

Feb. 24, 1970

A. G. BODINE

3,496,677

SONIC POLISHING METHOD AND APPARATUS

Filed Sept. 8, 1967

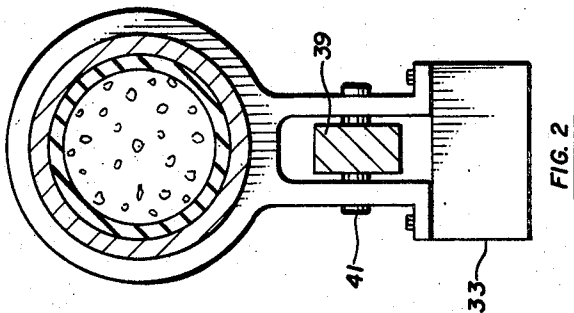


FIG. 2

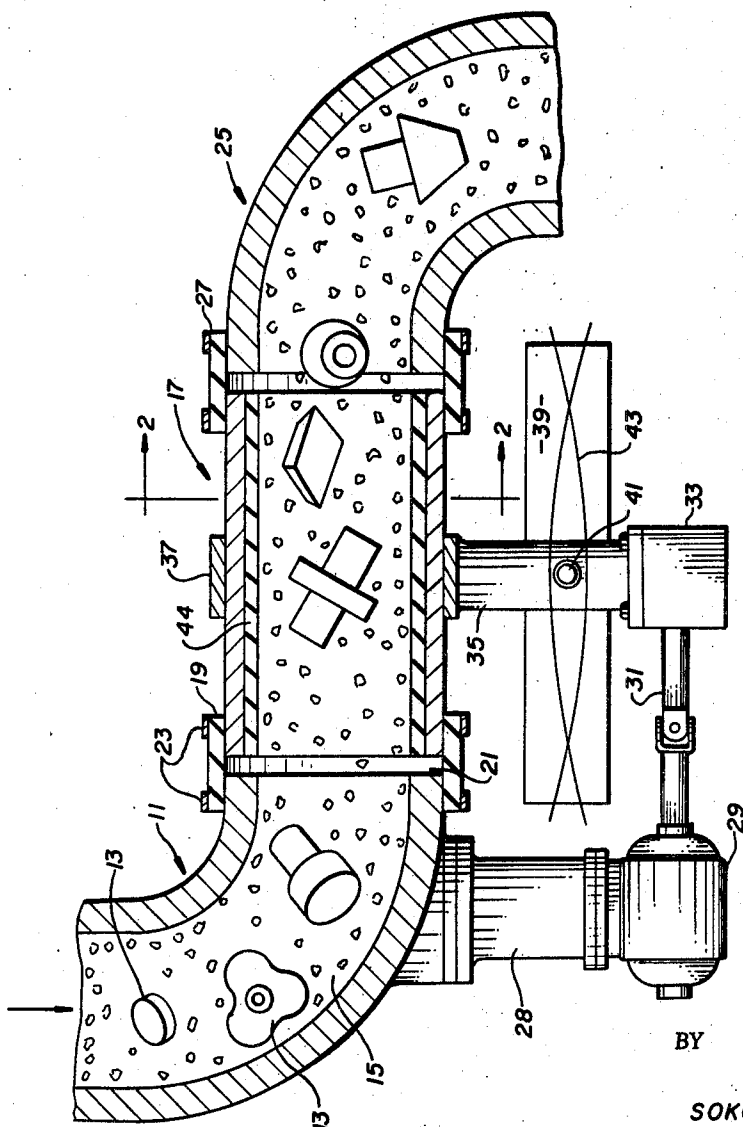


FIG. 1

INVENTOR.
ALBERT G. BODINE

BY

SOKOLSKI & WOHLGEMUTH
ATTORNEY

1

2

SONIC POLISHING METHOD AND APPARATUS

Albert G. Bodine, 7877 Woodley Ave.,
Van Nuys, Calif. 91406

Filed Sept. 8, 1967, Ser. No. 666,415

Int. Cl. B24b 19/00, 31/00

U.S. Cl. 51—7

7 Claims

ABSTRACT OF THE DISCLOSURE

Method and apparatus for surface treatment of parts in a suitable grit medium, wherein the parts continually pass through a conduit which also contains the grit material. A portion of the conduit is subjected to constant sonic resonant elastic vibration wherein the parts and particulate matter are continuously vibrated.

Prior to the herein invention, parts have been polished and cleaned by a grit procedure which consisted of immersing the parts to be cleaned or polished in a grit or abrasive particle medium. In some prior art devices this is accomplished by disposing the parts in the grit in a large barrel. The barrel is then rotated, and parts and grit tumble so that the parts strike against each other and against the particles of the abrasive or grit. Tumbling barrels of this type are used to slightly polish the surface of the parts, and to remove sharp corners, edges and burrs which have remained as the result of machining operations in which the parts were originally formed. This tumbling process is a finishing step in the production of small machined parts. The grit normally used in the tumbling barrels are pebbles of aluminum oxide, pebbles of metal particles such as steel shot, and various predetermined shapes of abrasive materials, some in the form of little biscuits which have particularly sharp abrasive surfaces. The use of this type of material in this manner is conventional and well known in the art.

In addition to the utilization of a tumbling barrel to effect a cleaning of parts in a grit or abrasive medium, a system exists where the barrel rather than being tumbled is vibratorily shaken. Instead of rotating the barrel about its axis to achieve tumbling, the vibratory technique involves mounting the barrel on a soft spring suspension. A vibrator is connected to the barrel to effect a bodily shaking. The vibration causes the abrasive medium together with the parts to be finished therein to impact against each other in a relatively mild manner to effect the deburring and polishing operations. The vibratory barrels vary in size from one or two cubic feet up to twenty cubic feet in size. For the larger barrels, extremely heavy-duty vibrators are required in order to accomplish the necessary vibration. Thus, in order to go to larger barrels, there results bearing limitations in the vibrators required. In turn, this limits the amount of acceleration of vibration which can be applied to the barrel. Thus, as can be seen, since the barrel is quite heavy and the material therein is also heavy, extremely large forces are required to vibrate the system. The smaller barrels are not as suitable to large quantity or mass production techniques; yet, as indicated, the large barrels present inherent machinery limitations.

The herein invention overcomes the foregoing problems in the prior art devices and provides an improved method for cleaning and polishing parts in an abrasive medium. The system comprises a conduit through which the parts and abrasives are flowed. The conduit is provided with a lateral passage which is part of a resonant vibration system. The lateral portion is preferably acoustically isolated from the rest of the conduit and is vibrated resonantly. To accomplish the resonant vibration, an orbiting-

mass oscillator is coupled to an elastic member and to the conduit. The conduit has a small dimension across its diameter as compared to a wavelength of the vibration frequency. By having a relatively small diameter a "sonic dipole" effect is achieved wherein opposite walls of the conduit vibrate 180° out of phase in response to elastic resonant vibration. This alternately applies accelerating forces in opposite directions within the lateral portion of the conduit and provides extremely high activation of the parts in the abrasive medium. Thus, only a small portion of abrasive medium and parts are treated at one time—that being within the affected lateral portion of the conduit. In view of this, a continuous process for treating the parts evolves wherein a minimum of vibratory energy is required. It is believed the invention will be better understood from the following detailed description and drawings, of which:

FIG. 1 is a cross-sectional view of the device of this invention; and

FIG. 2 is taken along lines 2—2 of FIG. 1.

It has been found most helpful in analyzing the operation of the device of this invention to analogize the acoustically vibrating circuit involved to an equivalent electrical circuit. This sort of approach to analysis is well known to those skilled in the art and is described, for example, in Chapter 2, of "Sonics" by Hueter and Bolt, published in 1955 by John Wiley and Sons. In making such an analogy, force F is equated with electrical voltage E , velocity of vibration u is equated with electrical current i , mechanical compliance C_m is equated with electrical capacitance C_e , mass M is equated with electrical inductance L , mechanical resistance (friction) R_m is equated with electrical resistance R , and mechanical impedance Z_m is equated with electrical impedance Z_e .

Thus, it can be shown that if a member is elastically vibrated by means of an acoustical sinusoidal force $F_0 \sin \omega t$ (ω being equal to 2π times the frequency of vibration) that

$$Z_m = R_m + j \left(\omega M - \frac{1}{\omega C_m} \right) = \frac{F_0 \sin \omega t}{u} \quad (1)$$

Where ωM is equal to $1/\omega C_m$, a resonant condition exists, and the effective mechanical impedance Z_m is equal to the mechanical resistance R_m , the reactive impedance components ωM and $1/\omega C_m$ cancelling each other out. Under such a resonant condition, velocity of vibration u is at a maximum, power factor is unity, and energy is most efficiently delivered to a load to which the resonant system may be coupled.

It is important to note the significance of the attainment of high acoustical "Q" in the resonant system being driven, to increase the efficiency of the vibration thereof and to provide a maximum amount of energy for the surface treatment operation. As for an equivalent electrical circuit, the Q of an acoustical vibration circuit is defined as the sharpness of resonance thereof and is indicative of the ratio of the energy stored in each vibration cycle to the energy used in each such cycle. Q is mathematically equated to the ratio between ωM and R_m . Thus, the effective Q of the vibrating circuit can be maximized to make for highly efficient high-amplitude vibration by minimizing the effect of friction in the circuit and/or maximizing the effect of mass in such circuit.

Of significance in the implementation of the method and devices of this invention, is the high acceleration of the components of the elastic resonant system that can be achieved at sonic frequencies. The acceleration of a vibrating mass is a function of the square of the frequency of the drive signal times the amplitude of vibration. This can be shown as follows:

The instantaneous displacement y of a sinusoidally vi-

brating mass can be represented by the following equation:

$$y=Y \cos \omega t \quad (2)$$

where Y is the maximum displacement in the vibration cycle and ω is equal to $2\pi f$, f being the frequency of vibration.

The acceleration a of the mass can be obtained by differentiating equation (2) twice, as follows:

$$a=\frac{d^2y}{dt^2}=-Y\omega^2 \cos (\omega t) \quad (3)$$

The acceleration a thus is a function of Y times $(2\pi f)^2$. At resonance, Y is at a maximum and thus even at moderately high sonic frequencies, very high accelerations are achieved making for correspondingly high vibrational forces at the cleaning interfaces.

In considering the significance of the parameters described in connection with Equation 1, it should be kept in mind that the total effective resistance, mass, and compliance in the acoustical vibration circuit are represented in the equation and that these parameters may be distributed throughout the system rather than being lumped in any one component or portion thereof.

It is also to be noted that an orbiting-mass oscillator may be utilized in the device of the invention that automatically adjusts its output frequency to maintain resonance with changes in the characteristics of the load. Thus, in the face of changes in the effective mass and compliance presented by the load, the system automatically is maintained in optimum resonant operation by virtue of the "lock-in" characteristics of applicant's unique orbiting-mass oscillator. The orbiting-mass oscillator automatically changes not only its frequency but its phase angle and therefore its power factor with changes in the resistive impedance load to assure optimum efficiency of operation at all times.

Referring now to FIG. 1, there is seen the device of this invention which comprises a first conduit section 11 containing parts 13 to be treated and suitable grit or abrasive material 15. As shown by the arrow, the parts are admitted to section 11 from a suitable source and can be hand fed into this portion of the conduit, or are automatically dispensed at given intervals. A separate lateral section 17 is separated from the first section 11 by a band of elastomeric material such as rubber 19 which surrounds the two sections at the gap 21 therebetween. The elastomeric material 19 is held in place by two adjustable steel bands 23 which can be tightened to provide suitable tension on the material. A final section 25 serves as an exit means for the material from the lateral section 17. Section 25 is separated from section 17 by a band of elastomeric material 27 in the same manner as previously described with regard to section 11. Thus, as can be seen, the lateral section 17 is isolated from the inlet section 11 and outlet section 25 of the conduit and is not in contact therewith but separated through an elastomeric material which can serve to accommodate any vibrations in the lateral conduit 17 without undue transmission thereof to the other two sections of the apparatus. The material, which includes the grit 15 and parts 13, flows through the system by gravity with the vibration in the lateral section 17, as will be explained, aiding to prevent any clogging in that portion of the system. It should be mentioned that the parts 13 and the grit or cleaning material 15 do not necessarily occupy the entire volume within the conduit, thus allowing for a freedom of movement therethrough, utilizing the gravity flow alone to promote the movement. The conduit can be supported by attachments (not shown), which can be fastened to a wall or to a suitable stand. Alternatively, a support structure could be utilized to support the auxiliary equipment utilized to vibrate the lateral section 17. The support structure forms no part

of the invention and would be apparent to anyone skilled in the art. Thus a description is not believed to be necessary.

Extending downwardly from the inlet section 11 is a support 28 for motor 29. Motor 29 in turn is affixed to universal drive connection 31, which drives an orbiting-mass oscillator 33. Orbiting-mass oscillators of this type are well known and a suitable such oscillator is disclosed in my Patent No. 3,217,551. The mass in the oscillator of this invention orbits about an axis substantially parallel to the section 17. Affixed to the oscillator 33 and extending upwardly therefrom toward section 17 is a coupler arm 35, having a collar 37 surrounding the section 17 at its mid-portion. The coupler arm 35 serves to couple the vibratory energy from the oscillator 33 to the section 17. Between the section 17 and the oscillator 33, the coupling arm 35 is hollow and contains an elastic resonating bar 39 extending therethrough as seen particularly in FIG. 2. The resonating bar 39 is rigidly supported by a pin 41 extending therethrough. Resonating bar 39 has generated therein a standing resonant wave pattern 43. The bar 39 serves to provide elastic compliance to balance out mass reactance in the resonant vibration system that comprises the coupling arm 35, section 17 and the material within the section. The bar 39 and coupling arm 35 can be of any suitable elastic material, with steel being preferred.

It is preferred that the lateral section 17 have a liner 44 of elastomeric material such as rubber. The liner 44 serves to provide a better impedance match at the interface between it and the material in the section. This results in a more effective transfer of the energy into the parts and material within the section, without setting up a highly vibratory interface at the point of contact between the surface and the material. It should be pointed out that liner 44 is not mandatory to the operation of the device, but does provide improved results. Likewise, the lateral section 17 does not have to be isolated from sections 11 and 25 by the elastomeric rings 19 and 27, respectively. It is apparent, however, that a vibratory system would be more effective where the section 17 is so isolated to prevent undue dissipation of the vibratory energy into the remaining portion of the over-all conduit.

Thus it can be seen that in having a conduit lateral section 17 the dimension across its diameter will always be relatively small compared to the previously described barrels. Since the orbiting-mass oscillator's rotor orbits about an axis parallel to the longitudinal axis of the section 17, the section walls will elastically vibrate in the gyratory pattern established by the orbiting mass. This acts, as previously indicated, as a "sonic dipole" wherein the opposite walls of the conduit section 17 vibrate 180° out of phase, alternately applying accelerating forces in opposite directions. Since the diameter of the conduit is relatively small as compared with a wavelength of the vibratory energy, the alternating forces are applied effectively throughout the entire material in the conduit section. This highlights another advantage of this invention, in that the sonic action is isolated in a small discrete volume of abrasive medium within the lateral conduit section. Thus the abrasive medium does not constitute an infinite medium which can absorb energy by radiation dissipation such as any type of oscillator working into an infinite medium. An example of such an infinite medium would be in a tank or barrel-type apparatus where the speed of sound in the abrasive is so slow that it accounts for a substantial number of wavelengths in a lateral dimension of the barrel. Alternatively, the conduit is a small fraction of a wavelength across its diameter.

Thus as can be seen, a continuous process for effectively cleaning particles in an abrasive or grit medium is described. This system can utilize a relatively low-energy force since the vibratory energy is concentrated in a relatively small area.

5

I claim:

1. Apparatus for polishing and cleaning of parts in an abrasive medium comprising:

a conduit through which said parts and abrasive medium can flow;

a lateral portion in said conduit;

means for resonantly vibrating said lateral portion whereby said parts and medium are brought into intimate contact, the diameter of said conduit being small as compared with a wavelength of said resonant vibration, the opposite walls of said lateral portion thereby vibrating as a sonic dipole in phase opposition to each other.

2. The apparatus of claim 1 wherein said conduit has portions other than said lateral portion, said lateral portion being acoustically isolated from the other portions of said conduit.

3. The apparatus of claim 2 wherein said acoustic isolation comprises:

a separate tubular conduit section forming said lateral portion and

elastomeric material affixed to each end of said section connecting it to the remaining portions of said conduit.

4. The apparatus of claim 1 wherein said means for resonantly vibrating said lateral section comprises: an orbiting-mass oscillator and

an elastic arm connecting said oscillator to said section.

5. The apparatus of claim 4 additionally comprising:

a bar of elastic material affixed to said arm in which a resonant standing wave can be developed.

6

6. The apparatus of claim 1 additionally comprising a liner of elastomeric material covering the inner walls of said lateral section.

7. A method of polishing and cleaning parts in an abrasive medium comprising:

continuously passing said parts and abrasive medium through a conduit having a lateral portion, and resonantly vibrating said lateral portion at a frequency whereby the opposite walls thereof vibrate in phase opposition to each other as a sonic dipole while said parts and abrasive medium are passing through said portion.

References Cited

UNITED STATES PATENTS

2,967,434	1/1961	Mahlfeldt et al.	51—163
3,336,701	8/1967	Moore	51—7
3,248,826	5/1966	Van Fossen	51—7
3,380,195	4/1968	Bodine	51—7
3,217,551	11/1965	Bodine	74—87
3,071,900	1/1963	Balz	51—163

FOREIGN PATENTS

133,260 8/1929 Switzerland.

JAMES L. JONES, JR., Primary Examiner

U.S. Cl. X.R.