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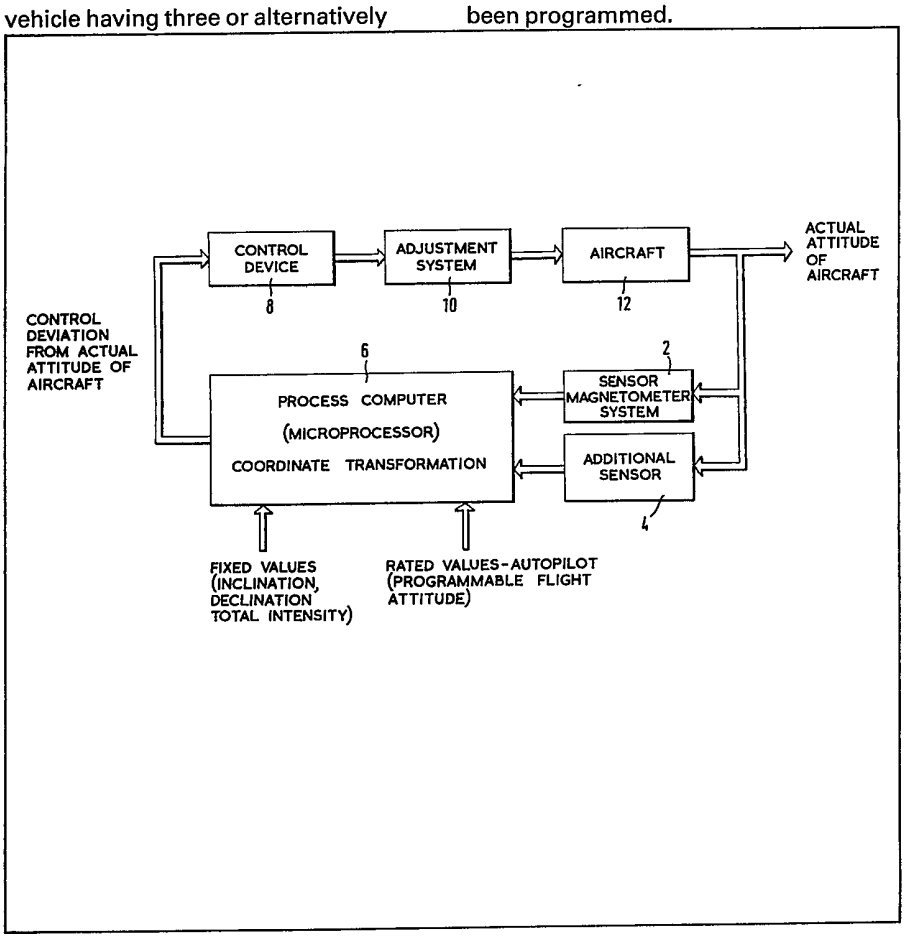
(71) Applicants **Deutsche Forschungs - und Versuchsanstalt fur luft- und Raumfahrt e.V, Linder Hohe, 5000 Koln 90, Fed. Republic of Germany.**
(72) Inventors **Rudiger Karmann, Peter Hamel.**
(74) Agents **Walford & Hardman Brown, Trinity House, Hales Street, Conventry, CV1 1NP.**

(54) **Steering and stabilisation system for vehicles**

(57) A steering and stabilisation system for a vehicle including a sensor (2) for the determination of attitude of the vehicle having three or alternatively two, magnetometers mounted in the vehicle with respect to the direction of the fore-and-aft axis thereof to determine each co-ordinate of a set of three orthogonal co-ordinates of attitude of the vehicle and an additional sensor (4) of attitude, e.g. a pendulum or a device responsive to the Earth's electric field, to provide supplementary information relating to one of the co-ordinates of attitude determined by the magnetometers. The system includes a microprocessor (6) by which the orthogonal co-ordinates determined by the magnetometers are transformed into respective geodetic co-ordinates and signals representative of the transformed co-ordinates and signals representative of the supplementary information are coupled and control signals, required for a control and adjustment system (8, 10) of the vehicle (12), are calculated in accordance with signals representative of a predetermined motion of the vehicle with which the computer (6) has been programmed.



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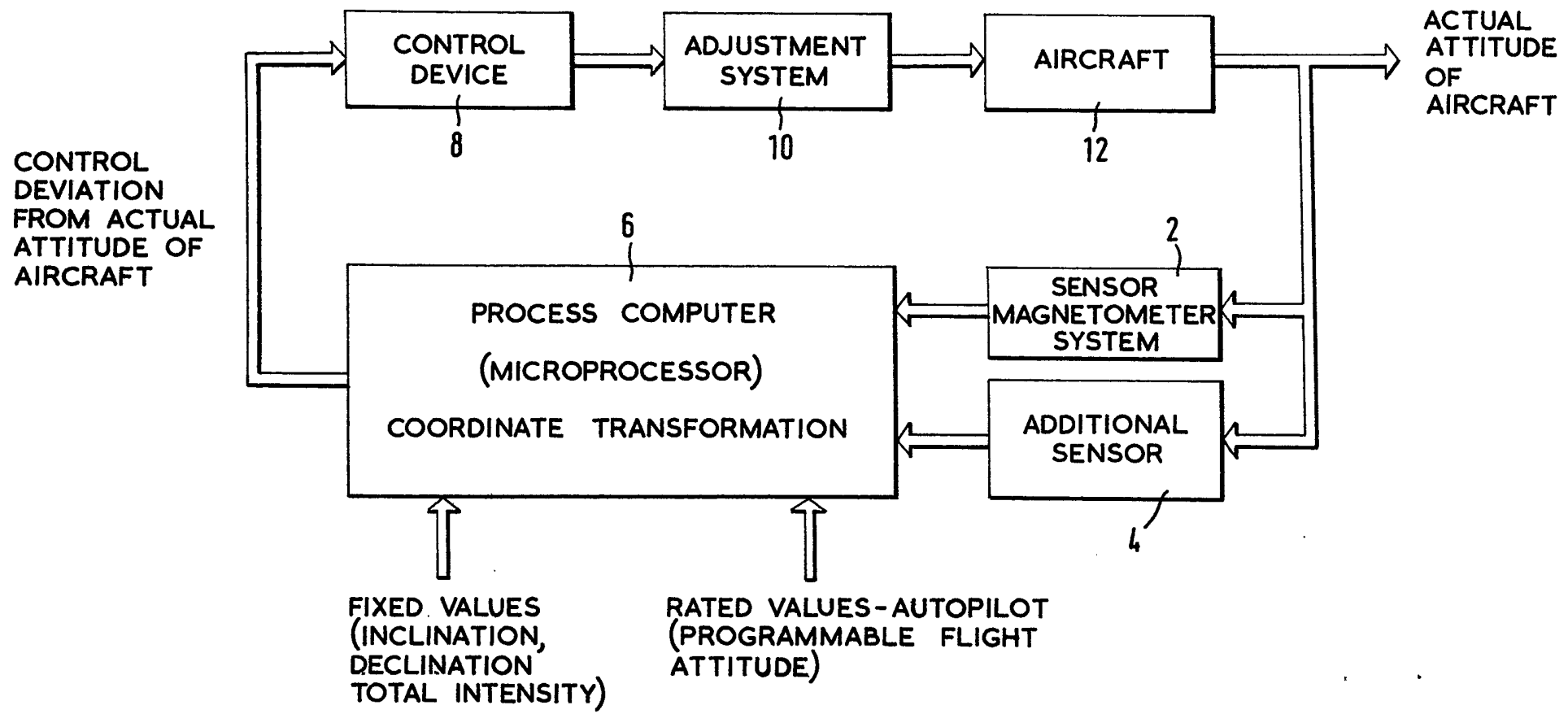
CONTROL DEVICE
8
ADJUSTMENT SYSTEM
10
AIRCRAFT
12
ACTUAL ATTITUDE OF AIRCRAFT
CONTROL DEVIATION FROM ACTUAL ATTITUDE OF AIRCRAFT
6
PROCESS COMPUTER
(MICROPROCESSOR)
COORDINATE TRANSFORMATION
2
SENSOR MAGNETOMETER SYSTEM
ADDITIONAL SENSOR
4
FIXED VALUES (INCLINATION, DECLINATION TOTAL INTENSITY)
RATED VALUES-AUTOPILOT (PROGRAMMABLE FLIGHT ATTITUDE)

SPECIFICATION

Steering and stabilisation system for vehicles

The invention relates to a steering stabilisation system for vehicles, particularly, but not exclusively, aircraft and ships, including means for the determination of attitude of a vehicle of the type comprising at least two magnetometers so mounted in the vehicle with respect to the direction of the fore-and-aft axis thereof as to determine each co-ordinate of a set of three orthogonal co-ordinates of attitude of the vehicle; means for the transformation of the orthogonal co-ordinates determined by the magnetometers into respective geodetic co-ordinates, and an additional sensor of attitude to provide supplementary information relating to one of the co-ordinates of attitude determined by the magnetometers.

Attitude determining means of the above-mentioned type having three magnetometers are known and are characterised by the fact that it is possible to use constructional elements of low cost to produce a sufficiently accurate system and also an assembly which occupies a small volume.

It is an object of the invention to devise a steering and stabilisation system employing attitude-determining means of the aforesaid type and which has a small installation volume and can be manufactured at low cost.

According to the invention, a steering and stabilisation system for a vehicle including means for the determination of attitude of the vehicle comprising at least two magnetometers so mounted in the vehicle with respect to the direction of the fore-and-aft axis thereof as to determine each co-ordinate of a set of three orthogonal co-ordinates of attitude of the vehicle; means for the transformation of the orthogonal co-ordinates determined by the mgnetometers into respective geodetic co-ordinates, and an additional sensor of attitude to provide supplementary information relating to one of the co-ordinates of attitude determined by the magnetometers, also includes a process computer by which, during use of the system, signals representative of said transformed co-ordinates and signals representative of said supplementary information are coupled and control signals, required for a control and adjustment system of the vehicle, are calculated in accordance with signals representative of a predetermined motion of the vehicle with which the computer has been programmed.

The means for the determination of attitude may be of the type having three magnetometers so mounted in the vehicle and fixed with respect to the direction of the fore-and aft axis thereof as to determine the three orthogonal co-ordinates of attitude of the vehicle.

Alternatively, the means for the determination of attitude may be of the type having two magnetometers pivotally mounted in the vehicle for turning about an axis of yaw but so fixed with respect to the direction of the fore-and-aft axis as to determine three orthogonal co-ordinates of attitude of the vehicle.

Conveniently, the process computer is a microprocessor.

The microprocessor may include input means for receiving data of the earth's magnetic field in the operational region of the vehicle, namely the inclination, declination and total intensity, whereby the microprocessor can calculate the attitude of the vehicle at any instant.

In addition, the microprocessor may have input means for receiving additional data providing a programme of a predetermined course of motion of the vehicle. The programme of the course of motion may be dependent on time or on location or route.

The magnetometers employed are preferably each of the type having magnetic field null point compensation and the controlled attitude of the vehicle may be adjustable by feeding a compensating current to a compensating coil of the magnetometer.

The system may additionally include an induction coil co-ordinated with a generator of supplementary signals representative of rate of change in an angle of attitude of the vehicle, said supplementary signals being applicable to the control and adjustment system of the vehicle.

The induction coil may be a triple coil having one winding thereof associated with each co-ordinate of said set of three orthogonal co-ordinates.

The steering and stabilisation system according to the invention is illustrated by way of example in the accompanying drawing as a block circuit diagram showing the steering and stabilisation of an aircraft and is described in detail in the following with reference to the circuit diagram.

For the determination of the actual attitude of the aircraft a sensor 2 is provided which is designed as a magnetometer system having three fixed magnetometers (i.e., a triple or triaxial magentometer) built into the aircraft with axes at right angles to each other and one of the axes lying in the direction of the fore-and-aft axis of the aircraft, thereby to determine a set of three orthogonal coordinates of attitude of the vehicle. It is alternatively possible to use, instead of an orthogonal triaxial magnetometer system, a biaxial system capable of pivoting through 90° about the vertical axis (z-axis) i.e. the axis of yaw in the form of an x-z or y-z system but otherwise fixed with respect to the fore-and-aft axis of the aircraft. In the tri-axial system the choice between the x- and y-components is made in accordance with the course, since in the East-West direction the course determination is preferably carried out by means of the x-z magnetometer components while in the North-South direction the determination of course is preferably carried out by means of the y-z magnetometer components.

In addition to the sensor 2 which includes the magnetometer system, there is an additional sensor 4 which generates the supplementary information for one of the three flight attitudes and which is necessary, in addition to the output signals of the magnetometers, for the unambiguous determination of the flight attitude. A pendulum may be used as the additional sensor. It is, however, also possible to use a sensor which responds to the Earth's electric field.

The output signals of the sensor 2 and of the

additional sensor 4 are fed to a process computer 6, for which it is possible to use a micro-processor. Data of the Earth's magnetic field for the operating region of the aircraft, namely the inclination, declination and total intensity, are fed to the computer 6 as standards. The components of the Earth's magnetic field recorded by the magnetometer system are transformed into geodetic co-ordinates in the computer with the aid of the stored values of the Earth's magnetic field.

The sensor 2 is mounted in a fixed position in the body of the aircraft and so the transformation of co-ordinates which occurs is from co-ordinates fixed with respect to the aircraft body to coordinates fixed with respect to the Earth's magnetic field.

In addition, rated values for the attitude and the course of the aircraft are fed into the computer. Such rated values may, for example, stipulate a horizontal straight-line flight of the aircraft. It is, however, also possible to feed a time-dependent and/or a location- or route- dependent programme to the computer.

The transformed magnetometer signals are coupled in the computer with the supplementary values from the additional sensor. The necessary control voltages are calculated by the computer in accordance with the predetermined rated value and are fed to the control system 8. The adjustment system 10, by means of which the attitude of the aircraft is brought from the actual value to the predetermined rate value, is activated by means of the computer.

Since the data of the Earth's magnetic field can be regarded as approximately constant over a geographical range of latitude of 200 to 250 km, the steering and stabilisation system according to the invention operates with sufficient accuracy over this range if data for the Earth's magnetic field at the centre of the operating region are provided as standard values. It is also possible to feed in data of the Earth's magnetic field relating to a plurality of regions and then to switch to the relevant values in each case according to the position of the aircraft at the time.

It is sufficient in many cases to make the co-ordinate transformation linear according to a predetermined flight attitude, for example in horizontal straight-line flight. Such a linear transformation will then allow the use of an electrical resistance matrix for the coordinate transformation. This leads to a significant reduction in the computer capacity necessary.

In a preferred embodiment, magnetometers having compensating coils are employed. By feeding a compensating current to the compensating coil it is possible to produce required flight attitudes in a simple manner. Unloading of the computer is again produced by means of analogue magnetic field null point compensation.

Steering and stabilisation systems as described in the foregoing example with reference to the drawing can be constructed at relatively low cost and with low space requirement. The cost of such a steering system is considerably lower than those of known steering and stabilisation systems of equivalent efficiency. The steering and stabilisation system according to the invention is therefore suitable for equipping unmanned aircraft as well as small aeroplanes.

The steering and stabilisation system, described in the foregoing example with application to an aircraft, can also be used for ships, and in particular for small boats, such as sailing boats, which are subject to large rolling motion and in which the normal magnetic compass is not sufficient to achieve a determination of course with the necessary accuracy.

In stabilisation systems, a certain rate of change in attitude angle is frequently required in order to achieve a sufficient dynamic stability. For this purpose so-called induction coils may advantageously be provided. The output signals of a triple induction coil, mounted in a fixed position in the vehicle, are then subjected to the same co-ordinate transformation. The rate of change in the attitude angle is derived by the addition of a generator of supplementary signals. A second additional sensor may be provided for this purpose.

It is, however, also possible to obtain the supplementary signals by means of time differentation of the signals of the additional sensor of attitude. The time differentation of these signals can be calculated in the micro-processor or by means of an additional electronic circuit.

CLAIMS

1. A steering and stabilisation system for a vehicle including means for the determination of attitude of the vehicle comprising at least wo magnetometers so mounted in the vehicle with respect to the direction of the fore-and-aft axis thereof as to determine each co-ordinate of a set of three orthogonal co-ordinates of attitude of the vehicle; means for the transformation of the orthogonal co-ordinates determined by the magnetometers into respective geodetic co-ordinates, and an additional sensor of attitude to provide supplementary information relating to one of the co-ordinates of attitude determined by the magnetometers, the system also including a process computer by which, during use of the system, signals representative of said transformed co-ordinates and signals representative of said supplementary information are coupled and control signals, required for a control and adjustment system of the vehicle, are calculated in accordance with signals representative of a predetermined motion of the vehicle with which the computer has been programmed.

2. A steering and stabilisation system according to Claim 1 in which there are three magnetometers so mounted in the vehicle and fixed with respect to the direction of the fore-and-aft axis thereof as to determine the three orthogonal co-ordinates of attitude of the vehicle.

3. A steering and stabilisation system according to Claim 1 in which there are two magnetometers pivotally mounted in the vehicle for turning about an axis of yaw but so fixed with respect to the direction of the fore-and-aft axis as to determine the three orthogonal co-ordinates of attitude of the vehicle.

4. A steering and stabilisation system according

to any preceding claim in which the process computer is a microprocessor.

5. The steering and stabilisation system according to Claim 4, in which the microprocessor includes input means for receiving data of the earth's magnetic field, namely the inclination, declination and total intensity, relating to the operational region of the vehicle.

6. The steering and stabilisation system according to Claim 4 or 5, in which the microprocessor includes input means for receiving additional data providing a programme of a predetermined course of motion of the vehicle.

7. The steering and stabilisation system according to Claim 6, in which the programme of the course of motion is dependent on time.

8. The steering and stabilisation system according to Claim 6, in which the programme of the course of motion is dependent on location or route.

9. The steering and stabilisation system according to any one of the preceding Claims in which each magnetometer has magnetic field null point compensation and the controlled attitude of the vehicle is adjustable by feeding a compensating current to a compensating coil of the magnetometer.

10. The steering and stabilisation system according to any one of the preceding claims in which the means for said co-ordinate transformation is an electrical resistance matrix.

11. The steering and stabilisation system according to any preceding claim 4 - 8 in which the means for said co-ordinate transformation is part of said microprocessor.

12. The steering and stabilisation system according to any one of the preceding claims additionally including an induction coil co-ordinated with a generator of supplementary signals representative of rate of change in an angle of attitude of the vehicle, said supplementary signals being applicable to the control and adjustment system of the vehicle.

13. The steering and stabilisation system according to Claim 12 in which said induction coil is a triple coil having one winding thereof associated with each co-ordinate of said set of three orthogonal co-ordinates.

14. The steering and stabilisation system according to Claim 12 or 13 in which another additional sensor is provided as the generator of said supplementary values.

15. The steering and stabilisation system according to any one of the preceding Claims 1 - 11 in which said additional sensor of attitude includes a generator of supplementary signals for the determination of rate of change in angle of said one co-ordinate of attitude and time differentials of signals from the additional sensor of attitude are determined as said supplementary signals.

16. A steering and stabilisation system for a vehicle, including a magnetometer system for the determination of attitude of the vehicle, constructed and arranged substantially as described herein with reference to the accompanying block circuit diagram.

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