FRACTURE DENSITY MODEL SYSTEM, METHODS, AND APPARATUSES

RELATED APPLICATIONS

[0001] This application claims priority to United States Provisional Patent Application No. 63/109,033, entitled FRACTURE DENSITY MODEL SYSTEM, METHODS, AND APPARATUSES, filed November 3, 2020, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to explosives. More specifically, the present disclosure relates to methods, systems, and apparatuses for predicting fragmentation size of rocks from a blast.

SUMMARY OF INVENTION

[0002a] According to a first aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises a plurality of blastholes and a free face;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from each of the plurality of blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the plurality of blastholes;

simulating a shock wave reflection at a free face of the model by simulating blasts at a plurality of ghost holes beyond the free face to determine reflective fractures in each of the plurality of volume elements;

combining the pre-existing joint fractures, the explosive fractures, and the reflective fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity.

[0002b] According to a second aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises rows of blastholes;

determining pre-existing joints in the plurality of volume elements;

sequentially simulating blasts for each of the rows of blastholes;

determining explosive fracture intensities in the plurality of volume elements from the blasts, wherein fractures from the blasts are determined after each of the rows of blastholes is detonated;

simulating a shock wave reflection from the blasts at a free face of the model to determine reflective fracture intensities in the plurality of volume elements, wherein the free face location is shifted after each of the rows of blastholes is detonated and fractures from the shock wave reflection are determined after each of the rows of blastholes is detonated using the location of the free face;

combining the pre-existing joints, the explosive fracture intensities, and the reflective fracture intensities to determine a total fracture intensity in the plurality of volume elements; and

predicting fragmentation sizes for the plurality of volume elements based on the total fracture intensity.

[0002c] According to a third aspect of the present invention, there is provided a non-transitory computer-readable storage medium, the computer-readable storage medium including instructions that when executed by a computer, cause the computer to:

segment a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises rows of blastholes;

determine pre-existing joint fractures in the plurality of volume elements;

sequentially simulate blasts for each of the rows of blastholes, and for each simulated blast:

determine explosive fractures caused directly by a blast in the plurality of volume elements;

determine a location of a dynamic free face for the model, wherein the location of the dynamic free face is shifted after each simulated blast; and

simulate a shock wave reflection at the dynamic free face of the model to determine reflective fractures in the plurality of volume elements;

combine the pre-existing joint fractures, the explosive fractures, and the reflective fractures to determine a total fracture intensity in the plurality of volume elements; and

predict fragmentation sizes for the plurality of volume elements based on the total fracture intensity.

[0002d] According to a fourth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises a plurality of blastholes and a free face;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from each of the plurality of blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the plurality of blastholes;

simulating a shock wave reflection at a free face of the model to determine reflective fractures in each of the plurality of volume elements;

combining the pre-existing joint fractures, the explosive fractures, and the reflective fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity; and

predicting fragmentation size regions in a resulting muck pile.

[0002e] According to a fifth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises a plurality of blastholes and a free face;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from each of the plurality of blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the plurality of blastholes;

simulating a shock wave reflection at a free face of the model to determine reflective fractures in each of the plurality of volume elements;

combining the pre-existing joint fractures, the explosive fractures, and the reflective fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity; and

calculating cost and time to remove material from the blast site based on the fragmentation sizes and available equipment.

[0002f] According to a sixth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises one or more blastholes and multiple geologic layers;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from the one or more blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the one or more blastholes, wherein the explosive fractures in each of the plurality of volume elements is affected by which of the geologic layers the plurality of volume elements are located within;

combining the pre-existing joint fractures and the explosive fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity.

[0002g] According to a seventh aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises one or more blastholes and multiple explosive layers representing an explosive product with varying explosive energy within the one or more blastholes;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from the one or more blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the one or more blastholes, wherein the explosive fractures in each of the plurality of volume elements is affected by the varying explosive energy;

combining the pre-existing joint fractures and the explosive fractures and the reflective fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity.

[0002h] According to an eighth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

receiving input data from sensors disposed on a drill;

determining geologic properties based on the input data;

segmenting a model of at least a portion of a blast site into a plurality of volume elements, wherein the model comprises one or more blastholes and wherein each of the plurality of volume elements includes the geologic properties;

determining pre-existing joint fractures in each of the plurality of volume elements;

simulating blasts from the one or more blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the one or more blastholes, wherein the explosive fractures in each of the plurality of volume elements is based on the geologic properties;

combining the pre-existing joint fractures and the explosive fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity.

[0002i] According to a ninth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

receiving an input specifying a desired fragmentation size;

segmenting a model of at least a portion of a blast site into a plurality of volume elements;

determining pre-existing joint fractures in each of the plurality of volume elements;

performing a plurality of simulations of blasts, each of the plurality of simulations associated with a different blast design;

determining explosive fractures in each of the plurality of volume elements from the plurality of simulations of blasts;

combining, for each of the plurality of simulations, the pre-existing joint fractures and the explosive fractures to determine a total fracture intensity in each of the plurality of volume elements;

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity for each of the plurality of simulations;

determining a final blast design from the plurality of simulations which provides a fragmentation size closest to the desired fragmentation size; and

outputting the final blast design to a graphical user interface (GUI).

[0002j] According to a tenth aspect of the present invention, there is provided a method for explosive blast modeling, the method comprising:

segmenting a model of at least a portion of a blast site into a plurality of volume elements;

determining pre-existing joint fractures in each of the plurality of volume elements;

performing a root mean squared error (RMSE) study to determine fracture density model fitting parameters for a site;

simulating blasts from one or more blastholes;

determining explosive fractures in each of the plurality of volume elements from the blasts from each of the one or more blastholes, wherein the explosive fractures in each of the plurality of volume elements is based on the fracture density model fitting parameters for the site;

combining the pre-existing joint fractures and the explosive fractures to determine a total fracture intensity in each of the plurality of volume elements; and

determining fragmentation sizes for each of the plurality of volume elements based on the total fracture intensity.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0003] To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer to the figure number in which that element is first introduced.

[0004] FIG. 1A illustrates the stresses placed on the rock element by a shock wave emitted from the blasthole in accordance with one embodiment.

[0005] FIG. 1B illustrates a resulting radial crack or fracture in the rock element in accordance with one embodiment.

[0006] FIG. 2A illustrates a 3D model of a portion of a blast site in accordance with one embodiment.

[0007] FIG. 2B illustrates the 3D model segmented into a plurality of volume elements in accordance with one embodiment.

[0008] FIG. 3A illustrates a top planar view of the 3D model before any simulated blasts in accordance with one embodiment.

[0009] FIG. 3B illustrates a top planar view of the 3D model after simulated blasts from the first blasthole and the second blasthole in accordance with one embodiment.

[0010] FIG. 4 illustrates vector mechanics equations that may be used in fracture density modeling (FDM) for calculation of distance functions and detection of charge positions with respect to a rock element in the blast, in accordance with one embodiment.