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944,504

944,504



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Date of filing Complete Specification: March 21, 1960.

Application Date: March 23, 1959.

No. 34407/63

Complete Specification Published: December 18, 1963.

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Index at Acceptance:—B7 K.

International Classification:—B 64 c.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Vehicle for travelling over Land and/or Water

WE, HOVERCRAFT DEVELOPMENT LIMITED, a British Company, of 1 Tilney Street, London, W.1., do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to vehicles for operating over a surface and which are supported above that surface by one or more cushions of pressurised gas.

The specification of Letters Patent No. 854,221 describes and claims a vehicle which comprises means for causing a fluid to issue from the lower part of the vehicle in such a way as to result in the formation and maintenance of at least one curtain of moving fluid which travels across the gap that in operation exists between the surface over which the vehicle is to hover or travel and the structure of the vehicle and, together with the said structure and surface, encloses a space into which the said fluid, or gas other than the said fluid, flows so as to result in the formation of a pressurised cushion or cushions by which the vehicle is wholly or partly supported, the pressure of the cushion causing, and in its turn being contained due to a change of direction of the moving fluid which results in a curvature of the curtain and in which the means for forming the curtain are such that in cruising conditions the thrust due to the stream of fluid finally leaving the vehicle is substantially less than the weight of the vehicle when loaded.

The same system of support is applicable to mobile platforms and to aircraft and aircraft carriers such as those described and claimed in the specifications of Letters Patent Nos. 893715, 894644, 895341. The term vehicle as used herein is to be under-

stood, where the context permits, as including mobile platforms, aircraft and aircraft carriers.

The invention is based on the concept that a restoring force can be made available on the vehicle by providing means for varying the position of a supporting cushion relative to the vertical axis through the centre of gravity of the vehicle.

According to the invention there is provided a gas cushion supported vehicle comprising means for forming beneath the vehicle a supporting gas cushion the boundary of which surrounds the vertical axis through the centre of gravity of the vehicle wherein means are provided for varying the position of the centre of pressure of the cushion relative to the vertical axis through the centre of gravity of the vehicle so as to provide a stabilising moment on the vehicle.

The supporting cushion may or may not be subdivided with separate compartments. Alternatively or in addition one or more further cushions may be formed outside the main supporting cushion or cushions. In the latter case, the main supporting cushion or cushions hereinafter will be referred to as the primary cushion or cushions, which the further cushion or cushions will be referred to as the secondary cushion or cushions of pressurised gas.

Where the cushion or cushions are contained for at least part of their peripheries by curtains of moving fluid formed one within the other, the outermost curtain system will be referred to as the primary curtain, while the inner curtain system will be referred to as the secondary curtain. It will be assumed for convenience in the following descriptions of certain embodiments of the invention that where curtains are referred to the curtain-forming fluid is air.

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substantially

although it can be another gas, such as engine exhaust gases or a liquid such as, for example sea water.

For a better understanding of the invention, and to show how the same may be put into effect, reference will now be made to the accompanying drawings like parts having like references, in which:—

Figure 1 is a side elevation of a vehicle having a vertical primary supporting cushion of pressurised gas and an annular secondary cushion of pressurised gas,

Figure 2 is a diagrammatic front elevation of the vehicle illustrated in Figure 1, showing one form of air flow when the vehicle is tilted, the tilting being shown to an exaggerated degree for clarity.

Figure 3 is an inverted plan view of the vehicle illustrated in Figures 1 and 2,

Figure 4 is a diagrammatic partial cross section of a vehicle showing a further embodiment of the invention,

Figure 5 is a diagrammatic partial cross section of a vehicle illustrating a further embodiment of the invention,

Figures 6a and 6b are diagrammatic illustrations of an embodiment of the invention, showing means for varying the position of a curtain forming port in the bottom of a vehicle,

Figures 7a and 7b are diagrammatic illustrations of a means for varying the ejection angle of a curtain forming port.

Figures 1, 2 and 3 show a form of vehicle described and claimed in co-pending application No. 34405/63 (Serial No. 944503) in which a stepped pressure distribution is obtained beneath the vehicle by forming a primary cushion surrounded by a secondary annular cushion at a pressure during normal operation intermediate between the primary cushion pressure and atmosphere. The vehicle has a base portion 1 which carries a passenger and/or freight carrying portion 2. The portion 2 may also contain the engines driving the air compressors which supply the air for forming the curtains. As will be seen in Figure 3 the bottom of the vehicle has two ports 3 and 4 the outer or primary port 3 being adjacent to the periphery of the base 1 of the vehicle and the inner or secondary port 4 being spaced inwardly from and substantially parallel to the primary port.

When in operation, air curtains are formed by air issuing from the ports 3 and 4 and form and maintain a primary cushion 5 and a secondary annular cushion 6.

If the vehicle for any reason tilts, as shown to an exaggerated degree in Figure 2, the radius of curvature of the primary curtain formed by port 3 decreases at that part of the vehicle which approaches the surface so that the pressure of the secondary cushion increases locally. The in-

crease in pressure in the secondary cushion provides a righting moment which tends to stabilise the vehicle.

The operation of such a vehicle is fully described in the specifications of the above mentioned application and will not be described further herein.

Figure 4 shows a simple arrangement for moving the effective boundary of a cushion so as to move its centre of pressure in which two ports 34 and 35 are supplied with air by ducts 36 and 37 respectively. A hinged flap 38 is mounted at the junction of the two ducts 36 and 37, the position of the flap controlling the air fed from a compressor via duct 39 to each of the ducts 36 and 37. By rotating the flap one way, at the correct circumferential location or locations, anti-clockwise in Figure 4, the air flowing to the inner curtain can be cut off and that flowing to the outer curtain released. Reverse rotation of the flap has the reverse effect. The effective boundary of the cushion is thus shifted, at the location or locations at which the flap is rotated, from the position of port 35 to the position of port 34 so that the centre of pressure of the cushion will be shifted correspondingly.

In the arrangement shown in Figure 4 where the flap controls a port following a circular configuration it must be made of flexible material or sectors of stiff material with radial joints of flexible material.

Figure 5 illustrates diagrammatically an alternative method of varying the relative flows of air to the primary and secondary curtain ports, using a sliding plate. A flat plate 65 is mounted on the bottom surface of the vehicle, arranged to slide inwardly and outwardly over the openings 66 and 67, the plate being provided with ports 68 and 69. The ports 68 and 69 co-operate with the openings 66 and 67 respectively to define the actual positions at which the curtain forming air issues. The widths of the ports 68 and 69, and their positioning relative to the openings 66 and 67, is such that in a mid position equal flows of air occur through the ports 68 and 69 whilst in one extreme position or the other, a flow of air occurs through one or other of the ports equal to the combined flow when the ports are in the said position, no flow occurring through the other port. Flows of air between these two extremes will occur depending upon the position of ports 68 and 69 relative to the openings 66 and 67. Air is fed to the ports via a duct 70.

As only the outer edge of opening 66 and the inner edge of opening 67 normally take an effective part in defining the width of the actual opening through which the curtain forming air flows, these openings are made wider than the ports 68 and 69. Vanes may be provided in the openings 66 and 67.

Whilst the flat plate is shown as being fitted inside the bottom of the vehicle, it can readily be fitted on the outside but is liable to be damaged. Again, the relative positionings of the ports and openings can be reversed, the narrow ports 68 and 69 being formed in the bottom of the vehicle and the openings 66 and 67 being formed in the sliding plate 65.

Figures 6a and 6b illustrate diagrammatically a method for moving the position of a port relative to the bottom of a vehicle. Mounted over a wide opening 71 is a slidable flat plate 72 having a narrow port 73. The port 73 may be in the form of an annular configuration. As shown in Figure 6a, the port 73 is in its central position. By moving the plate in or out, in a generally radial direction, the position of the port and thus the curtain, relative to the centre of the vehicle, can be varied. It will be seen that if the position of the port is altered only on, for example, one side of the vehicle this will have the effect of moving the edge of the cushion. If the port 73 is moved inwards towards the centre of the vehicle, as shown in Figure 6b the edge of the cushion will be moved inwards which will have the effect of moving the centre of pressure of the cushion away from the centre of gravity of the vehicle, towards the side remote from that in which the port 73 has moved and the vehicle will tend to drop on the side where the port 73 has been moved. The movable plate 72 is easily provided for straight portions of the ports in the bottom of the vehicle, but where the ports are curved, it will be necessary to provide for the plates to slide one over the other as they are moved in and out to allow for the variation in the circumferential distance. Both primary and secondary curtain ports may be formed in this manner, the sliding plates being moved together or independently Vanes, 74, may be provided in the side opening 71.

Figures 7a and 7b illustrate a further method of varying the position of a curtain, and thus the edge of a cushion, relative to the centre of the vehicle. The port is in the form of a nozzle 76, the nozzle being annular in form and of flexible construction, or a series of separate nozzles in an annular configuration. The nozzle 76 is mounted in the bottom of the vehicle so that it projects through the bottom surface of the vehicle and the angle of ejection of the air issuing from it can be rotated about a horizontal axis. Figure 7a shows the nozzle in its normal position, the curtain 77 issuing in a direction towards the cushion which the curtain is supporting. By rotating the nozzle until it is vertical, as shown in Figure 7b the curtain 77 issues vertically and the edge of the cushions will have

moved outwards slightly. A vertical curtain is not able to support such a high pressure in the cushion as a curtain having an initial direction towards the cushion, both curtains being of the same flow. However, if desired, the weakening effect of moving the nozzle to a vertical direction can be mitigated at least to some extent by arranging for the nozzle to widen as it rotates. It will be seen that with the construction shown in Figures 7a and 7b with the walls of the nozzle pivoted at 78 and 79 to the bottom of the vehicle, some widening of the nozzle does in fact take place as it rotates to a vertical position. Again, the construction of such a nozzle is simple for straight ports, but suitable elasticity must be provided in the case of curved ports to allow for the variation of peripheral extent of the other nozzles walls as they are rotated.

Whilst the vehicles described have been those having simple curtain systems, the various methods of stabilising and altering the trim described above can also be applied to vehicles having more complex curtain systems. Examples of such systems are those in which the curtains are in the form of closed vortices, and those in which at least part of the air forming the curtains is recovered and re-energised, the recovered air being circulated back to the original curtain or being used to form an additional curtain.

In the examples described above and illustrated in the accompanying drawings the curtain-forming fluid is considered as issuing from the vehicle in a downwards direction at an angle to the vertical, with a component of direction inwards toward the centre of the cushion. The angle may vary but generally is between 45° and 60° to the vertical.

Where the moving of the position of a port or ports, is used for varying the trim of a vehicle, this provides a convenient means for maintaining the attitude of the vehicle over obstacles such as rocky ground or waves at sea. Taking as an example, a vehicle travelling over waves at sea, the trim of the vehicle can be controlled by a simple mechanism, such as a gyroscopically controlled valve so that the vehicle remains on a substantially even keel.

The operation is as follows.

When the front of the vehicle meets a wave, which causes a locally reduced height and thus a locally increased pressure rise in the cushion, the vehicle tends to lift at the front. A suitably controlled valve detects this rise and varies the position of the curtain forming port or ports, so that the centre of pressure moved in a sense to counteract the lifting tendency caused by the wave. A reverse effect is created when



An annulus or a series of ports in

recirculated



accelerations



position of the

the front end is over a wave trough. Such a trim control can be used to counteract undesirable movements of the vehicle at any point on its periphery. The vehicle thus operates on a substantially even keel and does not have imposed upon it undesirable vertical accelerations due to passing over obstructions.

However, when a vehicle is operating over waves a number of times longer than the length of the vehicle, or over land undulations having characteristics similar to long waves, there is not the same need to maintain the vehicle on an even keel as the vertical accelerations are quite moderate. The vehicle can thus travel at a constant height form the surface following the surface profile. In order to obtain such an operating mode when a control means responsive to attitude variation of the vehicle is used for the said curtain position variation, it is necessary to provide an over-ride which renders the control means inoperative when for example the vertical accelerations or the frequency of the vertical movement is below a predetermined value. Alternatively the response of the control means responsive to attitude variations may be given a suitable time constant rather than over-ride so that its effectiveness gradually approaches zero for very slow variations.

Attention is drawn to specification No. 9900 '59 (Serial No. 944502) from which the present application is divided.

WHAT WE CLAIM IS:—

1. A gas cushion supported vehicle comprising means for forming beneath the vehicle a supporting gas cushion the boundary of which surrounds the vertical axis through the centre of gravity of the vehicle wherein means are provided for varying the centre of pressure of the cushion relative to the vertical axis through the centre of gravity of the vehicle so as to provide a stabilising moment on the vehicle.

2. A gas cushion supported vehicle comprising means for forming beneath the vehicle a primary supporting gas cushion the boundary of which surrounds the vertical axis through the centre of gravity of the vehicle, means for forming at least one secondary supporting gas cushion at least part of the boundary of which is common with at least part of the boundary of the primary cushion and means for varying the position of the common boundary whereby the position of the centre of pressure of at least the primary cushion is varied relative to the vertical axis through the centre of gravity of the vehicle so as to provide a stabilising moment on the vehicle.

3. A vehicle as claimed in claim 1 or claim 2 comprising means for causing a fluid to issue from the lower part of the vehicle

and form at least one curtain of moving fluid which flows towards the surface above which the vehicle is supported, said curtain forming at least part of the boundary of at least one cushion of pressurised gas beneath the vehicle.

4. A vehicle as claimed in claim 1 and claim 3 wherein the means for varying the position of the centre of pressure of the cushion comprises means for moving the effective position of at least part of the curtain of moving fluid.

5. A vehicle as claimed in claim 2 and claim 3 in which at least part of the curtain of moving fluid forms the said common boundary between the primary cushion and a secondary cushion wherein the means for varying the position of the centre of pressure of the primary cushion comprises means for moving the effective position of the said part of the curtain of moving fluid.

6. A vehicle as claimed in claim 4 or claim 5 in which the fluid for forming the curtain issues through a supply port formed in the lower part of the vehicle, wherein the means for moving the effective position of the curtain comprises means for moving the supply port.

7. A vehicle as claimed in claim 6 wherein the means for moving the effective position of the curtain comprises a member mounted in the lower part of the vehicle for movement in a direction normal to the periphery of the cushion of pressurised gas, the supply port being formed in the movable member.

8. A vehicle as claimed in claim 6 wherein the means for moving the effective position of the curtain comprises a movable structure depending below the bottom of the vehicle, at least the lower part of the structure being capable of movement in a direction normal to the periphery of the cushion of pressurised gas, the fluid forming the curtain issuing from the lower part of the structure.

9. A vehicle as claimed in claim 8 wherein said structure comprises at least one nozzle, the outlet of which forms a supply port.

10. A vehicle as claimed in claim 9 including means for rotating said nozzle about a horizontal axis extending substantially parallel to the periphery of the cushion.

11. A vehicle as claimed in any one of the preceding claims in which at least part of a boundary of a cushion is formed by a curtain of moving fluid, wherein the fluid is ejected with an inclination inwards away from the boundary of the cushion.

12. A vehicle as claimed in claim 11 wherein the curtain forming fluid issues at an angle between 45° and 60° to the vertical.

13. A vehicle as claimed in claim 10

the front end is over a wave trough. Such a trim control can be used to counteract undesirable movements of the vehicle at any point on its periphery. The vehicle thus operates on a substantially even keel and does not have imposed upon it undesirable vertical accelerations due to passing over obstructions.

However, when a vehicle is operating over waves a number of times longer than the length of the vehicle, or over land undulations having characteristics similar to long waves, there is not the same need to maintain the vehicle on an even keel as the vertical accelerations are quite moderate. The vehicle can thus travel at a constant height from the surface following the surface profile. In order to obtain such an operating mode when a control means responsive to attitude variation of the vehicle is used for the said curtain position variation, it is necessary to provide an over-ride which renders the control means inoperative when for example the vertical accelerations or the frequency of the vertical movement is below a predetermined value. Alternatively the response of the control means responsive to attitude variations may be given a suitable time constant rather than over-ride so that its effectiveness gradually approaches zero for very slow variations.

Attention is drawn to specification No. 9900/59 (Serial No. 944502) from which the present application is divided.

WHAT WE CLAIM IS:—

1. A gas cushion supported vehicle comprising means for forming beneath the vehicle a supporting gas cushion the boundary of which surrounds the vertical axis through the centre of gravity of the vehicle wherein means are provided for varying the centre of pressure of the cushion relative to the vertical axis through the centre of gravity of the vehicle so as to provide a stabilising moment on the vehicle.

2. A gas cushion supported vehicle comprising means for forming beneath the vehicle a primary supporting gas cushion the boundary of which surrounds the vertical axis through the centre of gravity of the vehicle, means for forming at least one secondary supporting gas cushion at least part of the boundary of which is common with at least part of the boundary of the primary cushion and means for varying the position of the common boundary whereby the position of the centre of pressure of at least the primary cushion is varied relative to the vertical axis through the centre of gravity of the vehicle so as to provide a stabilising moment on the vehicle.

3. A vehicle as claimed in claim 1 or claim 2 comprising means for causing a fluid to issue from the lower part of the vehicle

and form at least one curtain of moving fluid which flows towards the surface above which the vehicle is supported, said curtain forming at least part of the boundary of at least one cushion of pressurised gas beneath the vehicle.

4. A vehicle as claimed in claim 1 and claim 3 wherein the means for varying the position of the centre of pressure of the cushion comprises means for moving the effective position of at least part of the curtain of moving fluid.

5. A vehicle as claimed in claim 2 and claim 3 in which at least part of the curtain of moving fluid forms the said common boundary between the primary cushion and a secondary cushion wherein the means for varying the position of the centre of pressure of the primary cushion comprises means for moving the effective position of the said part of the curtain of moving fluid.

6. A vehicle as claimed in claim 4 or claim 5 in which the fluid for forming the curtain issues through a supply port formed in the lower part of the vehicle, wherein the means for moving the effective position of the curtain comprises means for moving the supply port.

7. A vehicle as claimed in claim 6 wherein the means for moving the effective position of the curtain comprises a member mounted in the lower part of the vehicle for movement in a direction normal to the periphery of the cushion of pressurised gas, the supply port being formed in the movable member.

8. A vehicle as claimed in claim 6 wherein the means for moving the effective position of the curtain comprises a movable structure depending below the bottom of the vehicle, at least the lower part of the structure being capable of movement in a direction normal to the periphery of the cushion of pressurised gas, the fluid forming the curtain issuing from the lower part of the structure.

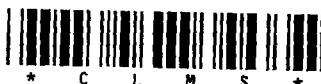
9. A vehicle as claimed in claim 8 wherein said structure comprises at least one nozzle, the outlet of which forms a supply port.

10. A vehicle as claimed in claim 9 including means for rotating said nozzle about a horizontal axis extending substantially parallel to the periphery of the cushion.

11. A vehicle as claimed in any one of the preceding claims in which at least part of a boundary of a cushion is formed by a curtain of moving fluid, wherein the fluid is ejected with an inclination inwards away from the boundary of the cushion.

12. A vehicle as claimed in claim 11 wherein the curtain forming fluid issues at an angle between 45° and 60° to the vertical.

13. A vehicle as claimed in claim 10



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and claim 11 including means for widening the nozzle as it rotates to assume a more critical inclination.

14. A vehicle as claimed in any one of the preceding claims in which at least part of a boundary of a cushion is formed by a curtain of moving fluid, wherein the curtain is in the form of a closed vortex.

15. A vehicle as claimed in any one of the claims 4 to 10 including control means connected to the means for moving the effective position of the curtain and responsive to variations in attitude of the vehicle, said control means being arranged to operate the means for moving the effective position of the curtain so as to produce a stabilising moment on the vehicle in opposition to said variations in attitude of the vehicle.

16. A vehicle as claimed in claim 15 including over-ride means responsive to vertical accelerations of the vehicle, said over-ride means operating to over-ride said control means where the vertical accelerations of the vehicle are below a predeter-

mined value.

17. A vehicle as claimed in claim 15 including over-ride means responsive to the frequency of the variations in attitude of the vehicle, said over-ride means operating to over-ride said control means when the frequency of the variations in attitude of the vehicle is below a predetermined value.

18. A vehicle as claimed in claim 15 wherein said control means includes means for varying the response of the control means in accordance with a time constant, whereby the operation of the control means reduces as the frequency of the attitude variations of the vehicle reduces.

19. A vehicle substantially as described herein and as illustrated in Figures 1, 2 and 3 and Figure 4 or Figure 5 or Figures 6a and 6a or Figures 7a and 7b of the accompanying drawings.

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