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The design of linings for rotary mills: a major factor in the throughput and consumption of energy and metal

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SYNOPSIS

A study was made of the performance of a rod mill operating without lifter bars and with different arrangements of lifter bars in the lining.

The results show that striking improvements in performance, increased throughput, and reduced consumption of liner metal and electrical energy can be obtained by a change in the geometry of the lifter-bar arrangements within a mill. Rod mills of equal size fitted with the same arrangement of lifter bars but operating at different speeds presented apparent anomalies in the relative consumption efficiency of electrical energy for the production of material smaller than 75 μm. Marked savings in the consumption of liner metal were achieved by the use of an arrangement of alternating lines of higher and lower lifter bars.

A study of the relative performances of two large tube mills showed that the use of lifter bars in one of the mills resulted in a marked reduction in the consumption of liner metal and electrical energy per ton of material smaller than 75 μm in the product.

SAMEVATTING

Daar is 'n studie gemaak van die werkverrigting van 'n staafmeul sonder ligstawe en nadat daar verskillende rangskikkings van ligstawe in die voering aangebring is.

Die resultate toon dat opvallende verbeterings in die werkverrigting, hoër deurvoer, en 'n laer verbruik van voeringmetaal en elektriese energie verkry kan word deur 'n verandering van die geometrie van die ligstaafrangskikking in die meul. Ewe groot staafmeule met dieselfde rangskikking van ligstawe wat teen verskillende snelhede werk, het skynbare anomalieë getoon wat betref die relatiewe doeltreffendheid van hul verbruik van elektriese energie vir die produksie van materiaal kleiner as 75 μm. Merkbare besparings in die verbruik van voeringmetaal is bewerkstellig deur die gebruik van 'n rangskikking van wisselende rye hoër en laer ligstawe.

'n Studie van die relatiewe werkverrigting van twee groot silindermeule het getoon dat die gebruik van ligstawe in een van die meule 'n merkbare verlating van die verbruik van voeringmetaal en elektriese energie per ton materiaal kleiner as 75 μm in die produk tot gevolg gehad het.

Introduction

The South African gold-mining industry grinds 100 Mt of ore per year to a fineness that permits a high percentage of the gold to be extracted by the cyanide-leaching process. At the conventional figure of 30 kW·h of electrical energy consumed per ton of material smaller than 75 μm produced, 2,4 million MW·h of electrical energy are utilized at a cost of over 70 million rands per annum. The other major working costs entailed in grinding are those of labour and the liner metal consumed in the process. The introduction of large autogenous mills, or of the more commonly used semi-autogenous mills, has brought about substantial reductions in labour costs, but the simultaneous effect on the costs of electrical energy and liner metal may sometimes be adverse, particularly in relation to the latter.

If the use of larger mills has very little, if any, effect on the two major cost components of grinding, the question arises as to what other factors can be considered as possible means of reducing the total costs of grinding. Fairly extensive tests on a number of industrial mills (both rod and tube mills) have indicated that a reduction in these costs can be effected by changes in the design and geometry of mill lining.

Testwork on Rod Mills

Although rod mills would not normally be included in new gold-milling plants, they can be expected to continue to play an important role in primary grinding. Benefits that have been secured by changes in the design and geometry of the lining of such mills may provide valuable indications of the manner in which similar benefits can be obtained in other milling situations. All rod mills are fitted with some type of lifter bar. Usually made of austenitic manganese steel, these bars are rectangular in section, fitting into slots in the backing blocks, and are bolted through the shell of the mill. Obviously, one major function of these bars is to provide 'lift' to the charge within the mill, which includes relatively massive steel rods that are almost as long as the mill and measure 90 to 100 mm in diameter when new. The height of the lifter bars and their distances apart should be adjusted to give the optimum lift to the grinding charge accompanied by the minimum of slip, which is always associated with inefficient utilization of the energy absorbed in turning the mill. By such means it should be possible for electrical energy to be used more effectively and for the consumption of the liner metal caused by undue slip of the grinding charge to be reduced. The changes in lifter-bar

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arrangement that can be effected in a given mill are usually constrained by the number of lines of bolt holes drilled in the shell. This irrevocably fixes the distance between the longitudinal lines of bars, and the only practical change that can be made is in the height of the bars.

Performance of an 8 by 12 ft Rod Mill

A fortunate set of circumstances made it possible for a study to be carried out of three different arrangements of lining in an 8 by 12 ft rod mill, which rotated at 21 r/min, i.e. 77 per cent of the critical speed[1]. The performance of the mill was measured as follows:

(a) when the lining consisted only of wave (or spacer) blocks, giving a virtually smooth surface,
(b) as indicated in Fig. 1, when the lining comprised 12 alternating lines of 75 mm bars and 12 lines of wave blocks, and
(c) when (as shown in Fig. 2) the lining comprised 24 lines of lifter bars, the centre-to-centre distance of the bars being 300 mm.

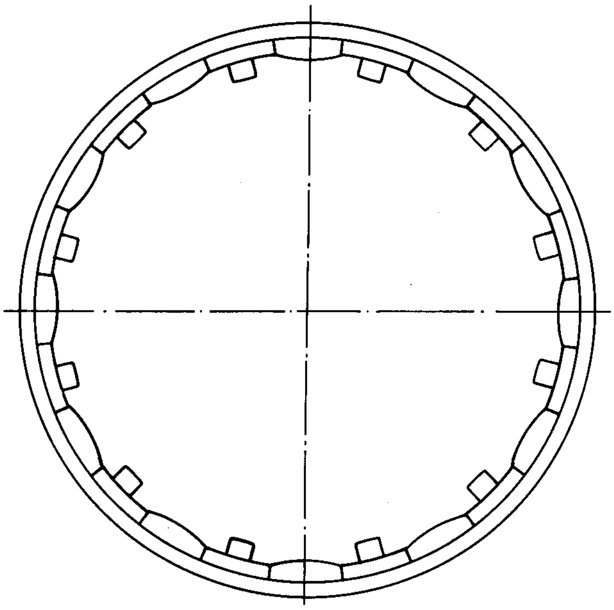

Fig. 1—Rod mill of 8 ft diameter fitted with 12 alternating lines of lifter bars and 12 alternating lines of spacer blocks

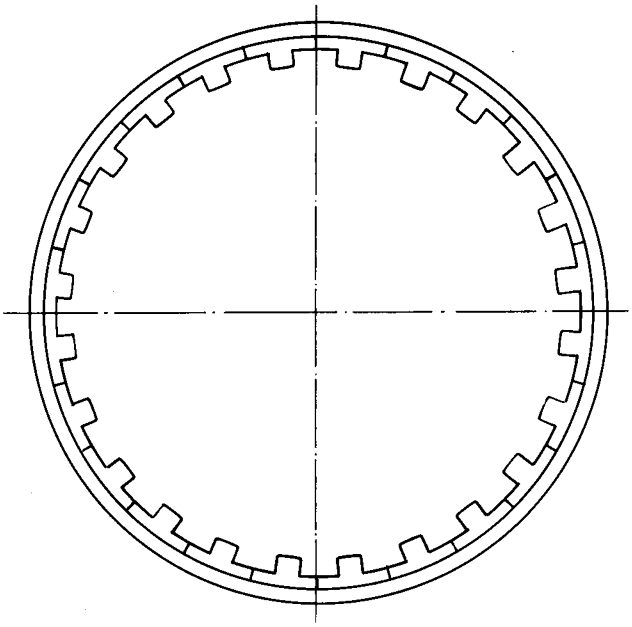

Fig. 2—Rod mill of 8 ft diameter fitted with 24 lines of lifter bars

Some of the basic operating conditions in the tests are given, together with the results, in Table I. It is highly unlikely that a rod mill would ever be used to mill gold ores when equipped with what is virtually a smooth lining, and the results given in Table I emphasize how unsatisfactory such a lining would be. Under these conditions, the mill could accept only a low feed rate, the consumption of electrical energy (per ton milled) and of liner metal were high, and the tonnage milled during the life of the lining was low, less than one-eighth of that obtained with other lining arrangements. It can be seen that the insertion of 12 alternating lines of lifter bars and 12 lines of wave blocks (which had been the standard arrangement within the mill for several years) yielded substantial improvements in mill performance. The insertion of 24 lines of lifter bars, which was a major change, gave very striking improvements in performance over that obtained with 12 lines of lifter bars. The feed rate could be raised by 11,5 per cent, the consumption of electrical energy was reduced to 80 per cent, and the consumption of liner metal by 43 per cent. Most striking of all, the tonnage milled before it became necessary for the lifter bars to be changed was increased by over 50 per cent. The only significant change associated with this marked improvement in performance was the reduction in the distance of the centre-to-centre line of the lifter bars from 600 to 300 mm.

TABLE I

RESULTS OF TESTS ON A ROD MILL OF 8 BY 12 ft (2,3 BY 3,6 m) OBTAINED WITH THREE DIFFERENT ARRANGEMENTS OF LINERS

Design of wear-resistant lining	Ore milled t	Feed rate t/h	Power consumption per ton milled kW·h	Consumption of liner metal per ton milled g
24 lines of spacer blocks; no lifter bars	53 201	51,0	3,25	160,1
Alternating lines of lifter bars (12) and of spacer blocks (12)	283 000	69,0	3,0	22,2
24 lines of lifter bars; no spacer blocks	457 000	77,4	2,42	12,6

The Effect of Mill Speed on Performance

The speed at which the mill rotates would evidently be expected to control the rate of feed (and hence the residence time of the ore in the mill) for a given fineness of grind. This is amply confirmed by the results obtained in a series of tests carried out on two rod mills of equal size (9 by 12 ft, i.e. 2,7 by 3,6 m) both of which were fitted with the same arrangement of 20 lines of lifter bars. One of them rotated at 21 r/min (82 per cent of the critical speed) and the other at 19 r/min (75 per cent of the critical speed)[1]. As shown in Table II, the mill rotating at the higher speed can accept a feed rate of 108 t/h, as compared with only 67 t/h for the slower mill. The product from the slower mill contained about 20 per cent material smaller than 75 μm, compared with 8 per cent in the product from the faster mill.

The results in Table III, which express the total consumption of electrical energy in relation to the tonnage of material smaller than 75 μm in the product from three mills, show that, on this basis, the slowest mill (at East Driefontein) is the most efficient, the consumption of electrical energy being only 65 per cent of the next lowest figure. In an attempt to assess the relative efficiencies of the different mills, the harmonic mean sizes were calculated. As shown in earlier work[1], if a characteristic diameter $\bar{D}$ is defined so that the surface area per unit mass of material is $K/\bar{D}$, then

$$K/\bar{D} = K\,\Sigma_{i=1}^{n} m_i/D_i .$$

Therefore,

$$\bar{D} = (\Sigma_{i=1}^{n} m_i/D_i)^{-1},$$

where m_i is the mass fraction of the i-th screen fraction, and
D_i is the arithmetic mean of the size limits of the i-th screen fraction.

Hence the appropriate size $\bar{D}$ is a harmonic mean of the size of the screen fractions weighted according to their masses.

The harmonic mean size of the screen fractions in the feed to the three rod mills and in their products are given in Table IV.

Earlier work[1] showed that the ratio of the theoretical work done in two mills per ton of ore milled can be expressed as

$$\frac{(\bar{D}_{f1}/\bar{D}_{p1} - 1)/\bar{D}_{f1}}{(\bar{D}_{f2}/\bar{D}_{p2} - 1)/\bar{D}_{f2}}.$$

Finally, the efficiency ratio for any two mills is given by the theoretical work ratio divided by the actual work ratio:

$$\text{Efficiency ratio} = \frac{|\,T(\bar{D}_f/\bar{D}_p - 1)/\bar{D}_f W\,| \text{ Mill 1}}{|\,T(\bar{D}_f/\bar{D}_p - 1)/\bar{D}_f W\,| \text{ Mill 2}},$$

where W is the total work done, and

TABLE II

COMPARISON OF THE EFFECTS OF CHANGES IN MILL SPEED AND SPACING OF LIFTER BARS ON ROD-MILL PERFORMANCE

Mill diameter ft	Speed of mill r/min	Speed of mill % of critical	Number of lines of lifter bars	Ore milled per set of lifter bars kt	Feed rate t/h	Power consumed per ton milled kW·h	Material in product < 75 μm %
9	21	82	20	276	108	3,3	7 to 8,5
9	19	75	20	226	67	4,8	19 to 21
8	21	77	24	457	77	2,4	6 to 7

TABLE III

CONSUMPTION OF ELECTRICAL ENERGY IN RELATION TO TONNAGE OF MATERIAL SMALLER THAN 75 μm IN THE PRODUCT OF THREE ROD MILLS

Rod mill	Speed % of critical	Centre-to-centre distance of lifter bars mm	Ore milled: Total t	Ore milled: Material <75 μm in product t	Consumption of electrical energy: Total kW·h	Consumption of electrical energy: Per ton milled kW·h	Consumption of electrical energy: Per ton of material <75 μm in product kW·h
No. 1 (9 by 12 ft) East Driefontein	75	420	225 757	45 151	1 081 376	4,8	24,0
No. 2 (9 by 12 ft) Kloof	82	420	275 809	22 065	904 653	3,3	41,0
A (8 by 12 ft) Free State Saaiplaas*	77	600	282 701	18 430	851 430	3,01	45,7
A (8 by 12 ft) Free State Saaiplaas†	77	300	457 470	30 139	1 106 539	2,42	36,7

* Fitted with 12 lifter bars and 12 wave blocks

† Fitted with 24 lifter bars and no wave blocks

TABLE IV

HARMONIC MEAN SIZE OF SCREEN FRACTIONS IN THE FEED TO THREE ROD MILLS AND IN THEIR PRODUCTS

Rod mill	Harmonic mean size of the screen fractions weighted according to mass	
	Feed ($\bar{D}_f$) mm	Product ($\bar{D}_p$) mm
East Driefontein	5,74	0,0978
Kloof	2,298	0,193
Free State Saaiplaas	3,14*	0,238*
	2,24†	0,266†

* Mill fitted with 12 lifter bars and 12 wave blocks
† Mill fitted with 24 lifter bars and no wave blocks

By use of the results shown in Table II and the expression given above, the efficiency ratios of the three rod mills were calculated, the results relating to the rod mill at East Driefontein being expressed as unity (Table V).

TABLE V

CALCULATED VALUES FOR EFFICIENCY RATIOS

Rod mills	Efficiency ratios
Kloof: East Driefontein	0,69
Free State Saaiplaas*: East Driefontein	0,78
Free State Saaiplaas†: East Driefontein	0,72

* Mill fitted with 12 lines of lifter bars and 12 lines of wave blocks
† Mill fitted with 24 lines of lifter bars and no wave blocks

Compared with the rod mill at East Driefontein, the Kloof mill treats 60 per cent more material and consumes only two-thirds of the energy per ton milled. However, based on the efficient utilization of electrical energy for the creation of new surface area in the product, it is only 69 per cent as efficient. It should be noted that the mills are very similar to one another in that they have the same dimensions and the same lining design, and they are operated with an equal volume of grinding charge. The mass of ore in the mill at any given moment is relatively small compared with the mass of the mill shell, lining, and rods. It would therefore be reasonable to conclude that the energy expended (ΔW) in one revolution will be the same for each mill; ΔW can be expressed as follows:

$$\Delta W = \frac{dW}{dT} \cdot \frac{dT}{dt} \tau, \quad \text{.................................} \quad (1)$$

where

$\frac{dW}{dT}$ is the electrical energy consumed per unit mass of ore milled (kW·h/t),

$\frac{dT}{dt}$ is the feed of the ore (t/h), and

τ is the mill period (expressed for convenience, in hours, in the calculations to follow).

By use of the numerical values for these quantities given in Tables II and III,

$$\Delta W(\text{Kloof}) = \frac{3{,}3 \times 108}{21 \times 60} = 0{,}283 \text{ kW·h, and}$$

$$\Delta W(\text{East Drie}) = \frac{4{,}8 \times 67}{19 \times 60} = 0{,}282 \text{ kW·h.}$$

This confirms that the energy dissipated per revolution is the same in the two mills. The mass of ore milled per revolution is significantly different in the two mills, the ratio being

$$\frac{\left(\frac{dT}{dt} \cdot \tau\right)_{\text{East Drie}}}{\left(\frac{dT}{dt} \cdot \tau\right)_{\text{Kloof}}} = \frac{\frac{67}{19 \times 60}}{\frac{108}{21 \times 60}} = 0{,}69.$$

This ratio of the efficiencies of the two mills is exactly the value calculated earlier (Table V). It can be concluded that the ratio of the mill efficiencies can be fully accounted for by the fact that the throughput of ore per revolution is substantially less at East Driefontein than it is at Kloof. As the same energy is dissipated in one revolution in each mill, more new surface area must be created in the mill at East Driefontein than in that at Kloof.

This finding is supported by an investigation[2] into ball milling, which showed that the harmonic mean size of the mill product decreases linearly with decreasing feed rate.

Parallel calculations are not applicable to the results from the rod mill at Free State Saaiplaas, although the same mill was operating with different feed rates but also with three different lining arrangements. These different arrangements resulted in marked changes in the transmission of energy to the grinding charge and to the motions produced in it. The enormous significance of these changes in lining have already been discussed.

Whether the consumption of electrical energy in relation to the tonnage of material smaller than 75 μm produced is the correct criterion for the assessment of rod-mill efficiency is perhaps open to question. On a more practical basis, the most important function of a rod mill is to break down coarse particles (say smaller than 20 mm) as rapidly as possible and not to produce a finely ground product at a much slower feed rate, since fine grinding is the essential function of tube mills.

Mill Speed in Relation to Rod Trajectories

Higher mill speeds exert a profound influence on the trajectories of the rods. Fig. 3 shows the calculated trajectories of rods from the layer closest to the shell, $K_{(L)}$ and $ED_{(L)}$ being the trajectories in the faster and slower mills respectively. Stress is laid on the fact that these trajectories are calculated purely in relation to a rod in the layer closest to the shell, no allowance having been made for any effects that may arise from inter-rod connections and frictional forces. Nevertheless, Fig. 3 clearly suggests that, in the faster mill, the impactive effects of the falling rods on the 'toe' of the charge must be more violent and that the relative motion between layers of rods and particles of ore within the inner burden of the mill should be much more pronounced. These more violent movements of rods would be expected to enhance the desired purpose of the mill in crushing the coarse particles in the feed.

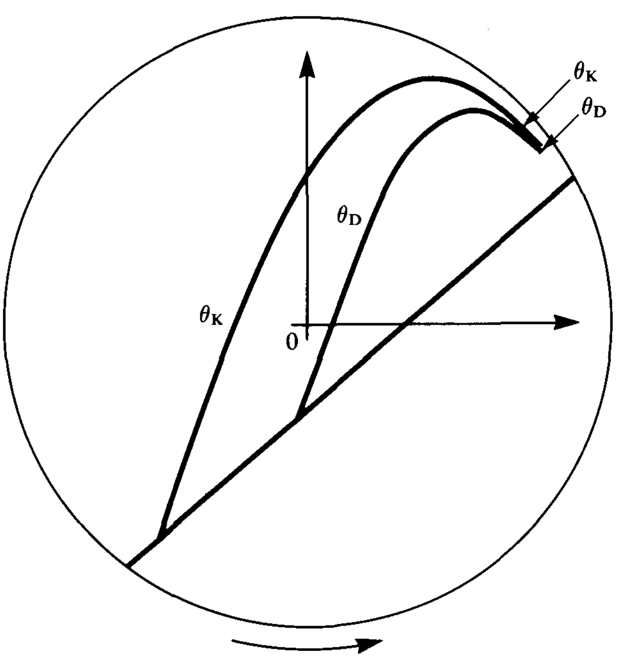

Fig. 3—Calculated trajectories of rods in the 9 by 12 ft mills at Kloof (θK) and East Driefontein (θD)

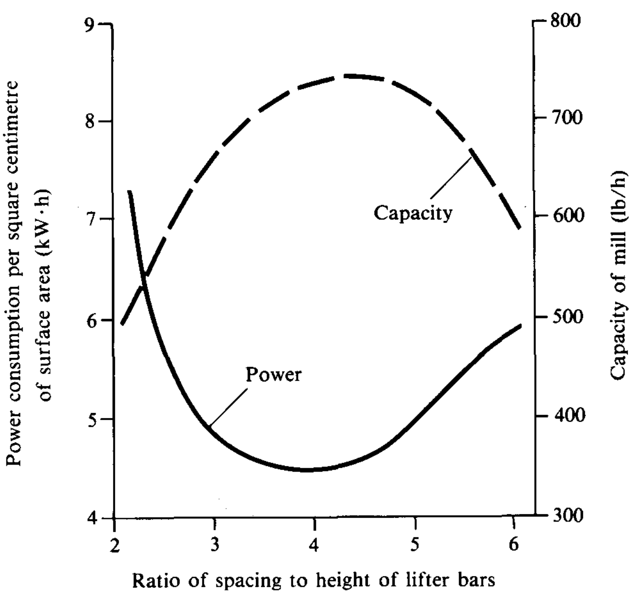

Fig. 4—Effect on capacity and power consumption of changes in the spacing-to-height ratio of lifter bars (after Meaders and McPherson[2])

Spacing-to-height Ratio of Lifter Bars

The effects on rod-mill performance of changes in the spacing-to-height ratio of lifter bars have been investigated by Meaders and McPherson[3] and by Coles and Chong[4]. Fig. 4 shows the very marked effects that Meaders and McPherson[3] obtained by changing the spacing-to-height ratio of lifter bars in an experimental mill. As is obvious, the optimum in both parameters is at a ratio of 4 to 4,5. In tests carried out on autogenous mills of large diameter (21 and 34 ft), Coles and Chong[4] report favourable results when using respective ratios of 2,3 and 1,8 for new bars. Meaders and McPherson's results suggest that a 40 per cent reduction in power consumption per ton milled may be possible if the correct spacing-to-height ratio of lifter bars is selected. The results reported in Table III conform to these findings. In the 8 ft mill fitted with 24 lines of lifter bars, the centre-to-centre distance of 300 mm, as compared with that of 420 mm in the 9 ft mills, is associated with the fact that the smaller mill takes only 73 per cent of the energy consumed by the higher-speed 9 ft mill, and grinds 65 per cent more ore before requiring new lifter bars. This suggests that the initial spacing-to-height ratio of lifter bars in the larger mill is greater than the optimum.

In the grinding of hard quartzitic gold-bearing ores, a major problem in the selection of the correct ratio is the rapid decrease in the total height of the lifter bars and the decreasing angle of contact between the lifter bar and the charge in the mill. For example, in both the 9 ft mill and the 8 ft mills, a very high rate of wear is found on the lifter bars in the ring at the feed end. A typical wear profile is shown in Fig. 5. The ratio of spacing to height increases much more rapidly than in any of the rings of bars towards the discharge end. This is probably not such a problem when a mill is grinding softer ores, since Coles and Chong[4] suggest that lifter bars should be replaced when the ratio in the type of autogenous mills they describe has risen from 2,3 to 5,5. For an optimum ratio of spacing to height to be maintained in rod mills grinding gold ores, more-frequent replacement of the lifter bars would probably be required. However, the increased consumption of metal in the lifter bars might be more than compensated for by increased savings in energy consumption and, possibly, by greater efficiency in grinding.

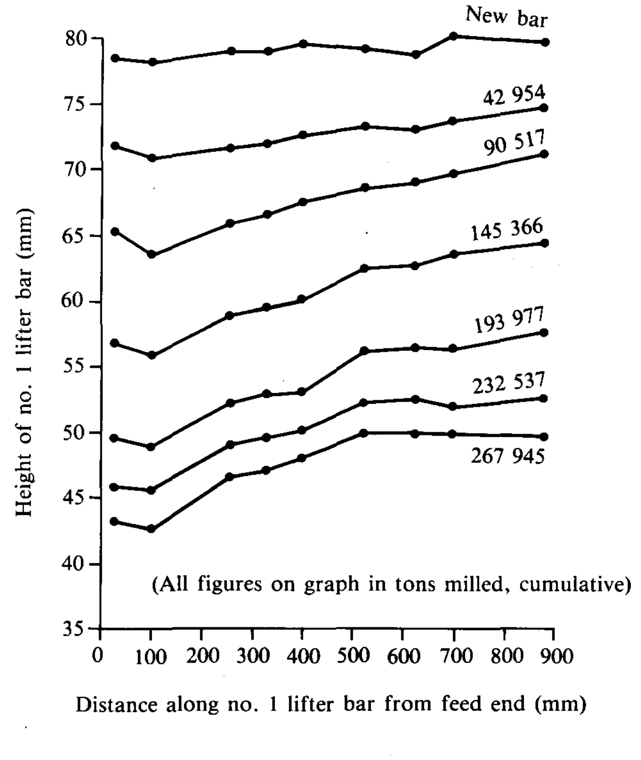

Fig. 5—No. 2 rod mill, Kloof: wear profile on no. 1 manganese-steel lifter bar, 75 to 80 mm high, installed on the 'trailing side' of a new no. 1 lifter bar 105 mm high

A practical formula for the ratio of spacing to height in lifter bars is used by the Skega company. This, however, is particularly applicable to rubber lifter bars.

Changing Heights of Lifter Bars

Further information on the effects of changes in the heights of lifter bars was obtained recently for a rod mill of 9 ft diameter[1]. By chance, the lifter bars to be used in a test line in the mill were cast to a height of 105 mm instead of the 75 mm standard height normally used. It was decided that the change in height of the bars in the test line should be monitored, and that the results should be compared with those for the adjacent line of 75 mm bars on the 'trailing side'. This line of 75 mm bars wore much more slowly than the other lines of 75 mm bars, the effect being particularly marked on the lifter bar at the feed end of the mill. The bars at the feed end suffer by far the most wear in this particular mill.

Fig. 5 shows the wear profile on the 75 mm bar that was fitted at the same time as the new 105 mm bar. When the 105 mm bar was halfway through its service life, a second 75 mm bar was fitted and the wear profile on this second 75 mm bar is shown in Fig. 6. Obviously, the rate of wear on this second bar is much faster than on the first, as is shown by a comparison of the profiles in Figs. 5 and 6. This set of observations suggested that significant savings in liner metal, and hence shorter downtimes for the replacement of worn lifter bars, might result from the use of a lining consisting of alternating lines of higher (105 mm) and lower (75 mm) lifter bars[5].

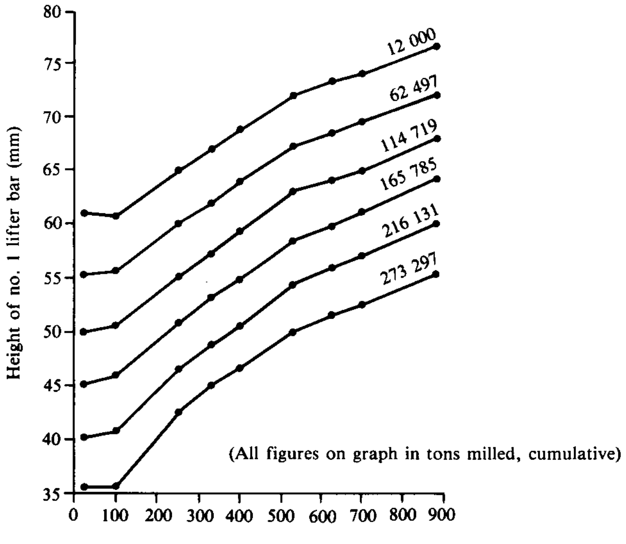

Fig. 6—No. 2 rod mill, Kloof: wear profile on replacement no. 1 manganese-steel lifter bar, 75 to 80 mm high, installed on the 'trailing side' of the original no. 1 carbon-steel lifter bar when this was halfway through its service life

Such a lining could be kept in service until the initially 'higher lifter bars' had worn down to about half of their height, when they would be regarded as lines of 'lower lifter bars'. During shut-down, the alternating lines of the original 'lower lifter bars' would be removed and replaced by lines of new 'higher lifter bars'. The suggested arrangement of alternating lines of higher and lower lifter bars is shown in Fig. 7.

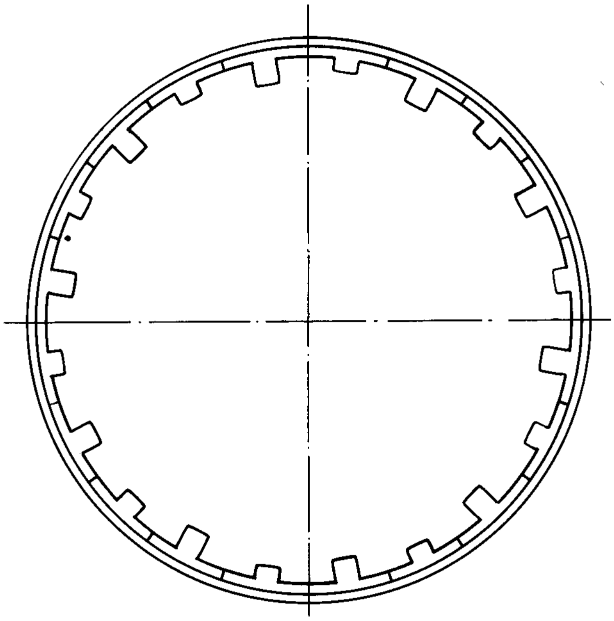

Fig. 7—Rod mill of 9 ft diameter fitted with 10 alternating lines of 105 mm bars and 10 alternating lines of 75 mm bars

This liner arrangement was tested on two complete runs, and successful results were obtained. As shown in Table VI, when only lines of 75 mm bars were used (as in former practice), all 20 lines of lifter bars had to be replaced after 275 kt of ore had been milled. When the modified arrangement of alternating lines of higher and lower lifter bars was adopted, over 370 kt of ore could be milled before the replacement of lifter bars became necessary, and only 10 lines of lifter bars had to be replaced. If due allowance is made for the greater mass of the 105 mm replacement bars, the saving in mass of the replacements was about 30 per cent. In addition, a marginal reduction of about 3 per cent was effected in the consumption of electrical energy per ton of ore milled. Fears were expressed that the higher lifter bars might cause rods to cataract onto the descending area of the mill lining, causing increased wear but, as indicated, the total wear of the lining was reduced.

TABLE VI

EFFECTS PRODUCED BY A CHANGE IN THE ARRANGEMENT OF LIFTER BARS IN THE 9 BY 12 ft ROD MILL AT KLOOF MINE

Arrangement of lifter bars in the mill	Ore milled before change of lifter bars became necessary kt	Power consumed per ton milled kW·h	Replacement of lifter bars
20 lines of 75 mm bars	276	3,28	Replace all 20 lines of bars
10 alternating lines of 105 mm bars and 10 alternating lines of 75 mm bars	370	3,18	Replace only 10 lines of bars originally 75 mm with 10 lines of 105 mm bars. Saving in lifter-bar metal 33%

Although they were previously unaware of the fact, the authors have recently been informed that it is common practice in the U.S.A. to replace alternate lines of lifter bars in semi-autogeneous mills to achieve a high–low configuration.

Lifter Bars in Large Tube Mills

Confirmation that possible benefits from the application of lifter bars could extend to mills other than rod mills was obtained from testwork carried out on a tube mill of 16 by 30 ft (4,8 by 9,0 m) at East Driefontein Mine. Staff of Gold Fields of South Africa Ltd, in conjunction with the mine staff, carried out preliminary tests to ascertain whether lifter bars could be fitted securely on top of the grid liners of manganese steel that are commonly used in this mill. These lifter bars were cast with a number of pads on the underside, which fitted into some of the recesses in the grids and were then bolted through the grids to the shell of the mill. This design proved to be highly satisfactory. The staff at Gold Fields then decided to fit the entire mill with 32 lines of lifter bars round the inner circumference of the mill, the centre-to-centre distance of the lines being 18 inches (450 mm), and the new bars projecting about 100 mm into the mill. The spacing-to-height ratio of the lifter bars when first installed was approximately 3,5.

Measurements carried out on two selected lines of lifter bars showed a progressive and roughly linear increase in the wear of the bars from the feed to the discharge end of the mill. This appears to be common in tube mills, whereas experience with rod mills indicates the opposite, i.e. severe localized wear at the feed end with reduced wear towards the discharge end. As a result of the severe wear in the large tube mill when fitted with the standard grid liners, the grids in rings 5, 6, and 7 had to be replaced first. Over a prolonged period of use, the life of rings 5, 6, and 7 was 200 days. The grids in rings 1 to 4 had shown slightly less wear, giving an average life of 220 days.

The mill was completely fitted with lifter bars on 23rd March, 1981, and new lifter bars had to be fitted on alternate lines in rings 5, 6, and 7 on 12th October, 1981, viz a life of about 7 months for half the lifter bars. On 10th November, 1981, new lifter bars were fitted to alternate lines in rings 1 to 4, a life of about 8 months for half the lifter bars. Very little wear occurred on the grid liners and, in contrast to previous experience, the grid liners did not need to be replaced until after 1500 days of service. Effectively, therefore, the average life of lifter bars throughout the mill is 12 to 16 months. A further advantage is that the dismantling of worn lifter bars and the fitting of new bars, particularly on alternating lines, is a much simpler and faster maintenance operation than the removal and replacement of complete rings of grid liners.

The arrangement of the mill units at this mine permitted direct comparisons to be made of the performance of the test mill with that of an identical mill operating with the relatively smooth lining of grids. Primary grinding is carried out by a rod mill, and the underflow from the cyclone circuit is returned to the two parallel 16 by 30 ft tube mills, the return pulp passing through a splitter that is believed to give a fairly exact half of the flow to each mill. Regrettably, there is no instrument capable of giving an accurate measure of pulp flow; therefore, it was assumed that the split between the two mills is fairly accurate. A value that can be determined reasonably accurately is the production of material smaller than 74 μm in the discharge from each of the tube mills. This, together with the metered power drawn by each mill, enables some fairly valid comparisons to be made. The relevant results from the two mills during the period of test are given in Table VII. The results are the daily figures for the material smaller than 74 μm produced and for the electrical power consumed averaged over a month.

In spite of the inevitable surges and fluctuations in performance, it is clear that tube mill no. 6 fitted with lifter bars is yielding a significantly higher tonnage (7,75 per cent) of material smaller than 74 μm per kilowatt-day and is producing that tonnage at a lower energy consumption. However, possibly the most important feature of the results is that tube mill no. 6 is drawing only 90,4 per cent of the power drawn by tube mill no. 5. This, again, is subject to fluctuations from month to month but, over a period of 13 months, the reduction in power consumption was almost 10 per cent.

That this reduction is a real feature appears to be completely confirmed by the results in Table VIII, which relate to the performance of the two mills for a period of 12 months after 32 lines of lifter bars had been fitted in tube mill no. 5. When both mills were fitted with lifter bars, the results relating to the performance of the two mills were almost identical. The average power consumption in tube mill no. 5 during this period of 12 months was 91,5 per cent of that given in Table VII for the previous period of 13 months. The effect of the lifter bars in reducing the power drawn by the mill appears to be completely confirmed, and a reduction of 8,5 to 10 per cent is indicated for these two tube mills. At a power cost of 2,5 cents per kilowatt-hour, the annual saving in power costs for each mill would be at least R40 000.

In the discussion on the use of higher lifter bars in rod mills, reference was made to fears that higher lifter bars might throw the grinding media at a higher level so that they impact upon the descending lining of the mill shell and thus give rise to excessive wear of the lining. In this connection, the information obtained on the trajectories of pebbles in this large tube mill is of interest. By the use of an instrumented bolt as a means for monitoring the trajectories, it was shown[6] that a very significant proportion of the pebble charge appears to be impacting on the descending lining of the mill, some at points above the horizontal centre line of the mill. Yet, as shown, the life of the lining in this mill proved very much longer than it was before the lifter bars were fitted. This indicates therefore that there is little basis for the fears that severe wear of the lining will result from greater cataracting throw of the grinding media.

Conclusions

(1) Lifter bars are very commonly fitted to rod mills, but the test results show clearly that additional benefits can accrue from the use of the optimum number of lines of bars in a given mill.

(2) A change in speed of a mill has substantial effects on the feed rate, power consumption, and fineness

TABLE VII

THE PERFORMANCE* OF TWO 16 BY 30 ft (4,86 BY 9,12 m) TUBE MILLS, NO. 6 MILL BEING FITTED WITH 32 LINES OF LIFTER BARS AND NO. 5 MILL WITH GRID LINERS

Tube mill no. 5				Tube mill no. 6					
Production of material <74 µm t	Total power consumed kW·h	Power consumed per ton of material <74 µm produced kW·h	Material <74 µm produced per kilo-watt-day t	Production of material <74 µm t	Total power consumed kW·h	Power consumed per ton of material <74 µm produced kW·h	Material <74 µm produced per kilo-watt-day t	Increase in production of material <74 µm per kilowatt-day of no. 6 over no. 5 %	Total power consumption in no. 6 as percentage of no. 5 %
1588,8	51 323,4	32,3	0,743	1597,5	44 758,9	28,01	0,857	15,3	87,2
1658,4	52 928,6	31,91	0,752	1644,15	48 838,3	29,70	0,808	7,4	92,2
1764,8	51 455,0	29,16	0,823	1549,89	43 590,84	28,13	0,853	3,6	84,7
1666,2	51 676,9	31,01	0,774	1537,70	46 574,48	30,29	0,792	2,3	90,1
1565,1	51 584,5	32,96	0,728	1552,53	46 101,27	29,69	0,808	11,0	89,4
1560,9	50 441,1	32,31	0,743	1542,75	45 689,82	29,62	0,810	9,0	90,6
1467,7	51 114,2	34,83	0,689	1438,89	48 970,6	34,03	0,705	2,2	95,8
1520,6	49 468,4	32,53	0,738	1491,40	46 591,29	31,24	0,768	4,0	94,2
1519,7	49 193,4	32,37	0,741	1513,40	45 023,7	29,75	0,807	8,9	91,5
1559,9	47 941,9	30,73	0,781	1515,86	44 084,0	29,08	0,825	5,6	91,9
1500,6	51 208,0	34,13	0,703	1469,80	45 479,8	30,94	0,776	10,4	88,8
1362,9	51 817,6	38,02	0,631	1345,80	45 804,16	34,04	0,705	11,7	88,4
1538,6	50 154,7	32,6	0,736	1536,98	45 845,9	29,83	0,805	9,4	91,0
Average									
1559,5	50 792,9	32,68	0,737	1518,2	45 950,2	30,33	0,794	7,75	90,4

* Daily figures for material smaller than 75 µm produced and electrical power consumed averaged over a month; the averaged results cover a period of 13 months

TABLE VIII

THE PERFORMANCE* OF TWO 16 BY 30 ft (4,86 BY 9,12 m) TUBE MILLS FITTED WITH LIFTER BARS

Tube mill no. 5				Tube mill no. 6			
Production of material <74 µm t	Total power consumed kW·h	Power consumed per ton of material <74 µm produced kW·h	Material <74 µm produced per kilowatt-day t	Production of material <74 µm t	Total power consumed kW·h	Power consumed per ton of material <74 µm produced kW·h	Material <74 µm produced per kilowatt-day t
1548,46†	49 410,5	31,91	0,752	1541,2	47 790,4	31,01	0,774
1366,2	44 939,2	32,89	0,730	1429,8	47 321,8	33,1	0,725
1498,4	46 964,06	31,34	0,766	1485,6	47 129,6	31,73	0,756
1398,15	44 621,28	31,91	0,752	1384,92	45 894,45	33,14	0,724
1455,17	46 114,35	31,69	0,757	1445,58	46 514,17	32,18	0,746
1357,15	46 690,75	34,40	0,698	1331,59	45 986,67	34,54	0,695
1449,77	47 017,52	32,43	0,740	1410,31	46 522,08	32,99	0,727
1462,22	47 379,39	32,40	0,741	1432,49	47 147,21	32,91	0,729
1486,99	47 019,64	31,62	0,759	1507,57	46 880,79	31,1	0,772
1486,70	47 455,14	31,92	0,752	1520,19	47 447,31	31,21	0,769
1506,52	47 319,39	31,41	0,764	1533,07	47 055,12	30,69	0,782
1417,64	46 512,94	32,81	0,731	1447,27	46 413,77	32,07	0,748
1530,42	46 137,70	29,86	0,804	1559,89	47 144,99	30,22	0,794
Average							
1451,02	46 514,28	32,056	0,7495	1457,35	46 788,16	32,87	0,747

* Daily figures for material smaller than 74 µm produced and electrical power consumed averaged over a month; the averaged results cover a period of 12 months

† During this period, lifter bars were fitted to no. 5 mill; the results are not included in the averages

of grind produced.

(3) The results obtained appear to confirm that the use of the optimum spacing-to-height ratio for lifter bars is of importance in the design of mills.

(4) Even simple changes within a given liner design, e.g. the fitting of alternating lines of lower and higher lifter bars, can effect significant improvements in liner life and power consumption.

(5) The fitting of lifter bars into large tube mills, as pioneered by Gold Fields of South Africa Limited, can give greatly reduced wear on the grid liners, a reduction in the power drawn by the mill, and an increase in the tonnage of material smaller than 75 μm produced per unit of power consumed.

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Engineering in disarray?*

Is the engineering profession in disarray? Recent press reports have suggested that it is. However, at the latest Board meeting of the Federation of Societies of Professional Engineers (FSPE), senior members of the profession rapped The Engineers' Association of South Africa (EASA) over the knuckles for spreading *'disinformation'*.

The learned societies, such as the Institutions of Agricultural, Civil, Electrical, Mechanical, Chemical, Industrial, and Mining and Metallurgical Engineers are quite clear in their role, which is to look after the continued *professional* development of their members. The learned societies are the whole basis of the engineering profession—the information on which engineering advances are grounded flows from the deliberations of these institutions.

The learned societies are not going to disappear—it would be irresponsible for them to do so. They represent a force in education that no other body could replace. They represent a first screening of qualifications and experience without which the South African Council for Professional Engineers (SACPE) could not function. They represent the continuity of expertise in their individual disciplines on which progress is based. Their resources are considerable, and those resources are used for the development of our land. Their Councils are elected from the most senior and respected members of the profession, whose qualifications and experience are given freely for the benefit of all members.

The learned societies have banded together in FSPE, through which they represent the voice of engineering at the highest levels in the land. They regret that EASA has seen fit to withdraw from FSPE, and, by loudly crying from outside the mainstream, has created the impression that the profession is in disarray. The FSPE Board stated clearly that it is not prepared to put up any longer with such divisive activities.

It recognizes that EASA, as a long-standing body, may have viewpoints that deserve consideration. It recognizes that EASA's voice, crying in the wilderness to which it has removed itself, may be heard to a degree that is totally unrepresentative of its numbers. However, it feels strongly that the future of the profession must be built first and foremost around developing skills in the individual disciplines, and only secondarily through the social gatherings and regional associations provided by EASA. While EASA remains outside the engineering profession, it is suggested that its members should reflect upon the above issues, and work towards persuading its leadership to stop sowing seeds of dissension. In the wilderness, there is barren ground!

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