 can then rotate the control face section 17 by means of a transmission plate 23 and a control rod 24. The control face section 14 can be adjusted continuously in this manner in response to the movements of the bridge girder at the point in question, as measured by the detector 19.

As will be seen from fig. 5, which shows a cross-section of the entire bridge girder, the control unit 20 may be connected to the corresponding control unit 25 at the opposite side of the bridge girder. The system at this side corresponds completely to the system just described. When the two control units 20, 25 can exchange information, provision can be made better for the mode

of oscillation which is possibly about to occur at the point in question. If both detectors 19, 26 e.g. detect an upward movement, an initial vertical oscillation will be involved, and both control face sections 14, 17 will therefore be adjusted such that they cause a downward force. If, on the other hand, the detector 19 measures an upward movement, while the detector 26 measures a downward movement, a torsional oscillation is involved, and the control face section 17 will therefore be adjusted to give a downward force, while the section 14 is adjusted to give an upward force so as to counteract the torsional oscillation.

However, for the control units 20, 25 to perform these adjustments of the control face sections, the control units must know the wind direction, because this decides how the control face sections are to be adjusted to give the desired forces. Thus, fig. 5 also shows a wind sensor 27 capable of providing the control units with information on the direction of the wind. The sensor 27 may also be adapted such as to give information on the actual wind velocity. The wind sensor 27 is connected to the control unit 20 in the figure. Another possibility will be that each of the control units 20, 25 has its own wind sensor. The sensor 27 can be mounted on the underside of the bridge as shown, since the air flow here is most undisturbed by the bridge, but other positions are possible.

Correspondingly, the detectors 19, 26 can be replaced by a common detector which can be utilized by both control units 20, 25, and the common detector must then just also be capable of measuring angular rotations of the bridge about the longitudinal axis of the bridge girder.

As appears from fig. 3, the control faces are divided into sections in the longitudinal direction of the bridge, and figs. 4 and 5 show the structure of such a section. Each of these sections can operate independently, as just described; but improved control can be obtained if all the sections are moreover connected to a common main control unit. Fig. 6 shows an example of how the local control units and the detectors can be connected to a main control unit 28. The complete information obtained by considering all sections simultaneously is important in that it shows the mode of oscillation (or combination of several ones) in which the bridge moves. This information can be used for optimizing the total control of the overall system of control faces. The main control unit 28 can provide the local control units with this information, and these can then allow for this in their control of the control face sections in question. However, it is also possible to let the main control unit 28 take over the entire control, since the main control unit itself collects information from all detectors and then directly controls the control face sections. The wind sensors are not shown in fig. 6, but these can be connected in the same manner as the motion detectors.

In the event that it is the main control unit 28 which is responsible for the control of the control face sections,

it will be appreciated that the number of detectors does not have to be the same as the number of control face sections. Thus, it is conceivable that a minor number of detectors evenly distributed in the longitudinal direction of the bridge can give the main control unit 28 sufficient information on the instantaneous state of oscillation of the bridge, while the control face sections must be mounted with a smaller spacing to provide optimum control. For mechanical reasons too there may be a limit to the length of the control face sections it is desired to use.

A system like the one shown in fig. 6 will of course be vulnerable to errors in the main control unit 28. A safer system can therefore be obtained by using several main control units. Fig. 7 shows an example in which two main control units 28 and 29 are provided. To give the greatest possible security if one of the units 28, 29 fails, every other section is connected to the main control section 28, while the remaining ones are connected to the main control unit 29. Thus, each main control unit is connected to a group of sections. It is shown in fig. 7 that the sections 30, 32 are connected to the main control unit 28, while the sections 31, 33 are connected to the main control unit 29. Of course, the distribution of sections between the two control units can also be effected according to other criteria. If more than two main control units are used, the sections are distributed correspondingly between the control units. The overall security of the total system is increased by the number of main control units and thus the number of independent sections.

The system described here, as also appears from fig. 3, involves separate control face sections, each of which is controlled by a local control unit 20, 26. However, embodiments are also conceivable in which a long, continuous control face is employed on each side of the bridge. This control face may then be made of a flexible material so that the local control units can move a section of the control face.

It is not necessary to have control faces in the entire length of the bridge. The mounting of these can be limited to the areas of the bridge where their effect will be optimum, and these positions will typically be the areas which can be caused to oscillate violently. This will usually be the central point of the bridge in case of symmetric modes of oscillations and near the quarter point of a span in case of asymmetric modes of oscillations.

Fig. 8 shows an alternative embodiment of the invention. Instead of arranging the control faces on pylons below the bridge girder, the faces are here integrated in the actual bridge girder. Here the outermost edge of the actual bridge girder is divided into sections capable of moving in a vertical direction and thereby changing the geometry of the bridge. In a manner similar to the one described before these faces utilize the energy of the wind for subjecting the bridge girder to the action of a force in an upward or downward direction. The figure shows the sections 34, 35, 36, the section 34 being adjusted to change the forces on the bridge girder in a

downward direction, while the section 36 is adjusted to change the forces on the bridge girder in an upward direction with the wind directed toward the shown sections.

The sections are adapted to rotate about an axis of rotation 37, and the mode of operation appears more clearly from fig. 9. It will be seen from this figure that the outermost part 34 can rotate about the axis of rotation 37. The uppermost position of the section is shown by the dashed line 38, while 39 correspondingly shows the lowermost position of the section. As before, the movement of the section is controlled by means of a hydraulic cylinder 40 and a control rod 41. As described before, the hydraulic cylinder 40 is controlled by a servo pump, which is in turn controlled by a local control unit. Otherwise, the control corresponds to the one described before.

This embodiment obviates the additional control faces which are suspended below the bridge. This is important in terms of costs and also gives the bridge an aesthetically nicer appearance.

The control algorithm used in the local control units and the main control units, respectively, depends on the actual bridge concept, provision being made for many conditions, such as e.g. the span of the bridge and the dimensions of the bridge girder. The control algorithms are based on the necessity that the control faces are constantly to deliver forces which are oppositely directed to the movements of the bridge edge. In case of torsional movements of the bridge girder this can be done in principle e.g. by allowing the control faces to move with the same frequency as the torsional movement of the bridge girder, but merely phase shifted with respect thereto. Phase shift will typically be of 60 to 90°. Also the actual shape of the control faces depends on the bridge concept in question.

The foregoing is examples of how a system of the invention can be designed, and it will be appreciated that details can be changed in many ways within the scope of the invention as defined by the appended claims. Thus, e.g. other shapes of the control faces can be used than those described here, and the control system can be expanded so as to allow for additional, measured parameters.

Claims

1. A system for counteracting wind induced oscillations in a bridge girder (11) on long cable supported bridges, wherein a plurality of control faces (14, 15, 16, 17, 34, 35, 36) arranged substantially symmetrically about the longitudinal axis of the bridge are adapted to utilize the energy of the wind for automatically reducing said oscillations in response to the movement of the bridge girder, **characterized** in that the control faces (14, 15, 16, 17, 34, 35, 36) are divided into sections in the lon-

gitudinal direction of the bridge, and that a plurality of detectors (19, 26) are provided for measuring the movements of the bridge girder, and that a local control unit (20, 25) associated with each control face section (14, 15, 16, 17, 34, 35, 36) is adapted to control the control face section in question (14, 15, 16, 17, 34, 35, 36) in response to information from one or more of said detectors (19, 26).

2. A system according to claim 1, **characterized** in that said detectors (19, 26) are distributed in the longitudinal direction of the bridge, and that each control unit (20, 25) controls the associated control face section (14, 15, 16, 17, 34, 35, 36) in response to information from the closest detector or detectors (19, 26).
3. A system according to claim 1 or 2, **characterized** in that the detectors (19, 26) are arranged substantially symmetrically about the longitudinal axis of the bridge such that there is a detector (19, 26) for each local control unit (20, 25), and that each control unit (20, 25) controls the associated control face section (14, 15, 16, 17, 34, 35, 36) in response to information from the associated detector (19, 26).
4. A system according to claims 1-3, **characterized** in that it moreover includes a main control unit (28) which is adapted to receive information from a plurality of said detectors (19, 26) and, in response thereto, to transmit control signals to a plurality of said local control units (20, 25).
5. A system according to claim 4, **characterized** in that each local control unit (20, 25) controls the associated control face section (14, 15, 16, 17, 34, 35, 36) in response to a control signal received from the main control unit (28).
6. A system according to claim 4 or 5, **characterized** in that it includes at least two main control units (28, 29), and that each main control unit (28, 29) is adapted to receive information from a plurality of said detectors (19, 26) and to transmit control signals to a plurality of said local control units (20, 25).
7. A system according to claims 1-6, **characterized** in that it includes a plurality of sensors (27) for measuring the wind direction, and that the local control units (20, 25) or the main control units (28, 29) moreover control said control face sections (14, 15, 16, 17, 34, 35, 36) in response to signals from these sensors (27).
8. A system according to claim 7, **characterized** in that said sensors (27) are moreover capable of measuring wind velocity.

9. A system according to claims 1-8, **characterized** in that the control faces (14, 15, 16, 17) are arranged below the bridge girder (11) and at a distance from it where the air flow is almost undisturbed by the bridge girder.

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10. A system according to claim 9, **characterized** in that the control faces (14, 15, 16, 17) are secured to the bridge girder (11) by pylons (18) on the underside of the bridge girder (11).

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11. A system according to claims 1-8, **characterized** in that the control faces (34, 35, 36) are formed by segments of the surface of the actual bridge girder (11), the outermost part of the bridge girder (11) in the transverse direction of the bridge being adapted to move so that the cross-section of the bridge girder (11) and thereby its aerodynamic properties are changed.

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12. A method of counteracting wind induced oscillations in a bridge girder (11) on long cable supported bridges, wherein a plurality of control faces (14, 15, 16, 17, 34, 35, 36) arranged substantially symmetrically about the longitudinal axis of the bridge utilize the energy of the wind for automatically reducing said oscillations in response to the movement of the bridge girder, **characterized** in that the control faces (14, 15, 16, 17, 34, 35, 36) are divided into sections in the longitudinal direction of the bridge, and that a plurality of detectors (19, 26) measure the movements of the bridge girder, following which a local control unit (20, 25) associated with each control face section (14, 15, 16, 17, 34, 35, 36) controls the control face section in question (14, 15, 16, 17, 34, 35, 36) in response to information from one or more of said detectors (19, 26).

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13. A method according to claim 12, **characterized** in that one or more main control units (28, 29) receive information from a plurality of said detectors (19, 26) and, in response thereto, transmit control signals to a plurality of said local control units (20, 25).

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14. A method according to claim 12 or 13, **characterized** in that a plurality of sensors (27) measure the wind direction and transmit signals on this to the local control units (20, 25) or the main control units (28, 29), following which these moreover control the said control face sections (14, 15, 16, 17, 34, 35, 36) in response to the signals from the wind sensors (27).

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Patentansprüche

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1. System zur Kompensierung windinduzierter Schwingungen in einem Brückenträger (11) einer

von langen Seilen getragenen Brücke, wobei eine im wesentlichen symmetrisch um die Längsachse der Brücke angeordnete Vielzahl von Steuerflächen (14, 15, 16, 17, 34, 35, 36) in der Lage sind, die Windenergie zu nutzen, um die Schwingungen automatisch in Abhängigkeit der Bewegung des Brückenträgers zu verringern,

dadurch gekennzeichnet, daß

die Steuerflächen (14, 15, 16, 17, 34, 35, 36) in der Längsrichtung der Brücke in Abschnitte aufgeteilt sind, und daß eine Vielzahl von Fühlern (19, 26) zum Messen der Bewegungen des Brückenträgers vorgesehen sind, und daß eine lokale Steuereinheit (20, 25) in Verbindung mit jedem Steuerflächenabschnitt (14, 15, 16, 17, 34, 35, 36) in der Lage ist, die in Frage stehende Steuerfläche (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit von Informationen aus einem oder mehreren der Fühler (19, 26) zu steuern.

2. System nach Anspruch 1,

dadurch gekennzeichnet, daß

die Fühler (19, 26) entlang der Längsrichtung der Brücke verteilt sind, und daß jede Steuereinheit (20, 25) den zugeordneten Steuerflächenabschnitt (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit der Informationen des nächstliegenden Fühlers oder der Fühler (19, 26) steuert.

3. System nach Anspruch 1 oder 2,

dadurch gekennzeichnet, daß

die Fühler (19, 26) im wesentlichen derart symmetrisch über die Längsachse der Brücke angeordnet sind, daß es einen Fühler (19, 26) für jede lokale Steuereinheit (20, 25) gibt, und daß jede Steuereinheit (20, 25) den zugeordneten Steuerflächenabschnitt (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit der Information des zugeordneten Fühlers (19, 26) steuert.

4. System nach Anspruch 1 bis 3,

dadurch gekennzeichnet, daß

es darüberhinaus eine Hauptsteuereinheit (28) hat, die in der Lage ist, Informationen von einer Vielzahl der Fühler (19, 26) zu empfangen, und in Abhängigkeit hiervon Steuersignale an eine Vielzahl von lokalen Steuereinheiten (20, 25) zu übertragen.

5. System nach Anspruch 4,

dadurch gekennzeichnet, daß

jede lokale Steuereinheit (20, 25) den zugeordneten Steuerflächenabschnitt (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit von aus der Hauptsteuereinheit (28) erhaltenen Steuersignalen steuert.

6. System nach Anspruch 4 oder 5,

dadurch gekennzeichnet, daß

es wenigstens 2 Hauptsteuereinheiten (28, 29) hat, und daß jede Hauptsteuereinheit (28, 29) in der Lage ist, Informationen von einer Vielzahl der Fühler (19, 26) zu erhalten und Steuersignale an eine Vielzahl der lokalen Steuereinheiten (20, 25) zu übertragen.

7. System nach einem der Ansprüche 1 bis 6,
dadurch gekennzeichnet, daß
es eine Vielzahl von Fühlern (27) zum Messen der Windrichtung hat, und daß die lokalen Steuereinheiten (20, 25) oder die Hauptsteuereinheiten (28, 29) darüberhinaus die Steuerflächenabschnitte (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit von Signalen dieser Fühler (27) steuert.
8. System nach Anspruch 7,
dadurch gekennzeichnet, daß
die Fühler (27) darüberhinaus in der Lage sind, die Windgeschwindigkeit zu messen.
9. System nach einem der Ansprüche 1 bis 8,
dadurch gekennzeichnet, daß
die Steuerflächen (14, 15, 16, 17) unter dem Brückenträger (11) und mit einem Abstand ihm gegenüber angeordnet sind, an dem die Luftströmung nahezu durch den Brückenträger ungestört ist.
10. System nach Anspruch 9,
dadurch gekennzeichnet, daß
die Steuerflächen (14, 15, 16, 17) am Brückenträger (11) mittels eines Tragrohrs (18) an der Unterseite des Brückenträgers (11) befestigt sind.
11. System nach einem der Ansprüche 1 bis 8,
dadurch gekennzeichnet, daß
die Steuerflächen (34, 35, 36) durch Abschnitte der Fläche des tatsächlichen Brückenträgers (11) gebildet sind, wobei der äußerste Teil des Brückenträgers (11) in der diagonalen Richtung der Brücke in der Lage ist, sich zu bewegen, daß der Querschnitt des Brückenträgers (11) und dadurch seine aerodynamischen Eigenschaften geändert werden.
12. Verfahren zur Kompensierung windinduzierter Schwingungen in einem Brückenträger (11) einer von langen Seilen getragenen Brücke, wobei eine im wesentlichen symmetrisch entlang der Längsachse der Brücke angeordnete Vielzahl von Steuerflächen (14, 15, 16, 17, 34, 35, 36) die Energie des Windes dazu nutzen, die Schwingungen in Abhängigkeit der Bewegung des Brückenträgers automatisch zu verringern,
dadurch gekennzeichnet, daß
die Steuerflächen (14, 15, 16, 17, 34, 35, 36) in Abschnitte entlang der Längsrichtung der Brücke aufgeteilt sind, und daß eine Vielzahl von Fühlern (19, 26) die Bewegungen des Brückenträgers mes-

sen, wonach eine mit jedem Steuerflächenabschnitt (14, 15, 16, 17, 34, 35, 36) verbundene lokale Steuereinheit (20, 25) die in Frage stehende Steuerfläche in Abhängigkeit der Information von einem oder mehreren der Fühler (19, 26) steuert.

13. Verfahren nach Anspruch 12,
dadurch gekennzeichnet, daß
eine oder mehrere Hauptsteuereinheiten (28, 29) Informationen von einer Vielzahl der Fühler (19, 26) erhält und in Abhängigkeit hiervon Steuersignale an eine Vielzahl der lokalen Steuereinheiten (20, 25) überträgt.
14. Verfahren nach Anspruch 12 oder 13,
dadurch gekennzeichnet, daß
eine Vielzahl von Sensoren (27) die Windrichtung messen und Signale hiervon an die örtlichen Steuereinheiten (20, 25) oder die Hauptsteuereinheiten (28, 29) übertragen, wonach diese darüberhinaus die Steuerflächenabschnitte (14, 15, 16, 17, 34, 35, 36) in Abhängigkeit von Signalen der Windsensoren (27) steuern.

Revendications

1. Système pour contrecarrer des oscillations induites par le vent dans une poutre (11) de pont sur de longs ponts suspendus à des câbles, dans lequel plusieurs faces de commande (14, 15, 16, 17, 34, 35, 36), disposées sensiblement symétriquement par rapport à l'axe longitudinal du pont, sont destinées à utiliser l'énergie du vent pour réduire automatiquement lesdites oscillations en réponse au mouvement de la poutre du pont,
caractérisé en ce que les faces de commande (14, 15, 16, 17, 34, 35, 36) sont disposées en sections dans la direction longitudinale du pont, et en ce que plusieurs détecteurs (19, 26) sont prévus pour mesurer le mouvement de la poutre du pont, et en ce qu'une unité de commande locale (20, 25) associée à chaque section (14, 15, 16, 17, 34, 35, 36) de face de commande est destinée à commander la section de face de commande concernée (14, 15, 16, 17, 34, 35, 36) en réponse à une information provenant d'un ou plusieurs desdits détecteurs (19, 26).
2. Système selon la revendication 1, caractérisé en ce que lesdits détecteurs (19, 26) sont répartis dans la direction longitudinale du pont, et en ce que chaque unité de commande (20, 25) commande la section de face de commande associée (14, 15, 16, 17, 34, 35, 36) en réponse à une information provenant du détecteur ou des détecteurs (19, 26) les plus proches.

3. Système selon la revendication 1 ou 2, caractérisé en ce que les détecteurs (19, 26) sont disposés sensiblement symétriquement par rapport à l'axe longitudinal du pont de manière qu'il y ait un détecteur (19, 26) pour chaque unité de commande locale (20, 25), et en ce que chaque unité de commande (20, 25) commande la section de face de commande associée (14, 15, 16, 17, 34, 35, 36) en réponse à une information provenant du détecteur associé (19, 26). 5
4. Système selon les revendications 1-3, caractérisé en ce qu'il comprend, en outre, une unité de commande principale (28) qui est destinée à recevoir des informations de plusieurs desdits détecteurs (19, 26) et, en réponse à celles-ci, à transmettre des signaux de commande à plusieurs desdites unités de commande locale (20, 25). 10
5. Système selon la revendication 4, caractérisé en ce que chaque unité de commande locale (20, 25) commande la section de face de commande associée (14, 15, 16, 17, 34, 35, 36) en réponse à un signal de commande reçu de l'unité de commande principale (28). 15
6. Système selon la revendication 4 ou 5, caractérisé en ce qu'il comprend au moins deux unités de commande principale (28, 29), et en ce que chaque unité de commande principale (28, 29) est destinée à recevoir des informations de plusieurs desdits détecteurs (19, 26) et à transmettre des signaux de commande à plusieurs desdites unités de commande locale (20, 25). 20
7. Système selon les revendications 1-6, caractérisé en ce qu'il comprend plusieurs capteurs (27) destinés à mesurer la direction du vent, et en ce que les unités de commande locale (20, 25) ou les unités de commande principale (28, 29) commandent, en outre, lesdites sections de face de commande (14, 15, 16, 17, 34, 35, 36) en réponse à des signaux provenant de ces capteurs (27). 25
8. Système selon la revendication 7, caractérisé en ce que lesdits capteurs (27) sont capables en outre de mesurer la vitesse du vent. 30
9. Système selon les revendications 1-8, caractérisé en ce que les faces de commande (14, 15, 16, 17) sont disposées au-dessous de la poutre (11) du pont et à une distance de celle-ci où l'écoulement d'air n'est pratiquement pas perturbé par la poutre du pont. 35
10. Système selon la revendication 9, caractérisé en ce que les faces de commande (14, 15, 16, 17) sont fixées à la poutre (11) du pont par des pylônes (18) 40
11. Système selon les revendications 1-8, caractérisé en ce que les faces de commande (34, 35, 36) sont formées par des segments de la surface de la poutre réelle (11) du pont, la partie située la plus à l'extérieur de la poutre (11) du pont dans la direction transversale du pont étant destinée à se déplacer de manière que la section transversale de la poutre (11) du pont et, ainsi, ses propriétés aérodynamiques, soient modifiées. 45
12. Procédé pour contrecarrer des oscillations induites par le vent dans une poutre (11) de pont sur de longs ponts suspendus à des câbles, dans lequel plusieurs faces de commande (14, 15, 16, 17, 34, 35, 36), disposées sensiblement symétriquement par rapport à l'axe longitudinal du pont, utilisent l'énergie du vent pour réduire automatiquement lesdites oscillations en réponse au mouvement de la poutre du pont, caractérisé en ce que les faces de commande (14, 15, 16, 17, 34, 35, 36) sont disposées en sections dans la direction longitudinale du pont, et en ce que plusieurs détecteurs (19, 26) mesurent les mouvements de la poutre du pont, à la suite de quoi une unité de commande locale (20, 25) associée à chaque section de face de commande (14, 15, 16, 17, 34, 35, 36) commande la section de face de commande concernée (14, 15, 16, 17, 34, 35, 36) en réponse à des informations provenant d'un ou plusieurs desdits détecteurs (19, 26). 50
13. Procédé selon la revendication 12, caractérisé en ce qu'une ou plusieurs unités de commande principale (28, 29) reçoivent des informations de plusieurs desdits détecteurs (19, 26) et, en réponse à celles-ci, transmettent des signaux de commande à plusieurs desdites unités de commande locale (20, 25). 55
14. Procédé selon la revendication 12 ou 13, caractérisé en ce que plusieurs capteurs (27) mesurent la direction du vent et transmettent des signaux la représentant aux unités de commande locale (20, 25) ou aux unités de commande principale (28, 29), à la suite de quoi celles-ci commandent lesdites sections de face de commande (14, 15, 16, 17, 34, 35, 36) en réponse aux signaux provenant des capteurs (27) de vent.

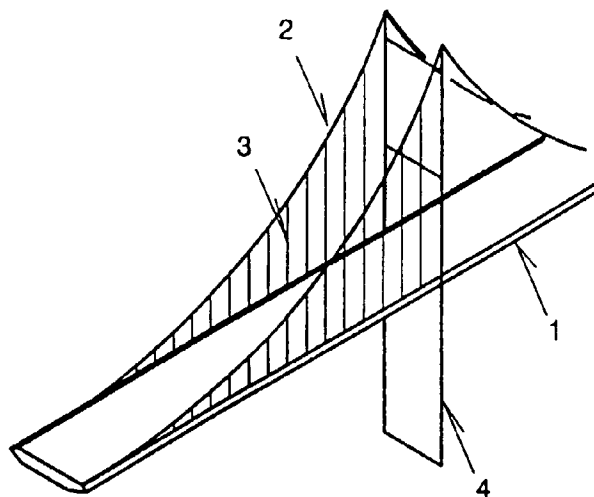


Fig. 1

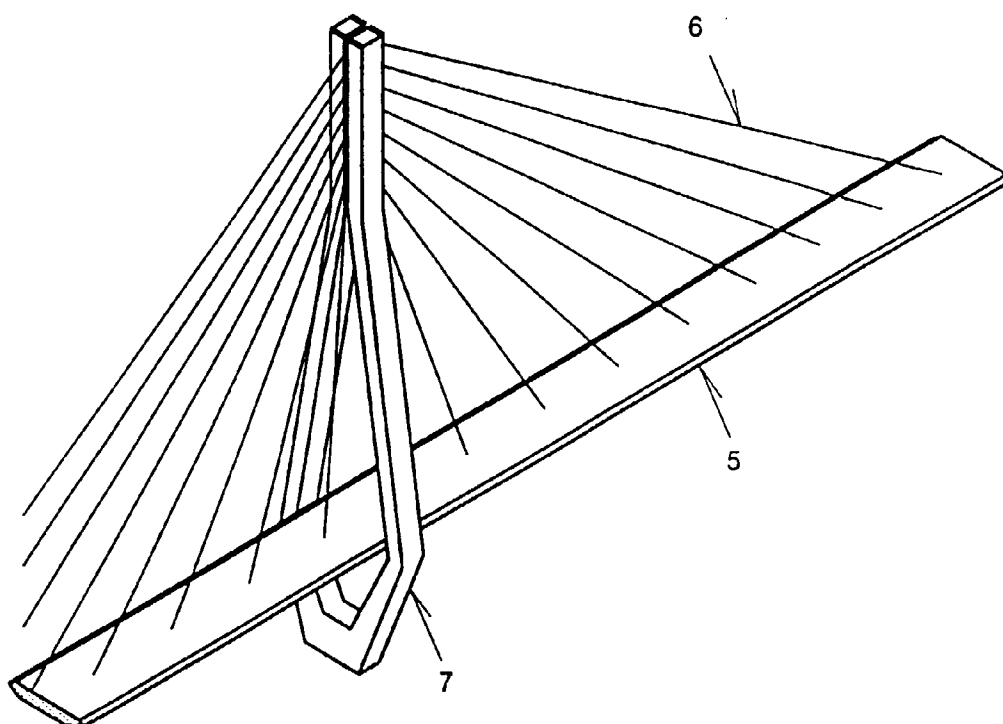


Fig. 2

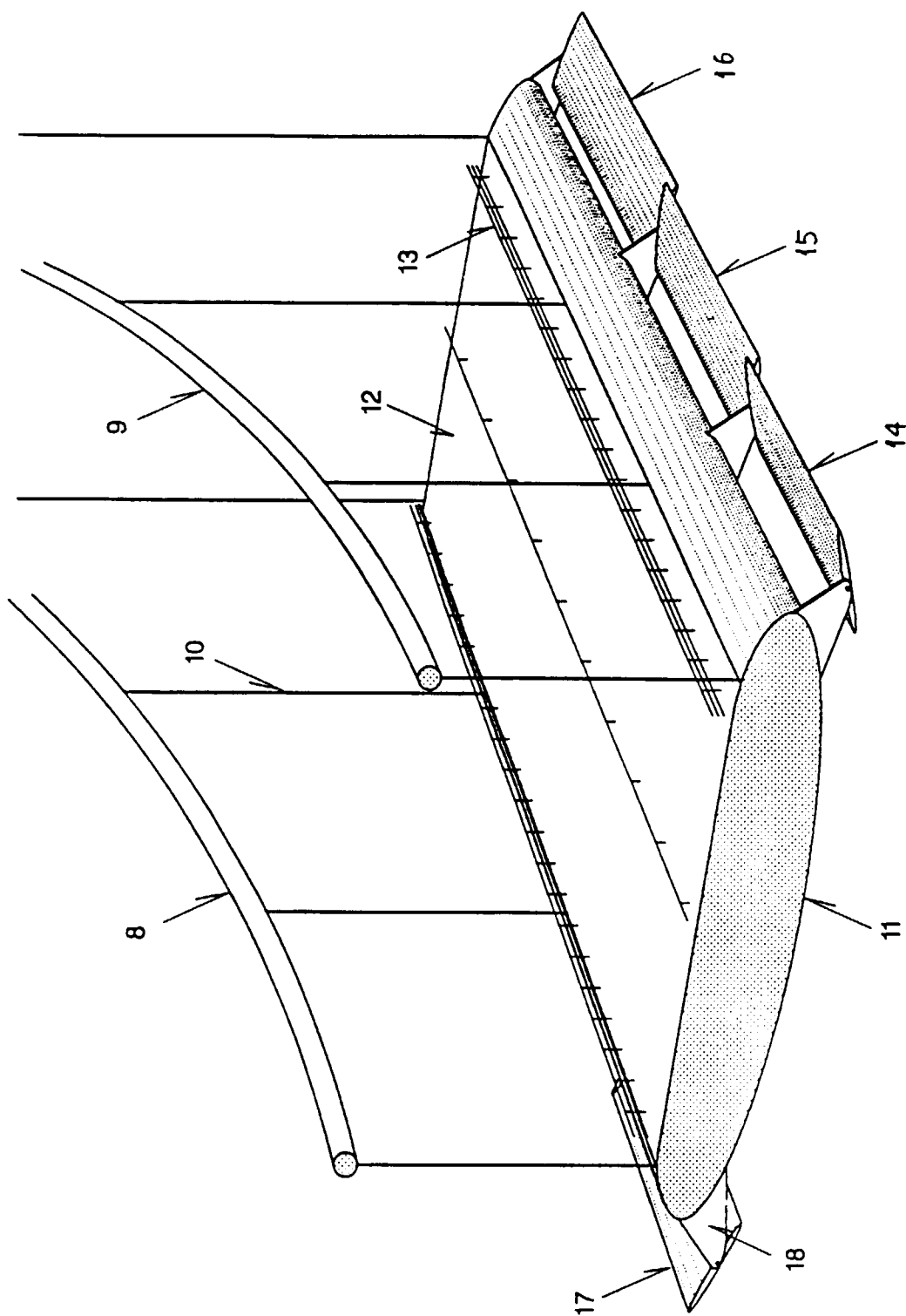


Fig. 3

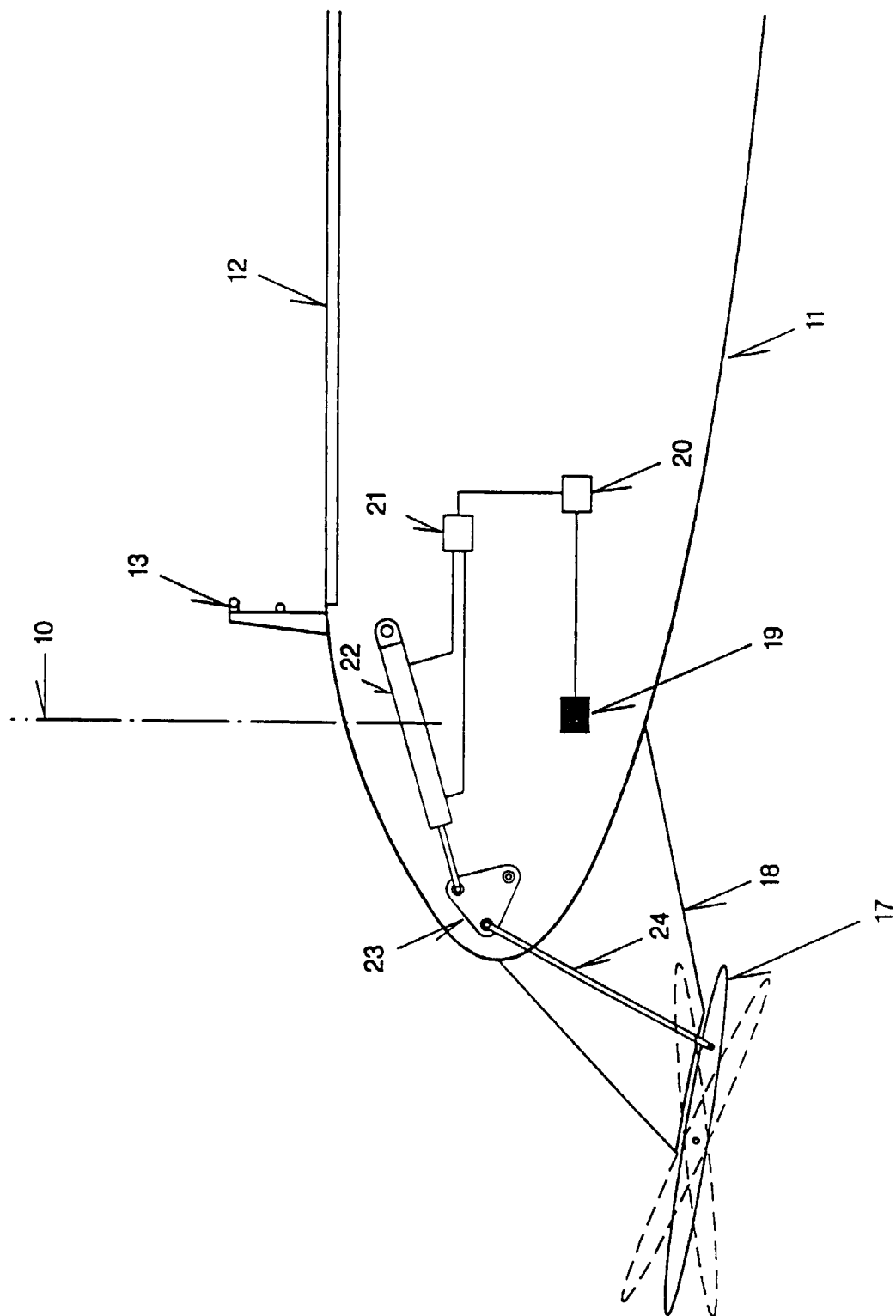


Fig. 4

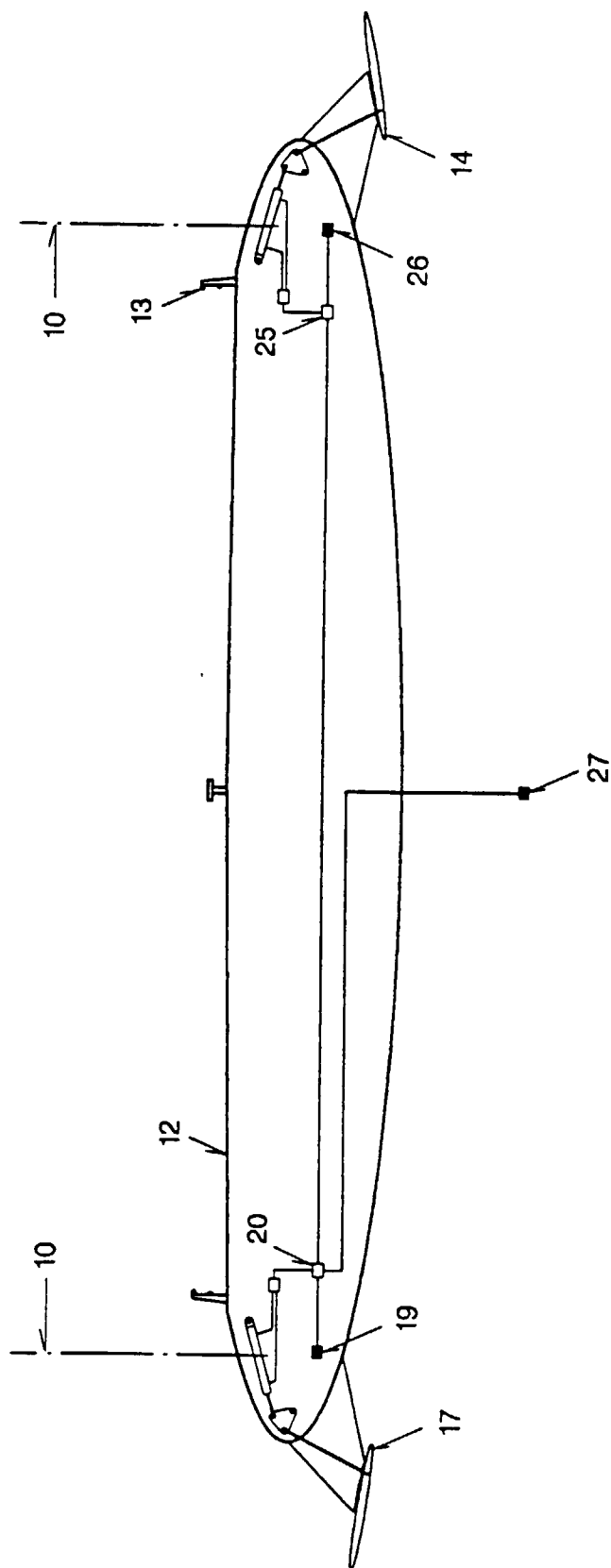


Fig. 5

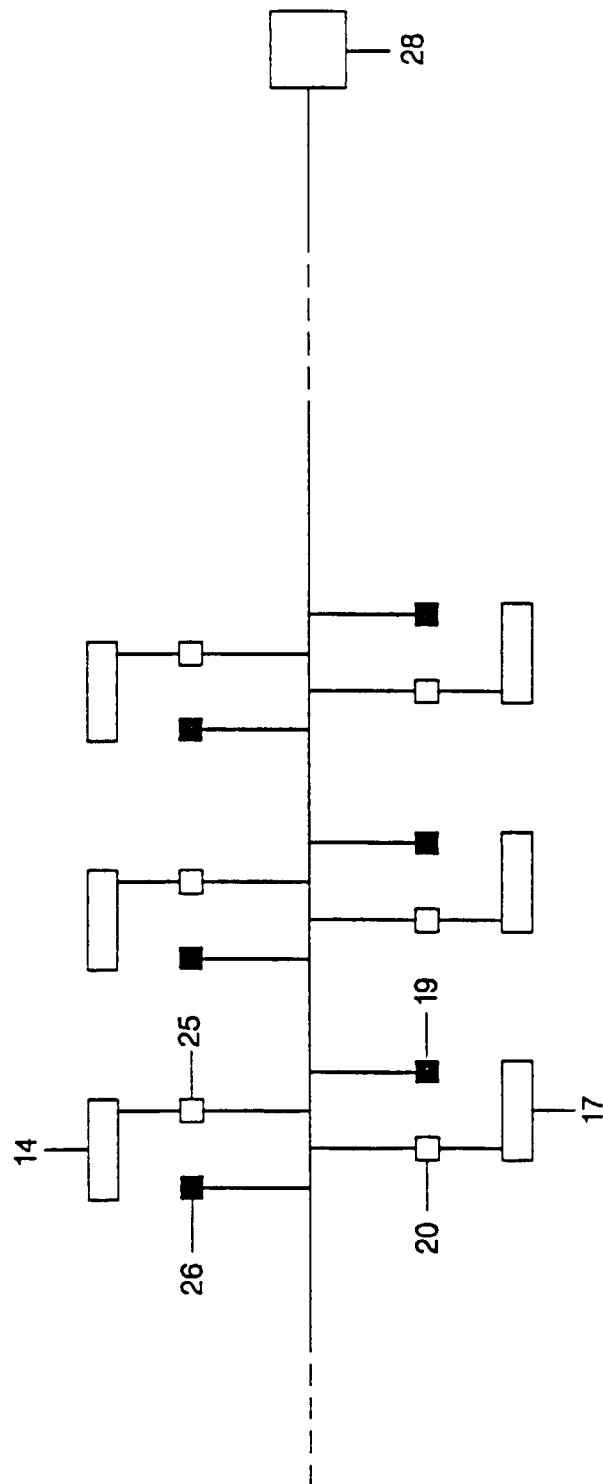


Fig. 6

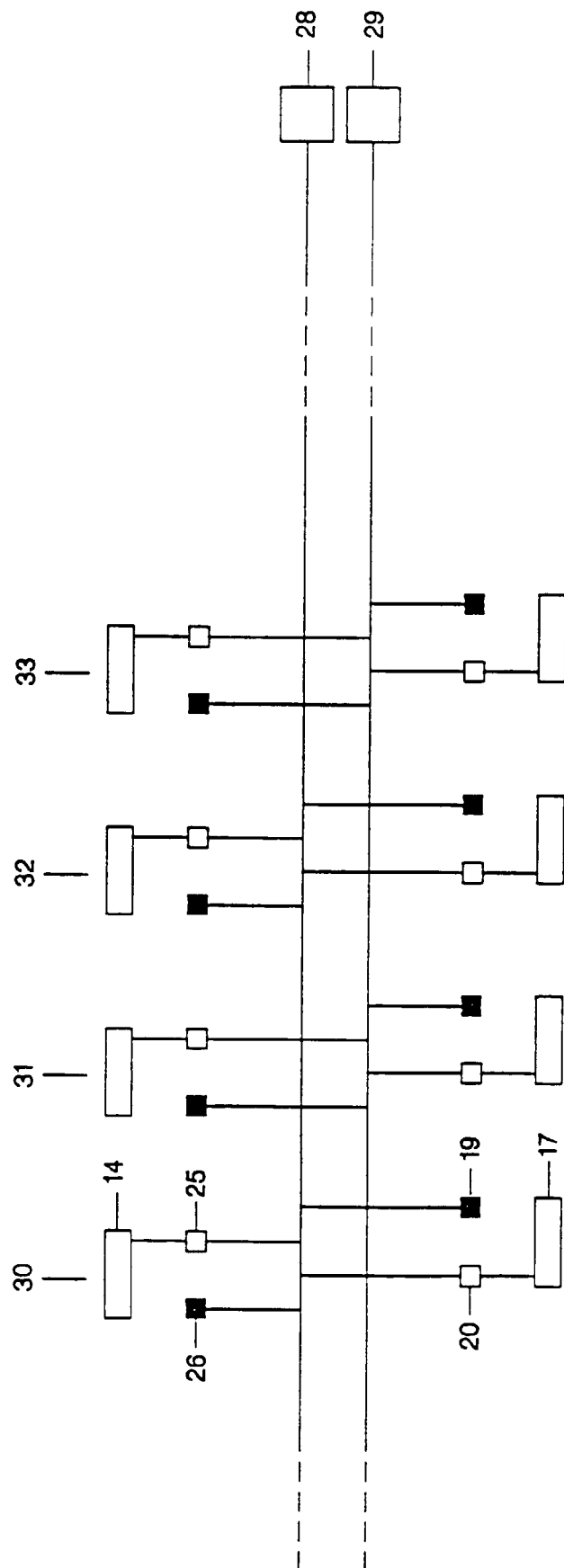


Fig. 7

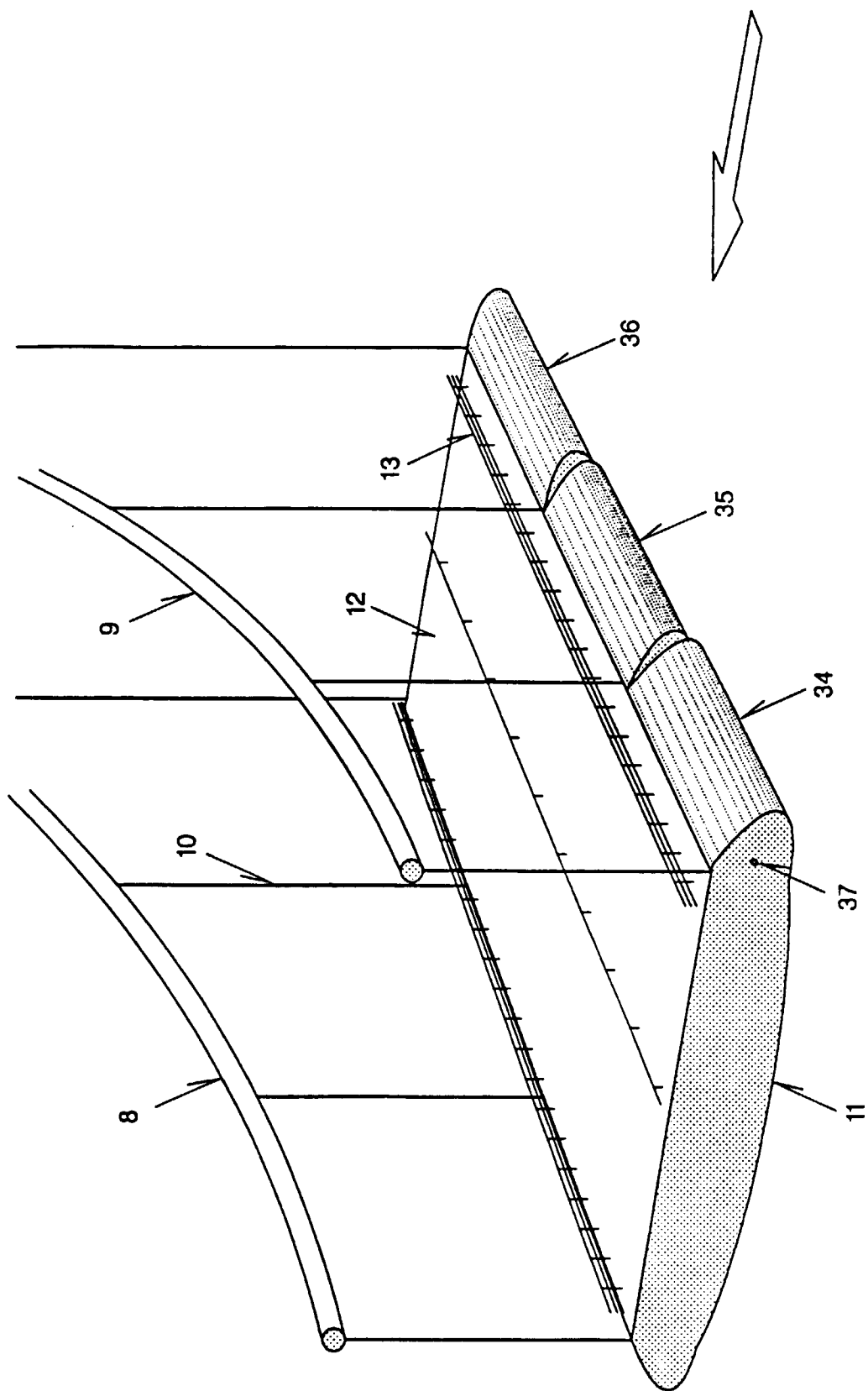


Fig. 8

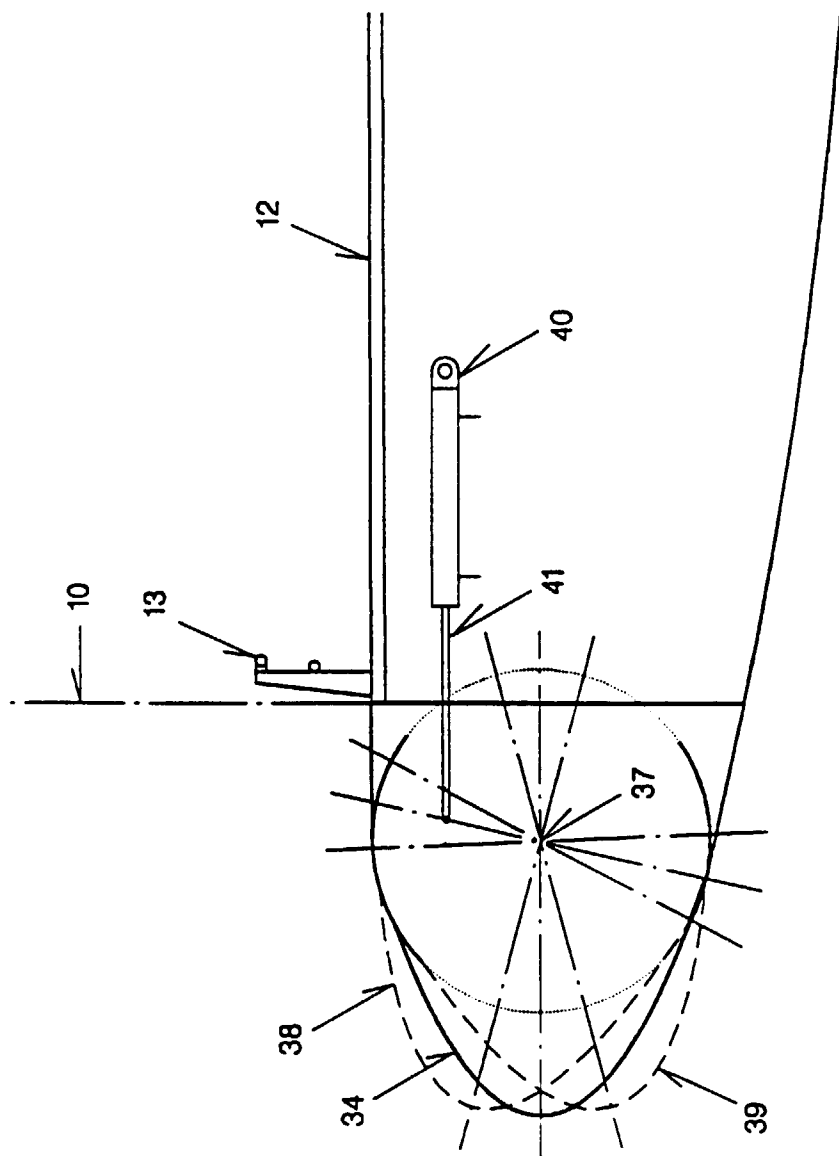


Fig. 9