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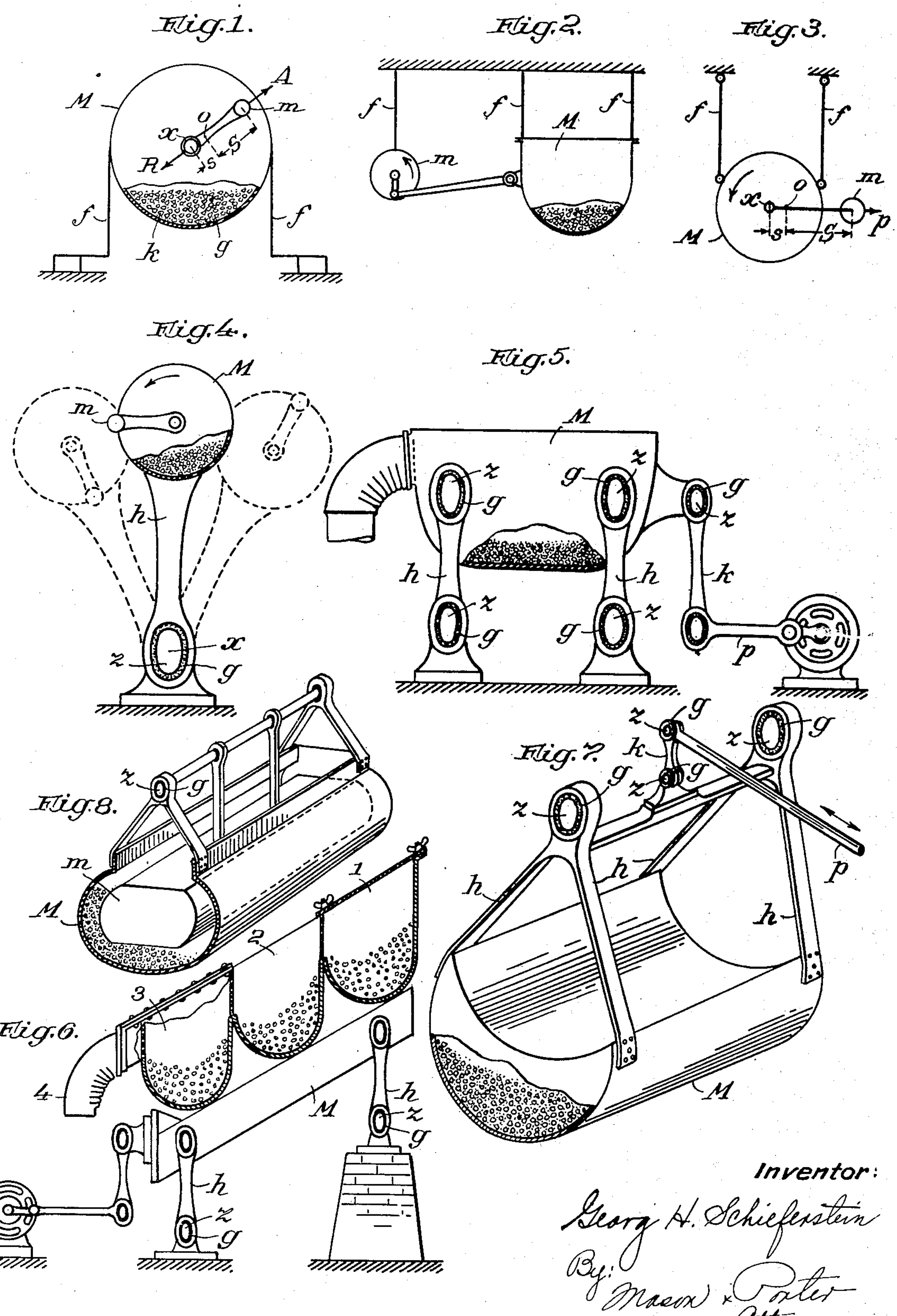

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APPARATUS FOR COMMINUTING DRY SUBSTANCES, PASTES, AND THE LIKE

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An apparatus has been proposed for grinding dry substances, pastes and the like by means of quartz sand or similar fine-grained grinding bodies with the aid of vibrations produced by unbalanced masses, characterised in that the grinding containers for receiving the material to be ground are arranged with their axes parallel to the shaft producing the vibrations and the containers are advantageously of tubular shape.

Also apparatus has been proposed for the grinding and comminution of such substances with employment of "mono-energetic" vibrations in a closed path (circle or ellipse).

The present invention depends upon the novel recognition that, in contradistinction to comminution by vibrations in a closed path (circle or ellipse) a comminution of dry substances, pastes and the like is more effective, simpler and cheaper to produce by employing apparatus which vibrate in an open path.

The point of view which first led to a comminution in a closed path was probably connected with the firmly rooted conception of grinding which is indeed connected with a comminution in a closed path.

The simplest form of the vibration process however is effected, as is known, in an open path, and vibrations in a closed path are derived from a combination of two vibrations which interact at a right-angle with a phase difference of 90°.

Since in the field of hard comminution, so far as vibrations are employed, the characteristic of known comminuting methods must be combined with the characteristic of the vibration process in some form, it therefore requires a thorough examination to determine what apparatus and what processes prove the simplest and most effective.

In this case however it is an incontrovertible fact, that, as already mentioned, the vibrations in an open path are simple, per se, and may be realised more cheaply, and because of the combined grinding and impact effect which results are more effective and more adaptable.

Thus the subject of the present invention is a new hard comminuting process and new apparatus for carrying out the said process.

The principles of operation and illustrative forms of practice of the invention are set out on the accompanying drawing in which

Figure 1 is a diagrammatic view showing the coupling forces in one type of vibration apparatus.

Figures 2 and 3 are conventionalized views of forms of a vibrating apparatus.

Figures 4, 5 and 6 show embodiments of the present invention as applied to masses supported upon mountings positioned at a low point thereof.

Figures 7 and 8 show forms of the invention in which the mounting is positioned at a high point of the apparatus.

In Fig. 1 a diagrammatic view is shown of the tube mill which consists of a large mass M and a small mass m.

The small mass is constructed in the form of one or two rotating unbalanced masses m and rotates about the central axis x.

During this rotation, there must of course be an equilibrium between the masses M and m and this is given on rapid rotation according to the Newton law by the equation

$$m.S=M.s$$

Hereby an ideal common centre of gravity O is formed at a distance s from the central axis, about which common centre of gravity the two masses carry out circular movements.

The circular movement of the small mass is a rotation about this point and the circular movement of the large mass is a vibration in a closed path (a circular vibration).

As a result of this circular vibration, the auxiliary grinding bodies disposed in the interior are set in rotation in a direction opposite to the circular vibration and thus grind the material to be ground. The action is quite minimal, however, since the action force A which acts upon the bearing x is equal to the reaction force R, so that there is an amount of work lost which corresponds to this normal force multiplied by the coefficient of friction.

For the rest there only remains over for the grinding action an amount of work produced by the circularly vibratory movements of the large mass on travelling along a fraction of the small path s. Since this travel frequently only amounts to fractions of a millimetre, the yield and hence the efficiency is extraordinarily small. The yield becomes somewhat better when employing an apparatus according to Fig. 2 which is already novel in the sense of the invention. The improvement is obtained because in this case slower vibrations with a larger amplitude in an open path can be produced by means of a larger crank.

In spite of all this however the efficiency in this case is the smaller, the higher is the frequency of vibration and the larger is the mass M which moves to and fro. The material to be ground is moved to and fro in the trough-shaped bodies, whereby the rollers or balls which are employed as auxiliary grinding bodies have a rolling action, which in the mean position is rotationally opposite to the direction of movement, and which in the end positions press the material with a large force component.

Naturally a hollow body according to Fig. 3 can also be constrained, by means of an unbalanced effect corresponding to the apparatus of Fig. 3, into to and fro vibrations similar to those of the apparatus according to Fig. 2, if the hollow body M is prevented from carrying out circular vibrations by employment of rigid springs or rigid links *f*, *f*, or is constrained to carry out vibrations in an open path, and the same effect is obtained as in Fig. 2.

Taking them all in all, apparatus in which only mass elements, cranks and eccentrics are employed for constraining rigid mass elements to carry out vibrations in an open or closed path, show the common fault of a relatively or unduly intolerably bad efficiency because in this type of movement only one kind of energy, in fact kinetic energy, is employed and the vibratory movement is limited to the exact maintenance of a predetermined amplitude.

Just because of this limitation, these intolerable losses are caused mainly by bearing friction but also by internal hysteresis work disturbing the material, which losses make such systems incapable of employment per se in practice in the art.

Systems of this kind have been characterised by the applicant as limited-travel systems and still better by Dr. Traude Schieferstein in the Dissertationschrift of May 6, 1936, page 7, as "mono-energetic" systems.

The highest attainable effect in the sense of the invention is obtained when "bi-energetic" vibration mechanisms are employed, that is apparatus in which the vibrating masses are mounted between elastic means, so that the kinetic energy, starting from the mean position, is converted by the time the limiting position has been reached into potential energy, and vice versa the potential energy is reconverted again into kinetic energy by the time the mean position has been regained.

With this conversion process, the losses in the interior of the elastic means, so far as it is a matter of rubber bodies, amount only to a maximum of 3–5% as has been established by measurement, since no other losses are present, so that "bi-energetic" systems in contradistinction to "mono-energetic" systems work with an efficiency which amounts to more than 90% according to the frequency, since bearing friction does not arise at all and there is only air resistance to be overcome.

The principle of "bi-energetic" types of vibrations is to be seen in Figs. 4, 5 and 6.

In Figs. 4 and 5 mechanisms are shown which carry out "bi-energetic" vibrations.

In Fig. 4 the mass M vibrates about a rotary axis X upon the lever *h*. The lever *h* terminates in an elliptical rubber mounting, the elastic part *g* of which is secured adhesively on the one hand to the internal pin *z* and on the other hand to the lever *h* itself which is constructed at its lower end as an elliptical annular body.

Hence the mass M can carry out vibrations as shown in broken lines about the elastic mounting *zg*, and is excited to vibration by a loose coupling which may be constructed as an unbalanced mass in the same way as in Figs. 1 and 3.

It is remarkable that in the case of Fig. 4 the loose coupling, that is to say the mass *m*, does not in this case move with a phase difference of 180° with respect to the mass M, but in the case which is to be taken of maximum efficiency (approximately the position of resonance) takes up a phase difference of about 90°. That is the exciting and the vibrating forces have not the relation to one another of action and reaction forces, but in each case the exciting mass precedes about 90° in front of the vibrating mass so that only the smallest exciting forces are transmitted and the loss becomes minimal.

This effect is still more marked in Fig. 5.

In this case the mass which is mounted in elliptical rubber springs *z*, *g*, *h*, is excited by a coupling *k* which is likewise constructed in the form of an elliptical rubber spring and moves to and fro horizontally.

The only losses which occur in this case are the hysteresis losses in the interior of the rubber rings amounting to between 3 and 5%, according to measurements. Further there is a loss outside the actual vibrating system in the crank pin *c* of the electric driving motor and finally there is a negligible, small amount of work to be done against the air resistance depending upon the frequency.

By way of example if it is imagined that the masses M of Figs. 4 and 5 are constructed as hollow chambers and are partially filled on the one hand with material to be ground and on the other hand with auxiliary grinding bodies, balls, rollers or other hard means capable of grinding, a comminuting machine is produced in this case in which, as already stated, more than 90% of the energy supplied is converted into useful work.

Naturally the grinding chambers of such systems may be constructed in known manner as simple- or multiple-trough chambers and they may also be so constructed that the forces and mass displacements produced by the vibrating masses are entirely compensated in known manner (see German Specification No. 514,156). The grinding chambers may also be employed in known manner in open or closed condition and they may be inclined at any desired angle to the horizontal etc.

These apparatus may also be driven in known manner at any desired frequency according to the number and resistance of the resilient assemblies *z*, *g*, *h* employed.

An example of an inclined trough-shaped chamber is shown in Fig. 6, in which M represents the vibrating mass divided into troughs. The troughs 1, 2, 3 may have sieve-like openings in their front walls similarly to the trough M of Fig. 5, through which the mass when it has been ground suitably fine may flow from chamber 1 to chamber 2, from there to chamber 3 and finally to the escape 4. The trough 1 is provided by way of example with a closable lid whilst the trough 2 is shown as being open and the trough 3 as being closed. The angle of inclination may be varied according to the material to be treated.

In Fig. 6 resilient assemblies *h*, *z*, *g* are employed which are disposed vertically so that the inclined sieve must also vibrate vertically. Of course the resilient assemblies may also be inclined as shown in broken line so that the sieve vibrates at an inclination to the horizontal.

In Fig. 7, the mass M is represented as a trough suspended from elliptical rubber mountings *z*, *g*, *h*, the trough being driven by a loose elastic coupling consisting of two resilient heads *z*, *g* and the shaft *k*, and by a suitable motor, through the intermediary of the connecting rod *p*.

It is at once obvious that with a suitable elongated hollow body, because of the long path which the grinding bodies travel, the crushing action due to kinetic energy plays a larger part than the pressing and hammering action of the grinding body at the end of the trough, especially when the grinding bodies are relatively massively constructed and corresponding low frequencies are employed. Conversely it will be seen that with a shorter travel and a narrower grinding chamber the force effect of the vibration process may be increased to a hitherto unknown height. In this case use is principally made of the potential energy of the vibration process.

In Fig. 8 a grinding chamber M, shown as being open, is represented, which vibrates to and fro upon two elliptical resilient assemblies z, g similar to those of Fig. 7.

A second mass *m* which vibrates with a phase difference of 180° with respect to the mass M is disposed in the interior of this grinding chamber.

This mass is readily influenced or damped by kinetic energy, but it does its work almost exclusively in potential form, in that the material to be ground which piles up as a result of the vibration process at the sides of the grinding chamber M is struck centrally there with a hard blow and comminuted.

The apparatus of Fig. 8 shows clearly that the two masses M and *m* are wholly compensated with regard to forces and mass effect, if for example they are driven according to German Specification No. 514,156 by two couplings acting with a phase difference with respect to one another of 180° or by one coupling with interposition of a reversing lever.

In many cases, especially where a rigid base is available, the 180° counteraction of the auxiliary grinding bodies and the material to be ground suffices. When this measure does not suffice, then without variation of the essence of the invention two grinding chambers with a phase difference of 180° with respect to one another may be excited to vibration according to the above mentioned basic German Specification No. 514,156, whereby an exact compensation of the force and mass effect is obtained.

The shape of the grinding chambers is dependent on the one hand upon the frequency and on the other hand upon whether it is desired to carry out the comminution by means of potential energy or kinetic energy or both.

If the radius of the grinding chamber on rotation about the elastic means is made equal to an arc about the point of rotation and if the grinding bodies after travelling a certain path come to rest through damping corresponding to the frequency chosen, then the grinding takes place in a purely kinetic manner.

The same is true for grinding chambers with a level floor which are moved parallelly.

On the other hand if the grinding chamber is so constructed that the inner surfaces tending in a curved or straight line towards the vertical lie close beside one another and if the grinding bodies are so to speak tossed about in a short path between these two surfaces, then the potential energy is being employed in an extreme manner.

The use of both forms of energy lies in between these two extreme cases.

The figures illustrated and described show devices which carry out so-called non-harmonic vibrations (see on this point German Specification 541,308 of November 15, 1923, Sch. 1,068,231/63c/40 and others).

This form of vibration has proved excellent in practice, because machines of this kind do not fall out of step upon variation in the load and supply of energy.

Naturally hard comminuting machines may also be constructed in which steel springs are employed, which in the shape of their curve show a linear course of vibration, hereby there is no alteration in the essence of the invention.

Further the grinding chambers and the apparatus shown are always only provided with one vibrating mass M, and of course produce vibrations at their base corresponding to the mass effect.

The introduction of ground material may be carried out according to its fineness by the way which is best per se, or also by sieving processes known per se or also by wind-sifting or other processes known per se.

The shape of the grinding chamber makes no alteration in the essence of the invention, even if it is not suited to the dimensioning and the most favourable movement of the auxiliary grinding bodies.

A shape which offers a progressively increasing resistance to the grinding bodies has been recognised as a particularly favourable shape of trough in relation to kinetic action upon the material to be ground. The most favourable shape for potential energy is that which tosses the grinding bodies from wall to wall with as little frictional resistance as possible, and in this way strikes the material to be ground as far as possible centrally as is shown in Fig. 8.

What I claim is:

1. Apparatus for the comminution of granular and pulverulent dry substances or pastes and the like materials, comprising a structure providing a grinding chamber, elastic means for mounting the structure and permitting the grinding chamber to assume a vibratory oscillating movement and effective for storing up energy in said elastic means and opposing elastic reaction forces at a non-linear rate to restrict the said movement, grinding bodies in the grinding chamber in contact with the material therein, and means for applying force upon the structure to oscillate the same and including elastic devices located in the driving system for storing the energy supplied by said force so that the energy delivered to the structure progressively increases, at a non-linear rate, to a maximum at a mean point of the stroke, said structure and its elastic supporting and force-applying means being constructed and arranged to cause the contents of the grinding chamber to be subjected to forces which progressively increase and decrease at a non-linear rate whereby the grinding bodies effect a comminuting action on the material to be ground essentially by kinetic energy in the mean position of the grinding chamber and essentially by potential energy, impact, or shock at the end positions thereof.

2. Apparatus for the comminution of granular and pulverulent dry substances or pastes and the like materials, comprising a hollow structure providing a grinding chamber, said structure being mounted and supported by an arm and a pivot associated therewith, the arm and pivot having interengaging portions which are of oblong cross-section in the plane of oscillating movement of the grinding chamber, a member of elastic material being located between said

portions of the arm and pivot for elastically absorbing energy during relative movement of the same, grinding bodies in the grinding chamber in contact with the material therein, and means for applying force to the structure for moving it to and fro, said force applying means including a rockable driving arm having an oblong opening for receiving an oblong pin included in the driving connection and an elastic member positioned in said opening and around said pin and being effective for delivering energy to the structure at a non-linear rate.

3. Apparatus for the comminution of granular and pulverulent dry substances or pastes and the like materials, comprising a hollow structure providing a grinding chamber, supporting means for said structure including an oblong pin and a wall of oblong cross-section surrounding said pin and elastic material filling the space between said pin and wall and being secured thereto, a mass located within the grinding chamber and supporting means for the mass comprising a second oblong pin and a second wall of oblong cross-section surrounding said pin and also including elastic material filling the space between said second wall and said second pin and being secured thereto, and mean for applying force to said structure for moving the same to and fro about a fulcrum established by said first pin and first wall.

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