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METHOD OF IMPROVING THROUGHPUT EFFICIENCY OF A ROTARY
DRUM MILL

The monitoring of a ball grinding mill or equivalent through electrical signals derived from the mill, in operation, has long been known. U.S. Patents 2,405,059; 2,766,941; 3,944,146; and 4,026,479 are
5 representative of typical monitoring systems.

Each of these systems depends upon sound signals derived from the mill operation. However, sound signals are neither pure nor primary signals, and their use leads to complex means for analysis and selection of different
10 operating characteristics. It is easily recognizable that a sound frequency, magnitude or characteristic pattern will change considerably with changes in loading, speed, material constituency, material particle size and other characteristics of the material. Also, in the mill
15 environment there are extraneous sounds which will affect such systems. Therefore for operation where significant ranges of materials and different ball mill conditions exist, a sound-operated system tends to be restricted to sensing a particular limited condition in a particular
20 mill to which it is custom tailored. It is therefore desirable to establish signals which are more universally significant and less susceptible to error from extraneous causes.

Furthermore, the sound-derived signals which are tailored to specific mill conditions are significantly altered by the physical nature of the materials being processed. Thus, for example, if a chemical additive to the raw materials affects the physical behaviour of the materials enough to improve the throughput efficiency of the mill, it also affects the sound. Thus, preselected patterns of sound signals may not properly detect material differences in throughput efficiency which should be monitored and controlled.

There are also other shortcomings of the prior art systems and methods, because the nature of the mill operation is not understood or has not been adopted as an integral part of the monitoring and control methods. Thus, for example, a number of interrelated variables may affect efficiency, such as the amount of charge of materials in the mill, the charge characteristics including the chemical additives used, and the ball grinding efficiency. Nevertheless, most systems and methods are responsive only to single control factors such as the rate of flow of materials through the mill, without regard to the grinding efficiency which could change drastically in characteristic depending upon other mill conditions. It is therefore desirable to employ control signals which are representative of complex interactions in the mill and yet are indicative of the true throughput efficiency of a uniform product.

Also it is desirable to have methods and signals available for both instantaneous on-line analysis and long term analysis, of mill conditions. Few control methods or systems afford a compatible dual capability of this sort.

It is also known to use chemical additives which affect the physical behaviour of the ground material in a manner increasing the output quantity of ground raw materials produced by the mill.

It is a general object of this invention to improve the prior art methods of controlling of grinding mills when using chemical additives which increase the output quantity of ground raw materials produced by the mill.

Accordingly, one aspect of the present invention provides a method of improving throughput efficiency of a rotary drum type mill driven by an electrical motor to grind input raw materials, comprising; introducing into the mill a chemical additive affecting the physical behaviour of the ground materials in a manner increasing the output quantity of ground raw materials produced by the mill; deriving from the electrical power delivered to the motor, motor power signal values over a signal range, representative of the raw material load magnitude in the mill, produced by the load magnitude of the raw materials in the drum; selecting a desired range of values of the mill operating efficiency identified by a magnitude range of said power signal, wherein the power signal magnitude corresponds to a raw material load magnitude in said

desired range of values of the mill operating efficiency; establishing an efficient proportion of chemical additives to raw materials within this operating range; and adjusting the feed of chemical additive and raw material in response to magnitude variations of said derived intermediate power signal magnitude to maintain the established efficient proportion within the magnitude range of said power signal, thereby to achieve efficient output of materials without waste of chemical additives.

10 Another aspect of the invention provides a method of improving throughput efficiency of a rotary drum type mill to grind input raw materials comprising the steps of:- introducing, with raw materials into the mill, a chemical additive affecting the physical behaviour of the ground materials in a manner increasing the output quantity of ground raw materials produced by the mill; deriving from an electric motor operating the mill a motor load signal at which the mill is operating at optimum grinding efficiency at an intermediate motor load value; and
20 controlling the amount of chemical additive introduced so as to substantially maintain said signal to optimize the output of ground raw materials.

It has therefore been established in accordance with the present invention that reliable, comprehensive
25 and convenient electrical control signals for the addition of the chemical additive may be derived from monitoring solely the power changes of an electric drive motor rotating the drum of the ball mill. Thus, the desired mill operating efficiency is established by the criterion of
30 running at a constant speed with a synchronous motor while

effectively grinding a charge of the desired constituency and the motor is operated in that condition at an intermediate point on a variably detectable range of the power curve.

5 This set of conditions permits the mill to be monitored and controlled simply, as a function of the amplitude of motor power signals which are easily detected and processed, and yet which carry comprehensive mill operational characteristics including the effect or
10 optimum usage of chemical additives capable of increasing the mill efficiency.

 The motor power signal magnitude may then be processed to produce control signals for purposes of operating displays and control functions, preferably in
15 a combination of signal magnitudes showing undershoot and overshoot of the desired mill operating efficiency and enabling control either by semi-automatic operator intervention or fully automated feed of materials and chemicals to attain optimum efficiency both instantaneously
20 and over the long term.

 For long term historical operation to analyse and monitor mill performance, the instantaneous real-time signal is stored and recalled when desired.

 A set of pictorial representations of actual
25 mill conditions enabling a semi-skilled operator to understand the nature of the mill condition without

analysis or interpolation is presented in response to the motor load signals.

Thus, the present invention enables a comprehensive and reliable mill analysis and understanding 5 to be determined from a simply derived and processed signal, namely the supply power to the motor. This process provides a novel manner of knowing, on the basis of motor power, whether the ratio of quantity of chemical additives in relation to the quantity of raw materials is too great 10 or too small, a heretofore unknown mode of operation as acknowledged by the aforesaid U.S. Patent No. 2766941.

In order that the present invention may more readily be understood the following description is given, merely by way of example, with reference to the 15 accompanying drawings, in which:-

Figure 1 is a block system diagram of a mill control system embodying the invention; and

Figure 2 is a graph displaying mill operating conditions used in accordance with this invention, 20 relating typical selected operational signal magnitudes to typical pictorial representations of the corresponding mill operating conditions.

As may be seen in Figure 1, a ball mill generally comprises a rotary drum 10, a separator 11, a feed line 12 25 to the separator and a recirculation line 13 for reintroducing coarse particles from feed line 12 and

separator 11 back into the rotary drum 10. The output grinding products passed by separator 11 are withdrawn by way of output line 14.

The rotary drum 10 is driven by the shaft 15 of an electric motor 16 having electrical supply conductors 17. Typically the drum is rotated at a known constant speed ascertained by gearing (not shown) and synchronous motor speed. Such motors will draw the necessary current from conductor 17 (which presents constant input voltage) to operate at constant speed under various load conditions. Thus, changes of line current will represent changes in the motor load. This parameter (current) is easily detected from an alternating current line (as represented by the ~ symbol) by means of an a-c coupled current transformer 18 about the conductor 17 so that a signal proportional to the motor power is conventionally produced in a suitable detector 19. This is the sole detected signal necessary to produce a comprehensive analysis of mill conditions.

In order to understand the invention better, it is desirable to consider some of the characteristics of mill operation. For this purpose reference will also be made to Figure 2 where there are two graphs having as common abscissa the load magnitude of the raw material in the rotary drum 10 driven by the motor 16 related to the charge of raw materials introduced into the drum 10 at input 20 from suitable raw material feed means 21.

Chemical additives are introduced by feed means 22 to affect the power loading on the motor indirectly, since the corresponding volumes and weights are small compared to those of the raw materials, such as 5 clinkers from which cement is to be ground. In considering the load, therefore, the amount of recirculated raw materials along line 13 and the drum input 20 is then also a factor. It is in this respect that the chemical additives at 22 affect the loading, since they are of a type that 10 will improve the output efficiency of ground materials at line 14. Typical chemicals used for such purposes are set forth in U.S. Patent 3,607,326.

Now consider the ordinate of Figure 2, which displays two scales representative of pertinent performance 15 characteristics, namely for the upper graph the motor current I (proportional to motor power at constant supply voltage) and for the lower graph the grinding efficiency (Eff) on the raw materials, this latter being a function of the grinding medium, of the density of the raw materials, 20 and of the flow pattern through the rotary drum. For better understanding of the nature of these parameters, reference is made to the simulated pictorial representations A to E. These views represent diagrammatically a transverse cross section of a drum 10 while it is rotating with grinding 25 medium balls and raw material load, to show the materials 2 and balls 31 at various volumetric charge loadings of the

drum from underload A to overload E. The loading condition C may be considered as the desired condition. It relates to a maximum grinding efficiency at point C on the lower curve Eff and to a chosen current operation datum C on the upper current curve I.

Referring to the lower, grinding efficiency curve, Eff, clearly for raw material load magnitudes which are either greater or less than the load magnitude for condition C, for example at points A, B, D, E, the grinding efficiency is reduced. However, the current characteristic I changes in magnitude over the entire range of points A, B, C, D, E. Thus, the current I characteristic provides a detectable control signal that can indicate whether various mill charge loads are too great or too small, thereby to permit monitoring and correction to an optimum operation characteristic.

Typically the motor current curve I will, over a measurable current range shown, decrease from an underloaded condition A to an overloaded condition E, typified by profiles of internal mill conditions. These profiles may be considered an average or integrated combination of the drum profile conditions at axial stations from one end to the other of the drum, since, as may be seen pictorially at 49 in Figure 1, the left hand input end of the drum may have a tunnel (shown as 48 in the display 49 of Figure 1, but also illustrated

in the entrance overloaded condition represented in Figure 2E). This tunnel results from overloading with input raw materials such as is shown in profile E, while the right hand end of the drum may conversely have a profile more like that of profile A, the average condition providing the preferred operating condition then being somewhat as C. These profiles A to E will be easily understood by unskilled or semi-skilled plant operators to indicate underloaded to overloaded conditions in the drum.

The pictorial drum representations depict rotation clockwise of the drum so that, as the load changes, the grinding medium balls 31 and the hatched charge 32 of raw material are centrifugally and frictionally carried in patterns such as indicated.

Higher motor current results when the raw material load A is lighter and lower motor current when the load E is heavier where the tunnelling effect is evident. It can be reasoned that if the balls 31 in an overloaded condition E drop on a thicker cushioned layer of raw materials then the grinding efficiency will be less than the condition C where a ball drop will impact a thinner layer of material. Also, in the underloaded condition A the efficiency is low because the balls are hitting balls rather than raw materials.

It is evident then that both the nature of the flow pattern through the rotating drum and the mill grinding efficiency are indicatable simply in terms of the parameter of motor horsepower or current. Also, a pictorial display of the mill conditions A to E will show an operator on premises a signal giving him a full understanding of the conditions so that he may calibrate automatic feed conditions or semi-automatically control feed rates. Conversely a load current reading such as might be displayed on meter 40 would not have a similar impact and could readily be overlooked because of attention necessary to monitor a continuously variable instantaneous reading and not flag critical conditions that require operator attention and understanding. These operational characteristics are described for example in the Cement Data Book, Walter H. Duda, Bauverlag, Wiesbaden, and in particular Chapter 5, pages 94 to 104.

It is not a trivial feature that this invention, because of its universal nature and the use of a single easily derived signal, namely motor current, can readily be adapted, and instrumentation can be added to existing ball mills, without change or custom installation other than possible internal instrument calibration.

The processing of the detected motor load current 19 is quite simple to provide all the necessary operator and control signal information as seen in Figure 1.

The output current reading 41 may be displayed as a current or power reading on meter 40 for an instantaneous reading. However, as above stated this has little impact on delivering the meaning to a relatively unskilled operator. Thus, a schedule of selected critical conditions requiring operator action, such as the aforesaid conditions A to E, can be selected for control purposes by simply monitoring the current amplitudes at selector 42 to select the corresponding current values A to E on the ordinate of Figure 1, for example. At any one of these conditions control (as suggested by block 43) can be triggered either semi-automatically by operator intervention, or fully automatically, to alter parameters such as raw material or additive feed rates.

The principal display 44 is pictorial, that is, actual pictures or diagrammatic views such as shown in Figure 2 are shown in video form, preferably along with the instantaneous real time reference signal at 45 as derived from a system clock 46.

This method of operation is also adaptable to storage and recall of mill operating conditions by means of any suitable analogue or digital recorder. The segregated amplitude signals at leads 50 are in effect digitalized signals that may be coded and stored in digital form. In this embodiment the analogue current signals 41 may be stored on for example a tape recorder

51, along with a periodic time indication, or at a series of time intervals sampled by the signals of clock 46. For example, starting at mill startup time on a working shift of eight hours, the mill operation may be sampled and stored every fifteen minutes throughout the shift for recall and readback, thereby implicitly carrying a time indicia. A digital system can, of course, store clock time for every sample, and thus the output on leads 50 could be stored therewith.

It is clear therefore that whenever deviations from expected mill throughput occur, the recordability of the signal is important to provide a historical review. Thus, the cause may be analysed and corrected, even without full time operator attendance and attention.

It is possible to derive a further flow pattern display such as lamp bank 47 which has an optimum central position so that under preferred operating conditions the internal flow pattern within simulated drum 49 will permit tunnelling 48 to proceed only to a predetermined distance along the length of the drum. As indicated above, the tunnelling of Fig. 2E is identified by reduced current from the desired operation current (condition C). Thus, the lights are lighted from left to right as a function of current to show flow tunnel 48 length conditions inside the drum 49 on the lamp array 47 as derived from the signals available 50. Thus, both the loading conditions

44 and flow conditions 47 are pictorially representable solely from the magnitude of the input motor current basic signal.

However, one other factor affects tunnelling 48, namely: raw material density. The fluffier or less dense the raw materials, the more fully (volume) loaded the drum is, as represented by the displays 44 (Fig. 2A to 2E). Thus, the central idealized flow lamp in bank 47 may not coincide with the preferred loading pattern Fig. 2C but may rather match Fig. 2B or Fig. 2D if the raw materials are more or less dense. Therefore, it may be desirable to shift the lamp lighting sequence of flow picture 47 to the right or left as a function of an input material density signal indicated at 52.

In controlling the mill it is important to correct for overloading and to revert back to more efficient operation. This is a critical condition regarding chemical additives. The feeds of raw materials and chemical additives then need to be adjusted to assure the same proportions of chemicals to raw materials, particularly during the period of reversion from overloading to normal operation. The ratio of chemical additives to raw materials may be selected especially to aid the system to return to an equilibrium condition at the desired operating condition.

Therefore, the present invention provides an improved and useful method of improving throughput efficiency

in a grinding mill using chemical additives, with procedures and steps which are simple, effective, and simply understood.

The invention thus provides methods particularly suitable for a grinding mill of the electric motor-operated rotary drum type, for producing cement. Mill output efficiency is improved and optimum feed of raw materials and chemical additives is permitted.

Various aspects of the mill operating method described above have also been described and claimed in our Published British Patent Application No. 2,090,770A (on Application No. 8139058 from which the present application is a Divisional).



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CLAIMS

1. A method of improving throughput efficiency of a rotary drum type mill driven by an electrical motor to grind input materials, comprising: introducing into the mill a chemical additive affecting the physical behaviour
5 of the ground materials in a manner increasing the output of ground raw materials produced by the mill; deriving, from the electrical power delivered to the motor, motor power signal values over a signal range, representative of the raw material load magnitude in the mill, produced by the load
10 magnitude of the raw materials in the drum; selecting a desired range of values of the mill operating efficiency identified by a magnitude range of said power signals, wherein the power signal magnitude corresponds to a raw material load magnitude in said desired range of values
15 of the mill operating efficiency; establishing an efficient proportion of chemical additives to raw materials within this operating range; and adjusting the feed of chemical additive and raw material in response to magnitude variations of said derived intermediate power signal magnitude to maintain the
20 established efficient proportion within the magnitude range of said power signal, thereby to achieve efficient output of materials without waste of chemical additives.

2. A method according to claim 1, including the step of reducing the feed of chemical additive when the power
25 signal indicates a raw material load magnitude in the mill greater than that for said desired mill operating efficiency.

3. A method of improving throughput efficiency of a rotary drum type mill to grind input raw materials



comprising the steps of:- introducing, with raw materials into the mill, a chemical additive affecting the physical behaviour of the ground materials in a manner increasing the output quantity of ground raw materials produced by the mill; deriving from an electric motor operating the mill a motor load signal at which the mill is operating at optimum grinding efficiency, at an intermediate motor load value; and controlling the amount of chemical additive introduced so as to substantially maintain said signal to optimize the output of ground raw materials.

4. A method of operating and monitoring an electric motor-operated rotary drum type mill, such method being substantially as hereinbefore described with reference to the accompanying drawings.
