LATEST DEVELOPMENTS IN MICROWAVE PROCESSING OF MINERAL ORES

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ABSTRACT

The mechanical size reduction of solids is an energy intensive and highly inefficient process. Therefore, there is great incentive to improve the efficiency of size reduction and mineral separation processes. Over several decades, this has promoted significant amounts of research,unfortunately, this has only led to small, incremental improvements in efficiency. One area which has shown significant promise for improving the efficiency of mineral comminution and separation processes is microwave assisted grinding.

Until recently the majority of testwork carried out concerning microwave treatment of minerals utilised standard multi-mode cavities, similar to that found in a conventional kitchen microwave oven. The multimode cavity whilst mechanically simple suffers from poor efficiencies and low electric field strengths, vital to high power adsorption. Whilst the influence of microwave energy from this type of cavity has been shown to have a significant influence on ores and minerals, the inefficiencies of the application method have led to conclusions that at present, microwave treatment of minerals (despite the numerous process benefits) is not viable.

More recent studies have presented studies describing the influence of high electric field strength microwave energy on minerals and ores. It is well known that microwave power density in a material (or volumetric power absorption) is directly proportional to the square of the electric field strength within the material. Therefore, it was shown that if local electric field strength can be magnified energy adsorption or heating rate can be amplified many times without the use of further energy. In turn this lead to reduced cavity residence times and reductions in the required microwave energy input per tonne. Detailed tests at the University of Nottingham have shown that in cavities with high electric field strengths the microwave energy consumption to achieve a desired reduction in strength can be as little as 2% of that required in previous work.

Investigations have been carried out on several economically important ores utilising a high electric field strength cavity for microwave treatment. A systematic approach was used in order to establish the influence of applied power level and exposure duration on each ore sample. Assessment was made of the influence of particle size on heating rate (this will have an effect on the delivery and presentation methods). During sample treatment, assessment was made of electrical energy consumption, the efficiencies of the system being calculated by standard methods. To support the test programme, results of numerical finite difference simulations are presented which illustrate the importance of microwave and ore variables on post treatment ore properties. The results of the simulations showed that if the microwave energy can be supplied to the sample very rapidly (in order of microseconds) then thermal conduction from the heated phase into the bulk ore can be minimised and thermally induced stress is maximised.

In order to validate the simulation predictions a series of experiments are reported which utilise a pulsed microwave energy delivery system on several ore types. Samples were exposed in a multimode cavity connected to a high voltage solid state modulator and pulse generator. The experimental set up was able to deliver pulses at applied power levels of 1-5MW and pulse durations of 1-4μs at frequency of 2.8GHz.

Scanning electron microscopy and image analysis were used to map the pattern of induced fracture across the pulsed treated samples. It was shown that peak power level was the major influence on the degree of fracture with the highest powers giving greater effects. It was also shown that the fracture induced was predominately grain boundary related and the fractures did not seem to run into each other causing weakening of the bulk ore structure as found in samples treated in continuous wave microwave systems. Treated and untreated samples were then processed by appropriate separation techniques to determine if more valuable mineral could be recovered as a result of treatment. It is shown that pulsed treatment positively influences the recovery of valuable minerals from the different ore types investigated.

Conclusions are made regarding the integration of pulsed microwave equipment into mineral processing flow sheets and preliminary techno-economic analyses are presented.