March 3, 1953 E. W. SMITH 2,630,274

COMMINUTING MACHINE WITH OPPOSED AND AXIALLY OSCILLATED ROTORS

Filed March 26, 1949 2 SHEETS--SHEET 1

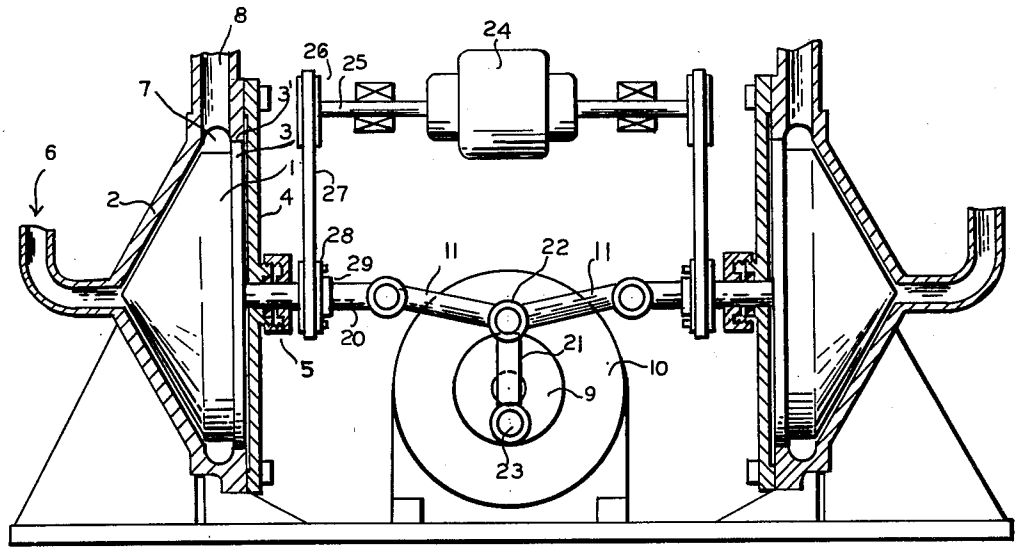


FIG. 1

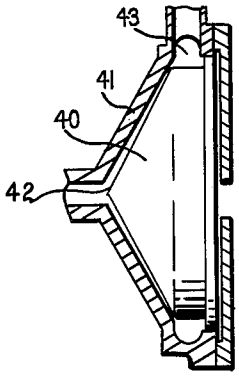


FIG. 5

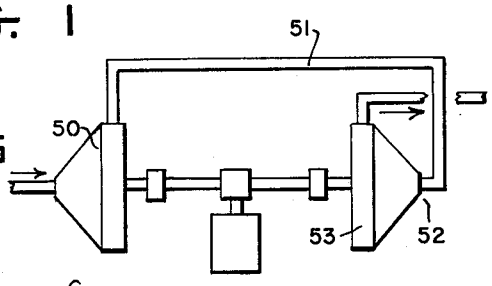


FIG. 6

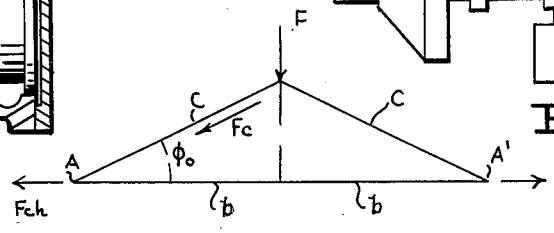


FIG. 2

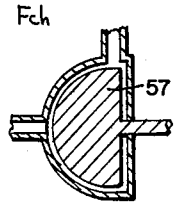


FIG. 8

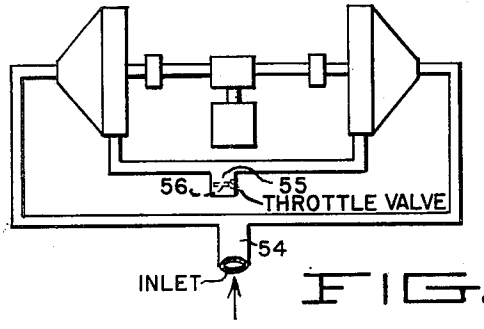


FIG. 7

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2 SHEETS—SHEET 2

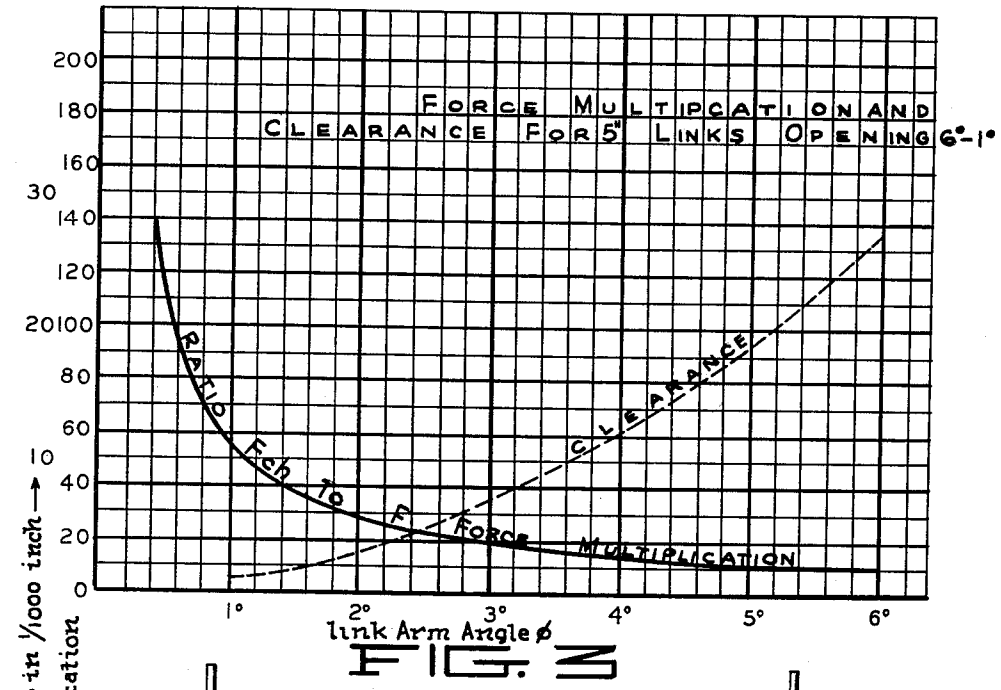


FIG. 3

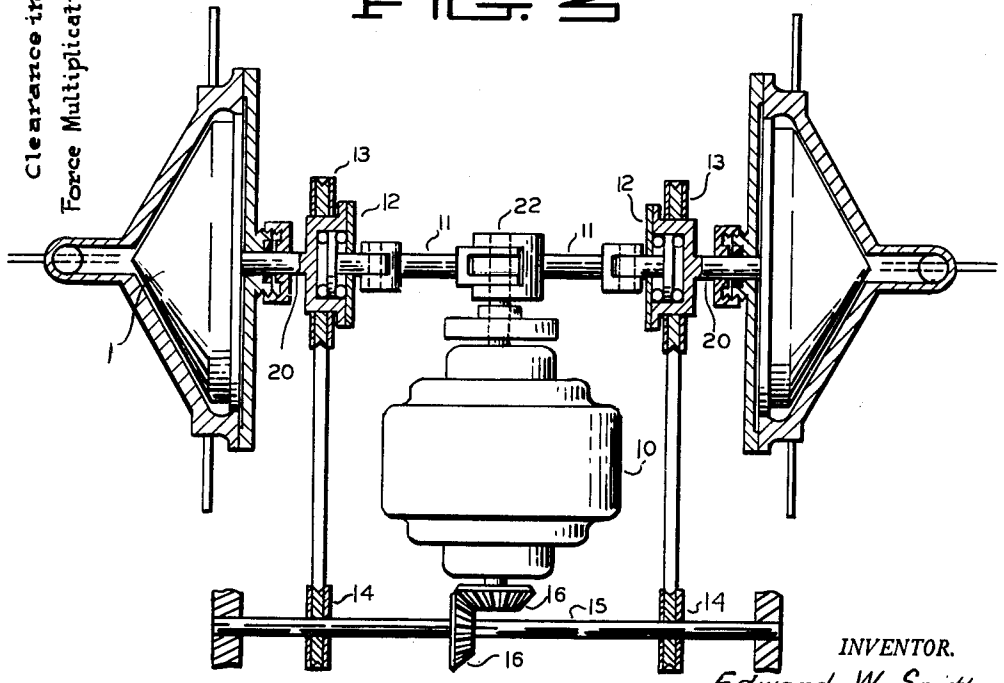


FIG. 4

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Patented Mar. 3, 1953 2,630,274

UNITED STATES PATENT OFFICE

2,630,274

COMMINUTING MACHINE WITH OPPOSED AND AXIALLY OSCILLATED ROTORS

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Application March 26, 1949, Serial No. 83,748

3 Claims. (Cl. 241—46)

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The present invention relates to an improvement in comminuting machines and more particularly to a machine for bringing about an intimate blending of a solid phase with a liquid phase. For example, in the grinding of paint pigment agglomerates are difficult to wet with the liquid. Furthermore, in order to obtain the maximum utilization of the pigment covering power, it is necessary that the individual particles be seduced to as fine a state of subdivision as possible.

This reduction of the particle size in the vehicle is normally accomplisned in various ways. Thus, for instance, the pigment and vehicle may be introduced into a ball mill and the required dispersion obtained by the constant mixing of the material, and the impact of the balls upon earh other and upon the sides of the mill as the mill is rotated. This procedure suffices for comparatively liquid mixtures of pigment and vehicle but is less suitable for high solids compositions because the mixture becomes so viscous that the full benefit of the impact of the balls is not obtained.

In the case of viscous mixtures, breaking down of agglomerates may be more effectively obtained by passing the material between two or more closely spaced rollers rotating at different speeds. By so doing a shearing action is applied to the mixture which eventually results in a more homogeneous product. It will be clear however that this latter method has certain drawbacks in that it is essentially a slow process for several reasons. For instance, the rolls cannot be rotated at a very high speed because in so doing the film of pigment and vehicle carried around on the roll surface tends to fly off due to centrifugal force. Consequently, in attempting to obtain the necessary shearing force difficulty is encountered because the range of speeds below which the rolls must be rotated to avoid the centrifugal force difficulties is relatively small.

In the present invention, a new method of comminuting is provided in which the particles are directly crushed by repeated blows at the same time that mixing by rotary agitation thoroughly disperses the finely divided particles in the liquid. In the present case, centrifugal action tends to aid the operation by providing a substantial velocity component parallel to the surface of the cone which tends to reduce the pressure required to force a given volume through the small clearance space between the wall and the cone. Centrifugal action as used in the present invention also aids in such action on the

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larger particles that they are discriminatorily positioned for better and more efficient crushing than the smaller particles with the result that a thorough and homogeneous mixture of fine particles is efficiently obtained.

Other and further advantages of the present invention will be more readily understood from the description of an embodiment as set forth in the specifications below when read in connection with the drawings in which:

Figure 1 shows a partial sectional elevation of one form of the invention.

Figure 2 shows a vector diagram of the forces as applied in a system as shown in Figure 1.

Figure 3 shows curves of force multiplication factor plotted against link arm angles.

Figure 4 shows a part sectional view of a modification of Figure 1, Figure 5 shows a modification of a detail of Figure 1. Figures 6, 7 and 8 show schematically detail modifications relating to the invention.

In one convenient embodiment of my invention, a cone-faced rotor 1 is adapted to rotate within a similar cone-shaped stator 2. The opposite end of the rotor may have a short cylindrical section 3 which matches a similar section 3 in the stator 2 and serves as a bearing for the rotor 1 permitting it to rotate and reciprocate along its axis. A cover 4 is provided which may conveniently be bolted to the stator and includes a packing gland 5 through which the rotor shaft 20 passes providing a seal against the leakage of the material being treated.

While there are many ways in which the combined rotating and reciprocating motion may be applied to the rotor, one convenient method is by the use of an eccentric 9 secured on the shaft of a motor 10. As the motor rotates the angle between the pair of link arms 11 and the axis of the rotor passes from a maximum in one direction, through zero, and to a maximum in the other. The link arms 11 are simultaneously operated by the crank 21 through a common pivoting connection 22. The crank arm 21 is pivoted to the plate 9 eccentrically at 23.

The shafts 20 will as a result of this link motion have a reciprocating motion longitudinal with the shafts, simultaneously outwards at both ends and then inwards in a balanced synchronism of motion and forces. A separate motor 24 having a drive shaft 25 and pulley 26 may drive by belt 27 the pulley 28 fixed to the shaft 29. A thrust bearing 29 on the shaft 20 permits the shaft 20 to be rotated while transmitting the reciprocating motion mentioned above.

In operation the material to be treated may be introduced at opening 6 at the apex of the conical space in the stator 2 and passes between the rotating rotor element 1 and the stator. The clearance between the two is variable, as will presently appear, with a maximum value sufficient to accommodate the largest particles likely to be present in the material being treated. In general, however, a maximum clearance of the order of $\frac{1}{32}$–$\frac{1}{16}$ of an inch will be found sufficient.

Mention has already been made of the fact that the element 1 is rotated within the stator 2. As the material passes between them, it is subjected to an intense shearing force because of the high relative speeds which can readily be obtained between the rotor and stator surfaces. In addition, as any particular particle moves outward toward the periphery, in addition to being subjected to increasing shearing stresses it is also given a high value of centrifugal force which tends to throw it off from the rotor if it should be clinging to it. As soon as this happens it impinges on the stator surface which tends to shatter agglomerates which may be present.

As an example of the magnitude of this force, with a cone-shaped rotor only 10 inches in maximum diameter, rotated at 1800 R. P. M. the maximum acceleration given to an individual particle will be substantially 500 times the acceleration of gravity and the average will be approximately 250 times the acceleration of gravity.

In examining such a system it will be apparent that the maximum shearing force effects will be attained with close clearances between the rotor and stator. On the other hand, close clearances tend to cause difficulties because the capacity is reduced on account of the small cross-sectional area through which the material being treated must travel. Furthermore, if the material being treated contains hard or gritty particles or other difficultly rupturable material, the combined forces just discussed may be insufficient to reduce them to the desired size.

In the present invention, these two types of difficulty are overcome in a novel manner. Mention has previously been made of the fact that the bearing of the rotor is adapted to permit reciprocation as well as rotation. This reciprocation of the rotor along its axis results in the clearance between the stator and rotor being periodically increased and reduced so that while the clearance is periodically reduced to a very low value, the average clearance is sufficient to allow a respectable rate of flow. Not only does this alternating clearance permit of high shearing forces without materially reducing the rate of flow, but it also provides an impact force of large value to shatter or crush particles which are present and which may be resistant to the shearing and centrifugal forces available.

The method by which extremely large forces are attained may best be understood by consideration of Figure 2. Let us assume a linkage system such as is shown therein having arms C, C of equal length and having a force exerted as shown. The horizontal component of the forces exerted along each link may be determined as follows:

Let $b=c \cos \phi_0$ and $\phi_0=\phi$ maximum where ϕ is the angle between the link c and the horizontal and b is the horizontal projection of the link at its greatest inclination.

Let ϕ start at ϕ_0 and decrease to zero.

Then the stroke or overall movement of points A and A' will be the total amount they move outward from the starting point.

Under the above conditions the horizontal stroke of the shaft 20 will be:

$$\text{stroke}=c \cos \phi - b$$

or

$$\text{stroke}=c \cos \phi - c \cos \phi_0$$

(1) maximum stroke$=c(1-\cos \phi_0)$ when $\phi=0$

Also if we assume a force F acting as shown, then the force acting at A and A' can be determined as follows:

The component of F acting along link c will be

$$Fc=\frac{F}{2}\left(\frac{1}{\sin \phi}\right) \tag{2}$$

and the horizontal component of F will be

$$Fch=Fc\ (\cos \phi)$$

Therefore:

$$Fch=Fc\ (\cos \phi)=\frac{F}{2}\left(\frac{1}{\sin \phi}\right) \cos \phi$$

$$=\frac{F}{2}\frac{\cos \phi}{\sin \phi}=\frac{F}{2} \cot \phi$$

$$Fch=\frac{F}{2 \tan \phi} \tag{3}$$

It will be apparent that forces of equal magnitude will be exerted at A and A' and, since tan ϕ is zero when ϕ is zero, the force exerted along the horizontal becomes infinite.

From the above it will also be clear that the balanced system shown in Figure 1 has for its purpose the provision of an arrangement whereby the locus of the point at which the force is applied to the combination may be a straight line in the vertical direction and also makes efficient use of the reaction force for if the balanced system were not used provision would have to be made for a solid member against which one end of the linkage system could press in order to apply force axially to the revolving rotor.

Insofar as the practical design of the equipment is concerned, it is desirable to have a relatively large number of impacts or closures per second of the gap between the rotor and stator and consequently the rotor should reciprocate at a fairly rapid rate, as for instance, 20 per second or more. Consequently at the ends of the stroke fairly substantial forces must be applied to the rotor to overcome and reverse the axial oscillation of it. This presents no problem at the end of the stroke where the rotor is closest to the stator but it does at the other end of the stroke where the angle made between the link arms and the axis of the rotor is at a maximum.

Since for most applications to which the present equipment is suited do not require great maximum clearance between the rotor and stator, the graph in Figure 3 has been computed to show the relationship between the force multiplication factor plotted as ordinate and the angle between the link arms and the rotor axis plotted as abscissae for a condition where the center to center lengths of the links are 5 inches. It will be noted from this graph that for an angle 5–6 degrees the force multiplication factor is approximately 10:1, i. e. the axial component of the force exerted along the shaft 20 of the system is 10 times the force exerted in the crank arm 21. Thus by designing the system in such a way that the maximum link-rotor axis angle ϕ does not materially exceed 6 degrees, the minimum

ratio of 10:1 according to Equations 1 and 3 can be maintained under all conditions. It will also be noted that at this angle the clearance can be approximately .024 inch assuming the included angle of the cone of the rotor is 120 degrees and the stroke at 6° for ϕ would be .0275 inch as computed by Equation 1 above.

For smooth operation and to avoid large peak loads on the motor the 10:1 ratio mentioned above is convenient although it can be made less if smoothness of operation can be sacrificed or a larger motor used.

Referring again to Figure 1, as has been stated, the material to be treated is brought into the equipment at the entrance opening 6 from whence it flows outward between the rotating and reciprocating rotor, and the stator. In so doing it is subjected to the shearing, impact, and centrifugal forces already mentioned and then passes into the annular groove 7 and passes out of the machine at the outlet opening 8.

In Figure 4 is shown a plan view in schematic form of a convenient means whereby both the reciprocating motion and rotatory motion may be obtained from the same motor. Thrust bearings 12 are interposed between the link system and the rotor shaft to permit of the rotor shaft being rotated without interference to the reciprocating link system already described. Pulleys 13 are belted to another pair of pulleys 14 mounted on a shaft 15 driven by a pair of gears 16, one of which is secured to the shaft of the motor 10. By proper choice of the motor speed and pulley ratios any desired relationship between the reciprocating frequency and rotational speed may be obtained.

The minimum clearance between the rotor and stator will depend to a great extent upon the material being treated and the degree of dispersion required. For very fine dispersions the minimum clearance may be made very small, while the maximum is made sufficient to accommodate the largest particle likely to be present in the material being furnished to the machine as has been stated previously.

With the tandem arrangement as shown a very flexible system is made available. For instance, for very fine dispersions the material may be introduced into one unit 50, as shown in Figure 6 and, after treatment, pass out of the outlet 51 into the inlet opening 52 of the second unit 53 for further treatment, or the two units may be fed simultaneously as shown in Figure 6 from the same source 54 and simultaneously discharge to a common exit 55. Other methods of giving a prolonged treatment in each unit will readily occur to the user as, for instance, by the use of a throttle valve 56 in the outlet line of the unit.

A circulatory system may be established in which the material may be fed from each unit to the other. In such a case, a circulatory motor may be employed but since each rotor provides considerable centrifugal force, this force may be used to force the material from one unit to the other. In this manner, material may be treated in batches, that is for a desired time and then removed after which a new batch may be introduced into the system.

In the detail shown in Figure 5, the contour of the conical member 40 may be slightly curved perhaps in a slight exponential form as shown at 57 in Figure 8 and the cavity or chamber with a corresponding contour 41 so that at the intake end 42 the space between the wall 41 of the chamber and that of the oscillating cone is wider than in the region toward the outlet passage 43. Or if desired, the walls may be straight as shown in Figure 1 but diverging slightly toward the apex of the cone so that the width of the passage near the apex is wider than at the base. By the use of an arrangement of this shape, the larger particles at their entrance are more directly treated and therefore crush to such a size so that at the exit passage the particles will be finally divided and treated between the two exit surfaces which are closer together than at the entrance end. In addition to this, if particles of uniform size are taken into the chamber, the crushing force of the cone will act only near the entrance end and therefore the force will be spread over a much smaller area than if particles of the same size extended over the whole surface of the cone.

Having now described my invention, I claim:

1. A system for comminuting materials in liquids comprising a pair of spaced housings having aligned axes of symmetry providing chambers having conical walls with vertices pointing in axial alignment in opposite directions and having inlet and outlet passages, a pair of similar axially aligned conical pistons positioned within each of said housings having substantially the same solid angle as said walls and having surfaces spaced close to and opposed to the wall of the chambers, means for moving said pistons in reciprocating axial motion simultaneously against said walls to exert repeated impacts between the walls with balanced opposing forces, and means for simultaneously rotating said pistons within the chambers, said pistons being spaced in relation to the walls of the chambers to provide shearing and centrifugal forces against the material and liquid in the chamber.

2. A system for comminuting solid materials in liquids, comprising a pair of spaced housings having aligned axes of symmetry providing chambers having conical walls with vertices pointing in axial alignment in opposite directions and having inlet and outlet passages, a pair of similarly aligned conical pistons positioned within each of said housings having substantially the same solid angle as said walls and having surfaces spaced close to and opposed to the wall of the chambers, and means for moving said pistons in reciprocating axial motion simultaneously against said walls to exert repeated impacts between the walls with balanced opposing forces, and means for moving said pistons including a pair of piston rods, one attached to each piston in axial alignment, a bearing for each piston rod in each of said housings, a pair of pivoted links having their ends connected to the said piston rods and means for moving said pivot in the direction of the bisector of the angle made by the links whereby said pivoted links oscillate through a small angle.

3. A system for comminuting solid materials in liquids, comprising a pair of spaced housings having aligned axes of symmetry providing chambers having conical walls with vertices pointing in axial alignment in opposite directions and having inlet and outlet passages, a pair of similarly aligned conical pistons positioned within each of said housings having substantially the same solid angle as said walls and having surfaces spaced close to and opposed to the wall of the chambers, and means for moving said pistons in reciprocating axial motion simultaneously against said walls to exert repeated impacts between the walls with balanced opposing forces, and means

for moving said pistons including a pair of piston rods, one attached to each piston in axial alignment, a bearing for each piston rod in each of said housings, a pair of pivoted links having their ends connected to the said piston rods and means for moving said pivot in the direction of the bisector of the angle made by the links whereby said pivoted links oscillate through a small angle, means providing a thrust bearing on said piston rods outside of said housing whereby said piston rods comprise two aligned parts, one of which may rotate with respect to the other, and pulley means operatively positioned on the rotatable part of said piston rods each for rotating the pistons simultaneously with the means for reciprocating the same.

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