# Abstract

The process of drag cutting in rocks is simulated using finite element method and validated experimentally.

The process of chip formation is modelled for a two dimensional orthogonal cutting tool and is developed in two stages. In the first stage, a preliminary linear stress analysis model is developed using a safety factor contouring method for the interpretation of stresses. The safety factor contours are presented for three pick geometries (positive, zero and negative tool rake angles). This simulation model is used for predicting the peak cutting force required for chip formation and the results are compared with the experimental observations for various input parameters.

In the second stage, a far more extensive simulation model is developed using the verified finite element solution code written for the preliminary model. This model is a non-linear finite element solution scheme using a novel mathematical model for progressive rock failure incorporating the non-linear rock properties, stress releases, and geometric non-linearity. This progressive rock failure model is developed using a modified rock failure criterion for intact rocks (Balmer (1958)). A displacement increment method is adopted for simulating the drag–cutting process by moving the cutter in the direction of cutting by a fixed and sufficiently small increments, and at the same time maintaining straightness of the rake face of the tool. Two types of failures are identified, *viz*, tensile failure and shear failure. An anisotropic element is considered in plane strain for rock elements failed under tension. Shear failure is assumed to take place in a number of steps and the rock properties are modified according to its post–failure behaviour. The complete simulations showing the mode and sequence of element failure under the action of drag cutter is presented for +15°, 0° and -15° rake angle tools. The effect of various input parameters, *viz*, depth of cut, flank wear, compressive strength of the rock, and rake angle on the predicted peak cutting force is studied and compared with experimental observations.

A two dimensional transient heat transfer model is developed for the study of temperature rise during continuous drag–cutting. The simulation results, *viz*, temperature built-up with time, and maximum stabilised temperature are compared with experimental results for various input parameters. The effect of frictional force and cutting speed on the temperature developed at the pick–rock interface is also studied and compared with the experimental observations.

Experimental investigations are undertaken to generate data for the validation of the above numerical simulation models, and to study the effect of various machine operating and rock parameters on the drag–cutting responses. The investigations are taken up in two stages. For the first stage experiments, a modified shaping machine is made use to conduct drag–cutting studies on coal using a commercial shearer pick. An octagonal ring type of dynamometer is designed and the effect of cutting speed and depth of cut on the cutting responses, *viz*, cutting force, thrust force, and chip sizes is studied. In the second stage, a continuous cutting setup is developed using a heavy duty drill machine to study the temperature rise and wear rate of cutter during drag–cutting.

A versatile and reliable procedure is developed to verify the integrity of finite element codes written to solve stress analysis and heat transfer problems. The central idea of this procedure is to force the code to solve a modified form of the applicable governing equations by imposing an exact solution on the original governing equations. This results in a set of analytical residual terms which are then added to the original governing equation set. These residuals are treated as artificial body forces or source terms as the case may be and are integrated into the basic equations by taking the weighted average over the volume of the elements. Demonstration is given via examples on its use to verify finite element solution and post–processing of problems with varied geometries, and boundary conditions. The use of the procedure to check convergence of the finite element solution is also given.