

Claims

1. An explosive delivery system comprising:
 - a first reservoir configured to store an energy-modulating agent;
 - a second reservoir configured to store an energetic substance;
 - a mixer configured to combine the energetic substance and the energy-modulating agent into an explosive, the mixer operably connected to the first reservoir and the second reservoir;
 - a delivery device operably connected to the mixer, the first reservoir, and the second reservoir, wherein the delivery device is configured to deliver the explosive into a blasthole;
 - and
 - processor circuitry to:
 - receive dimensions of the blasthole;
 - determine any change points within a geologic profile, wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole;
 - segment the blasthole into one or more groups separated by any identified change points;
 - determine a target explosive energy for each group based on a representative geologic value for each group, thereby generating a target energy profile comprising target explosive energy values along the length of the blasthole; and
 - control a flow rate of the energy-modulating agent to the mixer to vary an energy of the explosive as needed according to the target energy profile.
2. The explosive delivery system of claim 1, wherein the processor circuitry is further to:
 - determine that a first explosive group at a first energy value has been delivered to the blasthole and that a second explosive group at a second energy value is to be delivered to the blasthole; and
 - modify the flow rate of the energy-modulating agent such that the explosive delivered by the delivery device has the target explosive energy value associated with the second explosive group.
3. The explosive delivery system of claim 1 or claim 2, further comprising a memory storage device to store a table comprising target explosive energy values for a plurality of representative geologic values, wherein to determine the target explosive energy value for each group, the processor circuitry accesses the table and locates the target explosive energy value based on the representative geologic value associated with each group.
4. The explosive delivery system of claim 3, wherein the target explosive energy value associated with each representative geologic value is based at least partially on blast performance from one or more test charges.

5. The explosive delivery system of any one of claims 1-4, wherein the energy-modulating agent comprises a density-reducing agent, wherein the energetic substance comprises an emulsion matrix, wherein the explosive comprises an emulsion explosive, wherein the target explosive energy values comprise target emulsion density values, and wherein the target explosive energy profile comprises a target density profile.
6. The explosive delivery system of claim 5, wherein the density-reducing agent comprises a chemical gassing agent.
7. The explosive delivery system of any one of claims 1-6, wherein the processor circuitry is further to receive the geologic profile.
8. The explosive delivery system of any one of claims 1-7, wherein the processor circuitry is further to generate a geologic profile based on geologic data, wherein the geologic data optionally includes data determined directly or indirectly from seismic data, drilling data, drill cuttings, core samples, or combinations thereof, and optionally wherein the drill cuttings, core samples, or both may be analyzed using x-ray or gamma-ray fluorescence, scanning electron microscopy, other spectroscopy and microscopy techniques, and combinations thereof.
9. The explosive delivery system of claim 8, wherein the processor circuitry is further to receive drilling data, a diameter of the blasthole, and the length of the blasthole.
10. The explosive delivery system of any one of claims 1-9, wherein the processor circuitry is further to determine the representative geologic value for each group.
11. The explosive delivery system of claim 10, wherein the representative geologic is defined by a probability distribution, a maximum value, or a minimum value.
12. The explosive delivery system of any one of claims 1-11, wherein the processor circuitry is further to monitor a delivery rate of an emulsion matrix to determine, based on the dimensions of the blasthole, a current group of the blasthole.
13. The explosive delivery system of any one of claims 1-12, wherein the delivery device comprises a delivery conduit and the mixer is located proximal an outlet of the delivery conduit.
14. The explosive delivery system of claim 13, wherein the delivery conduit is configured to introduce a density-reducing agent to an emulsion matrix proximal an inlet of the mixer.
15. The explosive delivery system of any one of claims 1-14, wherein the processing circuitry is further to receive feedback comprising fragmentation size data from a previous blast and adjust the target energy profile for a future blast so that fragments from the future are closer to a target size.
16. The explosive delivery system of claim 15, wherein to adjust the target energy profile, the processing circuitry adjusts the geologic values or target explosive energy.
17. A method of delivering explosives comprising:

receiving dimensions of a blasthole;
determining any change points within a geologic profile;
segmenting the geologic profile into one or more groups separated by any identified change points;
determining a target explosive energy value for each group based on a representative geologic value for each group, thereby generating a target explosive energy profile comprising target explosive energy values for each group; and
delivering an explosive with explosive energy values according to the target explosive energy profile.

18. The method of delivering explosives of claim 17, wherein the wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole.

19. The method of delivering explosives of claim 17, wherein the wherein the geologic profile comprises geologic values representing geologic characteristics along a blast pattern.

20. The method of delivering explosives of claim 17, wherein determining any change points comprises:

calculating a cumulative difference between actual geologic values and a mean of the geologic values; and

determining a first peak value of the cumulative difference.

21. The method of delivering explosives of claim 18, further comprising comparing the first peak value to statistical noise in the actual geologic values and identifying the first peak value as a change point if the first peak value exceeds statistical noise.

22. The method of delivering explosives of claim 21, wherein comparing the first peak value to statistical noise in the actual geologic values and identifying the first peak value as a change point if the first peak value exceeds statistical noise comprises:

randomizing the actual geologic values to generate a plurality of randomly ordered geologic profiles;

calculating a cumulative difference and peak value for each of the plurality of randomly ordered geologic profiles;

determining the percentage of random peak values that exceed the first peak value; and

identifying the first peak value as a change point if the percentage is less than a selected confidence value.

23. The method of delivering explosives of any one of claims 20-22, further comprising identifying any additional change points by iteratively determining additional peak values of portions of the geologic values bounded by one or more previously determined change points and comparing each of the additional peak values to statistical noise in the relevant

portions of the actual geologic values, and identifying each of the additional peak values as a change point if each of the additional peak values exceeds statistical noise.

24. The method of delivering explosives of any one of claims 17-23, wherein determining a target explosive energy value for each group based on a representative geologic value for each group comprises determining a target emulsion density value for each group based on the representative geologic value for each group and wherein the target explosive energy profile comprises a target emulsion explosive density profile, and further comprising determining a maximum number of density changes achievable by delivery system equipment, a control system, or both.

25. The method of delivering explosives of claim 24, wherein determining the maximum number of density changes achievable by the delivery system equipment comprises evaluating the following: parameters of a blasthole, flow rate of delivery system equipment, and control system for the delivery system equipment.

26. The method of delivering explosives of claim 25, wherein the parameters of the blasthole include a blasthole length and a blasthole diameter.

27. The method of delivering explosives of any one of claim 17-26, further comprising modifying the target explosive energy profile with a stemming length, an air decking location and length, another region devoid of explosive, or combinations thereof.

28. The method of delivering explosives of any one of claims 17-27, wherein no change points are identified and a single target explosive energy value is used for the blasthole.

29. The method of delivering explosives of any one of claims 17-28, wherein multiple change points are identified, resulting in multiple groups with different explosive energy values.

30. The method of delivering explosives of any one of claims 17-29, wherein there are three or more different groups.

31. A method of determining an emulsion explosive density profile for a blasthole, the method comprising:

determining any change points within a geologic profile, wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole;

segmenting the blasthole into one or more groups separated by any identified change points; and

determining a target emulsion density for each group based on a representative geologic value for each group, thereby generating a target density profile comprising target emulsion density values along the length of the blasthole.

32. An explosive delivery system comprising:

a first reservoir configured to store an energy-modulating agent;

a second reservoir configured to store an energetic substance;
a mixer configured to combine the energetic substance and the energy-modulating agent into an explosive, the mixer operably connected to the first reservoir and the second reservoir;
a delivery device operably connected to the mixer, the first reservoir, and the second reservoir, wherein the delivery device is configured to deliver the explosive into a blasthole;
and

processor circuitry to:

receive a blast pattern comprising location data of a plurality of blastholes;
receive geologic values associated with the plurality of blastholes;
segment the blast pattern into one or more groups of blastholes;
determine a target explosive energy for each group of blastholes based on a representative geologic value for each group of blastholes, thereby generating a target energy profile comprising target explosive energy values for each blasthole in the plurality of blastholes; and
control a flow rate of the energy-modulating agent to the mixer to deliver, via the delivery device, the explosive with a target explosive energy value to the blasthole according to the target energy profile.

33. The explosive delivery system of claim 32, wherein the geologic values represent geologic characteristics of the plurality of blastholes, and wherein the geologic values comprise an average geologic value for each of the plurality of blastholes.

34. The explosive delivery system of claim 32, wherein an available amount of explosive material is used to determine the target explosive energy for each group.

35. The explosive delivery system of claim 32, wherein the processor circuitry is to determine any change points in the geologic values along a distance of the blast pattern.

36. The explosive delivery system of claim 32, wherein the processor circuitry is further to:

determine that the explosive has been delivered to a first group of blastholes at a first energy value and that the explosive is to be delivered at a second energy value to a second group of blastholes; and

modify the flow rate of the energy-modulating agent such that the explosive delivered by the delivery device to the second group of blastholes has the target explosive energy value associated with the second group of blastholes.

37. The explosive delivery system of any of claims 32-36, further comprising a memory storage device to store a table comprising target explosive energy values for a plurality of representative geologic values, wherein to determine the target explosive energy value for each group of blastholes, the processor circuitry accesses the table and locates the target

explosive energy value based on the representative geologic value associated with each group of blastholes.

38. The explosive delivery system of claim 37, wherein the target explosive energy value associated with each representative geologic value is based at least partially on blast performance from one or more test charges.

39. The explosive delivery system of any one of claims 32-38, wherein the energy-modulating agent comprises a density-reducing agent, wherein the energetic substance comprises an emulsion matrix, wherein the explosive comprises an emulsion explosive, wherein the target explosive energy values comprise target emulsion density values for each of the blastholes, and wherein the target energy profile comprises a target density profile for each of the blastholes.

40. The explosive delivery system of any one of claims 32-39, wherein the processing circuitry is further to receive feedback comprising fragmentation size data from a previous blast and adjust the target energy profile for a future blast so that fragments from the future are closer to a target size.

41. The explosive delivery system of claim 40, wherein to adjust the target energy profile, the processing circuitry adjusts the geologic values or target explosive energy.