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HYPERVELOCITY JET PRODUCING SYSTEM EMPLOYING
AN IMPACT CUMULATION PROCESS
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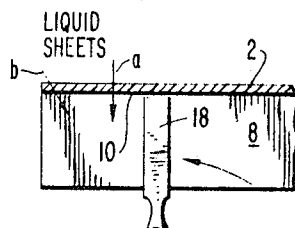
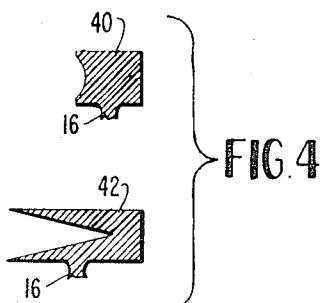
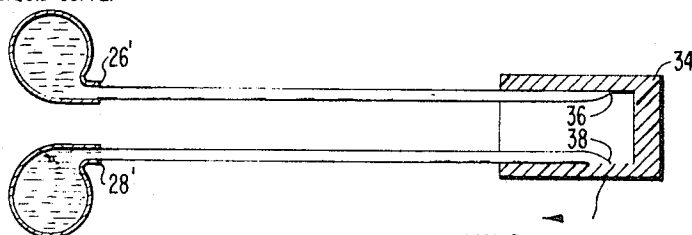
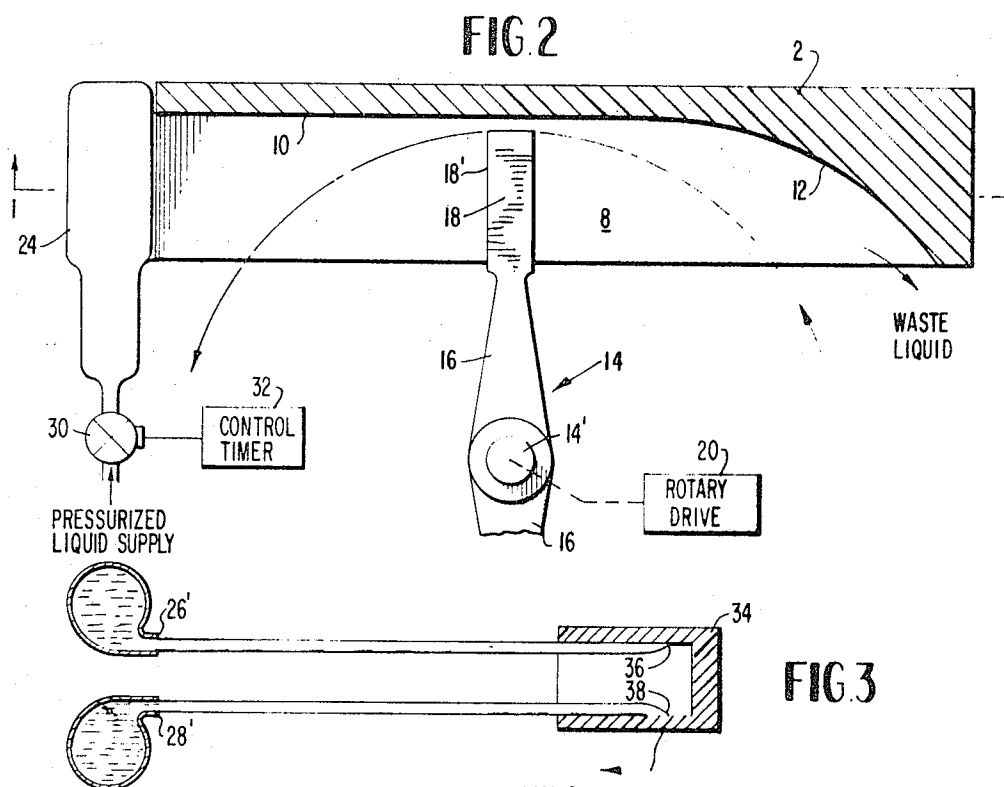
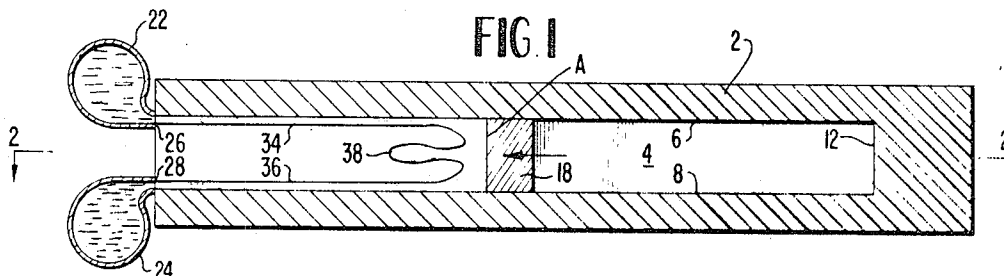


FIG. 3

FIG. 5

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HYPERVELOCITY JET PRODUCING SYSTEM EMPLOYING AN IMPACT CUMULATION PROCESS

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9 Claims

ABSTRACT OF THE DISCLOSURE

A device for discharging pulsed fluid jets utilizing an elongated housing having an axially extending slot. A rotor assembly is mounted adjacent to the slot, the latter having radially extending arms with impact heads thereon. A nozzle means is provided for feeding sheet-like jets of liquid along the inner wall surfaces of the slot while at the same time the rotor assembly is driven for bringing successively the impact heads mounted thereon through the slot for impacting the liquid sheets and converting the same to pulsed fluid jets along the axis of the slot.

This invention relates to an apparatus and method for producing high velocity fluid jets of material by an impact cumulation process and, more specifically, to such apparatus and method which repetitively produces hypervelocity jets having different geometric shapes depending upon the physical conditions governing the impact process.

Cumulation may be defined generally as a concentration of energy into a small volume of fluid by the interaction between two material surfaces, at least one of which behaves as a fluid when the surfaces collide at an angle. A simple example is the formation of a water jet under a boat bow moving ahead faster than the boat when its hull bottom planes at a small angle above the water surface. This phenomenon is caused by the hydrodynamic motion which produces a stagnation point on the hull a short distance back from the forward water line. Water streamlines above the stagnation streamline are forced to turn upward and reverse direction conserving their kinetic energy relative to the moving stagnation point and escaping forward with a velocity as much as twice the boat velocity.

The main object of this invention is to provide an apparatus which can produce the cumulative effect by converging collision of materials in either an axisymmetric geometry or a planar geometry to form a pulsed axisymmetric or planar jet of liquid or gas which utilizes the kinetic energy of a rotating member in an impact process.

Another object of the invention is to provide a repetitive jet pulsing device employing a rotating actuator impact member in conjunction with a high pressure liquid extrusion system.

A still other object of this invention is to provide a jet pulsing device in which a rotating actuator device cooperates with a high pressure liquid housing for repetitively ejecting pulsed liquid jet sheets.

A still further object of this invention is to provide a system for producing repetitive pulsed jet sheets of liquid of high stagnation pressure in the order of 50,000 to 200,000 p.s.i. or higher and having a velocity of at least 9600 ft. per second, and which is particularly useful for rock breaking, rock tunneling, mining, breaking concrete and a wide variety of other related applications.

It is a further object of this invention to provide a jet pulsing device employing a minimum of parts which can

be constructed in a simple and economical manner for producing a reliable and continuous operation.

In accomplishing the aforesaid objects of this invention, one embodiment utilizes a mechanically driven rotor assembly with one or more solid bars forming radial arms, the ends of which function as impact heads which successively pass through an internal slot provided in a housing assembly. The latter is provided with liquid injection nozzles through which liquid is injected steadily or intermittently to form sheets of liquid along the inner walls of the slot provided in the housing. When the rotor assembly is actuated, one or more of the impact heads associated with each of the arms will impact the leading edges of the liquid sheets formed along the walls of the slot, at which time a shock wave is generated in the liquid sheets which forces the liquid to converge toward the central plane between the liquid sheets and interact to form a cumulative plane sheet-like jet which moves toward the outlet end of the slot at an absolute speed which exceeds the speed of sound in the liquid.

Other objects and advantages will become apparent from a further study of the specification and drawing, in which:

FIG. 1 is a cross-sectional view of the system according to one embodiment of this invention taken along line 1—1 in FIG. 2;

FIG. 2 is a cross-sectional view partly in plan taken along lines 2—2 of FIG. 1;

FIG. 3 illustrates in a cross-sectional view a further embodiment of the invention utilizing a particular form of impact head that avoids the use of a housing;

FIG. 4 illustrates various embodiments of the impact head used with this invention according to FIGS. 1 and 2; and

FIG. 5 is a symbolic diagram showing the various directions in which the sheets of liquid can be directed to the housing interior.

Referring now to FIGS. 1 and 2, there is shown a housing 2 having an elongated shape and provided with an axially oriented slot 4 defined in this instance by parallel inner flat wall surfaces 6, 8. An upstanding side wall section 10 which separates the walls 6, 8 terminates into a curved portion 12 at the rear end of the housing, as best shown in FIG. 2. By this design the slot 4 forms an exit outlet end at the forward end of the housing 2. Adjacent the slot 4 is a mechanically driven rotor assembly 14 fixed to a rotatably mounted shaft member 14' and having a plurality of radially extending arms 16, two of which are shown in FIG. 2. Each of the arms 16 forms at its radial extension an impact head member 18 having a flat front surface area 18'. The heads 18 are adapted to pass through the slot 4 upon rotation of the assembly 14 by a suitable rotary drive 20 shown mechanically connected to the drive shaft member 14'. Adjacent the exit end of the slot 4, as best shown in FIG. 1, are a pair of liquid supply ports 22, 24, each having an outlet nozzle 26, 28, respectively, which lie adjacent the wall surfaces 6 and 8 at the exit or outlet end of the slot 4. The supply ports 22 and 24 are connected to a suitable pressurized liquid supply and may be each equipped with a control valve 30 operated by a suitable control timer 32. As will be explained below, the control valve 30 and its associated control timer will provide intermittent feed of liquid through the ports and their associated nozzles. It is contemplated, however, that a continuous flow of liquid may be supplied to the nozzles 26 and 28, in which case the control valve and timer may be dispensed with. Under suitable pressure and with the valve 30 open, liquid is conveyed by the ports 22, 24 and through the nozzles 26 and 28 which form sheet-like jet films of liquid 34, 36 along the walls 6 and 8, respectively. These free sheet-like jets of liquid 34 and 36

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are impacted upon by the rotating impact head member 18 of the rotating assembly 14 in a manner to be described below.

The method of operation according to this invention is as follows: With the sheet-like jets of liquid 34, 36 extending along the wall surfaces 6 and 8, respectively, as best shown in FIG. 1, the rotor arm 16 with its impact head 18 enters the slot 4 and interacts with the two sheets of liquid 34 and 36. Considering that the liquid injection into the slot 4 is intermittent, the leading edges of the two sheets of liquid 34 and 36 will arrive at a point *a* just as the impact head front face 18' also reaches point *a*, as shown in FIG. 1. Upon impact, a plane shock wave is generated in each sheet of liquid which then moves toward the inlet nozzles 26, 28, that is, the outlet or exit end of the slot 4. This shock wave moves at an absolute speed *S* which generally exceeds the speed of sound in the liquid. The shocked liquid then converges toward the central plane between the two liquid sheets 34 and 36 and interacts to form a cumulative plane sheet-like jet 38 which is then ejected through the space between the two nozzles 26 and 28. The theoretical velocity of this jet is twice the absolute shock velocity *S* and is therefore generally of more than twice the speed of sound in the liquid. Thus, with water, as one example, having a sound speed of 4800 ft. per second, the jet velocity should then be at least 9600 ft. per second. During the impact process, any excess liquid will run by the impact head 18 and exit along the curved rear wall portion 12 as shown in FIG. 2. It will be understood that with an intermittent operation, the liquid is fed to the slot 4 each time immediately prior to the time when one of the impact heads 18 approaches the point *a* shown in FIG. 1. The timing of the intermittent liquid feed may be controlled by the timer control 32 mechanically connected to the valve 30 which, in turn, controls the flow of the pressurized liquid supply through the ports 22 and 24.

The invention may be utilized in a continuous operation, that is, the liquid may be supplied under pressure to the ports 22 and 24 and continuously fed through the outlet nozzles 26 and 28 to form the sheet jets 34 and 36 along the walls 6 and 8, respectively. In this instance, the head 18 of the rotor assembly 14 initially impacts the leading edges of the liquid sheets 34 and 36 forming a sheet-like jet pulse, as above-described, which is ejected between the nozzles 26 and 28, while at the same time the rotor assembly 14 carries the impact head 18 out from the slot 4. At this very brief moment there will be an absence of liquid on the central area of the walls 6 and 8 since any excess liquid from the previous impact process will have exited from the slot along the curved wall portion 12. At the same time exiting from the nozzles 26, 28, liquid sheets will be forming along the forward area of the walls 6 and 8, and at this time the rotor assembly 14 has brought around the next one of its arms 16 along with its impact head 18 which has entered into the mid portion of the slot 4 to thereby again impact the leading edges of the liquid sheets in the manner above-described. This arrangement of continually supplying liquid to the nozzles 26 and 28 makes for a faster operation, that is, a higher rate of repetitive impacts between the liquid sheets and the head 18. For this purpose the rotor assembly 14 may be provided with more than two arms and these arms may be suitably angularly spaced from each other to provide the correct timing between pulsed jet ejection and liquid sheet feeding along the walls 6 and 8 of the slot 4.

It is also contemplated that the walls 6 and 8 of the internal slot 4 need not be flat surfaces arranged at right angles to the vertical wall 10 but may be curved to define a semicircle, such as to allow entrance and exit of the rotating impact head 18 which is similarly shaped in cross section. In this case the nozzle structure 26, 28 would also be semicircular to thereby feed a sheet of liquid along the corresponding semicircular internal wall surface of the slot 4.

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In FIG. 3 there is yet another embodiment shown in which the housing 2 along with the wall surfaces 6 and 8 have been entirely dispensed with. In this case liquid sheet jets are ejected from the nozzles 26', 28' directly into a U-shaped impact head 34 having parallel internal wall surfaces 36, 38 which are spaced apart a distance corresponding to the spacing between walls 6 and 8 shown in FIG. 1. The impact head 34 is connected to a supporting arm, such as described with respect to FIG. 2. In operation the impact head 34 reacts with the liquid sheets in the same manner as described above. In this case the base of the impact head between the wall surfaces 36, 38 acts as the impact area against which the leading edges of the liquid sheets are directed, the latter being guided along the inner surface walls 36, 38. It should be understood that the showing in FIG. 3 may apply to an annular nozzle form and the impact head 34 will then be cylindrical, that is, cup-shaped.

The impact head 18, as disclosed in FIG. 2, may utilize further embodiments such as shown in FIG. 4. Here an impact head 40 is shown having a front face concave impact area, while the impact head 42 is shown having a V-shaped grooved impact area. These various shapes of the impact area will act to change the configuration and velocity of the shock wave produced in the sheets of liquid interacting therewith. It is also contemplated that the two outlet nozzles 26, 28 which direct the sheet jets into the internal slot 4 of the housing 2 can be arranged at right angles to the axis of the housing or at an angle thereto. As shown in FIG. 5, the arrow *a* indicates a flow of the liquid sheets at right angles to the housing, and the arrow *b* indicates a flow at some angle to the axis of the housing. For this purpose the housing 2 may be provided with suitable ports communicating through the side wall 10. Any excess fluid, of course, would exit through the slot opening proper through which the impact head 18 traverses.

Although several embodiments of the invention have been depicted and described, it will be apparent that these embodiments are illustrative in nature and that a number of modifications in the apparatus and variation in its end use may be effected without departing from the spirit or scope of the invention as defined in the appended claims.

What is claimed is:

1. In a device for discharging hypervelocity pulsed liquid jets, the combination comprising, an elongated housing having an internal slot extending along its axial direction, an impact member movably mounted adjacent said slot, means for moving said impact member through said slot, and means for supplying a quantity of liquid into the interior of said slot, whereby said impact member impacts said supply of liquid in said slot for generating a shock wave therein and converting said liquid into a fluid jet along the axis of said slot.

2. In a device for discharging hypervelocity pulsed liquid jets, the combination comprising, an elongated housing having a slot extending along its axial direction and defining an open exit end, an impact member rotatably mounted adjacent to and in the plane of said slot, means supplying a liquid to the inner surface walls of said slot, and means for moving said impact member through said slot, whereby said impact member impacts said liquid in said slot for generating a shock wave therein and converting said liquid into a fluid jet along the axis of said slot.

3. In a device for discharging hypervelocity fluid pulsed jets, the combination comprising, an elongated housing having a slot extending along its axis and defining a pair of spaced parallel wall surfaces, an impact member rotatably mounted adjacent to and in the plane of said slot, means for supplying sheets of liquid to said wall surfaces, and means for moving said impact member through said slot whereby said impact member impacts said liquid on said wall surfaces for generating a shock wave therein and converting said liquid into a fluid jet along the axis of said slot.

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4. In a device for producing repeated hypervelocity fluid pulsed jets, the combination comprising, an elongated housing having a slot extending along its axial length, said slot defining spaced parallel wall surfaces, a rotor assembly having radially extended arms mounted adjacent said slot, each of said arms terminating in an impact head member, means for driving said assembly to move successively each of said impact members through said slot, means for feeding sheets of liquid along said wall surfaces of said slot, whereby each of said impact heads successively impacts said liquid for generating shock wave therein and converting said liquid into a fluid jet along the axis of said slot.

5. In a device according to claim 4, wherein said means for feeding sheets of liquid is located adjacent the exit end of said slot and in alignment with said wall surfaces of said slot.

6. In a device according to claim 4, wherein said means for feeding sheets of liquid is located to the side of said slot, said sheets of liquid extending in a direction normal to the axis of said slot.

7. In a device according to claim 4, wherein said means for feeding sheets of liquid is located to the side of said slot, said sheets of liquid extending in a direction at an angle to the axis of said slot.

8. In a device for discharging repetitively hypervelocity fluid pulsed jets, the combination comprising, nozzle means for emitting spaced parallel sheets of liquid, a U-shaped impact member, and means for driving said mem-

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ber to a position wherein said sheets of liquid engage the inside surface walls of said U-shaped impact member, whereby the base of said member impacts said liquid for generating a shock wave therein, and converting said liquid into a hypervelocity jet along the longitudinal axis of said impact member.

9. In a device for discharging repetitively hypervelocity fluid pulsed jets, the combination comprising, nozzle means for emitting an annular formed sheet of liquid, a cup-shaped impact member, and means for driving said member to a position wherein said sheet of liquid engages the inside surface walls of said cup-shaped impact member, whereby the base of said member impacts said liquid for generating a shock wave therein and converting said liquid into a hypervelocity jet along the longitudinal axis of said impact member.

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