APPARATUS FOR PULVERIZING VULCANIZED RUBBER AND RUBBER PRODUCTS

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ABSTRACT
An apparatus for pulverizing vulcanized rubber and rubber products includes an ovoid rotor housed within a casing whereupon during rotation of the rotor, and/or the casing, the rubber material is subjected to various cutting and shearing forces. Additional means may be provided for periodically altering the clearance between the rotor and casing whereby the grinding effects can be enhanced, and still further means may be utilized to alter the clearance in a different manner whereby in addition to being subjected to cutting and shearing forces the material also undergoes a crushing operation.

2 Claims, 20 Drawing Figures
APPARATUS FOR PULVERIZING Vulcanized RUBBER AND RUBBER PRODUCTS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a pulverizing apparatus and more particularly to an apparatus for pulverizing vulcanized rubber and rubber products.

2. Description of the Prior Art

Vulcanized rubber and rubber products have heretofore been pulverized or ground by means of a grinder of the impact type, a reciprocating shearing machine or a cracking roll. Since articles of this kind are characterized by a high degree of elasticity and often comprise fibers or other reinforcing means incorporated therein, even when they are subjected to the action of a grinder of the impact type, the grinding efficiency is very low whereby the articles are merely torn into strips and the like which are quite irregular in size.

In the instance of a reciprocating shearing machine, the articles are uniformly cut into small pieces, but the grinding efficiency is also extremely low, and even with the use of such a shearing machine of this type, it is relatively impossible to pulverize these articles into particles or granules. Accordingly, the pieces withdrawn from the shearing machine must be subjected to a post-shearing treatment by means of a grinding roll. Furthermore, in the instance of a cracking roll, it is also necessary to effect such post-grinding treatment with use of a grinding roll, and thus, the conventional techniques have serious production drawbacks.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved pulverizing apparatus.

Another object of the present invention is to provide an improved pulverizing apparatus which does not experience the drawbacks of conventional apparatus.

Still another object of the present invention is to provide an improved pulverizing apparatus which can be utilized to easily pulverize vulcanized rubber and rubber products.

Yet another object of the present invention is to provide an improved pulverizing apparatus which can be utilized to pulverize vulcanized rubber and rubber products while expending less power than normally required utilizing conventional techniques.

It is a further object of the present invention to provide an improved pulverizing apparatus exhibiting a substantially high degree of efficiency.

A yet further object of the present invention is to provide an improved pulverizing apparatus which can effectively pulverize vulcanized rubber and rubber products into particles of uniform size.

A still further object of the present invention is to provide an improved pulverizing apparatus which can effectively pulverize vulcanized rubber and rubber products into particles having any one of a plurality of predetermined sizes.

A yet still further object of the present invention is to provide an improved pulverizing apparatus wherein the material to be pulverized is subjected to variable frictional cutting, shearing, and crushing forces.

As a result of our research work conducted with the view toward providing a novel apparatus for pulverizing vulcanized rubber and rubber products, especially used rubber tires and rubber belts, amounts of which have been currently increasing greatly, which can overcome the foregoing defects of conventional techniques and which can pulverize these vulcanized rubber articles assuredly with high degree of efficiency, in accordance with this invention, there is provided an apparatus for pulverizing vulcanized rubber and rubber products, which packs a vulcanized rubber or rubber product between a rotor having an egg-shaped cross-section and a casing surrounding the rotor, and rotates the rotor relative to the casing to thereby impose upon the rubber material frictional forces due to frictional forces between the rubber material and the rotor and between the rubber material and the casing as well as shearing forces within the interior of the rubber material.

In a preferred embodiment of this invention for accomplishing the pulverization more effectively, a vulcanized rubber or rubber product may be packed between a rotor having an egg-shaped cross-section and a casing surrounding this rotor, and the rubber material is subjected to frictional forces due to such forces between the rubber material and the rotor and between the rubber material and the casing and also to shearing forces within the interior of the rubber material, by rotating the rotor relative to the casing and simultaneously changing the clearance formed between the outer periphery of the rotor and the inner wall of the casing.

According to this invention, pre-treatment required prior to the pulverization is extremely simple, and pulverization can be accomplished at a high rate of efficiency and the handling of the pulverized products is quite easy. More specifically, even a rubber material of a large dimension can be pulverized conveniently, and if the metal wires constituting the bead portions of tires have been removed in advance, reinforcing means, such as fibers, do in fact separate from the vulcanized rubber articles when they are pulverized into fine particles and these reinforcing means retain their fibrous form so as to be easily separable from the other pulverized products by means of a sieving screen or the like, whereupon the pulverized rubber products may be applied to a predetermined use while the fibrous products are easily disposed of by combustion or the like.

An apparatus for practicing this invention effectually comprises a rotor having an egg-shaped cross-section, a casing surrounding the rotor, a drive mechanism for rotating the rotor relative to the casing, and a clearance-changing mechanism adapted to change the clearance formed between the outer periphery of the rotor and the inner wall of the casing as the rotor rotates.

The clearance-changing mechanism is effective for imposing upon the packed vulcanized rubber or rubber product frictional forces due to such forces between the rubber material and the rotor and between the rubber material and the casing, and also shearing forces within the interior of the rubber material. Furthermore, this mechanism is effective for reducing the power required for pulverization.

As an effective clearance-changing mechanism, the casing may have an inner wall of non-circular cross-section, such as for example, convex and concave portions upon the surface of the inner wall, or a casing having an inner wall of circular cross-section, the center of which differs from the rotational axis of the rotor. As a more effective clearance-changing mechanism, there may also be employed a casing having a conical inner wall wherein the casing is capable of axial reciprocable
movement, or a casing having side wall sections which are capable of radial expansion and contraction. By providing such mechanism, cutting, shearing and crushing forces can be imposed upon the packed vulcanized rubber or rubber product regardless of the configuration and size thereof, and hence, effective pulverization can be attained.

In order to effectively impose such forces upon a packed rubber material such as Vulcanized rubbers and rubber products, it is also possible to utilize a drive mechanism for rotating both the rotor and the casing, or a mechanism for rotating the casing in a direction opposite to the direction of rotation of the rotor. By provision of such mechanisms, it is possible to prevent a non-uniform distribution of the packed rubber material within the casing caused by any deviation in weight of the particles, and therefore, pulverization can be accomplished uniformly throughout the entire extent of the rotor.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features, and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings, in which like reference characters designate like or corresponding parts throughout the several views, and wherein:

FIG. 1 is a cross-section view of a pulverizing apparatus constructed according to this invention and showing its cooperative components;

FIG. 2 is a side elevation view, partly in section, of the apparatus shown in FIG. 1;

FIG. 3 is a cross-section view of another embodiment of a pulverizing apparatus constructed according to this invention and showing its cooperative components;

FIG. 4 is a cross-section view of still another embodiment of a pulverizing apparatus constructed according to this invention and showing its cooperative parts, wherein the rotor casing is axially reciprocable;

FIGS. 5, 6 and 7 are cross-section views taken along the lines II—II, III—III and IV—IV of FIG. 4;

FIG. 8 is a view similar to that of FIG. 4 illustrating still another embodiment of the present invention wherein wall sections within the rotor casing are radially expansible and contractible;

FIGS. 9, 10 and 11 are cross-section views taken along the lines V—V, VI—VI and VII—VII of FIG. 8;

FIG. 12 is a cross-section view illustrating a casing of the present apparatus which includes a clearance-changing mechanism;

FIGS. 13 and 14 are views similar to that of FIG. 12 illustrating other embodiments of rotor and casing clearance-changing mechanisms;

FIG. 15 is a cross-section view of a further embodiment of the present invention in which a drive mechanism rotates the rotor casing in a direction opposite to the direction of rotation of the rotor;

FIG. 16 is a view similar to that of FIG. 15 wherein the rotor and rotor casing are eccentrically located relative to one another; and

FIGS. 17-20 are cross-section views of the apparatus shown in FIG. 16 illustrating the relative positions of the rotor and rotor casing at one-fourth revolution intervals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and more particularly to FIGS. 1 and 2 thereof, substantially oval or egg-shaped rotor 1 is rotatably supported within the end walls 3 of a substantially circular casing 2 through means of a bearing 4 whereby a clearance d exists between the rotor and casing due to the fact that the journal portion 5 of rotor 1 is eccentrically supported relative to the casing 2, the distance between the axes of rotor 1 and casing 2 being denoted h. The casing 2 is composed of substantially half sections bonded together, one sectional member 2' being supported upon a base 6 by means of legs 7 and including a vertically extending chute or hopper 8 for the deposition of material to be pulverized. The other sectional member 2'' is hinged to the first sectional member 2' and is so constructed that it can be opened by means of piston and cylinder devices 9 also supported upon base 6. A ram 10 is reciprocably mounted within the chute 8 so as to press a material M to be pulverized into the casing 2, whereby the pulverized product may be withdrawn from another chute 11 disposed below casing 2.

Referring now to FIG. 3 another embodiment of the present invention is disclosed in which two oval rotors 22 are employed, the substantially circular rotor casings 21 being connected together at a plane located equidistantly from each of the rotor axes. A material M to be pulverized is introduced through a vertically extending chute or hopper 8 centrally disposed atop the casings 21 under the influence of a press ram 10 movable within chute 8 and the pulverized product is withdrawn from a lid member 23 which is disposed within a lower central portion of the casings, and which is rotatable in the direction indicated by the arrow about a fulcrum shaft 24. Rotors 22 are angularly positioned within the casings 21 such that a phase difference of 90° exists therebetween, the journal portions of the rotors being supported within the end walls of the casings in a manner similar to that of FIG. 1, and they are rotated in opposite directions through means of a synchronizing device, not shown, such as for example, appropriate gearing, the chain lines 26 generally indicating the locus attained by the rotors relative to the casings as the rotors are rotated. In the instance that fine holes 27 are employed within the lid member 23, such holes render lid 23 a sieve whereby the pulverization process can be conducted in a continuous manner.

During the course of research, one experiment involved the utilization of apparatus such as that shown in FIG. 3 whereby rubber tires were pulverized. The distance d between the rotors 22 and the casings 21 was adjusted to 2.4 mm, the diametrical dimension H of the rotor 22 was 204 mm, and the rotational speed of the rotors 22 was 62 rpm. A rubber tire M was initially subjected to a pre-pulverization treatment whereby the conventional metal wires were removed from the bead portions and the tire was subsequently cut into blocks having a volume of approximately 3000 cm³, such as for example, 20 cm in length, 20 cm in width, and 7 cm in thickness. Approximately 100 kg of such blocks were then pressed into the casings 21 by means of a ram 10, and within 60 seconds, the blocks were finely pulverized to particles having an average size of 60 mesh. When the pulverization was continued for a duration of 120 seconds, the resulting particles had a size
of approximately 100 mesh with no substantial deviation or irregularity in particle size. Fibers utilized as re-inforcers were also obtained in strips having an average length of 50 mm and were easily separable from the pulverized rubber product by means of a sieving screen or the like.

As is seen from the foregoing, according to this invention, a vulcanized rubber article, pulverization of which has heretofore been very difficult or relatively and economically impossible according to conventional techniques, can easily be pulverized into fine particles at a high rate of efficiency. In view of the expected increase in use of articles of vulcanized rubber, this invention can be said to make great contributions to the art.

In order to be able to vary or adjust the size of the pulverized product particles as desired, the relative clearance between the rotors and the casings must be alterable, and consequently, a clearance-changing mechanism may be employed which comprises a casing having a conical inner wall portion and a rotor disposed within the casing whereby further means are employed to axially reciprocate the casing relative to the rotor, the clearance between the rotor and the conical wall portion thereby being adjusted as desired.

As is illustrated in FIGS. 4-7, a rotor shaft 201 provided with a feed screw portion 202 and a grinding rotor blade portion 203 is disposed within a longitudinal, horizontally disposed casing 204 having a vertically extending material inlet 205 at one end and a radially extending outlet 206 at the other end. A base 207 supports a driving gear 208 which is actuated by means of a motor, not shown, so as to in turn drive the rotor shaft 201 through several reduction gears. In this manner, material entering inlet 205 is continuously fed by means of screw 202 from the screw chamber 211 into a grinding chamber 212 having the egg-shaped grinding rotor blade 203 disposed therein, both ends of the rotor shaft 201 being rotatably supported upon bearing stands 209 and 209' via bearings 210 and 210'. The thrust load generated at the feed screw portion 202 is released by means of a thrust pad or bearing 210.

The inner wall of the grinding chamber 212, as well as the rotor blade 203 is formed so as to have a tapered configuration so that the chip clearance 1, between the chamber and blade at the inlet portion is greater than the chip clearance 2 between the chamber and blade at the outlet portion. A radial protrusion 213 is provided upon the exterior portion of the casing 204 so as to be interengaged with one end of a piston rod of a hydraulic piston and cylinder device 214 mounted upon base 207 whereby the casing 204 may be reciprocally moved in the horizontal direction by appropriate operation of device 214 so as to thereby adjust the chip clearance within the grinding chamber in order to satisfy the requirement of L1 > L2. A safety valve 215 may be mounted within the hydraulic circuit associated with the hydraulic device 214 so as to compensate for any overload brought about by the incorporation of different matter or the like.

In this manner then when material to be ground, such as for example, vulcanized rubber or rubber product, is charged from the inlet 205 and the rotor shaft 201 is rotated, the material is continuously fed from the screw chamber 211 to the grinding chamber wherein it is cut into particles of a size corresponding to the chip clearance between the grinding rotor blade 203 and the inner wall of the grinding chamber 212 while undergoing cutting and shearing forces within the grinding chamber 212, whereupon the ground material is ultimately withdrawn from the outlet 206. Since the chip clearance L1 at the inlet portion is greater than the chip clearance L2 at the outlet portion, the material is coarsely ground within the inlet portion of the grinding chamber 212 whereby the resulting particles are of a relatively large size corresponding to the chip clearance L1 at the initial stage, and as the material moves toward the outlet end of the casing, it is gradually ground to a size which corresponds to the chip clearance L2. Thus, at the final stage the material is ground into particles having a diameter corresponding to the chip clearance L2 adjacent to the outlet portion 206 of the grinding chamber 212 whereby the same may be recovered from the outlet 206 in the form of a finely divided product having a predetermined size.

It may thus be appreciated that if the position of the casing 204 is moved in the horizontal direction toward the right or left by means of the hydraulic cylinder 214, the chip clearances are changed and the particle size of the ground product can consequently be adjusted as may be desired. Accordingly, it is possible to obtain a ground product having a desired particle size. It will be further appreciated that as the chip clearance at the inlet portion is greater than the chip clearance at the outlet portion, the load imposed upon the rotor shaft at the initial stage of grinding can be diminished due to the fact that the material is not ground to a desired size within one step of the process, but on the contrary, such is gradually and successively ground to a smaller size along the entire length of the rotor blade. Therefore, the grinding operation can be conducted uniformly throughout the entire apparatus and the grinding efficiency increased while the occurrence of local abrasion or heat generation prevented, the result being that a rubber material can be ground to a prescribed size smoothly and easily at a relatively low expense of power with a substantial decrease in the possibility of encountering mechanical disorders in the apparatus.

In addition, the limitation upon the amount or size of the charged rubber material is effectively obviated for even when material of a relatively large size is charged into the apparatus, it can be gradually ground to a smaller size due to the gradual decrease in the chip clearance and finally to a finely divided product of a prescribed size with the sole use of the apparatus of the present invention. In accordance with this invention, there is thus provided a grinding apparatus especially suitable for grinding a highly elastic vulcanized rubber or vulcanized rubber product, the grinding operation being effectively independent of the size of the charged material.

While the clearance-changing mechanism disclosed in FIGS. 4-7 included an axially reciprocable casing, the clearance-changing mechanism may also comprise a casing having side walls capable of movement in the radial direction as shown in FIGS. 8-11. The apparatus of this embodiment includes a base 301, a substantially cylindrical horizontally disposed rotor casing 304 provided with a vertically extending inlet 302 at one end for feeding rubber material into the casing and a vertical, radially extending outlet 303 at the other end for discharging a ground product and a rotor shaft 307 lon-
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3,889,889 7 gitudinally disposed within casing 304 having a feed screw portion 305 adjacent the casing inlet and an ovoid grinding rotor portion 306 adjacent the outlet, a driving motor, not shown, and reduction gearing 308 being additionally provided to impart rotary motion to the shaft. The motor and gearing 308 are mounted upon the base 301 and serve to rotate another shaft 311 through means of an intermediate gear 309 and a small gear 310 associated with shaft 311. As will be apparent hereinafter, the apparatus is so constructed that the grinding chamber 317 in which grinding rotor 306 is disposed may be radially enlarged and contracted by means of the rotation of rotary shaft 311. Casing 304 of course also comprises a feed screw chamber 316 which houses the feed screw portion 305 and the casing 304 is appropriately supported upon base 301. The ends of the rotor shaft 307 are rotatably mounted within bearings 314 and 314', and 315 and 315', respectively provided within a bearing and a gear box 313, the latter serving to also house the gearing 308, a thrust load generated at the feed screw portion 305 being compensated for by means of the thrust bearing 315.

Referring now to FIGS. 9-11, the particular construction of the grinding chamber 317 is illustrated, the interior portion of the casing 304 corresponding to the grinding chamber 317 being so formed as to have a square cross-section while a plurality of pivotable wall sections are disposed within the square casing section. The pivotable wall sections are serially arranged in three groups, each group having four wall sections, such as, for example, 318a-318d, 319a-319d, and 320a-320d. The exterior portions of each wall section conforms to the respective square interior portion of the casing 304 while the interior portions of the wall sections are arch-shaped whereby chopped clearances L1, L2, and L3 are respectively formed between the outer periphery of the grinding rotor blade 306 and the arch-like inner faces 321a-321d, 322a-322d, and 323a-323d. Each of the side wall sections are respectively interlocked with pins 324a-324d, 325a-325d, and 326a-326d rotatable supported within casing 304 through means of eccentric shafts 327a-327d, 328a-328d, and 329a-329d which support the pivotable wall sections by means of leads mounted upon the rotor blade. In short, the grinding operation can be accomplished very smoothly if the pivotable wall sections are disposed within the grinding chamber 317 and is gradually ground to a size corresponding to the final predetermined chopped clearance.

It is possible to employ only one side wall sections for accomplishing the aforementioned grinding and crushing operations whereby the entire inner wall defining the grinding chamber may be uniformly expanded and contracted. In the embodiment illustrated in FIGS. 8-11, three groups of side wall sections have been provided for each group of side walls, and the lengths of the links are so set that the chopped clearances L1, between the group of wall sections positioned at the inlet side of the grinding chamber and the rotor blade is greater than the chopped clearances L2 and L3 between the respective groups of wall sections positioned toward the outlet side of the grinding chamber and the rotor blade so as to establish the relation whereby L1 > L2 > L3. By adopting such structure, the rubber material fed into the grinding chamber 317 undergoes crushing, cutting and shearing forces gradually and successively by each group of side walls, and is ground in a stepwise manner while its size is being gradually diminished. Accordingly, it is possible to prevent an extreme load from being imposed directly upon the rotor shaft 307 and the work of grinding is uniformly distributed along the entire longitudinal extent of the grinding rotor blade 306 whereby the grinding operation can be accomplished at a high degree of efficiency.

In conjunction with another preferred embodiment of the present invention within any two adjacent groups of side wall sections the lengths of the links may be predetermined such that the inner diameter of the grinding chamber defined by the side wall sections of the group upon the outlet side when the same are expanded is equal to the inner diameter of the grinding chamber defined by the side wall sections of the group upon the inlet side when the same are contracted, and the eccentric phases of the pins may be so set that the side wall sections of the two adjacent groups move in directions opposite to each other. Hence, during one cycle of expansion and contraction, the side wall sections of the two adjacent groups attain the same diameter and therefore, the rubber material is transported smoothly without stagnation and as it is finely ground, it is gradually forwarded toward the outlet by means of leads mounted upon the rotor blade. In short, the grinding operation can be accomplished very smoothly if the
chipped clearance between the side wall sections of the group nearest to the outlet and the rotor blade is predetermined according to the desired size of the ground particles and the length of the links of each of the other groups of wall sections is determined by adding the radial distance through which each of the wall sections of the group adjoining the group nearest to the outlet moves to the inner diameter of the wall of such adjoining group.

As a result of the above-described structure, the present invention makes it possible to repeat crushing, cutting and shearing operations by utilizing only one apparatus and therefore, according to this invention the grinding can be accomplished very effectively. Furthermore, since the walls of the grinding chamber are periodically expanded and contracted, stagnation of the rubber material between the rotor blade and the walls defining the grinding chamber can be completely prevented, with the result that the occurrence of local abrasion or heat generation is not brought about and no excessive load is imposed upon the rotor shaft. Accordingly, even a vulcanized rubber or rubber product having a high degree of elasticity can be smoothly and easily ground at a high rate of efficiency for a short time in the apparatus of this invention.

Referring now to FIGS. 12-20, there are disclosed several aspects or features of the present invention wherein a clearance-changing mechanism is provided such that the clearance between the outer periphery of the rotor and the inner walls of the casing may be altered one or more times during one rotation of the rotor. In accordance with one aspect of this embodiment there is provided an apparatus for grinding vulcanized rubber, vulcanized rubber products and the like, wherein a movable casing portion encompasses only the grinding rotor blade portion of the rotor shaft so as to define a grinding chamber which is rotatably supported independently of the other fixed casing portion surrounding the feed screw whereby the shaft and the movable casing are rotated in such a relationship that the chipped clearance formed within the grinding chamber is thereby changed and consequently the rubber material is ground while undergoing crushing, cutting and shearing forces between the rotor shaft and the movable casing.

In accordance with another aspect of this embodiment, there is provided a grinding apparatus as set forth above, wherein a suitable number of concave portions are formed upon the inner wall of the movable casing and the movable casing is rotated at a rotational frequency differing from that of the rotor shaft so as to thereby change the chipped clearance formed therebetween. Still further, the movable casing may be eccentrically rotated relative to the rotor shaft whereby the chipped clearance formed therebetween is periodically altered during rotation of the same.

As mentioned heretofore, the grinding apparatus of this invention is characterized in that the chipped clearance may be altered one or more times during one rotation of the rotor shaft. Means such as is shown in FIGS. 12-14 may be considered to be effective for attaining such alteration of the chipped clearance. In the mechanism illustrated in FIG. 12, one or more concave portions 414 may be provided within casing portion 413 which houses grinding rotor blade 411 therein and defines grinding chamber 412 therearound. Simultaneously with the rotation of the rotor blade 411, in a given direction, the casing portion 413 is rotated in an opposite direction, and in addition, may be rotated at a speed different from that of rotor 411.

Thus, the chipped clearance is altered one or more times during one rotation of the rotor blade 411, the different clearances being designated as \( L_1 \) and \( L_2 \) as seen in FIG. 12. Even in the instance that a rubber article becomes elastically deformed so as to have a wedge-like form as when it is caught between the rotor blade 411 and the inner face of the casing 413, such configuration of the material may be immediately and automatically changed due to a change in the chipped clearance whereupon the material may be interposed between the rotor blade and the casing wall at a different relative position whereby it will undergo cutting or shearing forces. As is seen from FIG. 12, upon both sides of the rotor blade 411 the relative configuration of the crescent-shaped grinding chamber 412 is continuously varied during the rotational cycles and the rubber material therefore also undergoes crushing forces caused by such variation in the grinding chamber volume. Furthermore, the rubber material can move freely within the grinding chamber and it is therefore possible to prevent the occurrence of the undesired phenomenon that the rubber material experiences frictional contact with the wall of the grinding chamber for an extended period of time whereby the material will remain stationary within the chipped clearance and the grinding chamber, and thus, the grinding can be accomplished at a high rate of efficiency.

The above-mentioned effects can be further increased when the concave portion 414 formed upon the inner face of the casing 413 are such as to have a configuration such as is shown at 414' in FIG. 13. More specifically, a shoulder portion 415 is formed adjacent to the concave portion 414' in such a manner that the shoulder 415 cooperates with the rotor blade 411 whereby the rubber material is subjected to a positive cutting action when caught between the head of the rotor blade 411 and the shoulder portion 415, and in addition it also undergoes a rolling force. Thus, the movement of the material is enhanced while the grinding efficiency is further improved.

As is apparent from the apparatus illustrated in FIG. 14, the rotational axis \( O \) of the rotor blade 411 is eccentrically located relative to the rotation axis \( O_2 \) of the casing 413 by a distance \( \alpha \) and consequently as rotational motion is imparted to the apparatus, the chipped clearance between the rotor blade and casing will be periodically changed and it is possible to attain an effect quite similar to those effects attained by utilizing the foregoing apparatus.

As a result of experiments it was confirmed that when vulcanized rubber or vulcanized rubber products are ground within any one of the foregoing apparatus, the above-mentioned deficiencies of conventional apparatus can be overcome and the grinding efficiency can be greatly improved over such conventional apparatus.

Preferred embodiments of apparatus of this invention employing the rotor and casing structure of FIGS. 12-14 will now be illustrated by reference to FIGS. 15-20. Referring particularly to FIG. 15, the apparatus of this invention comprises a driving member, such as for example, a motor 416 and reduction gearing, a substantially cylindrical casing 418 provided with an inlet 417 for charging rubber material to be ground, and a rotatable casing 413 and a rotor shaft 419 intercon-
connected with the reduction gearing. The rotor shaft 419 extends throughout the fixed and rotatable casings and includes a feed screw 422 disposed within casing 418 and a rotor blade 411 disposed within casing 413. The rotatable casing 413, as well as the rotor shaft are of course rotatably supported within various bearing members, including a forward bearing stand 420, which are in turn supported by means of a bed 421, while the fixed casing is supported upon an upstanding gearing housing 423.

The rotor shaft 419 is driven by means of the motor 416, a first pulley 424 associated with motor 416, a second pulley 426 which is connected to pulley 424 through means of a belt 425, and various gears 427, 428, 429, and 430 disposed within housing gearing 423. A coolant passageway 431 extends axially within the rotor shaft 419 and is supplied with a coolant, such as for example, water, by means of a water supply tube 432, cooling water thus being supplied and discharged to the rotor shaft by means of a rotary joint 433 mounted at the front end of the rotor shaft. A hopper, not shown, is provided upon the material inlet 417 of the casing 418 for the deposition therein of material to be ground, while the ground rubber material is withdrawn through a radial discharge outlet 445. A gear 434 is fixed to, or integral with a peripheral portion of the movable casing 413, and the movable casing 413 is thus interlocked with gear 428 through means of a gear 435 engaging gear 434, a shaft 436 associated with gear 435, and gears 437 and 438, gear 438 being co-axial with gear 428. In this manner, the construction is such that the casing 413 can rotate in a direction opposite to that direction of rotation of the rotor shaft 419.

The rotatable casing 413 has concentric portions and interposed therebetween is an annular water jacket 439 for cooling purposes. Supply and discharge of the water to and from the water jacket 439 are accomplished by means of a water supply tube 440 and a water discharge pipe 441 fixed upon bed 421. The water supply tube 440 and water discharge pipe 441 are respectively connected to a radial water supply passage 442 and a radial water discharge passage 443 which are provided at opposite ends of the water jacket 439, such being sealed by means of O-rings or packings 444.

When the grinding chamber, the cipped clearance may be altered as the rotor shaft 419 is rotated by adopting any one of the structures illustrated in the Figs. 12-14, whereby crushing forces, as well as cutting and shearing forces, are imposed upon the rubber material, and the intended object of this invention, i.e., conducting a grinding operation at a high rate of efficiency, can be attained. In the instance that the cipped clearance is altered by eccentrically locating the axis of rotation O1 of the rotor blade 411 relative to the axis of rotation O2 of the movabe casing 413 as illustrated in Fig. 14, an apparatus such as illustrated in Fig. 16 is provided. In this embodiment, the configuration of the grinding chamber 412' changes in a manner optimum to the grinding operation.

The manner of altering the configuration of the grinding chamber 412' will now be described with reference to Figs. 17-20. Fig. 17 illustrates the state from which both the rotor blade 411 and the movabe casing 413 are going to rotate, namely the starting positions of the blade 411 and casing 413. The perigee P1 is the point at which the rotor blade approaches the inner face of the movable casing 413 at the closest distance, while the apogee P2 is the position farthest from the inner face of the movable casing 413. Subsequently, as illustrated in FIG. 18, when the rotor blade 411 and the rotatable casing 413 rotate one-fourth of a revolution in directions opposite to each other, contrary to the starting state shown in FIG. 17, the perigee P1 is now at the point farthest from the inner face of the movable casing 413 while the apogee P2 is now at the point nearest thereto, due to the fact that the casing 413 is eccentrically offset relative to the rotor blade.

When the rotor blade 411 and movable casing 413 rotate another one-fourth of a revolution, as illustrated in FIG. 19, the positional relationship between P1 and P2 is similar to that observed at the starting positions, and when they rotate still another one-fourth revolution, the positional relationship between P1 and P2 is similar to that observed when they rotate one-fourth of a revolution from the starting positions, as illustrated in FIG. 20.

Thus, in the instance that the rotor blade 411 and movable casing 413 are rotated in reverse directions with a deviation of d provided between their centers of rotation O1 and O2, respectively, the perigee and apogee points P1 and P2 of the rotor blade 411, and points A, B, C and D upon the inner face of the moving casing 413, change their relative positions as the same are rotated, as shown in FIGS. 17-20, whereby the points P1 and P2 approach the inner face of the movable casing 413, twice during one rotation, and consequently the cipped clearance is successively changed within a range of L1 to L2 and the above-mentioned effects attained by this invention can be further enhanced.

Furthermore, the grinding chambers formed upon both sides of the rotor blade 411 change their configurations both longitudinally and laterally and the movement thereby imparted to the rubber material can be quite vigorous. This embodiment of this invention, if the rotational frequency F1 of the rotor blade 411 is different from the rotational frequency F2 of the movable casing 413, i.e., if the ratio of F1 : F2 is adjusted to 1 : 1 = δ, the points at which P1 and P2 approach the inner face of the movable casing 413 are variable and they are successively deviated from one another in correspondence to the difference in the rotational frequency between the rotor blade 411 and movable casing 413, whereby the grinding work can be made uniform.

As described above, in this invention the rotor shaft is rotated in a particular manner so that the cipped clearance within the grinding chamber is changed during rotation. As a result of this specific structure, even if the rubber material is elastically deformed and caught between the rotor blade and the inner wall of the grinding chamber, the condition of the rubber material is immediately and automatically altered and the rubber material can be acted upon by different forces with the result that stagnation of the rubber material and partial abrasion or heat generation can be effectively prevented, and the rubber material can be positively cut and sheared while reducing the load imposed upon the rotor shaft. Moreover, since the volume of the grinding chamber is altered during rotation, crushing forces are imposed upon the rubber material as well as cutting and shearing forces.

Accordingly, in this invention, even a vulcanized rubber or rubber product having a high degree of elasticity can be ground smoothly and easily and at a high rate of efficiency. Furthermore, if a suitable number of con-
cave portions are formed upon the inner wall of the movable casing as illustrated in FIGS. 12 and 13, it is possible to enhance the above effects by employing an apparatus having a relatively simple structure. Still further, if the rotor blade and movable casing are rotated under eccentric conditions, as illustrated in FIGS. 14 and 16–20 it is possible to alter the chipped clearance in a non-stepped manner and the above-mentioned crushing forces imparted to the rubber material can be greatly enhanced so as to conduct the grinding operation still more effectively.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is to be understood therefore that within the scope of the appended claims the present invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An apparatus for pulverizing rubber materials such as vulcanized rubber and rubber products, which comprises:
   a rotor having an egg-shaped cross-section;
   a casing surrounding said rotor;
   drive means for rotating said rotor relative to said casing; and
   clearance-changing means for changing the clearance formed between the outer periphery of said rotor and the inner wall of said casing as said rotor rotates, said clearance-changing means includes an inner wall of non-circular cross-section disposed within said casing.

2. An apparatus as set forth in claim 1, wherein said drive means further comprises a mechanism for rotating said casing in a direction opposite to the direction of rotation of said rotor.

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