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A WATER SKIPPING VEHICLE

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The invention relates to a vehicle operating in air and capable of projectile motion when skipping on a water surface.

(2) Description of the Related Art

[0004] A movable object such as a vehicle may travel in a projectile motion when skipping over a water surface. Such objects may be elastic and due to loads imposed on the body of the object during skipping on water; the object may be deformed by impact with the water surface.

[0005] As an example, a spherical object may be deformed to form a disc-like shape; thereby, increasing the contact area with the water surface. As the object deforms, a larger hydrodynamic force acts upon the object to lift off the water surface. The lift, generated upon impact with water, depends on an angle of impact.

[0006] Upon each impact with the water surface, the object may also lose kinetic energy which eventually causes the object to slow down between skips on the water surface. The energy loss depends on the elasticity of the object and a density of the object relative to the water. The lost energy limits the range of such objects.

SUMMARY OF INVENTION

[0007] A vehicle capable of travelling in air and over water while skipping on the surface of the water is provided. The vehicle comprises a propulsion system adapted to propel the vehicle in air and an arcuate lower surface formed of an elastomeric material with the lower surface configured to intermittently impact a water surface between consecutive trajectories of the vehicle when the vehicle is airborne.

[0008] Due to the impact force from the water surface coupled with an elastomeric response from the lower surface of the vehicle; a restorative force lifts off the vehicle upon impact on the water surface to produce a skipping effect. Between consecutive impacts on the water surface, the vehicle may be airborne.

[0009] The vehicle includes a propulsion system which restores the energy lost during impact of the vehicle with water. The propulsion system may include one or more propellers to propel the vehicle in air and to restore the energy level of the vehicle following each impact. The propulsion system maintains a desired velocity of the vehicle.

[0010] An on-board control system may regulate the operation of the propulsion system to adjust thrust level; thereby, steering the vehicle. The control system can change the trajectory of the vehicle by adjusting the velocity in order to adjust the angle of impact of the vehicle.

[0011] By combining the effect of impact force on the vehicle and the elastomeric response from the vehicle surface; the vehicle effectively skips over water surfaces. The effect of including a propulsion system is that lost energy is compensated after each impact; thereby, allowing the vehicle to travel over a large distance. The propulsive force coupled with the restorative force from impact reduces vehicle drag and improves vehicle efficiency.

[0012] By reducing the interaction time between the vehicle surface and water, drag is reduced relative to vehicles travelling through water. The intermittent skipping on water improves fuel efficiency relative to an airborne vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features of illustrative embodiments may be understood from the accompanying drawings in conjunction with the description. The elements in the drawings may not be drawn to scale. Some elements may be enlarged or minimized for the purpose of illustration and understanding of the disclosed embodiments wherein:

[0014] FIG. 1 is a view of a vehicle of the present invention with the vehicle adapted for airborne operation;

[0015] FIG. 2 is a view of the vehicle adapted to skip upon a water surface while impacting the surface; and

[0016] FIG. 3 is a flowchart of a method to operate the vehicle of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The following description relates to a vehicle 100 adapted to operate in air and capable of projectile motion when skipping on water. The vehicle 100 is shown in FIG. 1 and FIG. 2. A control system can to operate the vehicle 100 as shown in the method steps 300 of FIG. 3.

[0018] The vehicle 100 operates in air and is capable of skipping over a surface 202 of a water body 110. In FIG. 1, the vehicle 100 is airborne; while in FIG. 2, the vehicle impact water at an angle α.

[0019] The vehicle 100 includes an arcuate lower portion 104 such as having a spherical cap where the vehicle contacts the water surface 202. An upper portion 106 of the vehicle 100 may be flat or curved. The lower portion 104 is preferably formed from a material with a high elasticity. Because of the high elasticity (low elastic modulus) at ambient temperatures; the elastomers are compliant and deformable.

[0020] The elasticity of the material may be temperature dependent. Elastomeric materials used in forming the lower portion 104 are natural rubbers, styrene-butadiene block copolymers, polyisoprene, polybutadiene, ethylene propylene rubber, ethylene propylene diene rubber and nitrile rubbers. The lower portion 104 may be divided into sections with each section including a different elastomer and a different elastic modulus.

[0021] The vehicle 100 may include a system for propelling the vehicle while airborne. In this example, the propulsion system includes a propeller 108 operated by an energy source 110. In alternate examples, the vehicle 100 can have multiple propellers coupled to the vehicle. The energy source 110 may be a combustion engine or a turbojet engine. Alternatively, the energy source 110 may be an electric motor operated via an on-board battery.

[0022] As the vehicle 100 travels from a start location to a destination; the vehicle may be primarily airborne with a plurality of skips over the water surface 202. The vehicle 100 may follow a trajectory of a projectile between two consecutive skips. The skipping dynamics together with the propulsion moves the vehicle 100 forward.

[0023] As the elastomeric lower portion 104 impacts the water surface 202; the impact force coupled with the elastomeric response of the vehicle 100 provides a restorative force to facilitate lift off from the surface. As the vehicle 100 impacts the water, kinetic energy may be lost. Upon lift off, the speed of the propeller 108 is adjusted in order to recover the lost kinetic energy and to restore the velocity of the vehicle 100 to a velocity prior to the impact with water. The distance between two consecutive skips may be long enough for all perturbations in the vehicle body caused by the impact to fully diminish.

[0024] Also, between the consecutive impacts with water; the deformation caused to the elastomeric lower portion 104 may completely restore to the original state. In this way, a mechanism may be developed for propelling the vehicle 100 in air and over water with lower drag forces and improved fuel efficiency relative to airplanes.

[0025] The vehicle 100 may further include a control system 112. The control system 112, shown in FIG. 1, receives information from a plurality of sensors 114 and sends control signals to a plurality of actuators 116. The sensors 114 can include a gyroscope, compass, temperature sensor, and pressure sensor. A navigation system such as a global positioning satellite (GPS) may be coupled to a controller 12. As another example, the actuators may include the propeller 108, fuel injectors in the engine, etc.

[0026] The control system 112 may include a controller 118. The controller 118 is powered through onboard stored energy via a battery. Also, the controller 118 may be configured as a conventional microcomputer including a microprocessor unit, input/output ports, read-only memory, random access memory, keep alive memory, a controller area network (CAN) bus, etc. The controller 118 receives input data from the various sensors, processes the input data, and triggers the actuators in response to the processed input data based on instruction or code programmed therein corresponding to one or more routines. An example control routine for operating the vehicle 100 is described herein with regard to FIG. 3.

[0027] The position, angular velocity, and orientation of the vehicle 100 may be estimated by the controller 118 based on inputs from the gyroscope, the compass, and the GPS. In order to steer the vehicle 100 and to adjust the angel of impact **(α)** of the vehicle with the water surface 202; the speed of operation of the one or more propellers is adjusted to change thrust and direction of travel. The lift in the vehicle following the impact with water may be a function of the angle of impact. In one example, the lift may be proportional to the angle of impact. The angle of impact is in a range of 5-45 degrees.

[0028] The lower portion 104 of the vehicle 100 may include separate sections of elastomeric material with each section including a material of elastic modulus different from that of materials used in other sections. The elastomeric material may have temperature dependent elastic modulus. By adjusting which section of the lower portion 104 impacts with the water surface 202; the lift off may be adjusted and the direction of travel and velocity of the vehicle may be changed. As an example, if a section with an elastomer having a lower elastic modulus impacts with the water surface, a higher rebound may be attained relative to the vehicle impacting a higher elastic modulus section.

[0029] The systems of FIG. 1 and FIG. 2 provide for: a vehicle body with a curved lower surface; a propulsion system propelling the vehicle in air; and a controller storing instructions in non-transitory memory. When executed, the controller, in response to the vehicle skipping on a surface of water, adjusts operation of the propulsion system to increase a speed of operation of the vehicle from an initial speed of the vehicle prior to the skipping on the surface of water

[0030] FIG. 3 depicts a method 300 for operating the vehicle 100. The method 300 may be carried out by the control system 112 and may be stored at the controller 118 in non-transitory memory. Instructions for carrying out method 300 and all other method described herein may be executed by the controller 118 in conjunction with signals received from sensors of the vehicle 100. The controller 118 may also employ actuators to adjust operation of the vehicle 100, according to the methods described below.

[0031] At step 302, the propeller system operates to drive the vehicle in air with intermittent skips on a surface of water. One or more propellers of the propeller system operate via an engine or an electric motor to provide thrust for propulsion of the vehicle in air.

[0032] At step 304, the operating speed of the propeller system is adjusted such that the vehicle impacts the water surface at a desired angle. By impacting the water surface at the desired angle, the impact force from the water and the elastomeric response from the vehicle body provides a restorative force; thereby, enabling efficient lift of the vehicle off the water surface. The speed of one or more propellers may be decreased to ensure that the vehicle impacts with water at the desired angle.

[0033] At step 306, after an impact with water, the speed of the propeller system may be adjusted in order to recuperate the kinetic energy lost during the impact. The speed of one or more propellers may be increased such that the velocity of the vehicle increase to the velocity level prior to the impact, and perturbations in the vehicle caused by the impact may die down.

[0034] At step 308, the method of operation includes determining if a change in direction for the vehicle is desired. The controller may determine if steering of the vehicle in a direction is different such as based on operator input or changes in ambient conditions (such as wind speed).

[0035] If it is determined that a change in direction is not desired, at step 310, the vehicle operation can be maintained without any steering. If it is determined that a change in direction is desired, at 312, the impact angle of the vehicle with the water surface may be adjusted and/or a speed of the propeller system may be adjusted to steer the vehicle. As an example, the speed of one or more propellers may be increased or decreased to change the velocity and course of the vehicle. Also, the impact angle of the vehicle with the water surface at the immediately subsequent impact (during skipping) with water may be adjusted to change the direction of the vehicle as the lift changes based on the angle of impact. Also, for vehicles with different portions of the lower surface including different elastomers, the section impacting the water may determine the lift and the course of the projectile motion following the impact.

[0036] In this way, a propulsion system operates to maintain the vehicle to be airborne between two successive impacts of the vehicle with a surface of a water body, and a speed of the propulsion system is adjusted immediately following an impact of the vehicle in order to restore an amount of kinetic energy lost during the impact.

[0037] It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

A WATER SKIPPING VEHICLE

ABSTRACT OF THE DISCLOSURE

A vehicle is provided for operating in air and capable of projectile motion upon skipping on water. The vehicle includes a propulsion system adapted to propel the vehicle in air. The vehicle further includes an arcuate lower surface formed of an elastomeric material, the lower surface impacting a surface of a water body during skipping of the vehicle on water.

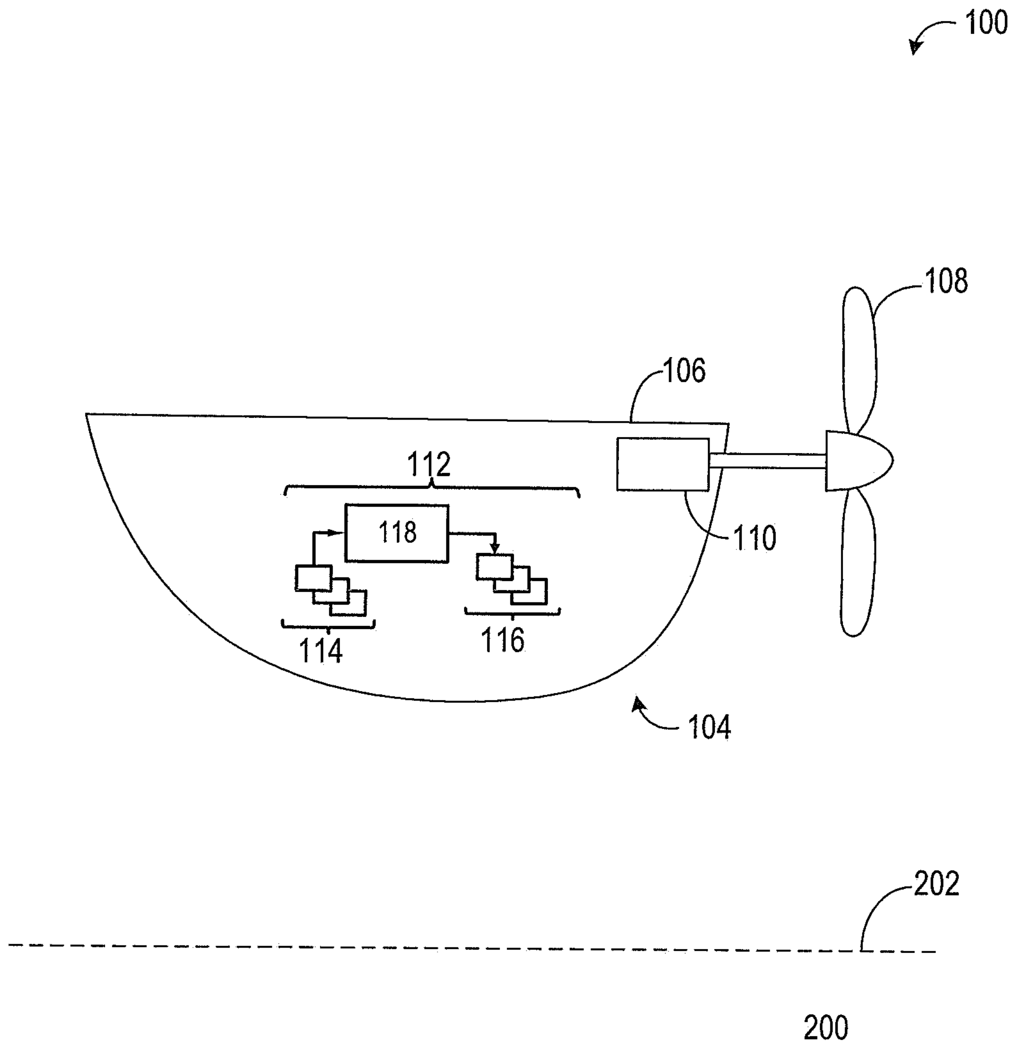

FIG. 1

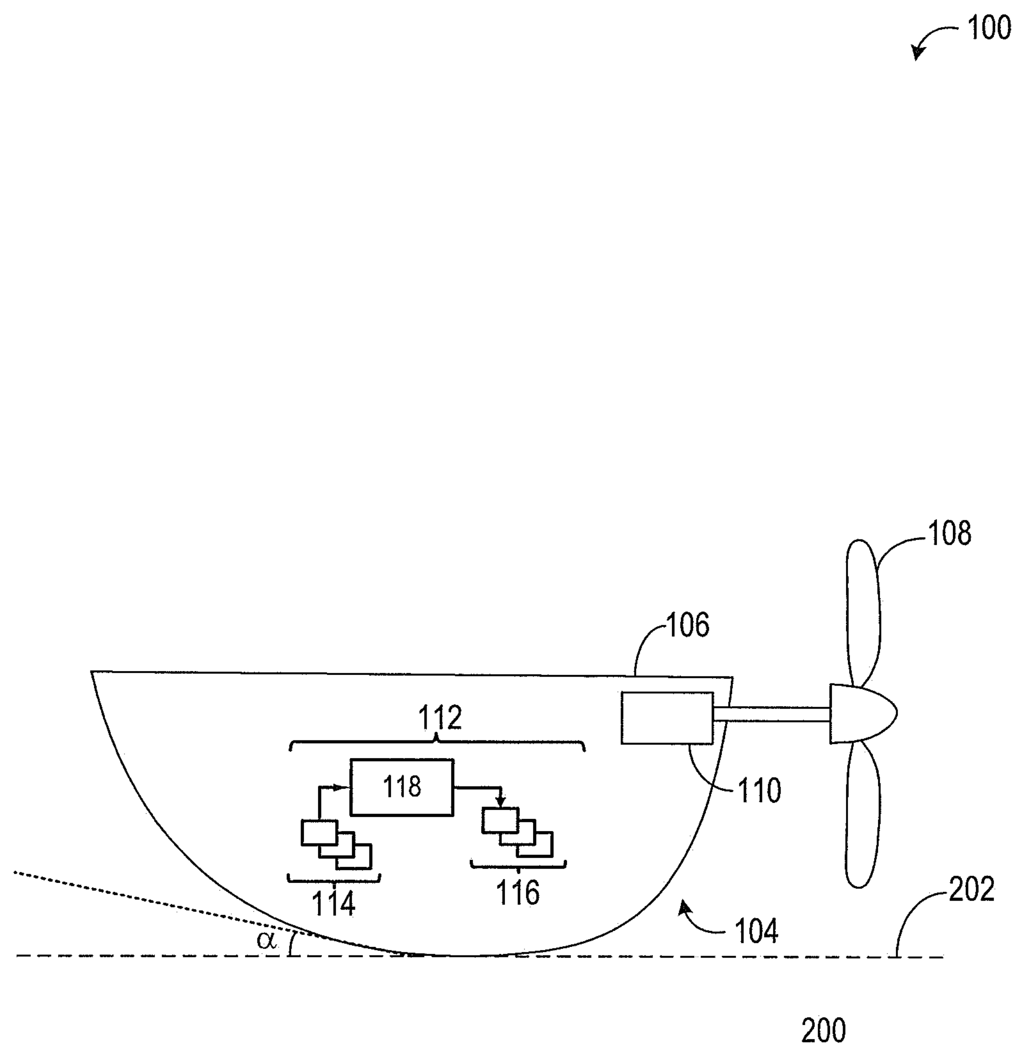

FIG. 2

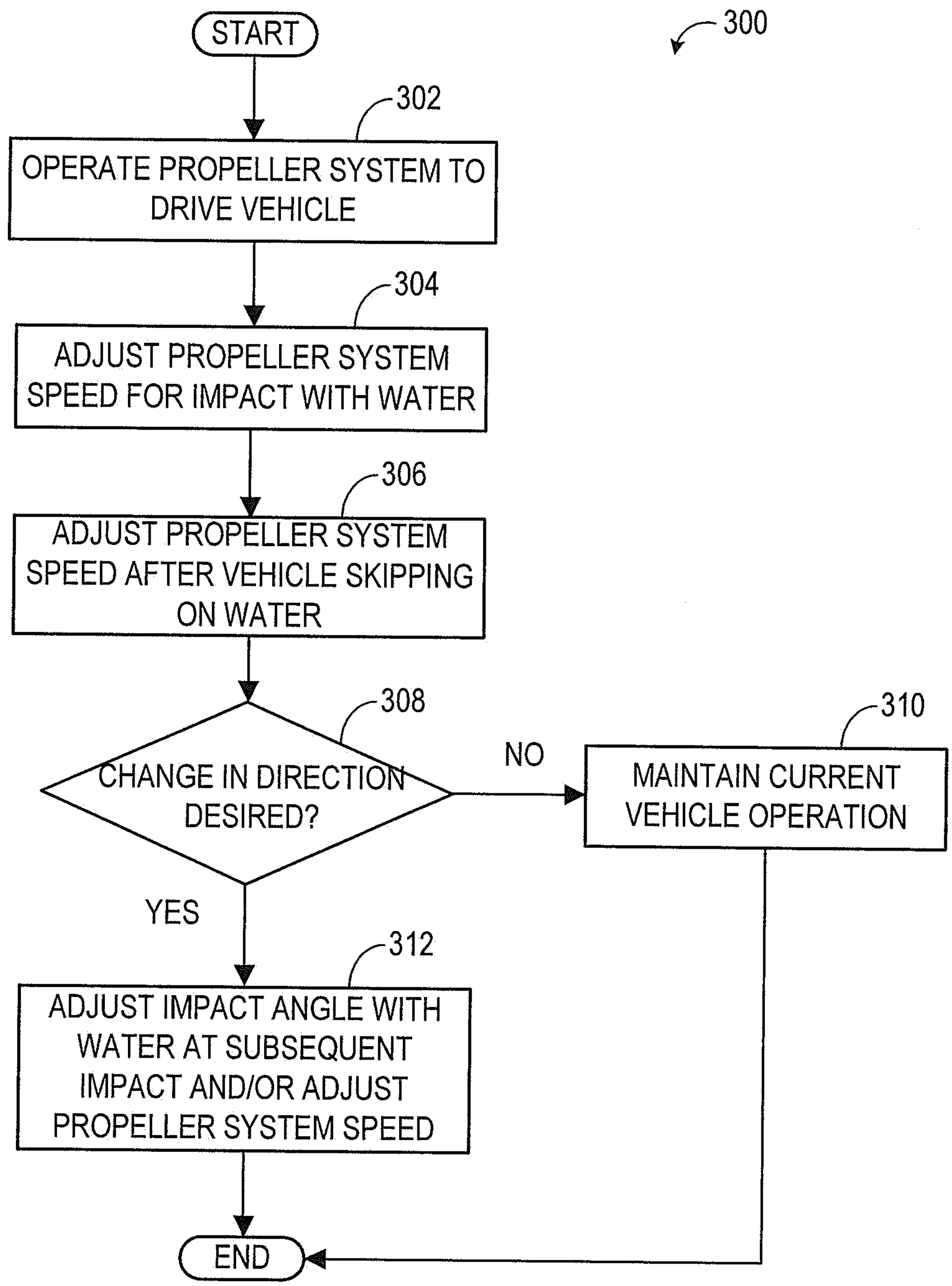
300
START
302
OPERATE PROPELLER SYSTEM TO DRIVE VEHICLE
304
ADJUST PROPELLER SYSTEM SPEED FOR IMPACT WITH WATER
306
ADJUST PROPELLER SYSTEM SPEED AFTER VEHICLE SKIPPING ON WATER
308
CHANGE IN DIRECTION DESIRED?
NO
310
MAINTAIN CURRENT VEHICLE OPERATION
YES
312
ADJUST IMPACT ANGLE WITH WATER AT SUBSEQUENT IMPACT AND/OR ADJUST PROPELLER SYSTEM SPEED
END

FIG. 3