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Physical information from the inside of a rotary mill

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SYNOPSIS

Electronic circuits were developed and successfully utilized to record, store, and continuously transmit to a remote station physical information relating to the impacts of pebbles on the shell liners of an industrial pebble mill, and of electrical conduction in the mineral pulp. The information was obtained by the instrumentation of some of the bolts that are used to clamp the liner blocks and lifter bars to the mill shell.

The features associated with the impact and conduction signals have been interpreted, and it is shown that such signals can lead to continuous measurements of the volume of the load in an industrial mill.

Information is given regarding the angular distribution of direct impacts of the pebbles onto the shell liners, the power required to promote impacts, the amount of material in flight, the impact velocity, and the average number of direct impacts with the shell liner that any given pebble undergoes in unit time in the given mill.

SAMEVATTING

Daar is elektroniese kringe ontwikkel en suksesvol aangewend om fisiese inligting oor die slae van rolklippe teen die rompvoerings van 'n industriële rolklipmeul, en ook elektriese geleiding in die mineraalpulp te registreer, te bewaar en voortdurend na 'n afgeleeë stasie oor te sein. Die inligting is bekom deur die instrumentasie van sommige van die boute wat gebruik word om die voeringblokke en ligstawe aan die meul se romp vas te klamp.

Die kenmerke van die slag- en geleidingseine is geïnterpreteer en daar word getoon dat sodanige seine kan lei tot die deurlopende meting van die volume van die lading in 'n industriële meul.

Daar word inligting verstrek oor die hoekverdeling van direkte slae van die rolklippe teen die rompvoerings, die krag wat nodig is om slae te bevorder, die hoeveelheid materiaal in vlug, die slagsnelheid en die gemiddelde getal direkte botsings met die rompvoering wat 'n gegewe rolklip in 'n tydeenheid in die gegewe meul ondergaan.

Introduction

It has been proposed[1] that the bolts used to clamp the liner blocks and lifter bars to the shells of ball, rod, and tube mills can be instrumented[2] in a variety of ways so that physical information can be obtained from the inside of such a mill. Some preliminary results relating to the impacts of pebbles against the inner wall of the shell of an industrial pebble mill were described, and it was shown that information from the inside of the mill could be received continuously at a remote station by telemetric methods.

The aim of the present paper is to describe the results of a further investigation, also related to the impacts of grinding elements on the mill shell, which has not only confirmed the preliminary results but has also yielded information on the angular range and distribution of the impacts, the amount of material in flight, and the power involved in projecting this material. The importance of the impacts in pebble milling is evident from the fact that skilled operators are able to tell whether a mill is 'on the grind' or 'going off the grind' by listening to the noise made by such impacts.

Measurements have also been made of electrical conduction[3,4] in the mineral pulp. Such measurements, when combined with those relating to the impacts, lead to a knowledge of the volume of the *en masse* pebbles in the mill — a quantity that could play a significant role in the control of pebble and autogenous mills, especially in run-of-mine milling.

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Apparatus and Methods

Although the methods by which bolts can be instrumented for the purpose of measuring physical quantities inside a mill have been described previously, a brief description is given here so that the present paper is self-contained.

Fig. 1(a) shows a bolt containing a blind hole to accommodate an insert onto which a piezo-electric sensor is mounted. The sensor is located in the bolt head. Electrical leads are passed down a groove machined along the length of the insert, or down a hole drilled along its axis in the manner shown. Thus, electrical signals can be fed from the sensor to recording and transmitting apparatus mounted on the outside of the mill. The piezo-electric device senses

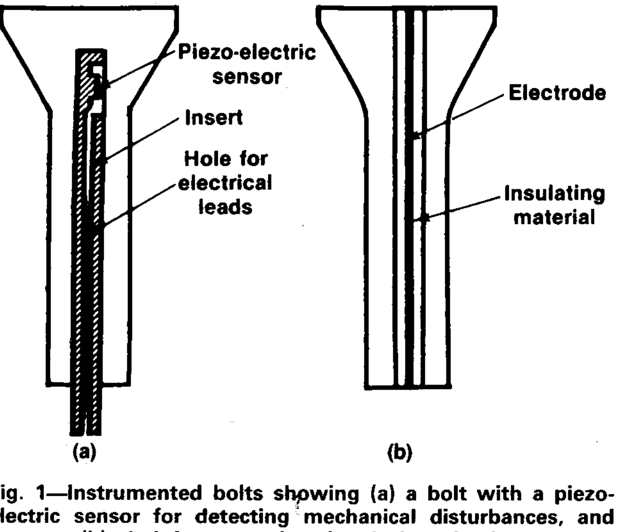

Fig. 1—Instrumented bolts showing (a) a bolt with a piezo-electric sensor for detecting mechanical disturbances, and (b) a bolt for measuring electrical conduction

mechanical disturbances that are communicated to it.

Fig. 1(b) shows a bolt that has been instrumented for the measurement of electrical conduction through the mineral pulp. Here the bolt has simply been fitted with an electrically insulated electrode. Enhanced electrical conduction will be registered by such a bolt whenever it is immersed in the mineral pulp within a mill.

Similar methods can be used in the instrumentation of bolts for the measurement of temperature, pressure, and other physical quantities.

Instrumented bolts were mounted into the no. 6 tube mill at East Driefontein Gold Mine, the recording and transmitting apparatus being mounted on the outside of the mill. This mill is 16 ft by 30 ft and rotates at approximately 16 r/min, which corresponds to about 82 per cent of the critical speed. The mill is fitted with grid liners and lifter bars (32 lines), and it is usually operated with a load of 50 per cent or slightly more. The motor power is about 2700 kW.

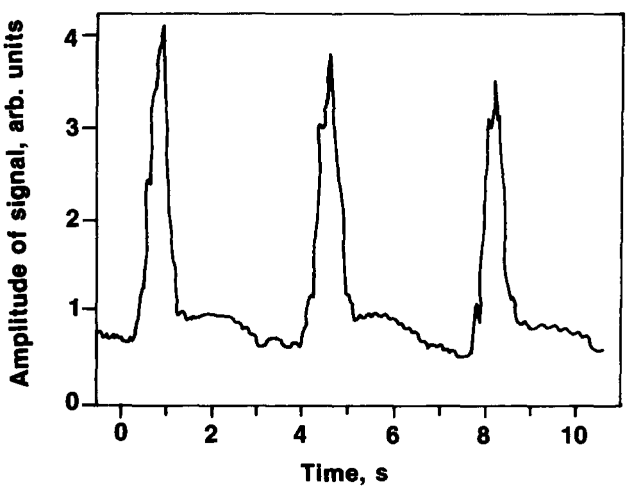

Fig. 2—A sequence of electronically processed piezo-electric signals

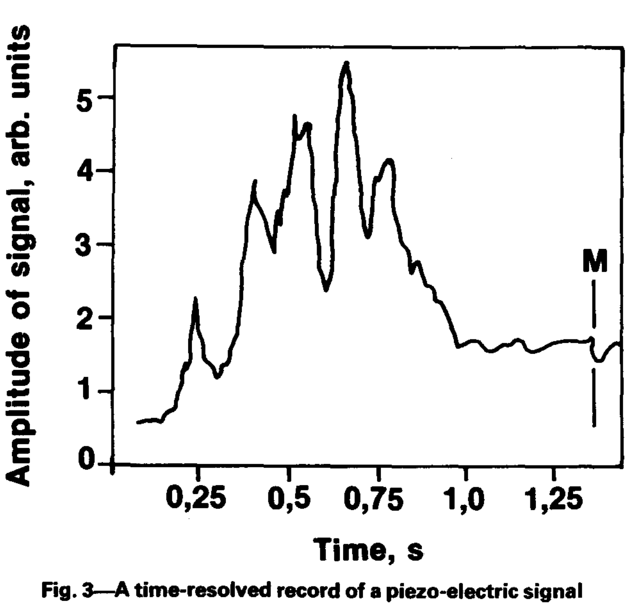

Fig. 3—A time-resolved record of a piezo-electric signal

Results

Electrical signals were obtained from bolts instrumented with piezo-electric and electrical-conduction sensors. The bolts were located in the same lifter bar about midway along the length of the pebble mill, and the piezo-electric signals were recorded onto one channel of a tape recorder. The conduction signals, which were used for the frequency modulation of a carrier wave, were recorded and transmitted radiometrically to a remote receiving station. All the signals were recorded over a period of more than 30 minutes while the mill was in operation.

An earlier paper[1] reported a frequency analysis of the piezo-electric signal, showing that peaks observed in the frequency spectrum are related to the impacts of pebbles in the immediate environment of the piezobolt. The piezo-electric signals were processed by rectification and integration over a time constant of about 2 ms. Fig. 2 shows that a sequence of processed piezo-electric signals consists of a series of fairly sharp peaks spaced regularly at intervals of about 3,75 s. The graphs also show that the piezo-electric peaks, which have a time duration of about 1 s, exhibit a considerable amount of structure.

Fig. 3 shows the time resolution of a piezo-electric peak. It demonstrates that a number of events occur in such a peak over a period of about 0,8 s. The event, which is labelled *M*, is due to a marking signal. The marker was registered during each revolution whenever the instrument bolts passed through the lowest point on the vertical axis through the centre of rotation.

Typical electrical-conduction signals are shown in Fig. 4, from which their periodicity is clearly evident. Points *M* indicate the lowest position of the bolt, and points *V* its highest position. At the positions *M*, the marking events occur at intervals of 3,75 s. The conduction signals consist essentially of plateaux, which are initiated at times that have been called *T*, and terminate sharply at times called *D*. The plateaux are separated by the peaks labelled α_c. These events are also periodic. Between α_c and the plateaux thresholds, a number of sharp subsidiary conduction peaks, which have been called *S*, always occur. The structure within *S* is quite random.

Discussion

The piezo-electric signals shown in Figs. 2 and 3 are separated by 3,75 s. This time interval is the period of the mill, which is given by 60/16 = 3,75 s, since the mill rotates at 16 r/min. The piezo-electric device senses mechanical disturbances that are communicated to it, and the positions of the signals in the trace relative to a marking signal show that they occur on the 'down-side' during mill rotation. The occurrence of these signals can therefore be attributed to impacts experienced by the bolt and its neighbourhood as they periodically move through the pebbles 'raining' onto the down-side of the mill.

Time resolution of the piezo-electric signals as shown in Fig. 3 reveals a considerable degree of structure. This phenomenon was investigated further by the superimposition of a number of such time-resolved records in the manner shown by Fig. 5, in which five selected records have

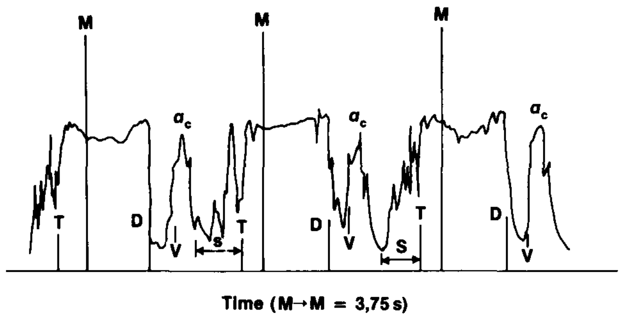

Fig. 4—A sequence of electrical conduction signals

been superimposed so that the markers at M coincide. Fig. 5 shows that at least five discrete events can be recognized before the bolt registers a noise continuum, with a threshold at T. The events have been labelled α, β, γ, δ, ε. Because of the occurrence of shifts and sub-structures, they are not strictly periodic with mill rotation, and, when a large number of time-resolved records are superimposed, anti-correlations occur and the discrete nature of events within a piezo-electric signal becomes obscured. However, events of varying complexity have been observed in every piezo-electric signal that has been resolved. For the sake of further analysis, it will be supposed that Fig. 5 is a fair representation of the events occurring within a typical piezo-electrical signal.

Since the rotational speed of the mill is known, the angular position of an event in a piezo-electric signal relative to the marker can be determined. For example, the time between α and M is about 1,12 s, and the angular speed of the mill is

$$\omega = \frac{16 \times 2\pi}{60} \text{ rad.s}^{-1}.$$

Hence, α occurs at an angle θ_α, before M, given by

$$\theta_\alpha = -1{,}12 \times \omega \times 180/\pi$$
$$\approx -107°.$$

The angular positions of the instrumented bolt corresponding to the various events in Fig. 5 were calculated and plotted on Fig. 6, which is a schematic diagram of the mill shell. The appropriate positions of the instrumented bolt are indicated. Of particular interest is the occurrence of two of the events above the horizontal axis when the instrumented bolt is at an angle greater than 90° from the lowest point, M.

The origin of the events α to ε is found as follows. To begin with, it is noted that, when pebbles are carried in circular paths by the rotary action of the mill, then, at some point in their upward motion, the radial forces acting on one of these objects add up to zero. At that point a parabolic trajectory can be initiated so that the pebble is projected back into the body of the mill. The trajectory can be described by an equation of the form

$$Y_n = Y_{on} + (X_{on} - X_n)\cot\theta_{on} - \frac{g(X_{on} - X_n)^2}{2V_{on}^2 \sin^2\theta_{on}}, \quad (1)$$

where X_{on} and Y_{on} are the co-ordinates of the point at which the trajectory is initiated with velocity V_{on}. The latter is directed normal to the radius R_n, whose inclination to the horizontal is given by

$$\theta_{on} = \tan^{-1}\frac{Y_{on}}{X_{on}}. \quad (2)$$

θ_{on} is called the departure angle.

For simplicity it can be supposed that, during their journey from M to D, the pebbles are carried upwards in superincumbent layers described by the suffix n; $n = 1$ describes the outermost layer in which they are in contact with the shell liner, $n = 2$ the second layer of the layers, and so on. The following assumptions are made:

(1) the pebbles are spherical with a diameter of 80 mm,

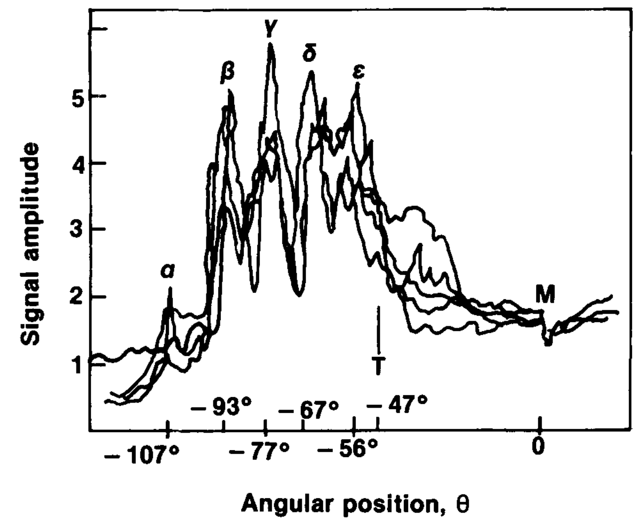

Fig. 5—Five superimposed time-resolved records of piezo-electric signals

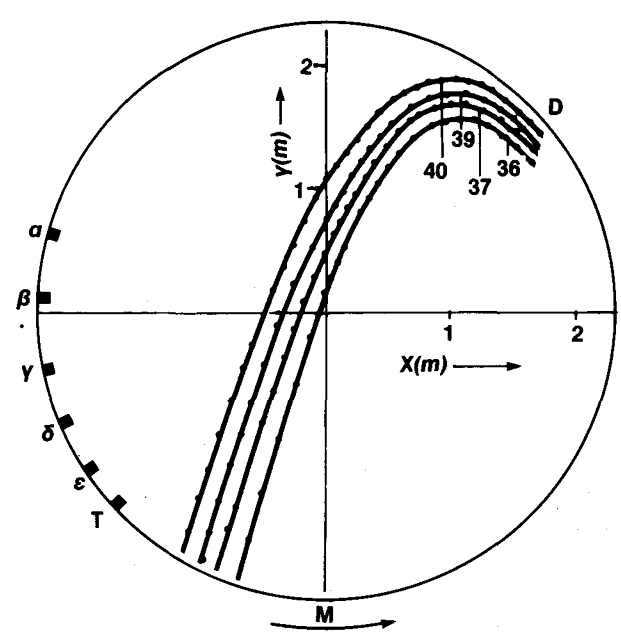

Fig. 6—Representation of the no. 6 tube mill, showing the positions occupied by the piezobolt when each of the events α to ε is registered

(2) they are keyed in to the rotary motion of the mill,
(3) interactions between pebbles in the neighbourhood of departure (defined by the symbol D) can be ignored, and
(4) the speed and dimensions are the same as those of the no. 6 tube mill at East Driefontein. The calculated parabolic trajectories are then as shown in Fig. 6.

The mismatch between the calculated trajectories in Fig. 6 and the successive positions of the bolt when the events α to ε are recorded is quite startling. The sharpness of the spikes in the piezo-electric signal suggests that the sensitive neighbourhood of a piezobolt is highly localized, but the calculated trajectories intersect the shell below T, where the piezobolt is registering a noise continuum. In other words, if they had followed the theoretical paths indicated in Fig. 6, the pebbles would have impacted onto the *en masse* load, and not directly onto the shell. It is therefore of interest to understand how the pebbles manage to achieve flight paths enabling them to impact, not only directly onto the shell, but onto the shell in neighbourhoods above the horizontal axis.

In the idealized calculations, the departure angles θ_{on} are determined by the speed of the mill and vary slightly with particle size. Thus, larger pebbles will have smaller θ_{on}; for example, for 100 mm pebbles θ_{on} is 39,8°, but for 60 mm pebbles it is 40,3°.

The idealized calculations ignore the interactions of pebbles with the various parts of their environment. The interactions are those between pebbles and lifter bars, pebbles and pebbles, and pebbles and muddy pulp. These interactions are now considered in turn.

The effect of the lifter bars is to key in the motion of the pebbles in the outer layers (n = 1, 2, and perhaps 3) to the rotary motion of the mill and to provide a lifting force that increases the angle of departure. For small pebbles, which have to slide off the surface of the lifter bars in the presence of friction, the angle of departure can be increased by more than 30°, but pebbles more than 100 mm from the shell remain unaffected. The implication is that one would observe only a localized event (perhaps two) in the angular range α to T, probably in the neighbourhood of γ. Therefore, the interactions with lifter bars only cannot explain a whole sequence of events occurring over an angular range of more than 60°.

Regarding the interactions between pebbles and pebbles, it can be noted that the pebbles are generally smaller than 100 mm in diameter and of various shapes. Attempts have been made to allow for these interactions, but such calculations as have been made suggest that the radial components of the forces of interaction could be large enough only fortuitously, and therefore the departure angles, only occasionally such, as to raise the points of intersection of the orbits to above T. Therefore, such interactions do not explain the fact that every time-resolved record exhibits events approximating α, β, etc.

Interactions between pebbles and pulp could give rise to weak adhesion of such a magnitude that, even though the mill is operated at only 82 per cent of the critical speed, some of the pebbles in the outermost layer 'centrifuge'. There is good evidence for this effect: it is known that, when a mill is stopped for inspection or maintenance, pebbles falling from the 'roof' are a not inconsiderable hazard. The adhesion therefore influences the angles of departure θ_{on}. So that this effect can be expressed quantitatively, it can be supposed that the force of adhesion F_A, can be written

$$F_A = f\, m\omega^2 R_n, \quad \ldots \quad (3)$$

where R_n is the radius of the nth layer, so that the adhesive force is proportional to the centrifugal force with proportionality constant f. On that assumption, the defining equation for the departure angle for pebbles in the nth layer becomes

$$m\,\omega^2 R_n\,(1 + f) - mg \sin\theta_{on} = 0, \quad \ldots \quad (4)$$

where

$$R_n = R_m - r\{1 + 2\sqrt{\tfrac{2}{3}}\,(n-1)\} \quad \ldots \quad (5)$$

and R_m is the internal radius of the mill. Equation (5) assumes close packing of equal spherical pebbles of radius r in the various layers n.

It was assumed that f = 0,55, r = 40 mm, and equations (4), (5), and (1) were used in the recalculation of the trajectories. The results are shown in Fig. 7, which provides a very good explanation of the events α to ε. It suggests that they are due to pebble impacts in the immediate neighbourhood of the instrumented bolt. This interpretation is supported by Fig. 8, in which the impact velocity at the point of impact is plotted as a function of the angular position of the latter. It can be seen that the impact velocity at position α is substantially smaller than that at any of the other points. This is in good agreement with the fact that the signal amplitude at α is the smallest, as shown in Figs. 3 and 5.

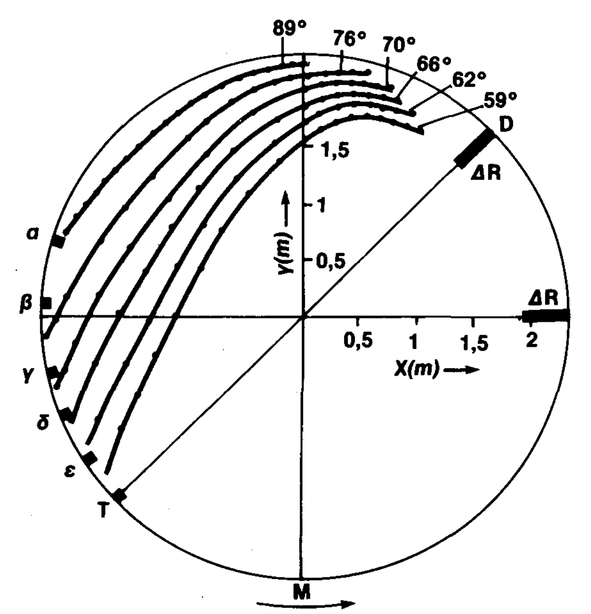

Fig. 7—Trajectories showing that, when allowance is made for some adhesion of the pebbles to one another and to the mill shell, the trajectories match the bolt positions at which the events α to ε of Fig. 5 were registered

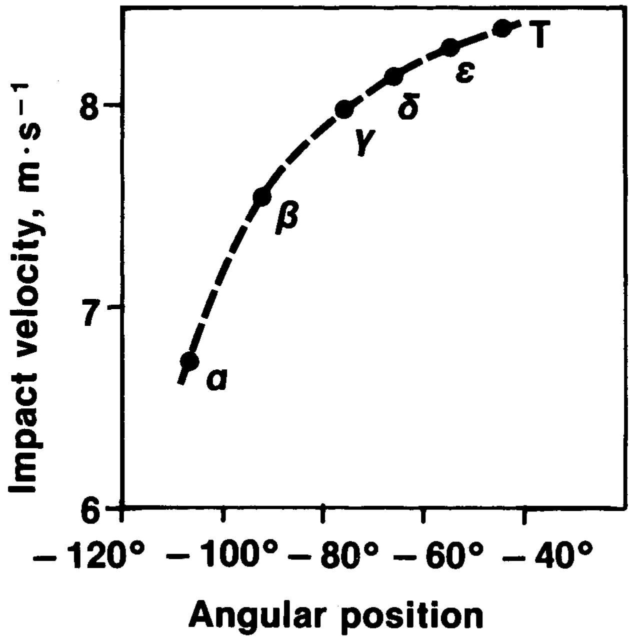

Fig. 8—Velocities of pebble impacts when the events α to ε occur

However, in the given mill, the pebbles are not equal spheres with radii of 40 mm, and they are not stacked neatly in closely packed layers as implied in equation (5). But Fig. 7 emphasizes a very important point: namely, that any material whose radial position is at $R_n < R_6$, in the neighbourhood of D, cannot be projected directly onto the shell above the position defined by T. Only material within the band $R_6 < R_n < R_m$ can make direct impacts onto the shell above T in the range α to T. The fact that the pebbles are of various sizes and shapes contributes to 'position-noise' in the angular positions of the events α to ε. A further factor arises from the variability in the adhesion that is promoted by the mineral pulp. Fluctuations in either the size of the pebbles or the adhesive force (or both) give rise to fluctuations or 'noise' in the angle of departure θ_{on}, and hence to fluctuations in the angular positions of α to ε. This explains why the events α to ε are not strictly periodic.

It has been pointed out that the occurrence of pebble impacts is useful to mill operators in their assessments of mill performance. If our interpretation of the events in a piezopeak is correct, then it can be shown that a very considerable mass of material is involved in these impacts. Fig. 7 indicates the length $\triangle R = R_m - R_6$ on a horizontal radius. All the material transported through the area $L \triangle R$, where L is the internal length of the mill, impacts directly onto the mill shell in the range α to T. During its circular motion, this material, if it is keyed in to the rotary motion, moves with average speed

$$\bar{v} = \tfrac{1}{2}(R_m + R_6)\omega. \qquad (6)$$

Hence, the mass of material impacting onto the shell in unit time, $\dot{m}$, is

$$\dot{m} = \varrho \bar{v} L \triangle R$$
$$= \tfrac{1}{2}\varrho L \omega (R_m^2 - R_6^2). \qquad (7)$$

Allowance is made for voidage and moisture by putting $\varrho = 2{,}0 \times 10^3\ \mathrm{kg \cdot m^{-3}}$.

Hence $\dot{m}$

$$= \tfrac{1}{2} \times 2 \times 10^3 \times 8{,}8 \times 2\pi \times (16/60) \times (2{,}29^2 - 1{,}92^2)$$

$\approx 23\ \mathrm{t \cdot s^{-1}}$ or $83\ \mathrm{kt \cdot h^{-1}}$. Therefore, a very considerable mass of material is involved in the impacts.

Considerable power is involved in promoting the impacts. The rate at which work is done in lifting the material that will undergo direct impacts from M up to the point where it is projected into flight is

$$P = \dot{m}gh,$$

where g is the gravitational acceleration and h is the mean height through which the material is lifted. The power is approximately,

$$23\ \mathrm{t \cdot s^{-1}} \times 10\ \mathrm{m \cdot s^{-2}} \times \text{about } 4\ \mathrm{m}$$
$$\approx 900\ \mathrm{kW},$$

or about 33 per cent of the mill motor-power. Some of the power will be recovered because impacts due to the material being consolidated into the *en masse* regime, and the weight of that material, will exert turning moments in the direction of mill rotation.

Moreover, the mass of pebbles in the mill is about 145 t. It can therefore be inferred that, because the mill can be assumed to be a perfect mixer, unit mass makes 83000/145 ≈ 570 direct impacts with the shell every hour, and that, while the mill rotates at 16 r/min, any given pebble impacts directly onto the shell with an average frequency of about 9,5 impacts per minute at an impact velocity of about $7{,}5\ \mathrm{m \cdot s^{-1}}$.

Furthermore, it is possible, by use of a detailed balance argument, to estimate the amount of impacting material that is in flight: in a time $\triangle t$, the amount of material projected into flight from the *en masse* regime in the neighbourhood of D must be equal to that which is being consolidated into *en masse* material in the neighbourhood of T (Fig. 7). If $\triangle t$ is also the time that pebbles are in flight before colliding with the shell between α and T, then in that time a volume

$$V_f = \triangle R\, L\, \bar{v}\, \triangle t \qquad (8)$$

of material will leave the *en masse* regime. Numerical estimates of $\triangle t$ in the given mill are quite straightforward. $\triangle t$ is about 1,25 s on average. Therefore $V_f = 14{,}2\ \mathrm{m^3}$, equivalent to 28,4 t of material or 19,7 per cent of static load. This is a lower limit on the amount of material in flight at any given time.

The only experimental evidence that we have to compare with this result is that obtained from a photographic transparency of an experimental rod mill provided with lifter bars and transparent windows so that the motion of charge can be studied. It is clear that there will be vast differences in the modes of operation between this experimental rod mill with no ore pulp and a working industrial tube mill. Nevertheless, such a comparison can be useful.

Fig. 9 is a tracing of the transparency showing the configuration of the rods. The profile T–D was drawn in such a way that the rods above it are considered to be in flight, and those below it are *en masse*. The inclination of the line shows that the dynamic repose is about 47° and, since there were 300 rods in the mill and about 58 of them are in flight, the ratio corresponds to 19,3 per cent, which is

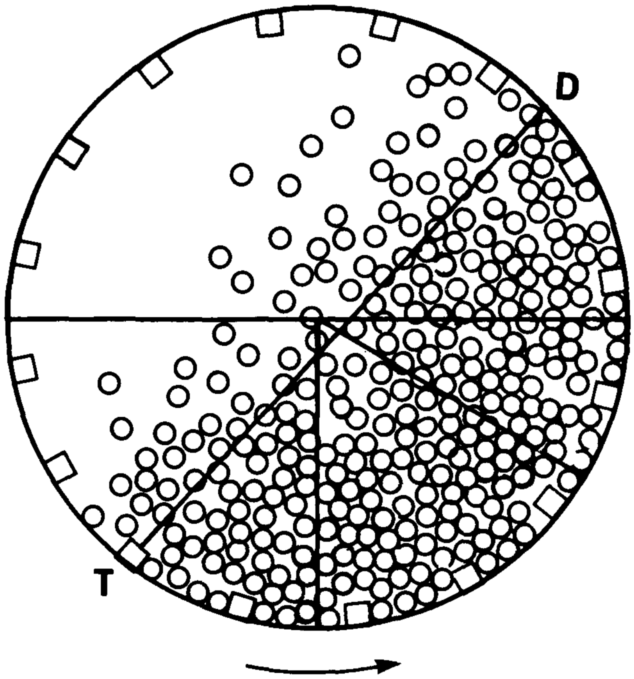

Fig. 9—A tracing, from a photographic transparency, of the dynamic configuration of rods in an experimental rod mill with lifter bars

in good agreement with the theoretical estimate given above.

The outstanding feature of the conduction signals shown in Fig. 4 is the periodicity of the conduction plateau between *T* and *D*. The interpretation is that electrical conduction is initiated whenever the bolt is wet. The threshold *T* is thought to be due to the bolt moving into and under the *en masse* material of pebbles and pulp, with the edge *D* occurring when the bolt emerges from the load. The time *TM* is 0,48 ± 0,02 s. In that time the mill rotates through 46°. Hence, *T* is at −46° from the vertical.

This position for *T* is in good agreement with that derived from the piezo-electric signals, where it was identified with the onset of continuum noise after the last piezospike, ε. The times *MT* are 1,40 ± 0,02 s, which correspond to rotation through 134°. Hence, *D* is at the position indicated in Fig. 7. If it is assumed that the load profile can be approximated by a plane through the line *TD*, then it can be seen that the load of the mill has been determined. Indeed, repetitive measurements of the time *TD* will be a measure of the load in a mill and might be useful in the control of the mill operation. The line *TD* in Fig. 7 suggests that the load was slightly more than 50 per cent when the experiment was conducted. Fig. 7 also suggests that, during operation, the angle of repose was about 46° — a value that is in good agreement with the inclination of the profile shown in Fig. 8.

The origin of the periodic conduction signal, α_c, is not clear at this stage. Its maximum occurred when the conductivity bolt was in the neighbourhood of the highest point. Drainage of liquid onto the sensitive area accounts well for this effect.

The non-periodic spikes that occurred just before the bolt entered *T* are probably due to intersections of the conductivity bolt with mud masses accompanying the pebble trajectories and to splashes.

Conclusions

Successful use was made, while a mill was in operation, of the bolts, used to clamp the liner blocks and lifter bars to a mill shell, that had been instrumented to sense physical conditions within an industrial mill, and of electronic apparatus that had been developed for measuring, processing, storing, and transmitting the physical information to a remote station, where it was monitored continuously.

Signals derived from the impacts of pebbles onto the mill shell were found to have a complicated structure, but the main features could be accounted for when it was appreciated that the mineral pulp promotes weak adhesion between pebbles and pebbles, and between pebbles and shell liner, which is rough.

Electrical-conduction signals, which are aimed at determinations of the volume of the load in a rotary mill, have previously been produced by Lanstiak[3] and independently by Moys[4]. Those obtained appeared to be very complex, but recognition of periodic features brought about considerable simplification in the interpretation of the main components. There is no doubt that it will be possible, by suitable electronic processing, to 'clean up' the conduction signals in future experiments. It has been shown that the so-called plateau regions associated with such measurements can be identified with the time that a conductivity bolt spends under the *en masse* load in a mill. Repetitive measurements of this time can therefore be used in the continuous observation of the magnitude of the *en masse* load in a mill. Knowledge of this important milling parameter can make a significant contribution towards optimization of the grind and control of the grinding unit in pebble and autogenous-milling circuits, especially in those treating run-of-mine material.

The present work suggest that, in the given mill, pebble impacts occurred above the horizontal mill axis, the dynamic angle of repose was about 46°, the mill load was slightly larger than 50 per cent, and the mineral pulp promoted weak adhesion of pebbles to pebbles, and of pebbles to mill shell, with a force of about 0,55 of the centrifugal force or about one-third of the weight of a pebble. It was shown that impactive processes play a very significant role in the given mill, not only as a useful indicator of mill performance, but about 84 kt of material per hour is projected onto the down-side shell and about 33 per cent of the motor power is involved in promoting impacts. At any given time, 20 per cent of the charge, equivalent to 28 t of material, is in flight. It is estimated that, while the mill rotates at 16 r/min, any given pebble collides with the shell at an average rate of 9,5 collisions per minute with impact speeds of about 7,5 $m \cdot s^{-1}$.

A considerable amount of new information therefore resulted from the use of instrumented bolts in a mill.

Piezo-electric devices in instrumented bolts are expected to have a long life since these objects, which are embedded in a bolt head, are not exposed directly to pebble impacts.

The life of conductivity bolts is not known at the present time, but they are easily manufactured from existing bolts and their replacement on maintenance days should not be excessively expensive or time-consuming.

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References

1. VERMEULEN, L.A., OHLSEN DE FINE, M., and SHAKOWSKI, F. Continous monitoring of information from the inside of a rotary mill. Paper presented at MINTEK 50, Sandton (Transvaal), March 1984.
2. *S.Afr. Patent,* appl. 83/6788.
3. LANSTIAK, B. Method for measurement of ball-mill loading. *Tenth International Mineral Processing Congress.* London, The Institution of Mining and Metallurgy, 1973. pp. 63-71.
4. MOYS, M.H. The measurement of parameters describing the dynamic behaviour of the load in a grinding mill. Paper presented at MINTEK 50, Sandton (Transvaal), March 1984.

Coal—supply, transport, and environment

CoalTrans '84, the 3rd International Coal Trade Transportation and Handling Conference and Exhibition is to be held in London from 1st to 3rd October, 1984. The meeting will be opened by Ian MacGregor, Chairman of the U.K. National Coal Board, and will review coal demand-and-supply factors, environmental aspects, and transportation costs.

Coal buyers from Asia, notably Japan, and from major utilities and steel producers in Europe, will set out their requirements in various demand scenarios, and in a major debate critically assess coal quality for factors such as sulphur content and BTU per ton.

The extent to which coal suppliers would be exposed to dramatic rises in transport costs should the freight market firm up overall, or more probably for particular ship sizes, will be quantified. Other papers, designed to assess all facets of transport choice, will compare rail and barge rates worldwide, and examine in detail various distribution and transhipment techniques.

Environmental factors are increasingly becoming more critical. The possible costs in terms of both reduced coal demand, and investment levels needed for the remedial action proposed by current environmental campaigns in both Europe and the U.S.A., will be assessed. Ian Torrens, head, resources and energy division, OECD, France, will analyse the many technological solutions now available to overcome acid rain and other environmental hazards, and their effectiveness in practice.

Finally, delegates at the Conference will hear detailed analyses of both metallurgical and thermal coal demand, and how various political variables could affect the future position of the industry.

Previous meetings, held in London and Paris in 1980 and 1981, were attended by an average of 550 coal buyers and industry interests from around the world.

Details of the current programme can be obtained from the Conference Manager, CS Publications Ltd, McMillan House, 54 Cheam Common Road, Worcester Park, Surrey KT4 8RJ, England. Tel: 01-330 3911. Telex: 8953141 Carsys G.

Ground control in mining

The Fourth Conference on Ground Control in Mining is to be held in Morgantown, U.S.A., from 22nd to 24th July, 1985. This conference series, begun in 1981, is becoming widely acknowledged as a forum for the exchange of information among researchers, consultants, manufacturers, and operators in the mining industry and profession.

Papers are invited in the field of ground/strata/roof control, including theoretical, problem solving, and applied subjects.

Send 200-500 word abstracts by 7th January, 1985, to Jay Hilary Kelley, Coordinator, Department of Mining Engineering, West Virginia University, P.O. Box 6070, Morgantown, WV 26506-6070, U.S.A. Telephone: 304-293-5695.

Papers will be selected by the Organizing Committee and the authors notified by 14th February, 1985. Final manuscripts will be due by 8th April, 1985.

Space will be available for literature display only. Organizations interested in displaying literature should contact the Organizing Committee for reservations by 29th April, 1985.