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APPARATUS FOR DETERMINING THE TOUGHNESS OF ABRASIVE BODIES

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Fig. 2.

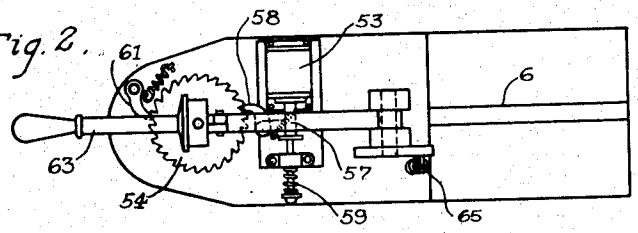
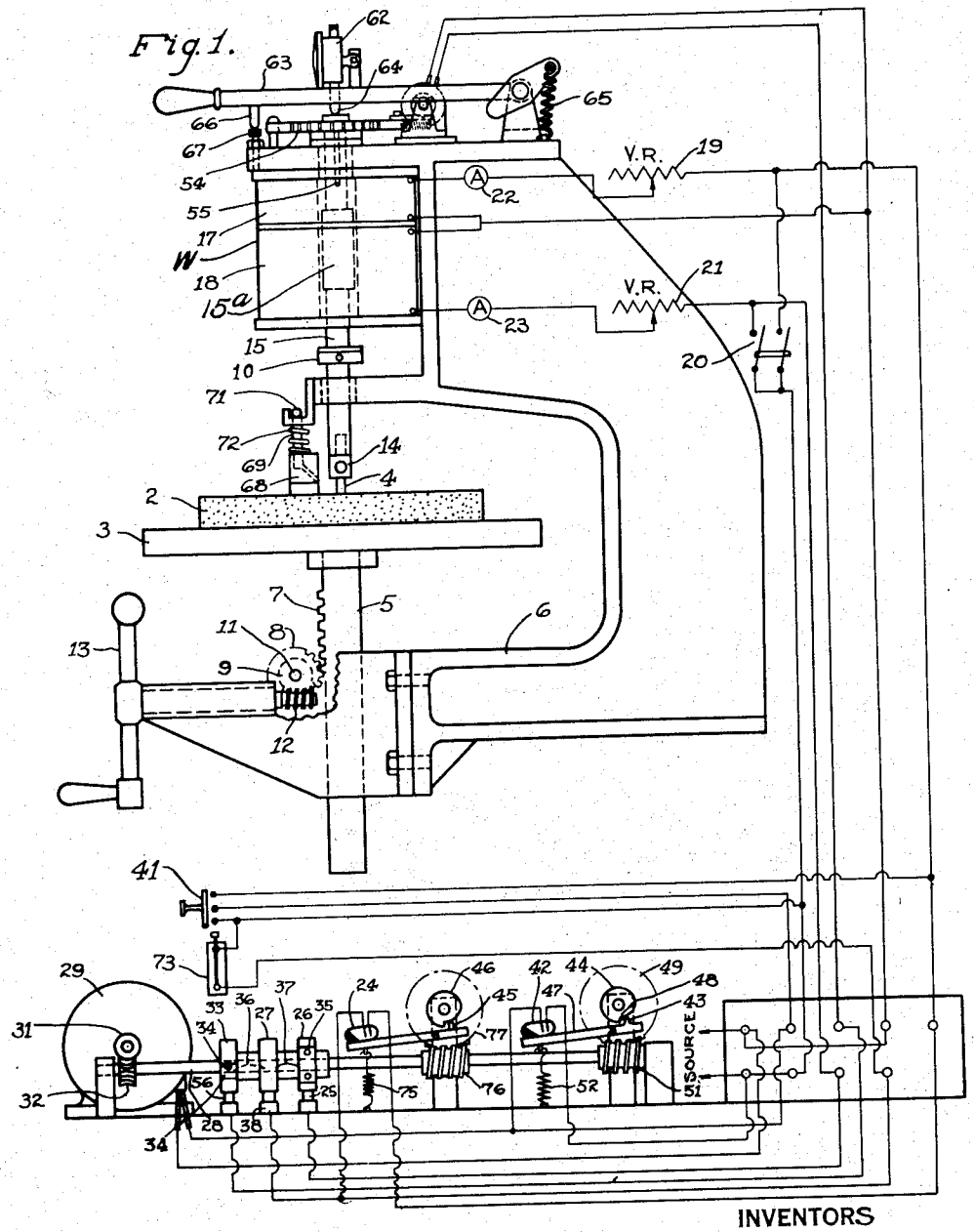


Fig. 1.



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APPARATUS FOR DETERMINING THE TOUGHNESS OF ABRASIVE BODIES

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3 Claims. (Cl. 265—13)

This invention relates to the art of classifying bonded abrasive articles and the like, and more particularly to an improved apparatus for determining the "toughness" of the bonded structure. The term "toughness' as used herein is defined as being that characteristic of a body by which it resists disintegration under impact blows imposed upon relatively small areas.

Abrasive bodies are regularly made in varying degrees or grades of toughness depending upon the particular work which they are to do. This range of grades is obtained in artificial abrasives, such as silicon carbide or crystalline alumina, by changes in methods of manufacture. For example, various grades or variations in toughness may be obtained (1) by the use of different bonding materials, (2) by different methods of curing, (3) by the use of different proportions of bond and granular abrasive, and (4) by the use of different combinations of abrasive particle sizes. Because of the effect of these variables, and others, on the toughness of the finished product, considerable skill and care are required in the manufacture of abrasive articles so that they will have a predetermined degree of toughness that is best suited for a specific purpose. Therefore it is desirable to have a simple and reliable apparatus by which the toughness of finished abrasive bodies can be tested with a view to learning whether they possess the characteristics desired. The grinding properties and the suitability of the abrasive article for the particular work for which it is intended are largely dependent upon the toughness of said article as here defined.

The impact method of testing has previously been used in cases where the force of the impact blow of a tool was determined by the action of gravity on said tool when allowed to fall through a given distance. A method of determining the toughness of bonded granular articles which involves gravity action and electro-magnetic operation is described in Patent No. 2,003,863, June 4, 1935, application filed October 9, 1929. In the method described in this patent, a plunger carrying an impact tool is raised to a definite height, rotated a part of a revolution and permitted to fall under the influence of gravity to strike the article under test. This is repeated a definite number of times and the depth of penetration of the tool (into a surface of the article) is measured and taken as an indication of the toughness of said article. The detritus, formed by the impact action of the tool, is removed by means of a fluid stream directed at the point of impact.

The only method of varying the force of the impact blow (described in the patent referred to above) for a given weight of plunger comprises changing the distance through which the plunger is permitted to fall. Such regulation of the force of the impact blow is quite limited since the acceleration due to gravity is constant.

The toughness of commercial abrasive bodies, bonded granular articles, and the like vary within very wide limits. Some of the ceramically bonded articles are so soft that they can be disintegrated by even a slight pressure of impact blow, whereas some of the organically bonded articles possess a very high toughness characteristic. For this reason the degree of regulation of the force of the impact blow afforded by a mechanism acting under the action of gravity alone is not sufficient to meet the requirements imposed by the great variation in the toughness of the articles to be tested.

In our improved apparatus for determining the toughness of bonded granular articles we control the force of the impact blow so that it is not dependent upon the action of gravity for its magnitude. The desired result is accomplished by subjecting the moving member, which causes an impact between a tool and the test article, to a controllable and predetermined force, rather than to a constant force such as gravity. After impact the moving member is returned to its original or starting position by a force acting in the opposite direction. The latter force may be continuous, the force causing impact being sufficient to overcome it and produce the desired impact blow. In this case the moving member is returned to its starting position as soon as the force for producing impact is removed. Or if desired the force causing return of the movable member may be applied periodically and at the instant the impact-producing force is removed. If the force (for causing return of the movable member) is continuous, the opposing force, (which produces the impact) may be balanced against it to any desired degree, even when the member carrying the impact tool is acting in the direction in which it would normally be accelerated by gravity. Thus, by varying the force for producing impact in comparison with the opposing force for causing return of the movable member, any desired regulation of the force of the impact blow may be obtained. For example, it will be possible to adjust the forces acting on the movable member to such values that the minimum force of the impact blow produced is negligible. Also by simply readjusting these forces it is possible to produce an impact blow of maximum force,

the magnitude of which is a great many times larger than the minimum force of the impact blow.

Figure 1 is a side view of an electro-magnetically operated apparatus embodying an approved form of our invention and showing the electrical control mechanism and circuits in connection therewith diagrammatically.

Figure 2 is a plan view of the apparatus shown in Figure 1.

The detritus formed by the action of the impact tool is removed from the point of impact by means of a fluid stream issuing from the nozzle 68 as shown in Figure 1. This is necessary to prevent particles from collecting at the point of impact and impeding the penetrating action of the tool.

As disclosed and claimed in the aforementioned patent we found it necessary to vary the tool size with the grit size. A particular tool was used for each range of grit sizes, said tools being of such sizes that for each corresponding grit size there was approximately the same average number of granular particles exposed to each impact blow of the tool. However an increase in the size of the tool used in testing a body of given toughness, caused a corresponding decrease in the depth of penetration of the tool. This is misleading and causes considerable confusion since the depth of penetration is usually taken as an indication of the toughness of the test article. In order to simplify the interpretation of the machine readings we have found in the present apparatus that it is desirable to vary the force of the impact blow with each change in tool size, so that for any given tool size the energy expended per unit area will be the same. Thus the same depth of penetration will be obtained on bonded granular bodies possessing the same toughness characteristics, even though they contain different size grain and are tested with different size tools.

According to our present apparatus we may also vary the force of the impact blow so that for any given test article the depth of penetration of the tool will be approximately the same. In this case the depth of penetration will be measured and referred to some standard scale, that is, the results may be interpreted as a ratio of the energy expended through the impact action of the tool as compared to a unit depth of penetration or as compared to the volume of the recess produced by the drilling action of said tool.

For the sake of convenience the devices shown in the accompanying drawing are shown in the vertical position. These devices are not limited to this position and will operate successfully with the movable member moving in any desired direction.

In the form of device shown in Figure 1 the test article 2 is supported on a table 3 that is in adjustable relationship to the tool 4. The table is rigidly attached to a post 5, which is slidably mounted in the frame 6 and is movable vertically by means of a rack 7 which engages a pinion 8. The worm gear 9 is mounted to turn with the pinion 8 on a common shaft 11 and meshes with a worm 12 which is also journaled on the frame 6 and turns with the ball handle 13.

Above the table is arranged the tool 4 which is adapted to engage the upper side of the test article 2 and which may be of any suitable form so that upon striking the specimen it will cut or break down a part of the same and form a mark or recess therein. This tool is mounted in a detachable chuck 14 which is threaded into the end of a reciprocating and intermittently rotating plunger or ram 15.

Reciprocation of the plunger and tool is effected by electromagnetic means. The solenoid W is composed of two separate coils 17 and 18 wound on the same form and in such a manner that the magnetic pull exerted by the coil 17 opposes the magnetic pull exerted by the coil 18. As illustrated in Figure 1, raising of the plunger and tool is effected by the magnetic pull of the coil 17 and descent of the same is effected by the magnetic pull of the coil 18, which last mentioned coil is energized periodically and overcomes the upward pull exerted on the plunger by the coil 17. Thus the force of the impact blow delivered by the plunger and tool is dependent upon the differential electromagnetic force exerted by the coils 17 and 18, and this differential force is varied by changing the relative strength of the magnetic fields set up by the two coils. The strength of the magnetic fields set up by the two coils 17 and 18 may be adjusted to any desired value by means of the variable resistances 19 and 21. The electrical switch 20, which is normally open, is closed thus connecting the coils 17 and 18 directly to the source of electrical energy. The current in the coil 17 is adjusted by means of the variable resistance 19, to some definite value, (as indicated by the ammeter 22) which produces an electromagnetic field of sufficient intensity to move the plunger to the "up" or starting position. The upward movement of the plunger 15 is arrested by the stop collar 10 on the plunger 15, striking the lower part of the solenoid W. Then the current through the coil 18 is adjusted by means of the variable resistance 21, to some predetermined value, which produces an electromagnetic field of sufficient intensity to overcome the magnetic pull exerted by the coil 17 and produce an impact blow of desired magnitude. After adjustment is secured the switch 20 is opened. Although this reciprocating electromagnetic plunger mechanism and its automatic controlling switch mechanism may be variously constructed, the form shown in the drawing is satisfactory and as there shown is constructed as follows:

The letter W represents a compound solenoid comprising the two coils 17 and 18. This solenoid surrounds the central part of the plunger 15, the larger section 15*a* of the plunger being made of iron to serve as a core or armature therefor, while the remainder of the plunger consists of non-magnetic material. One terminal of the coil 17 is connected to one side of an electrical supply line and the other terminal is connected through the ammeter 22 and variable resistance 19 to the mercury contact switch 24, which maintains an electrical circuit during the testing operation and breaks this circuit just as the last impact blow is struck, thus leaving the plunger and tool in engagement with the test article. One terminal of the coil 18 is connected to one side of the electrical supply line and the other terminal of said coil is connected through the ammeter 23 and variable resistance 21 to the brush contact 25. The rotating members 26, 27 and 33, mounted on the shaft 28 and driven by an electric motor 29 through the worm 31 and worm gear 32, are of an electrically insulating material but have electrical conducting segments 34 and 35 inserted in the members 33 and 26 respectively and are electrically connected by means

of the jumper connections 36 and 37 to a conducting ring which covers the entire periphery of the member 27 and makes continuous electrical contact with the brush 38. With each revolution of the shaft 28 the conducting segment 35 makes electrical contact with the brush 25 thereby completing an electrical circuit to the solenoid coil 18. Said coil becomes energized, and its magnetic pull overcomes the magnetic pull of the opposing solenoid coil 17 and causes an impact of the plunger 15 and tool 4 against the test article. Further rotation of the shaft 28 causes the conducting segment 35 to move away from the brush 25 thereby breaking the electrical circuit to the solenoid coil 18, and the plunger is returned to its original position (as determined by the stop collar 10) by the magnetic pull of the solenoid coil 17.

Operation of the machine is started by means of a switch 41 having preferably the form of a push button which closes the circuit across the open contacts in the mercury switch 42 thereby completing the electric circuit to the driving motor 29 until the trip pin 43 engages the periphery of the high face of the notched timing disc 44 and the mercury container is tilted so as to close the contacts associated therewith. The same push button also closes the circuit across the open contacts in the mercury switch 24 thereby completing the electrical circuit to the solenoid coil 17 until the trip pin 45 engages the periphery of the high face of the timing disc 46 and the mercury container is tilted so as to close the contacts associated therewith. After a definite number of impact blows have been struck the electrical circuit to the driving motor 29 is automatically broken by the mercury switch 42 thereby stopping the control mechanism. At the instant the last impact blow of a test operation is made, the mercury switch 24 breaks the electrical circuit to the solenoid coil 17 thereby leaving the plunger and tool point in engagement with the test article so that the depth of penetration of said tool below the surface of the test article may be determined.

In the drawing the above-mentioned mercury switch 42 is mounted on one arm of a vertically swinging lever 47, the opposite end of which has a trip pin 43 adapted to engage a notch 48 in the periphery of the timing disc 44, which is turned by a worm wheel 49 mounted on the same shaft with the last mentioned disc and meshing with a worm 51 on the shaft 28. When the trip pin engages the periphery of the high face of the timing disc 44 the mercury container is tilted so as to close the switch contacts associated therewith, but when the notch 48 in this disc is presented to this pin the latter is raised into said notch by the action of the spring 52 and the mercury container is tilted so as to break the electrical circuit. The notch 48, in the periphery of the timing disc 44, is so located with respect to the trip pin 43 that the mercury switch 42 will tilt and cut off the electrical supply to the driving motor 29 at the instant which will cause the shaft 28 to come to rest in such a position (see Figure 1) that neither the brush 25 and segment 35 nor the brush 56 and segment 34 will make electrical contact. In a like manner the mercury switch 24 is operated by the disc 46. The timing of the mechanism, which operates the mercury switches 42 and 24 and the rotary switch contacts 26, 27 and 33 is such that the circuit of the solenoid coil 17 is closed during the entire testing operation, and the circuits of the solenoid coil 18 and ratchet coil 53 are opened and closed a predetermined number of times and the plunger and tool are thereby raised and propelled against the test article a corresponding number of times between each starting and stopping operation of the motor 29. For example, the shaft 28 may be turned twenty-five times during each revolution of the timing disc or cam 44 whereby the plunger and tool will be reciprocated a corresponding number of times.

While the plunger and tool are removed from the test piece the same are rotated a fraction of a revolution so as to present the tool in different angular positions to the test piece and cause the tool to cut or drill a circular recess into the test article during each cycle of operation. The means whereby this intermittent movement is imparted to the plunger and tool may be described as follows:

The numeral 54 represents a ratchet wheel having a hub which is journaled in the upper part of the frame and receives the upper part of the plunger 15 said plunger and ratchet wheel being compelled to turn together but the plunger being free to slide vertically in this hub by reason of engagement with a spline 55. On top of the frame is mounted the coil 53 of the plunger rotating mechanism. One terminal of the coil 53 is connected to one side of the electrical supply line and the other terminal is connected to the brush contact 56. With each revolution of the shaft 28 the brush contact 56 completes an electrical circuit through the conducting segment 34 to the other side of the electrical supply line. The coil 53 is adapted to attract an armature 57, provided with a feed pawl 58 which engages the ratchet wheel 54. When the coil 53 is energized the armature 57 is attracted and the feed pawl 58, by engaging the ratchet wheel 54 turns the latter and the plunger and tool connected therewith move forward one tooth or step. Return movement of the armature is effected by a spring 59 and backward movement of the ratchet is prevented by a detent pawl 61 mounted on the frame.

In making a test the test article 2 supported by the table 3 is raised to some zero or starting point as indicated by the gauge 62. After a predetermined number of impact blows have been made, a reading of the gauge is again taken and the difference between this and the "zero" reading is the depth of penetration of the tool during the test. The gauge 62 is mounted on a vertically swinging lever or arm 63 pivoted at its rear end on the frame 6. A movable shifting pin 64 is connected with the indicating mechanism of the gauge 62 and adapted to engage with the upper end of the plunger. The gauge lever is yieldingly held in its elevated position by a spring 65 and the descent of this lever is arrested by a foot 66 thereon adapted to engage an adjustable stop 67.

A stream or blast of fluid under pressure is delivered toward the place on the test article where the same is operated on by the tool. This is practically carried out by a nozzle 68 having its outlet turned toward the place of impact and connected with the end of a tubular neck 69 which is guided on the frame and connected with a conduit 71 (shown as end opening in Figure 1) which supplies the fluid under pressure to the nozzle. The nozzle is yieldingly held in its depressed position by a spring 72 interposed between the nozzle and the frame so that by raising the work piece against the nozzle the latter can yield as it adapts itself to the working position.

The main circuit of the machine which supplies the solenoid coils 17 and 18 and the ratchet coil 53 may be opened by means of a normally closed switch 73. Thus should it be desired to stop the machine before the regular number of impact blows have been struck, the switch 73 is opened. This breaks the electrical circuit to the solenoid coils 17, 18 and 53 but permits the control mechanism to continue its operation under power from the motor 29 until the latter is stopped by the action of the mercury switch 42. After the control mechanism has stopped, the switch 73 is closed and the machine is ready for another test run.

While the above described apparatus for determining the relative toughness of test articles is intended primarily for bonded bodies of an abrasive or ceramic nature, it may also be used to determine the relative toughness of soft metals, vulcanized fibrous bodies, hard rubber and other articles where a test for toughness is desired.

We claim:

1. An apparatus for determining the characteristics of bonded granular articles and the like, comprising a support for the article, a tool adapted to engage said article, the mass of the impacting part being kept constant throughout a series of determinations, electromagnetic means for causing said support and tool to move one relatively to the other for causing an impact of said tool against said article, electromagnetic means for varying the velocity of the impact blow, electromagnetic means for intermittently turning said tool, a gauge adapted to indicate the depth of penetration of said tool into said article, and fluid pressure means for removing the detritus from the point of impact.

2. Apparatus for determining the characteristics of bonded granular articles comprising a tool, a solenoid coil for impelling the tool against a test piece, a solenoid coil for returning the tool to retracted position, switch mechanism for controlling the reciprocation of the tool including timing mechanism to bring about a predetermined number of reciprocations of the tool and a motor for actuating said switch mechanism including said timing mechanism.

3. Apparatus for determining the characteristics of bonded granular articles comprising a tool, a solenoid coil for impelling the tool against a test piece, a solenoid coil for returning the tool to retracted position, switch mechanism for controlling the reciprocation of the tool including timing mechanism to bring about a predetermined number of reciprocations of the tool and a motor for actuating said switch mechanism including said timing mechanism, said timing mechanism including means to discontinue the electromagnetic force impelling the tool at the end of the last impact stroke.

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