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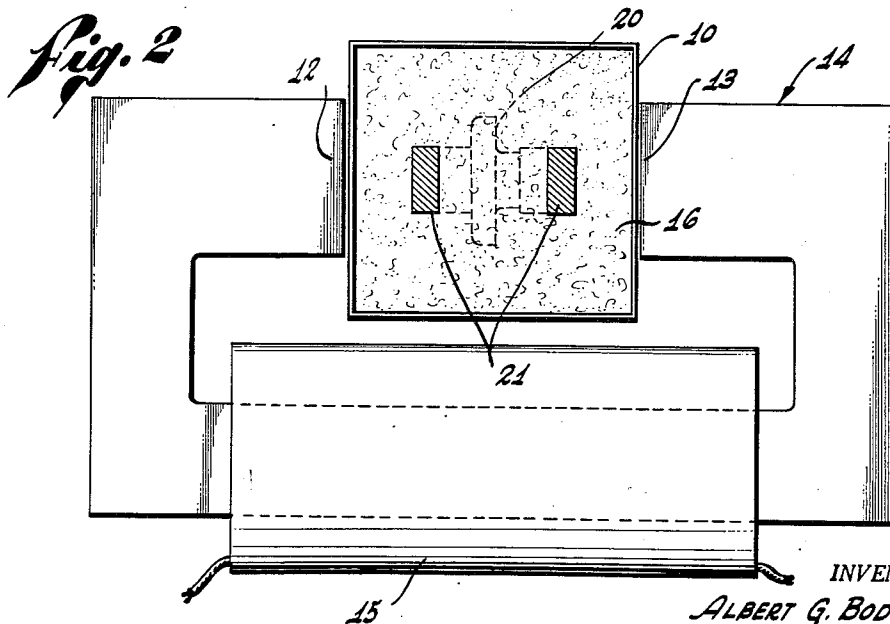
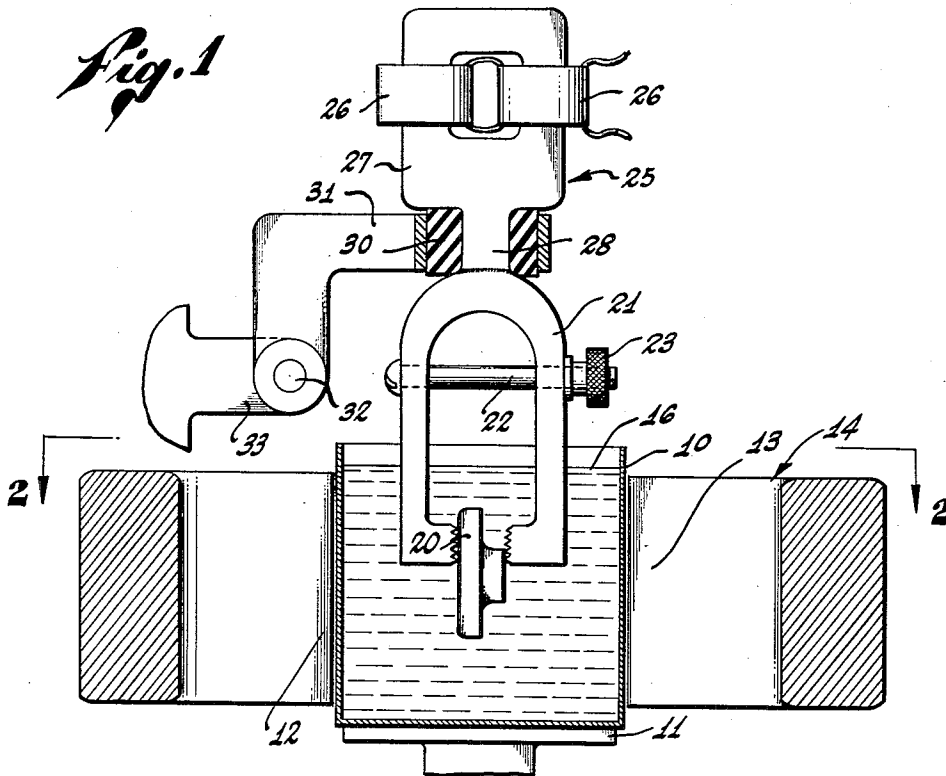
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METHOD AND APPARATUS FOR SONIC POLISHING AND GRINDING

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2 Sheets-Sheet 1



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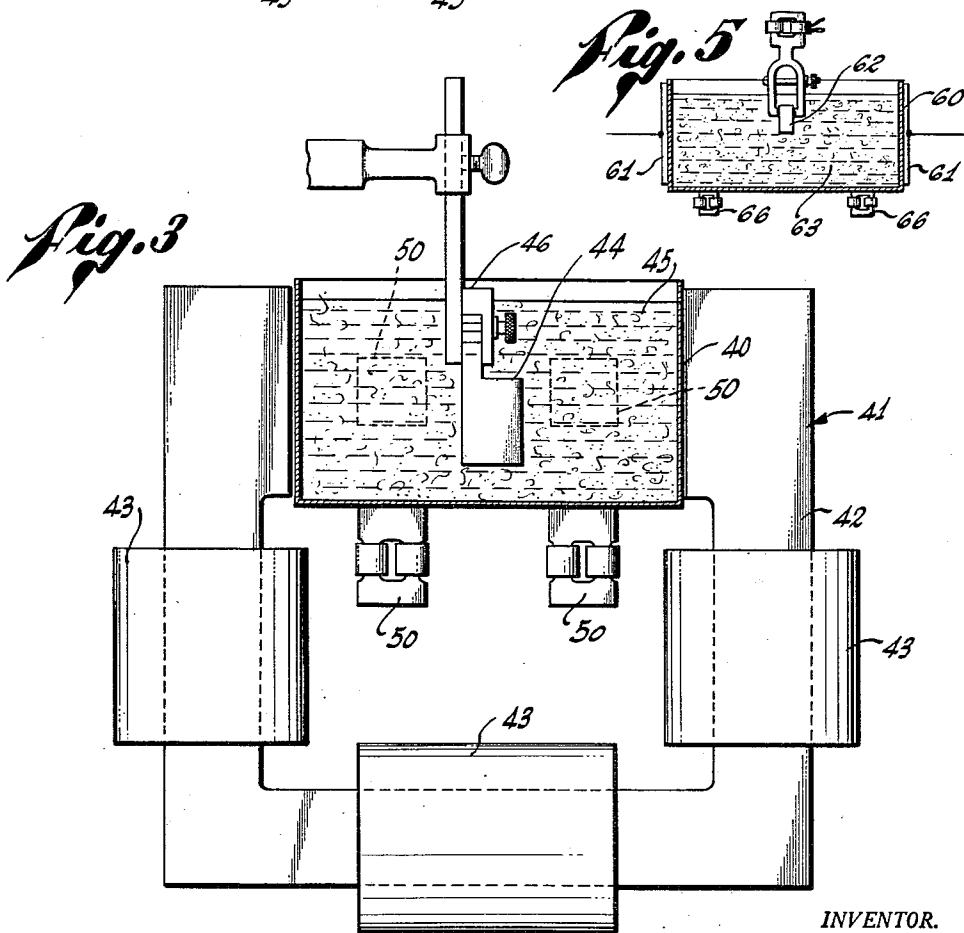
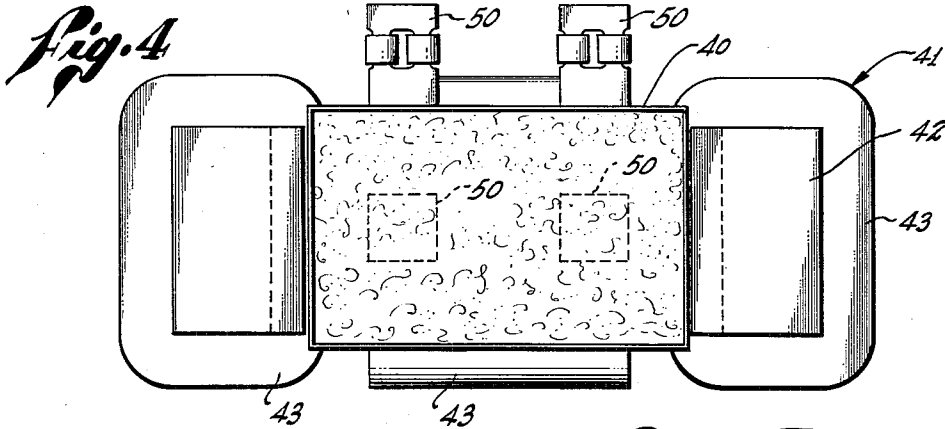
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METHOD AND APPARATUS FOR SONIC POLISHING AND GRINDING

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2 Sheets-Sheet 2



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METHOD AND APPARATUS FOR SONIC POLISHING AND GRINDING

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10 Claims. (Cl. 51—7)

This invention relates to the grinding and polishing of articles by the general method of establishing relative oscillations between the surface of the article to be treated and abrasive particles in contact with such surface, utilizing acoustic methods and apparatus for establishing and maintaining such oscillations.

In my prior Patent No. 2,460,918, I disclosed a method and apparatus for polishing the surfaces of articles by immersing them in a fluid suspension of fine abrasive particles and transmitting sound waves through such suspension so as to set up high frequency oscillations of the particles in surface contact with the articles.

The present invention is directed to improvements in the basic process of said prior patent, and its general object is improvement of said process in the direction of increased speed and effectiveness, and a superior final surface finish.

A more specific object is the provision of an improved abrasive medium.

According to the present invention, I utilize an abrasive medium which, in common with my original process, utilizes fine abrasive particles in contact with the article, but has the novel characteristic that, instead of being completely fluid, it may be rigidified, either partially or totally. As one illustrative example, the medium may consist of a thick or paste-like mixture of oil, graphite or molybdenum sulfide, and fine abrasive particles, for instance, tungsten carbide, aluminum oxide, silicon carbide, or the like. The abrasive medium is typically more in the nature of a paste or a semi-solid than of a free liquid or powder. After the article to be polished has been suspended in this abrasive medium, the medium is then rigidified, which may be carried out by the application of a moderately high pressure, or, in my preferred practice, by incorporating iron (ferro-magnetic) particles in the medium and subjecting it to a strong magnetic field. Such field rigidifies the abrasive medium by magnetic action on the iron particles. Relative oscillation, at low amplitude but high frequency, is then established between the article to be polished and the rigidified mass, and this may be done by transmitting sonic waves through the rigidified mass, or through the article to be polished, or the article may simply be bodily vibrated at low amplitude and high frequency, utilizing as a driver a suitable transducer exemplified by a magnetostriction sound wave generator. The result is a faster and more efficient polishing action, and a superior final finish.

The invention will be better understood from the following detailed description of several illustrative embodiments thereof, reference being had to the accompanying drawings, in which:

Fig. 1 is a side elevational view, partly in section, of apparatus embodying one form of the invention;

Fig. 2 is a view taken in accordance with line 2—2 of Fig. 1;

Fig. 3 is a view partly in elevation and partly in vertical section showing another embodiment of the invention;

Fig. 4 is a top plan view of the apparatus of Fig. 3, the

work piece and suspension means therefor being omitted; and

Fig. 5 is a vertical sectional view illustrating somewhat diagrammatically another embodiment of the invention.

In the embodiment of Figs. 1 and 2, numeral 10 designates generally a non-magnetic cup or container supported on a suitable base 11, and positioned between the opposed pole pieces 12 and 13 of a powerful electromagnet designated generally at 14, and whose core is shown to be provided with a D. C. winding 15.

This container 10 is filled with the desired semi-fluid or paste-like mixture 16 of lubricant, abrasive particles, and iron particles, for example, lubricating oil, fine particles of aluminum oxide, and particles of iron, in suitable proportions to furnish a medium capable of being rigidified by the action of the magnetic field between pole pieces 12 and 13 on the iron particles contained in the medium. Characteristically, the mixture is of a thick or paste-like consistency. The oil or graphite serves as a carrier for the particles of iron and abrasive, facilitating insertion of the part to be treated and tending to assure intimate contact of the abrasive particles with all surfaces of the part to be treated. The relative proportion of iron particles to abrasive particles is susceptible to considerable variation, but a suitable "mix" is easily made of sufficient iron particles that the mixture will rigidify suitably under the magnetic field established, and sufficient abrasive particles to give the polishing action desired. It will be seen that considerable latitude is available. This latitude is of definite advantage, since for some articles having complicated shapes or undercuts, more rigidity is desirable to assure maintenance of the abrasive mass in contact with all surfaces of the article. For such cases, a certain sacrifice of abrasive is justified by the advantage of greater rigidity, and therefore more iron particles and less abrasive particles will be used. Also, the character of finish depends somewhat upon the ratio of rigidity of the mass to its abrasiveness, and may be varied by adjusting this ratio. Finally, certain extremely hard magnetizable substances, such as powdered tungsten carbide, may serve the functions of both rigidifying and abrasion. For articles of relatively soft material, such as aluminum, iron particles will serve as the abrasive as well as the rigidifying substance.

Suspended in this abrasive medium 16 is the work piece 20 to be treated, and in the illustrative embodiment shown in Figs. 1 and 2, the part 20 is gripped between the jaws of a U-shaped clamp 21, the two arms of which are adapted to be drawn towards one another and into tight engagement with the work piece by means of a screw 22 and knurled nut 23.

In the embodiment of Figs. 1 and 2, relative oscillation between part 20 and the rigidified abrasive medium 16 is accomplished by vibrating of the clamp 21 at moderately high frequency (for example, 20,000 C. P. S.) and low amplitude, accomplished by means of a magnetostriction vibrator generally designated at 25. This magnetostriction vibrator 25 shown to be energized by coils 26 surrounding opposite legs of its core 27, has extending downwardly from the said core 27 a short bar part or leg 28 suitably affixed, as by welding, to the yoke of the clamp 21. The arrangement is such that the alternate increases and decreases in length of the core 27 will cause alternating compression and tension pulses of elastic deformation (sound waves) to be launched and transmitted through the leg 28, clamp 21 and the work piece 20. That is to say, as described in the introductory portion of the specification, sound waves are set up in the system and transmitted through the article to be polished. As shown, the leg 28 connecting the magnetostriction core 27 with the clamp 21 is mounted in a rubber block 30 carried by

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a bracket arm 31 pivotally mounted at 32 on a fixed support 33, and it will be understood that the arm 31 may be moved on said pivot to remove the clamp 21 and the work piece from the operating position shown to a retracted position in which the clamp and work piece are removed from the treatment chamber. A suitable lock or detent, not shown, may of course be provided to secure the arm 31 in the operating position of Fig. 1.

In operation, the electromagnet 14 is energized, causing the iron particles in the medium 16 to be moved into parallelism with the magnetic field, which has the effect of substantial rigidifying the entire mass of the medium 16. The magneto-striction device 25, understood to be provided with any conventional type of energizing circuit, is then operated, and causes the part 20 to be acoustically vibrated at high frequency but low amplitude relative to the rigidified abrasive fluid medium in which it is immersed. This action rapidly polishes the part. The character of the finish varies with the particle size of the abrasive, the larger the particle sizes yielding a more satin-like finish, and the smaller the particle size, the more glossy the finish. The finish so obtained is superior to that obtainable with a simple liquid suspension of abrasive particles. Complex lateral vibrations can also be accomplished by unbalance in the mass, as by simple installation of the work piece off-center.

Figs. 3 and 4 show a modification, in which a non-magnetic cup or container, designated at 40, is again placed between the poles of an electromagnet 41, whose core 42 has direct current windings 43. The work piece 44 is immersed in the abrasive medium 45, made up as before to contain a finely divided abrasive material, iron particles, and, preferably, a lubricant such as graphite or oil. The work piece is shown to be suspended by means of clamp 46.

In this case, as before, a magnetic field produced through the medium 45 in which the work piece is immersed rigidifies the medium. The transducer (vibration generator) is not in this case, however, directly coupled to the work piece, but instead, to the container 40, and therefore to the rigidified abrasive medium within the container. For this purpose I have illustratively shown the container to have coupled thereto a plurality of magneto-striction generators, two such generators 50 being shown coupled to the bottom of the container, and two indicated at 51 to one side thereof.

The generators or transducers 50 may bodily vibrate the container and the rigidified mass contained therein, or may send sonic waves (elastic waves of compression and rarefaction) therethrough, depending upon the frequency and wavelength of the transducer as compared with the physical dimensions of the container. If the dimensions of the container are large relative to a wavelength, sonic waves may be set up in the rigidified mass, and by proper adjustment of wave frequency, a condition of standing wave resonance may be realized under which vibration amplitude at certain nodal points is maximized. Such standing wave phenomena depend, of course, upon wave reflection by the container boundaries, with reinforcement and interference at nodal and anti-nodal regions within the mass. It is clearly possible to position the work piece to be polished in a nodal region, at which maximized vibration amplitude is realized, and such is one advantageous practice of my invention.

In any case according to the invention, relative vibration, at moderately high frequency though relatively small amplitude, is established between the work piece and the rigidified abrasive mass in which the work piece is immersed. The work piece is very rapidly finished or polished by this process, and an improved finish is obtained. The rigidified paste gives a better surface finish than does a free liquid to which abrasive particles have been introduced. Particularly for the case in which sonic waves are transmitted through the immersion medium, this may be attributed in part to improved wave transmitting

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characteristics, since a rigidified medium can transmit shear waves, which are not transmitted by fluids or liquids. Also, there are no problems of cavitation, as with liquids.

In the practice of the invention, it is desirable under some circumstances to interrupt the operation of the transducer from time to time, thereby relaxing the rigidified fluid and permitting it to regain intimate contact with the surfaces of the work piece. By thus permitting the fluid to become relaxed, worn particles of abrasive immediately adjacent the work piece are also permitted to settle back into the fluid mass to some extent, to be replaced by fresh abrasive particles. Also, by stirring the fluid mass during such periods of relaxation, worn abrasive material can be completely replaced.

It is also possible and advantageous to operate individual transducers somewhat independently, creating different sound wave vibrations or patterns alternately, so as to vary the direction of vibration between the rigidified fluid mass and the work piece. This is actually a phase modulation process. This procedure tends towards the achievement of a still better finish, the abrasive action being in first one direction and then another. For example, the two transducers 50 of Figs. 3 and 4 may be operated alternately with the two transducers 51, or the transducers may be operated at different frequencies and/or phases. This procedure also, of course, assures polishing of all surfaces of the work piece.

A further modification is shown, somewhat diagrammatically, in Fig. 5, where the container 60 is placed between two electrode plates 61 across which is maintained a suitable difference of potential, so as to set up an electrostatic field between the electrode plates, and therefore through the container. The container is in this case constructed of any suitable non-conductive material. The work piece is indicated at 62. The semi-fluid suspension for the abrasive particles 63 is in this case a starch solution, which has the known property of becoming rigidified under the influence of an electrostatic field. Otherwise, this practice of the invention is similar to those previously described, and transducers can be employed of either of the types mentioned in the foregoing. That is to say, the work piece can either be vibrated by a directly connected transducer 65, e. g., a magneto-striction generator, or equivalent, or on one or more such generators can be coupled to the container or its contents, as indicated at 66.

Various modifications of the method and apparatus of the invention will suggest themselves to those skilled in the art, and the invention is accordingly to be regarded as limited only in accordance with a fair construction of the following claims.

I claim:

1. The method of polishing articles that comprises, immersing the article to be polished in a semi-fluid lubricant material containing fine abrasive particles, rigidifying said fluid, and effecting relative acoustic vibratory movement between said rigidified fluid and said article.

2. The method of polishing articles that comprises, immersing the article to be polished in a semi-fluid lubricant material containing fine abrasive particles, rigidifying said fluid, and acoustically vibrating said article relative to said rigidified fluid.

3. The method of polishing articles that comprises, immersing the article to be polished in a semi-fluid lubricant material containing fine abrasive particles, rigidifying said fluid, and acoustically vibrating said rigidified fluid.

4. The method of polishing articles that comprises, immersing the article to be polished in a semi-fluid lubricant material containing fine abrasive particles, rigidifying said fluid, and transmitting sound waves through said rigidized fluid.

5. The method of polishing articles that comprises, immersing the article to be polished in a semi-fluid lubricant material containing fine abrasive particles, rigidifying said fluid, establishing an acoustic standing wave in said

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rigidified fluid, and locating said article at a velocity antinode of said standing wave.

6. Apparatus of the character described comprising: a container, a semi-fluid material in said container bearing fine abrasive particles and in which an article to be polished may be immersed, means for supporting said article in said material, means for rigidifying said material about said article, and means for effecting relative acoustic vibration between said article and rigidified material.

7. Apparatus of the character described comprising: a container, a semi-fluid material in said container bearing fine abrasive particles and in which an article to be polished may be immersed, means for supporting said article in said material, means for rigidifying said material about said article, and means for transmitting sound waves through said rigidified material about said article.

8. Apparatus of the character described comprising: a container, a semi-fluid material in said container bearing fine abrasive particles and in which an article to be polished may be immersed, means for supporting said article in said material, means for rigidifying said material about said article, and means for acoustically vibrating said article relative to said rigidified material.

9. Apparatus of the character described comprising: a container, a semi-fluid material in said container bearing fine abrasive particles and in which an article to be

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polished may be immersed, means for supporting said article in said material, means for rigidifying said material about said article, and means for generating acoustic waves and transmitting said waves through said supporting means to said article for acoustically vibrating said article relative to said rigidified material.

10. Apparatus of the character described comprising: a container, a semi-fluid material in said container bearing fine abrasive particles and in which an article to be polished may be immersed, means for supporting said article in said material, means for rigidifying said material about said article, and means for transmitting sound waves through said article.

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