6 PLANT SIMULATION

6.1 Simulation of the quaternary plant

With the updated Microsim unit model library, plant simulation may now be attempted. The plant is divided operationally into the four subsections given in chapter 2 and these subsections are separated by stockpiles. It is the quaternary plant (SP4) which produces more than 50% of the final products and it is in this plant that changes are made to produce either two or three ore products. It is also the only sub-plant in which crushing occurs in steady state. For this reason it was decided to simulate first the quaternary plant (SP4) where a feed size distribution could also be measured. In the simulation study of this sub-plant we examine the proportion of ores produced.

The flowsheet for SP4 is given in figure 7. The following simulation study uses the new Whiten model for the shorthead crushers, the new gyradisc model for the fines crusher and the efficiency model with plant efficiency data throughout. All the relevant information for this plant was entered into Microsim.

A simulation of normal operating conditions was done using as input a measured size distribution and flow rate for streams one and three. The products of such a flowsheet are lumpy ore in stream six and fine ore in stream eight. The size distributions of these product streams are given in figure 28, together with measured values.

From the Microsim mass balance the respective flow rates of fine and lumpy ore were 770tph and 1670tph. The combined feed rate to the sub-plant was 2450tph. The mass balance is thus accurate to within half of a percent. The other source of lumpy ore is the output from the medium drum plant, whereas the output from the fine cyclone plant is also fine ore. If these output values from the medium drum and fine cyclone plants are combined with the simulated output from SP4, the overall production ratio of fine to lumpy ore for the plant is calculated to be 36:64. This is in very good agreement with the recorded ratio of 35:65 obtained during normal operation, hence validating our choice of models.

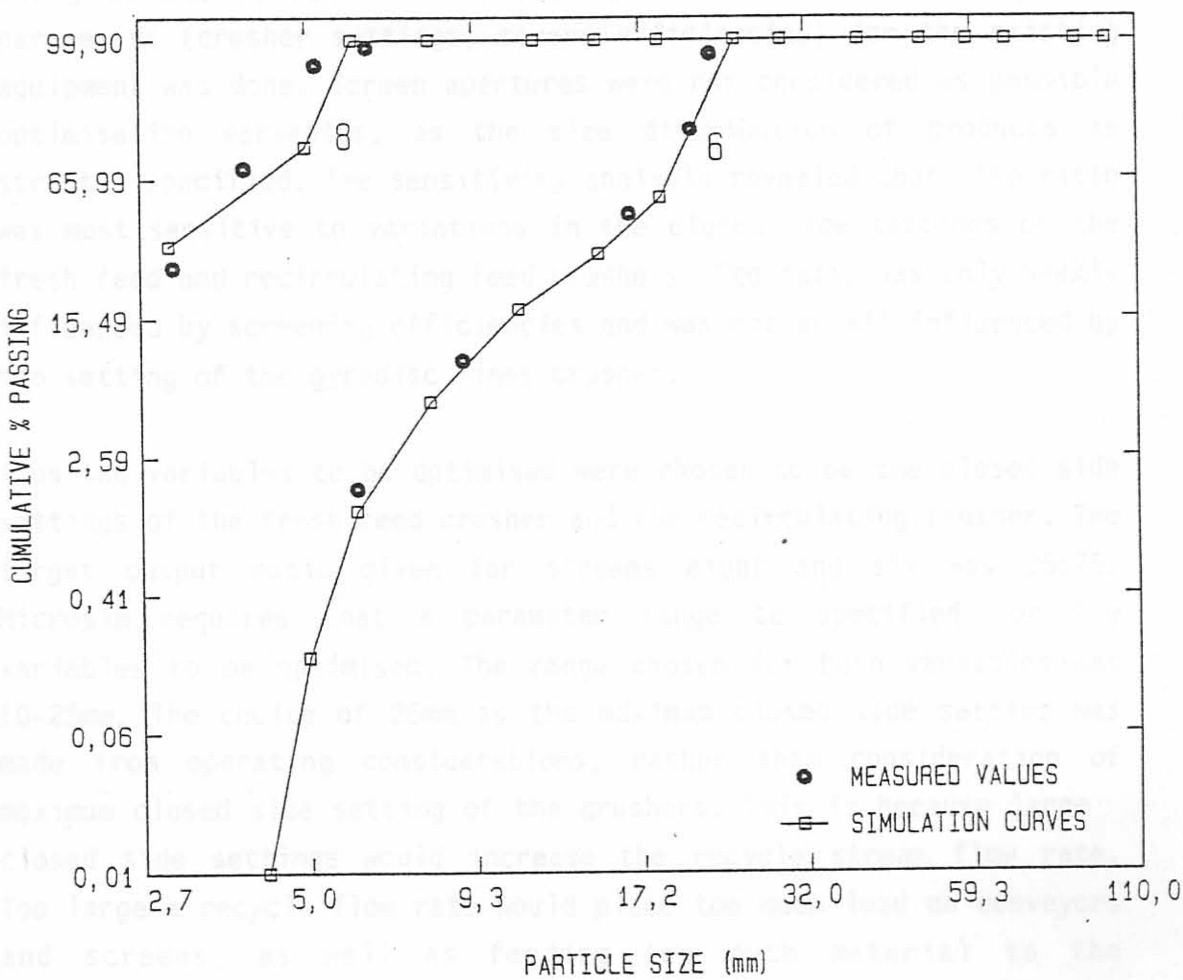

Fig 28 Rosin-Rammler plots for output streams from sub-plant 4 by simulation and measured values

6.2 Optimisation of the lumpy:fine ore ratio

It has been mentioned that the fine to lumpy ore ratio is to be improved (to 25:75 if at all possible), in order to reduce the existing fine ore stockpile. With the optimisation capability of Microsim Version 3.0, studies were done attempting to attain this ratio.

Firstly, using the simulation of the quaternary plant, a sensitivity analysis was performed. A ten percent variation in changeable parameters (crusher settings, screen efficiencies) for the existing equipment was done. Screen apertures were not considered as possible optimisation variables, as the size distribution of products is strictly specified. The sensitivity analysis revealed that the ratio was most sensitive to variations in the closed side settings of the fresh feed and recirculating feed crushers. The ratio was only weakly influenced by screening efficiencies and was not at all influenced by the setting of the gyradisc fines crusher.

Thus the variables to be optimised were chosen to be the closed side settings of the fresh feed crusher and the recirculating crusher. The target output ratio given for streams eight and six was 25:75. Microsim requires that a parameter range be specified for the variables to be optimised. The range chosen for both variables was 10-25mm. The choice of 25mm as the maximum closed side setting was made from operating considerations, rather than consideration of maximum closed side setting of the crushers. This is because large closed side settings would increase the recycle stream flow rate. Too large a recycle flow rate would place too much load on conveyors and screens, as well as feeding too much material to the recirculating feed crusher.

Using these constraints, the optimisation calculations were run using Microsim. It was necessary to change the default step size for the optimum to be reached in 20 optimisation iterations.

The optimum values of the closed side settings were given by Microsim to be 25mm for both the fresh feed crusher and the recirculating crusher. However, the target ratio of fine to lumpy ore was not reached using these settings. The increased flow rates in various streams required that some slight modifications to screening efficiencies be made by using a rule of thumb method. This did not influence the output flow rates significantly. The final flow rates of fine and lumpy ore respectively were 733tph and 1686tph. This corresponded to a ratio of 34:66 when these streams were combined with the output from the fine cyclone and medium drum plants respectively.

This improvement in ratio is small, indicating that the quaternary plant is presently running at close to the best production ratio possible with the given feed. The improvement in ore ratio should now however be economically evaluated, as the power draw to the crushers and conveyor belts will have changed.

Crushing is obviously the most important operation to determine the ratios of ores produced by the plant. In order to improve the fine to lumpy ore ratio toward the 25:75 target, modifications will have to be made in the primary to tertiary comminution units. This can be done by increasing the size distribution of the input to the quaternary plant or by improving the increasing the amount of material to the medium drum plant and decreasing that to the fine cyclone plant.

6.3 Production of direct reduction ore

When the plant is required to produce direct reduction ore in addition to fine and lumpy ore, a few modifications are made to the flow of material in the plant. The product from the coarse cyclone plant is not fed to the quaternary plant at all (i.e. stream 3 in figure 7 is eliminated). Rather, this fine cyclone plant product is screened at 5mm and the -8/+5mm material is diverted to the direct reduction ore bed with the -5mm fraction going to the fine ore bed. The gyradisc crusher is eliminated from the quaternary plant flowsheet, and the top product of the secondary screens is routed to the direct reduction ore bed. The lower decks of the primary screens are effectively replaced with screens of 11mm aperture, by using an alternate bank of screens fitted with the correct lower decks.

With this new configuration the flow rate to the quaternary plant has been reduced to 2000tph. Simulation of this flowsheet yielded the following production rates of the three ores:

359tph fine ore
468tph direct reduction ore
1166tph lumpy ore.

By combining these flow rates with the flow rate of respective ores from the fine cyclone plant, coarse cyclone plant and medium drum plant, the plant production ratio for the ores is found to be 27:21:52 (fine:direct reduction:lumpy ore). This is compared to the 29:18:53 split obtained in from operating data. Again, Microsim, using the new crushing models and using known screening efficiencies provides an accurate means of simulating this quaternary plant for different products and flow rates.

6.4 Overall plant simulation

The entire plant as given in figures 1 to 7 is sufficiently small to be used as a single flowsheet by Microsim, which has a maximum of 100 for both the total number of units and the total number of streams. However, it is better to keep the sub-plants separate to aid evaluation of results.

It is in the primary to tertiary comminution units of sub-plant 1 that further improvement to the ratio of fine to lumpy ore can be made. However, this sub-plant does not operate in a steady state throughout as the primary gyratory crusher is fed from tip trucks and units downstream experience surges of feed. These surges lessen with distance downstream. Simulation of this sub-plant will now be attempted.

As the size distribution of run-of-mine cannot be determined, the rock fragmentation model given in section 3.5 will be used to estimate this size distribution.

For the blasting procedures used in the iron ore mine a Rosin-Rammler distribution with a representative size of 633mm and an exponent of 0,92 was obtained using this model.

Sub-plant 1 was then simulated using the Nordberg gyratory model for the primary crusher, the modified Whiten model for secondary and tertiary comminution and the ideal screen model for the grizzly feed screens, together with the plant parameters. The input (which represents the rock fragmentation model) and output size distributions are shown in figure 29, together with measured values of the output of sub-plant 1.

The percentage retained at 25mm is 31%, instead of 61% as recorded on plant. This implies that the simulator overestimates the +25mm fraction of the feed to the washing and screening plant by about 50%. Hence the flow rate to the quaternary plant from the medium drum plant will show a similar error. This will give flow rates out of range for simulating the quaternary plant.

The simulated results show an output consistently coarser than that occurring in practice. This unacceptably large error could be due

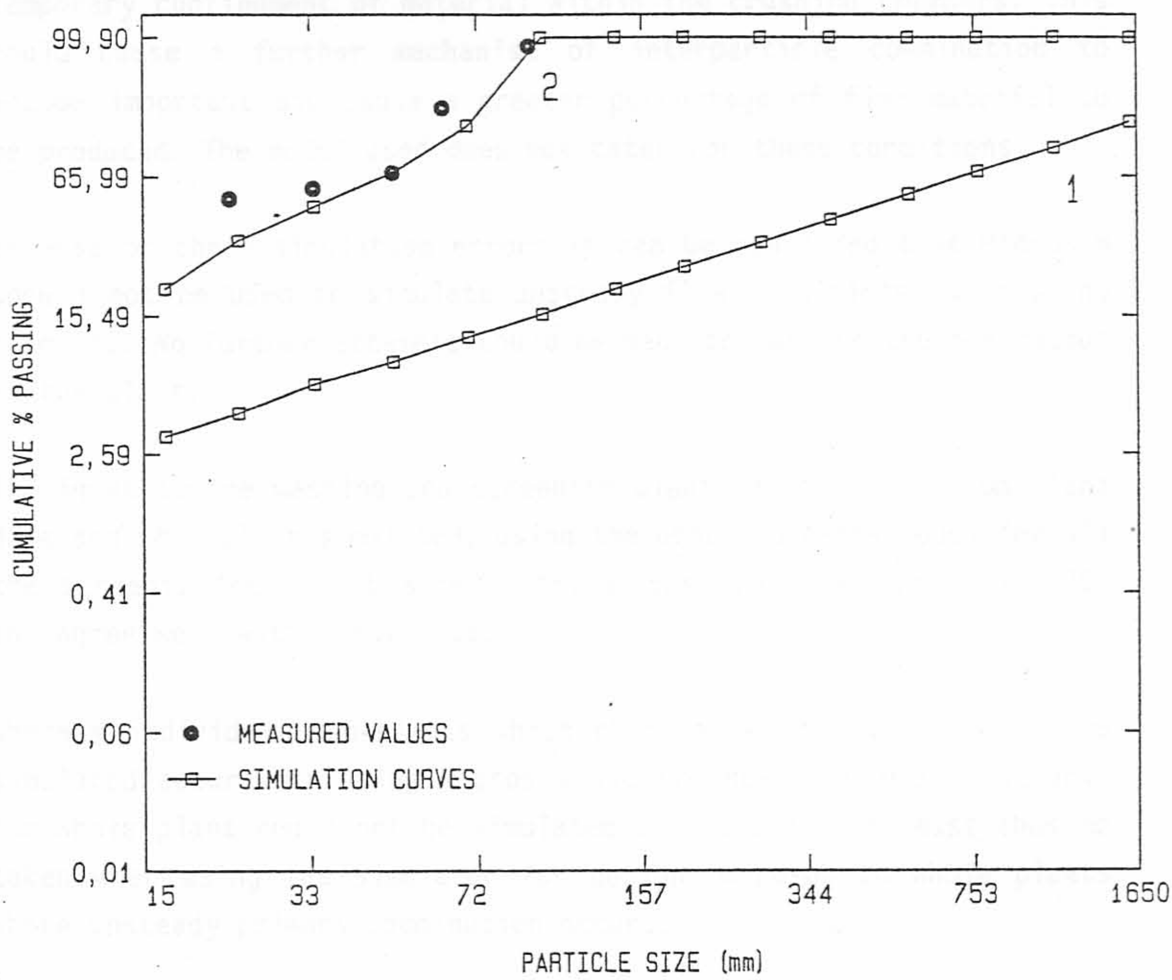

Fig 29 Rosin-Rammler plot of feed and output from sub-plant 1 by simulation, and measured values

either to inaccuracy of the gyratory crusher model, or to the lack of steady state in this sub-plant.

The Nordberg gyratory model used provides a fixed size distribution as output, regardless of input size distribution, and is a general model for any ore. This could provide erroneous results for an ore like haematite.

The surges of feed to the secondary and tertiary crushers could cause temporary confinement of material within the crushing chambers. This could cause a further mechanism of interparticle comminution to become important and cause a greater percentage of fine material to be produced. The model used does not cater for these conditions.

Because of these simulation errors it can be concluded that Microsim should not be used to simulate unsteady flow conditions in crushing circuits. No further attempts could be made to improve the ore ratios in the plant.

The input to the washing and screening plant was obtained from plant data and this plant simulated, using the enhanced Karra model for all the screens. The output size distributions are given in figure 30, and agree well with plant data.

Whereas individual sub-plants which operate in steady state may be simulated accurately using Microsim and the new unit model library, the whole plant could not be simulated accurately. Care must thus be taken when using the simulator for design purposes on whole plants where unsteady primary comminution occurs.

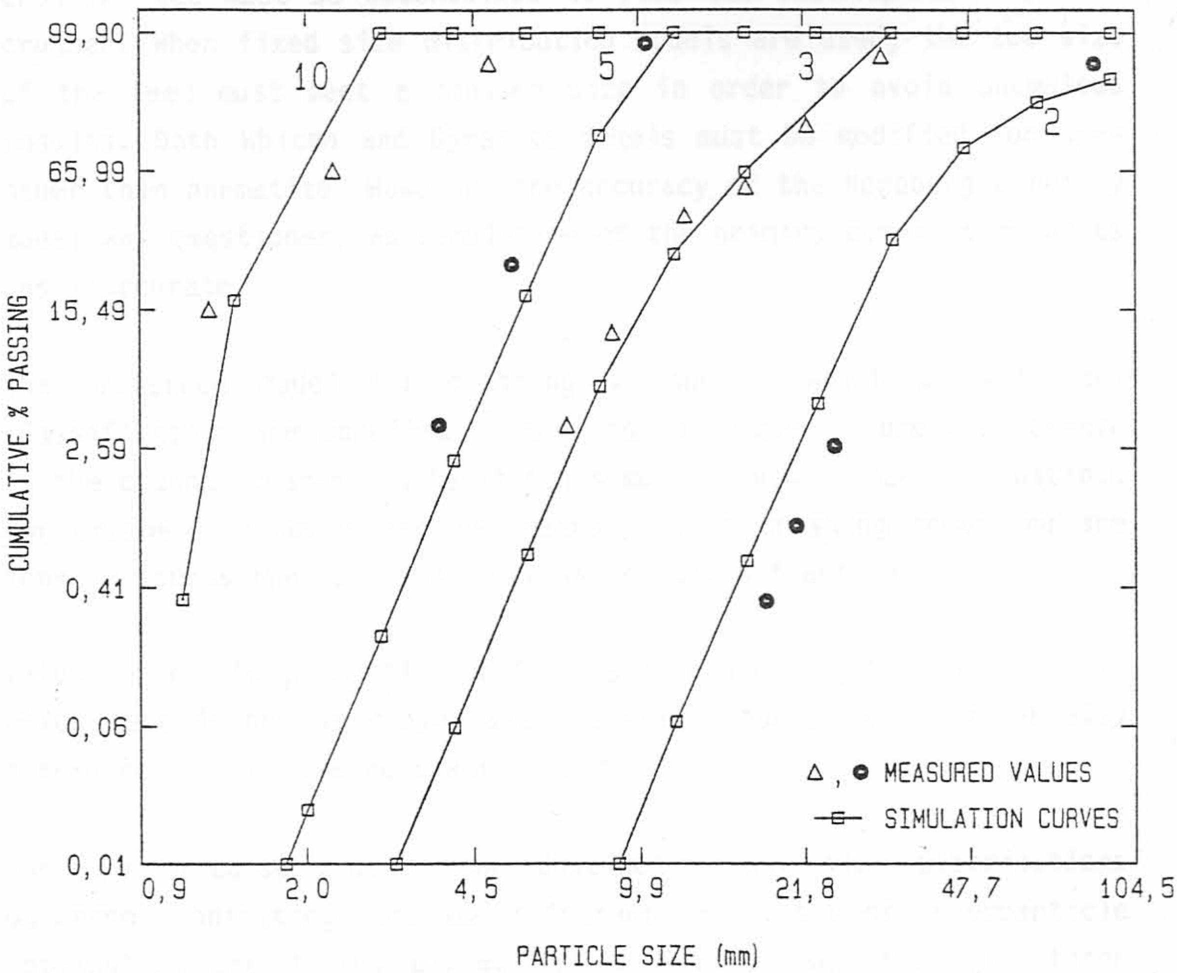

Fig 30 Rosin-Rammler plot of output from sub-plant 2 by simulation, and measured values

7 CONCLUSIONS

7.1 Crushing models

Accurate steady state crushing models have been developed which have applicability to the iron ore beneficiation plant. The models are restricted to design capacity ranges and do not apply to surge-fed or choke-fed crushing applications, where a further mechanism of interparticle comminution could be occurring. The top size of the crusher feed must be ascertained to pass the feed aperture of the crusher. When fixed size distribution models are used, the top size of the feed must meet a minimum size in order to avoid anomalous results. Both Whiten and Gyradisc models must be modified for ores other than haematite. However, the accuracy of the Nordberg Gyratory model was questioned, as simulation of the primary comminution units was inaccurate.

The preferred model for crushing is one in which breakage and classification are modelled in turn for a number of breakage events in the crusher chamber, like Whiten's model. Such a model is suitable for crushers in which the two mechanisms of crushing occurring are tensile stress fracture and compressive stress fracture.

Values of K, the proportion of fines produced during breakage events, which depends on the closed side setting, should be experimentally determined, to ensure accuracy of simulation.

For the gyradisc crusher two distinct output size distributions occurred, indicating that two different mechanisms of interparticle comminution are taking place. It is hypothesised that the finer distribution results from interparticle abrasion, whereas the coarser results from fracture by compression. It was established that the CSS is indeed the predominant parameter for gyradisc crushing of a given ore, and that feed rates are not important for values within the normal operating range.

The greatest number of size classes possible should be used when simulating crushing circuits to obtain the most accurate results. The top size should be chosen to coincide with the top size of feed, thereafter size classes should be chosen with due consideration for other units in the circuit.

7.2 Screening models

Screening is best modelled using a partition curve approach to the process, as was done in this work.

The improved Microsim is equipped to deal with all decks used on the ore benficiation plant, including poly decks with non-square apertures. Using the new models various sub-plants have been accurately simulated.

The screening models developed rely on either empirical data, or on both empirical and experimental data. The screening process is sensitive to screen motion, on which very little modelling has been done up to now. Dependence of screening performance on feed properties has been suitably modelled, either by an empirical approach, like Karra, or from a consideration of mechanism, like Ferrara & Preti. The enhanced Karra model can be used where no data exist and hence is a powerful tool for ascertaining performance of new screens.

The Rose model accounts for unsteady variation of screening performance, but this unsteady variation is irrelevant in steady-state simulation.

For accuracy to be attained when simulating screening operations, it is imperative that size classes be chosen with care, as discretisation errors of steep partition curves can become large. It is recommended that size classes also be chosen to coincide with screen apertures.

The screening models are transferable to other screening applications with little or no extra data required for the simulation.

7.3 Microsim and simulation

Microsim has been used to solve a range of simulation and optimisation problems on the ore beneficiation plant. Accuracy was high on sub-plants where steady state conditions prevailed.

It is the responsibility of the user to ensure that results are within operating ranges of equipment in the flowsheet, and to obtain consistent input data.

For crushing and screening applications, the choice of a large number of size classes is important. It is recommended that the user edit the program TYPEDEF.PAS to increase the maximum number of size classes to suit the application, observing the memory capacity of the microcomputer. If necessary, the number of grade classes may be reduced.

Optimisation should be done more than once, with various step sizes, as any premature termination of the optimisation routine will then be detected.

It is not possible to choose size classes to coincide with screen apertures if these screen apertures are variables to be optimised. This could lead to inaccurate results when a boundary and the representative size of a given class fall on different sides of the screen aperture.

The user is responsible for ensuring that model parameters which depend on optimisation variables are updated once an optimum has been found and the simulation repeated with these consistent values.

Microsim, when used skillfully, is a worthy simulator.

7.4 Closure

The improved Microsim Version 3, tailored for use on an iron-ore beneficiation plant, is a powerful tool with which process engineers and managers can assess inexpensively capabilities of the plant. It can be a valuable aid to solving many ore dressing production and design problems.

Ultimately the accuracy of Microsim depends on the quality of input data to the simulator and on the evaluative skills of the user.