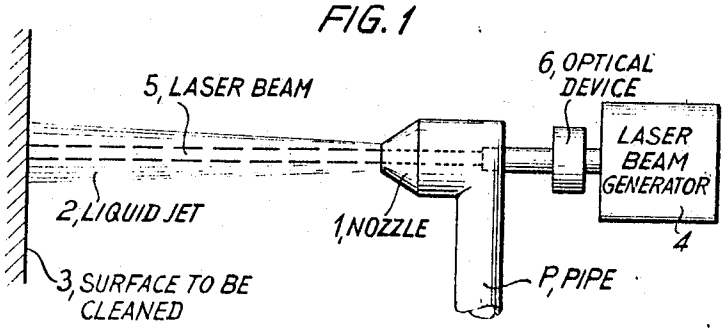
March 31, 1970 H. SCHNEIDER 3,503,804

METHOD AND APPARATUS FOR THE PRODUCTION OF SONIC OR ULTRASONIC WAVES ON A SURFACE

Filed April 25, 1967

FIG. 1



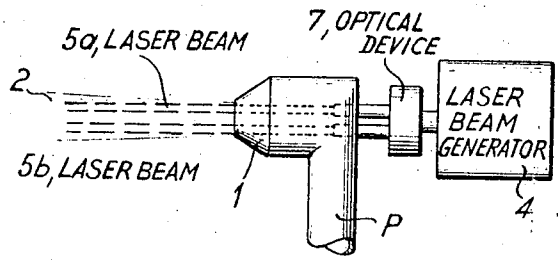


FIG. 2

FIG. 3

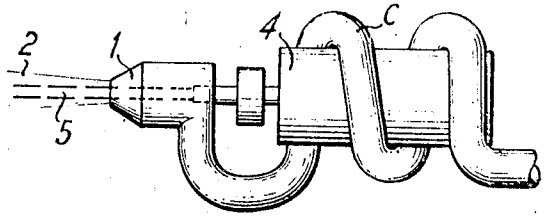


FIG. 4

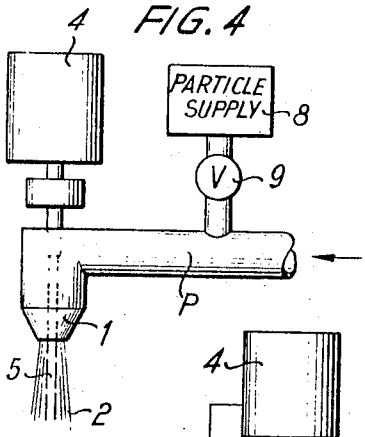
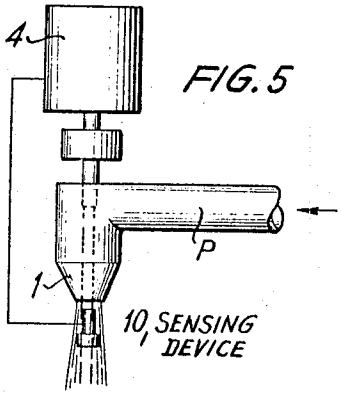


FIG. 5



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METHOD AND APPARATUS FOR THE PRODUCTION OF SONIC OR ULTRASONIC WAVES ON A SURFACE

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ABSTRACT OF THE DISCLOSURE

A method and device for producing energy on a surface together with a jet of water for example to clean the surface, there being provided a nozzle for generating a liquid jet and a device such as a laser generator for producing a laser beam coaxially with the liquid jet, so that when the liquid jet and laser beam strike the surface to be cleaned, there is a combined action between the jet and the energy of the laser beam.

BRIEF SUMMARY OF THE INVENTION

The invention relates to a method for the production of sonic or ultrasonic waves on surfaces, and to devices for carrying out this method.

The production of sonic or ultrasonic waves on surfaces from a remote location is desirable in a very great number of applications, as for example for the cleaning of these surfaces. The cleaning of the surfaces of solids is presently achieved by means of chemical substances, which, however, in most cases require the additional use of mechanical forces. Thus, surface-active substances must, for the full development of their effect, be used in hot suds and/or be agitated vigorously. The same is true of solvents of all kinds, if they are not able to transform the impurities into a true solution. The auxiliary means necessary to produce these effects are voluminous and expensive and yet fulfill their purpose only partially. Moreover, where the use of thermal energy, mechanical energy, and/or kinetic energy can be used only insufficiently or not at all, for example on relatively large objects, such as buildings, automobiles, ships, streets and the like, cleaning becomes very expensive, and sometimes even impracticable. Also for objects which due to their size and complex form have inaccessible surfaces, effective cleaning aids were heretofore unusable, and a simple liquid jet was used. The liquid jet, which is of particular importance, offers in itself an abundance of advantages, which, however, are so weakened in their sum of disadvantages, not overcome until now, that only in the rarest cases could a really satisfactory end result be achieved with a liquid jet.

It is known, for example, that in the cleaning of vehicles, a liquid jet directed onto the dirty areas with great pressure removes the coarsest impurities but is unable to take away the finer particles on the surface. Direct contact and rubbing with a brush, sponge and the like is necessary to eliminate this residue of dirt. Even when adding surface-active substances, a lacquered surface cannot be cleaned with the liquid jet alone so that it appears visually more or less clean, because the remaining fine dirt particles produce a dull, cloudy appearance on the surface. The addition of thermal energy improves matters but is uneconomical, especially because much of the thermal energy applied is lost outside of the actual sphere of action.

An attempt has been made to add to the liquid jet other forms of energy, as for instance a pulsing, the frequency of which can be ultrasonic. The latter would be most

effective if a good deal of the applied energy were not lost outside of the actual sphere of action on the surface to be cleaned. Known for example are devices with which ultrasonic sound is generated inside a vessel containing a liquid, and also known are devices which impart pulses to a liquid jet up to the ultrasonic frequency range. In the case of the liquid container it is possible to set the entire contents thereof in vibration. With a liquid jet, however, the ultrasonic vibration is produced in the liquid before it leaves the outlet, that is, not in the free jet itself. Although the pulses do propagate within the free jet, only a fraction of the original energy still exists at the point of impingement of the jet on the surface to be cleaned.

In contradistinction, an object of the invention is to provide a method and device by means of which energy pulses, in particular sonic or ultrasonic pulses, or heat, can be produced within a free liquid jet as close as possible to the region of the desired zone of operation, that is, at the point of impingement on the surface to be cleaned.

This objective is achieved with the method according to the invention in that in a free liquid jet directed onto a region of a surface at which energy pulses are to be produced, before or in the outlet of the apparatus producing the jet, a beam, substantially coaxial with the liquid jet, of parallel or converging energy rays is focused onto said region. The rays are transformed into sonic or ultrasonic waves or into heat near or at the point of impingement of the liquid jet on the surface.

When using parallel radiation (in the range between infrared and ultraviolet), the energy inherent in the radiation is liberated only at the point of impingement of the liquid jet on the surface to be cleaned, in the form of heat or ultrasonic waves. This presupposes that the liquid does not offer any appreciable resistance to the radiation energy at least in the region of the jet length (clear liquid). The radiation energy can be emitted intermittently, that is, in pulses, so that an additional desired pulsing effect is obtained at the point of impingement of the liquid jet. Likewise, radiation high in energy can be concentrated by an optical system at any point of the free jet, so that intensified high energy is liberated thereat in the case of the impingement of the radiation. The radiation can impinge either on the surface to be cleaned itself, or on particles which are added to the liquid, with the object of converting the radiation into heat or mechanical energy in the region of the focal point zone of the energy radiation. Also optical systems may be used which produce several focal zones or focal points more or less removed from each other within the free liquid jet.

Laser radiation may be used in particularly advantageous manner as energy rays. With a device for the production of laser rays, one can produce an almost absolutely parallel energy radiation, in particular coherent light, without major energy losses occurring within the radiation producing device and on the path of the radiation outside the producing device for impingement on surfaces. The radiation emitted by a laser device passes through transparent media practically without losses. In the case of a straight transparent liquid jet, the radiation propagating in it in the direction of its longitudinal axis is fully maintained up to the point of impingement of the liquid jet. It is even found that with a slight curvature of the liquid jet, the energy radiation propagating rectilinearly is reflected at its outer faces and thus accompanies the liquid jet at least in part fully in its curvature. Due to its coherence, the laser radiation can be concentrated exactly at predetermined regions by corresponding optical systems.

The energy inherent in the parallel rays of the laser beam is sufficient to produce ultrasonic waves in a liquid medium, with formation of the desired cavitation, where in quick succession small vacuum spaces or respectively vapor bubbles are formed. If this occurs in the immediate vicinity of or in local coincidence with the dirt particles to be removed, these are detached from the surface and carried away in the liquid. The forces of adhesion which cause the finest dirt particles to adhere to a surface are sufficient to withstand the forces produced by a surface-active substance, so that the surface-active substance is unable to penetrate between the surface and the particle. This is not the case when waves of ultrasonic frequencies are added or used alone, whereby all particles are set in resonance and thus move in relation to the surface. Surface-active substances can then fully surround the particles. Even without the joint action of the surface-active substances, the particles are removed.

Hazards due to unintentional directing of the laser ray onto living organisms or "overshooting" are very largely avoided in that by reflection of the radiation at the inner wall of the liquid jet due to so-called total reflection at some distance from the outlet opening of the water jet, and upon the division thereof, the laser radiation is transformed into diffiused light. An arrangement can easily be constructed where the laser radiation is developed only in the presence of the liquid jet.

The danger of damage to a surface due to direct impingement of a laser ray thereon is largely eliminated on the one hand, by the fact that the laser ray is unable to penetrate into the material, and on the other hand, by the ample cooling afforded by the presence of the liquid.

The method of the invention can serve also to impart ultrasonic energy to movable or other bodies to which ultrasonic energy cannot be ordinarily imparted or can be imparted only under unfavorable conditions. Thus a higher cutting speed or machining on lathes can be attained by ultrasonic sound, which may be produced with the device described directly at the cutting or machining region. The laser ray-conducting and ultrasonic producing liquid jet can be utilized in a great number of fields, as it can be used in convenient manner at any desired point and is readily movable.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a diagrammatic illustration of the apparatus according to the invention,

FIGURE 2 is a diagrammatic showing of a modification of the apparatus of FIG. 1, relating to an optical device thereof,

FIGURE 3 shows a diagrammatic arrangement of a further modification of the apparatus of FIG. 1, relating to a cooling arrangement therefor,

FIGURE 4 shows diagrammatically a further modification of the apparatus of FIG. 1, and

FIGURE 5 shows diagrammatically a further modification of the apparatus of FIG. 1 relating to a safety arrangement therefor.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings there is shown diagrammatically in FIG. 1 an arrangement wherein a nozzle **1** is fed with liquid from a pipe P to generate a liquid jet **2**. The liquid jet is directed towards a surface **3** which may for example be a surface which is to be cleaned.

A laser generator **4** is positioned adjacent the nozzle to generate a beam **5** of coherent light which is directed substantially coaxial with the liquid jet **2** and which contacts the surface **3** within the confines of the liquid jet **2**. The liquid jet is formed of clear liquid so as not to constitute any resistance to the radiation energy of the beam **5**. The laser beam releases energy in the region of impingement with surface **3** in the form of ultrasonic waves. The combined effect of the ultrasonic wave generation and the liquid jet **2** on the surface **3** is effective to remove all dirt particles from the surface **3** and thereby leave the same cleaned. It is also possible to utilize the beam **5** so that heat is generated in the region where the jet impinges on the surface **3** and the combined effect of the jet with the heat generation can also be employed to clean surface **3**.

The nozzle **1** and the laser generator **4** are preferably supported together so that they can be aimed as a unit and played along the surface **3** to clean the entire area thereof.

To facilitate the cleaning of the surface, the laser generator may be constructed to emit pulses rather than a continuous beam. Moreover, by adjusting the frequency and intensity of the pulses the degree of cleaning action can be regulated.

An optical device **6** may be fitted on the laser generator **4** for the purpose of optically focusing the beam of rays **5** on the surface **3**.

In the modified arrangement shown in FIG. 2, an optical device **7** is fitted to the laser generator for the purpose of generating a plurality of individual spaced beams **5***a*, **5***b*.

The liquid jet **2** may be composed of ordinary water or it may contain water with surface active agents which aid in the removal of the dirt particles from the surface **3**.

The laser generator **4** develops heat during its operation and for cooling purposes the pipe P may be formed with a coil C which surrounds the laser generator for cooling the same with water flowing therein.

In FIG. 4 there is shown a supply means **8** for the addition of particles to the liquid which is being fed to nozzle **1**. The particles serve to transform the radiation energy from the beam **5**, striking them into vibration energy thereby aiding in the removal of dirt particles from the surface **3**. A valve **9** serves to control the quantity of particles introduced into the liquid fed to the nozzle, thereby controlling the magnitude of the vibration energy on the surface **3**. Similarly, control of the frequency of the generation of pulses of the laser beam **5** serves to regulate the magnitude of the vibration energy at the surface **3**.

In order to prevent the danager of damage to surface **3** due to direct impingement thereon of the laser beam **5** without the water jet, there is provided a device **10** which is coupled to the laser generator **4** for controlling the operation thereof in accordance with the flow of liquid from pipe P. In particular, the water sensing device **10** serves to permit operation of the laser generator **4** only when liquid is present in the pipe P and is flowing from the nozzle **1**.

Although the invention has been described hereinabove in conjunction with several illustrated embodiments, it is apparent that numerous modifications and variations of these embodiments will become evident to those skilled in the art without departing from the scope and spirit of the invention if defined by the attached claims.

What is claimed is:

1. Apparatus for generating energy at a surface comprising means for producing a liquid jet and for directing said jet against a surface, means for projecting a beam of rays having radiation energy within the jet towards said surface, the radiation energy of said beam of rays being converted in the region where the liquid jet strikes the surface into sonic or ultrasonic waves or heat, and an optical system disposed in the path of said beam for focusing the beam within the liquid jet.

2. Apparatus as claimed in claim **1**, wherein said optical system includes means for producing a plurality of individual beams of high energy concentration.

3. Apparatus as claimed in claim **1** comprising means coupling the two first said means such that the means

which projects the beam of rays is operative only when the liquid jet is produced.

4. A method of generating energy at a surface, said method comprising directing a free liquid jet against a surface, and projecting, substantially coaxially within the jet, a beam of laser rays having radiation energy which is added to that of the liquid jet, said radiation energy being converted, in the region where the liquid jet strikes the surface, into sonic or ultrasonic waves or heat.

5. A method as claimed in claim 4 comprising optically focusing the beam of rays on the surface.

References Cited

UNITED STATES PATENTS

2,980,123	4/1961	Lemelson	134—1 XR
3,373,752	3/1968	Inoue	134—1

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