# SYSTEMS FOR AUTOMATED LOADING OF BLASTHOLES AND METHODS RELATED THERETO

## RELATED APPLICATIONS

**[0001]** This application claims priority to United States Provisional Application No. 62/623,094 filed January 29, 2018, and titled "Systems for Automated Loading of Blastholes and Methods Related Thereto," and U.S. Provisional Application No. 62/782,917 filed December 20, 2018, and titled "Systems for Automated Loading of Blastholes in a Blast Pattern and Methods Relating Thereto," which are both hereby incorporated by reference in their entireties.

## TECHNICAL FIELD

**[0002]** The present disclosure relates generally to explosives. More specifically, the present disclosure relates to systems for delivering explosives and methods related thereto. In some embodiments, the methods relate to automated loading of blastholes and methods related thereto.

## SUMMARY OF INVENTION

**[0002A]** In one aspect, there is provided a method of delivering explosives which can include: receiving dimensions of a blasthole; determining any change points within a geologic profile, wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern, wherein determining any change points comprises: calculating a cumulative difference between actual geologic values and a mean of the geologic values, wherein the actual geologic values and the mean of the geologic values are associated with increments of the geologic profile, wherein the cumulative difference is determined by sequentially determining, for each increment, a current increment's cumulative difference by summing a prior increment's cumulative difference and a difference between the current increment's value and the mean; and determining a first peak value of the cumulative difference as a change point; 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.

**[0002B]** In another aspect, there is provided a method of delivering explosives which can include: receiving dimensions of a blasthole; determining any ~~change~~ inflection points within a geologic profile wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern; segmenting the geologic profile into ~~one or more~~ groups separated by any identified ~~change~~ inflection 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 the target explosive energy value~~s~~ for each group, 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; and delivering an explosive with explosive energy values according to the target explosive energy profile.

**[0002C]** In yet another aspect, there is provided a method of delivering explosives which can include: receiving dimensions of a blasthole; determining any ~~change~~ inflection points within a geologic profile wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern; segmenting the geologic profile into ~~one or more~~ groups separated by any identified ~~change~~ inflection 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 the target explosive energy value~~s~~ for each group, 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 delivering an explosive with explosive energy values according to the target explosive energy profile.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0003]** The embodiments disclosed herein will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. The drawings depict primarily generalized embodiments, which embodiments will be described with additional specificity and detail in connection with the drawings in which:

**[0004]** FIG. 1 illustrates a side view of one embodiment of a truck equipped with a system for automatically adjusting the density of an emulsion explosive for various segments in a blasthole.

**[0005]** FIG. 2A illustrates a flow chart of one embodiment of a method of delivering explosives.

**[0006]** FIG. 2B illustrates a flow chart of one embodiment of a method of delivering explosives based on geological characteristics of a blasthole with varying target explosive energy within a blasthole.

**[0007]** FIG. 3 illustrates a flow chart of one embodiment of a method of determining change points of a hardness profile of a blasthole.

**[0008]** FIG. 4 illustrates an example hardness profile plotted for a blasthole.

**[0009]** FIG. 5A illustrates an example cumulative difference calculated for the hardness profile of FIG. 4, plotted against randomly ordered hardness profiles using the same hardness values of the hardness profile of FIG. 4.

**[0010]** FIG. 5B depicts a graph of a distribution of the difference between the maximum and minimum values of the cumulative difference of the randomly ordered hardness profiles of FIG. 5A.

Claims

1. A method of delivering explosives comprising:

receiving dimensions of a blasthole;

determining any change points within a geologic profile, wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern, wherein determining any change points comprises:

calculating a cumulative difference between actual geologic values and a mean of the geologic values, wherein the actual geologic values and the mean of the geologic values are associated with increments of the geologic profile, wherein the cumulative difference is determined by sequentially determining, for each increment, a current increment's cumulative difference by summing a prior increment's cumulative difference and a difference between the current increment's value and the mean; and

determining a first peak value of the cumulative difference as a change point;

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.

2. The method of delivering explosives of claim 1, wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole.

3. The method of delivering explosives of claim 1, wherein the geologic profile comprises geologic values representing geologic characteristics along a blast pattern.

4. The method of delivering explosives of claim 1, 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.

5. The method of delivering explosives of claim 4, 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.

6. The method of delivering explosives of claim 1, 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.

7. The method of delivering explosives of claim 6, further comprising determining a maximum number of density changes achievable by delivery system equipment, a control system, or both, 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.

8. A method of delivering explosives comprising:

receiving dimensions of a blasthole;

determining any inflection points within a geologic profile, wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern;

segmenting the geologic profile into groups separated by any identified inflection 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 the target explosive energy value for each group,

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; and

delivering an explosive with explosive energy values according to the target explosive energy profile.

9. The method of delivering explosives of claim 8, wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole.

10. The method of delivering explosives of claim 8, wherein the geologic profile comprises geologic values representing geologic characteristics along a blast pattern.

11. The method of delivering explosives of claim 8, 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.

12. A method of delivering explosives comprising:

receiving dimensions of a blasthole;

determining any inflection points within a geologic profile, wherein the geologic profile comprises values representing geologic characteristics along a length of the blasthole or along a distance of a blast pattern;

segmenting the geologic profile into groups separated by any identified inflection 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 the target explosive energy value for each group,

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

delivering an explosive with explosive energy values according to the target explosive energy profile.

13. The method of delivering explosives of claim 12, wherein the geologic profile comprises geologic values representing geologic characteristics along a length of the blasthole.

14. The method of delivering explosives of claim 12, wherein the geologic profile comprises geologic values representing geologic characteristics along a blast pattern.

15. The method of delivering explosives of claim 12, wherein determining any inflection 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.

16. The method of delivering explosives of claim 12, further comprising comparing the first peak value to statistical noise in the actual geologic values and identifying the first peak value as an inflection point if the first peak value exceeds statistical noise.

17. The method of delivering explosives of claim 16, wherein comparing the first peak value to statistical noise in the actual geologic values and identifying the first peak value as an inflection 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 an inflection point if the percentage is less than a selected confidence value.

18. The method of claim 12, wherein the explosive comprises an emulsion.