BALL MILLS DESIGN AND OPERATION

Surging Problems and Their Avoidance

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The phenomenon of surging in a ball mill arises from the mill charge (ball and powder) oscillating within the mill shell; the oscillations being approximately those which would be executed by a solid pendulum, of the shape of the mill charge, hinged on the axis of rotation of the mill, and the motion being sustained by forces arising from the frictional force operative between the ball charge and the mill shell.

That surging arises from slipping between the charge and the mill shell is supported by the following observations: (1) Surging sometimes, though rarely, occurs when grinding materials such as cement clinker, or iron-stone which give rise to a high coefficient of friction; (2) surging rarely occurs in a mill fitted with adequate lifters.

Influence on Power Consumption

As would be expected, the surging of the charge in a ball mill is accompanied by cyclical variations in the torque necessary to drive the mill, and these torque variations give rise to surges in the current to the driving motor which are often of sufficient magnitude to throw out the circuit breakers; for example, during tests on a large tube mill the current was observed to fluctuate between 400 and 700 amperes when surging occurred. Even if this does not happen, however, such fluctuations are undesirable since, if maintained, they can lead to undue wear in, or possibly even fatigue failure of, the gear teeth and other elements of the driving mechanism.

A further important aspect of the problem is that it is probable that the grinding afficiency of the mill is reduced when surging occurs, whilst slipping between the ball charge and mill shell would be expected to lead to unduly rapid wear of the balls and mill liner and such increases in maintenance costs are highly undesirable.

Suppression in Practice

Surging is usually suppressed in practice by altering the speed of rotation of the mill or the magnitude of the ball charge, but it is desirable that sufficient information on surging should be available that the conditions may be chosen during design such that, whilst surging is eliminated, optimum grinding conditions are maintained.

The problem bas been investigated by Dr. H. E. Rose (Kings College University of London) and Mr. G. D. Blunt (now of the Ford Motor Co. Ltd.) as part of their research programme into the Dynamics of the Ball Mill in general, and the results are given in a paper to the Institution of Mechanical Engineers.

The problem was investigated by small-scale models and, although a complete analyses of all the variables has not been made, a criterion has been obtained by use of which it is possible to determine, whilst the design is still on the drawing board, wheter the charge of a proposed mill is likely to surge.

New Criterion for Design

The validity of the proposed criterion has been demonstrated by comparison with the published results relating to industrial mills; this comparison showing that all the mills considered are operated under conditions which are in accordance with those laid down in the present work. So far as is known, such a criterion has not previously been propounded, and it is believed that it is of considerable value to the designer and to the mill operator.

For the purpose of predicting the existence or non-existence of surging in a mill, it is only necessary to establish within which of two possible zones on a certain graph the point corresponding to the operating conditions of the mill falls; the relevant graph having for the abscissae the value of the ratio of the mill diameter to the ball diameter and for the ordinate the product of the mill filling and the mean coefficient of friction of the ball and powder charge of the mill. Thus, in order that a mill shall not surge, it is necessary that the mill filling and the ratio of mill diameter to ball diameter shall be so chosen in relation to the coefficient of friction, which is fixed by the nature of the material being ground, that the operating point for the mill shall within the non-surging zone on the graph mentioned.

It is suggested that if a mill can be operated under "non-surging" conditions, then, for lower first costs and maintenance costs, plain liners should be adopted, but if the mill cannot be operated under these conditions, then heavy lifters should be provided to suppress surging-even though the cost is thereby increased.