SYSTEM AND METHOD FOR BLASTING PARAMETER SELECTION

Field of Invention

The invention relates to method and system for optimizing productivity of a blasting operation, and more particularly to system and method for blasting parameter selection to predict and improve productivity of an abrasive grit blasting operation, for example, a rust/paint removal process in a shipyard.

Background

Abrasive grit blasting operation has been widely used in marine and offshore industry, especially a rust/paint removal process in a shipyard. Various solutions have been proposed to improve the performance of a blasting operation, e.g. some solutions aim at predicting an erosion rate by analysing grit-workpiece interaction during the blasting process. However, existing solutions are complicated and time-consuming because of the following reasons.

Firstly, a multiplicity of parameters are required to be collected or measured to implement the existing solutions for predicting blasting parameters, such as particle properties, air fluid properties, workpiece properties, particle impact speed and angle, particle-particle interaction, etc. Moreover, collection or measurement of some parameters is extremely difficult, for example, the particle impact angle can only be measured on the production site with a very expensive and complex experimental setup. Further, it is also impossible to accurately predict these parameters by simulation methods due to the difficulties in

characterizing features/arrangement of a production setup used in the process, e.g. hose arrangement, pressure fluctuation, etc.

In addition, none of the existing solutions is applicable to predict and optimize the productivity of a rust/paint removal process in a shipyard.

It is therefore desirable to provide a simple and effective solution for predicting and optimizing the productivity of a blasting operation, especially for a rust/paint removal process.

Summary of Invention

Embodiments of the invention provide a solution for selecting a blasting parameter, e.g. blasting gun speed, used in a rust/paint removal process to further improve the productivity thereof.

According to the first aspect of the invention, a system for blasting parameter selection is provided. The system comprises:

an image calibration module configured to calibrate an image of a work surface of a blasting operation, wherein the image is captured by a camera and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera;

a cutting power model determination module configured to ascertain a cutting power model based on at least two blasting spots in the calibrated image; and

a blasting parameter selection module configured to select a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

In some embodiments, the cutting power model determination module may be configured to ascertain the cutting power model by using a regression method, e.g. a standard linear least square method.

In some embodiments, the cutting power model determination module is further configured to ascertain the cutting power model based on a radius value of each of the at least two blasting spots, a cutting power value corresponding to each of the at least two blasting spots and a predetermined functional relationship between cutting power and radius of a blasting spot.

In some embodiments, the image calibration module is further configured to estimate the plurality of calibration parameters of the camera by using a predetermined calibration pattern. In one example, the predetermined calibration pattern may include a checkerboard consisting of a plurality of squares.

In some embodiments, the blasting parameter selection module is further configured to calculate a productivity value corresponding to each of a plurality of predetermined gun speed values based on the ascertained cutting power model, and select a gun speed value corresponding to the maximum productivity value, as the blasting gun speed to be used in the blasting operation, wherein the plurality of predetermined gun speed values are ascertained based on the upper limit gun speed value of the blasting system.

According to a second aspect of the invention, a method for blasting parameter selection is provided. The method comprises:

calibrating an image of a work surface of a blasting operation, wherein the image is captured by a camera and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera;

ascertaining a cutting power model for the blasting operation based on at least two blasting spots in the calibrated image by using a standard linear least square method; and

selecting a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

Brief Description of the Drawings

The invention will be described in detail with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a system for blasting parameter selection according to one embodiment of the invention;

Figure 2(a) shows the relationship between radius of a blasting spot and blasting time in a blasting operation;

Figure 2(b) shows the relationship between cutting power and radius of the blasting spot in the blasting operation in Figure 2(a);

Figure 3 is a flow chart illustrating a method for blasting parameter selection according to one embodiment of the invention;

Figure 4(a) shows a cutting power spectrum of a blasting operation on a work surface according to one example of the invention;

Figure 4(b) shows two adjacent single linear paths of the blasting gun according to one example of the invention;

Figure 5(a) shows the image captured by the camera and input into the image calibration module in Experiment I;

Figure 5(b) shows the image calibrated by the image calibration module;

Figure 6(a) shows the cutting power model ascertained by the eight selected blasting spots in Experiment I;

Figure 6(b) shows the validation results indicating the prediction errors corresponding to the seven selected blasting spots respectively;

Figure 7(a) shows the actual measurement results of the linear path width when the blasting gun speed values are selected as 10 mm/s to 100 mm/s;

Figure 7(b) shows a comparison between the actual measurement results in Figure 7(a) with the corresponding prediction results obtained by using the method proposed by embodiments of the invention;

Figure 8(a) shows the predicted productivity values corresponding to different blasting gun speed values from 0 mm/s to 100 mm/s.

Figure 8(b) shows the work surface on which a blasting operation with the gun speed value corresponding to the productivity value of 12 m^2/h is performed.

Detailed Description of Embodiments of the Invention

In the following description, numerous specific details are set forth in order to provide a thorough understanding of various illustrative embodiments of the invention. It will be understood, however, to one skilled in the art, that embodiments of the invention may be practiced without some or all of these specific details. It is understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the invention.

Embodiments of the invention provide a solution for selecting a blasting parameter for a rust/paint removal blasting process to predict and further improve the productivity of the blasting operation. In this solution, a relationship between various parameters of a blasting operation and surface finish of a blasted area is established to properly select a blasting parameter to be used in the blasting operation, e.g. blasting gun speed.

In embodiments of the invention, the following assumptions have been made:

(1) The rust/pain level is uniform, and

(2) The blasting gun is arranged to be perpendicular to the work surface at a constant distance, and

(3) The rust/paint on the work surface is to be removed by micro-cutting caused by solid particles, e.g. sand, steel grit, which are forcibly projected toward/onto the work surface, and

(4) The amount of cutting energy required to remove the same depth of rust/paint is the same.

(5) A blasted area refers to an area with a minimum quality of SA2.5, meaning thorough blast cleaning of rust/paint on the surface.

Figure 1 is a schematic diagram of a system for blasting parameter selection according to one embodiment of the invention. As shown in Figure 1, the blasting parameter selection system 100 includes an image calibration module 101, a cutting power model determination module 102 and a blasting parameter selection module 103.

The image calibration module 101 is configured to calibrate an image of a work surface of a blasting operation, wherein the image is captured by a camera 110 and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera 110.

The plurality of calibration parameters may include intrinsic parameters of the camera which allow a mapping between camera coordinates and pixel coordinates in the image frame, and extrinsic parameters which define the location and orientation of the camera with respect to the world frame. In some embodiments, to simplify the calibration process, the calibration parameters may be pre-determined and stored in the image calibration module 101, e.g. when the position of the camera used for capturing the image of the work surface remains unchanged with respect to the work surface.

Alternatively, in some other embodiments, to obtain more accurate calibration parameters, the image calibration module 101 may be further configured to estimate the calibration parameters of the camera 110. As the

method for estimating the calibration parameters of a camera is well known to a person skilled in the art, it will not be explained in detail. In one example, to estimate the calibration parameters, the image calibration module 101 may be further configured to extract corner points; calculate holography matrix and calculate transformation matrix. The cutting power model determination module 102 is configured to ascertain a cutting power model based on at least two blasting spots in the calibrated image. In some embodiments, the cutting power model determination module 102 may be configured to ascertain the cutting power model by using a regression method, e.g. a standard linear least square method. In some embodiments, the image calibration module may be further configured to estimate the plurality of calibration parameters of the camera by using a predetermined calibration pattern. The predetermined calibration pattern may include a checkerboard consisting of a plurality of squares.

In some embodiments, the cutting power model may be ascertained based on the Equation (1) below:

$$P_{cutting}(r) = Ae^{-Br} \quad (1)$$

where $P_{cutting}(r)$ is **the cutting power at radius r**, which is equal to the reciprocal of the blasting time required to obtain a blasting spot with the radius r, as shown in Equation (2),

$$P_{cutting}(r) = 1/t_{blasting} \quad (2)$$

where $t_{blasting}$ is the blasting time required for obtaining a SA 2.5 blasting spot of radius r,

where A and B in Equation (1) are coefficients associated with the cutting power model, which vary with changing of blasting parameter settings, such as pressure, grit federate, hose type, nozzle type, etc. That is to say, coefficients A and B can be used to define different blasting operation/setup, and once

coefficients A and B are determined, the functional relationship between the cutting power and radius of a blasting spot is defined.

Figure 2(a) shows the relationship between radius of a blasting spot and blasting time in a blasting operation. As shown in Figure 2(a), the radius of the blasting spot will increase gradually until it reaches an upper limit. Figure 2(b) shows the relationship between cutting power and the radius of the blasting spot in the blasting operation. It can be seen from the experimental results shown in Figure 2(b) that the cutting power will decrease exponentially as the radius increases. Therefore, the Equation (1) can be used to accurately indicate the relationship between the cutting power and the radius of the blasting spot. With the proposed cutting power model defined in Equation(1), in some embodiments, the cutting power model determination module 102 is further configured to calculate coefficients A and B of the cutting power model based on the radius value of each of the at least two blasting spots in the calibrated image.

The blasting parameter selection module 103 is configured to select a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed. In some embodiments, the blasting parameter selection module 103 is further configured to calculate a productivity value corresponding to each of a plurality of predetermined gun speed values based on the ascertained cutting power model, and select a gun speed value corresponding to the maximum productivity value, as the blasting gun speed to be used in the blasting operation, wherein the plurality of predetermined gun speed values are determined based on the upper limit gun speed value of the blasting system, i.e. each of the predetermined gun speed values should not be greater than the upper limit value. For example, if the upper limit value of the blasting gun speed is 100 mm/s, the predetermined gun speed values may include 60 mm/s, 70 mm/s, 80 mm/s and 90 mm/s. To further improve accuracy of the calculation, in some embodiments, the blasting parameter determination module 103 may be further configured to calculate the productivity value corresponding to each gun speed value based on a

predetermined overlap factor. The detailed calculation process will be explained below.

Figure 3 is a flow chart illustrating a method 300 for blasting parameter selection by using the basting parameter selection system 100 according to one embodiment of the invention.

In **Block 301**, the image calibration module 101 receives an image of a work surface of a blasting operation, wherein the image is captured by the camera 110 and includes a plurality of blasting spots with different radii.

In **Block 302**, the image calibration module 101 calibrates the received image based on a plurality of calibration parameters of the camera 110.

The purpose of this calibration step is to generate a calibrated image through which the radius value of each blasting spot to be used for selecting blasting parameter can be accurately determined. In the blasting operation, the camera is typically installed on a top surface inside of an enclosure of the blasting system and as the optical axis of the camera may not be perpendicular to the blasting surface, the image captured by the camera may have distortion and need to be calibrated so that the radius of each blasting spot in the image of the work surface can be accurately measured. The plurality of calibration parameters may include the intrinsic parameters and extrinsic parameters of the camera. In some embodiments, to simplify the calibration process, the calibration parameters may be pre-determined and stored in the image calibration module 101, e.g. when the position of the camera used for capturing the image of the

work surface remains unchanged with respect to the work surface. Alternatively, in some other embodiments, the image calibration module 101 may be further configured to estimate the calibration parameters of the camera 110. As the method for estimating the calibration parameters of a camera is well known to a person skilled in the art, it will not be explained in detail. In one example, the calibration parameters may be estimated through the following steps: extracting corner points; calculation holography matrix and calculating transformation matrix.

In **Block 303**, the cutting power model determination module 102 ascertains a cutting power model for the blasting operation based on at least two blasting spots in the calibrated image by using a regression method, e.g. a standard linear least square method.

In some embodiments, the cutting power model determination module 102 may ascertain a cutting power model based on the radius value of each of the at least two blasting spots, the cutting power value corresponding to each blasting spot and a functional relationship established between the cutting power and the radius of the blasting spot.

In some embodiments of this invention, Equation (1) may be used to indicate the functional relationship between the cutting power and the radius of the blasting spot. As such, the step of ascertaining the cutting power model in some embodiments includes determining the coefficients A and B of the cutting

power model based on the radius value of each of the plurality of blasting spots and the cutting power value corresponding to each blasting spot.

In **Block 304**, the blasting parameter selection module 103 selects a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

In some embodiments, to select a blasting gun speed to be used in the blasting operation, the blasting parameter selection module 103 may calculate a productivity value corresponding to each of a plurality of predetermined blasting gun speed values and then select the gun speed value corresponding to the maximum of productivity value as the blasting gun speed to be used. The method for calculating the productivity value corresponding to a gun speed value is explained below with reference to Figures 4(a) and (b).

Figure 4(a) shows a cutting power spectrum of a blasting operation on a work surface according to one example of the invention. The **cutting power spectrum** indicates the different cutting powers at different radii of the blasting spot when a stream of blasting sand is projected towards the work surface. As well known by a person skilled in the art, only area with sufficient cutting energy can satisfy the quality requirement SA2.5. In Figure 4(a), the blasting gun is moving at a speed of v, an arbitrary point P’ on the work surface will be exposed to a combination of different cutting power spectrum along L direction, i.e. the arbitrary point P’ will be continuously blasted by the blasting sand at different radii of different blasting spots. The different blasting spots correspond to

different cutting power spectrum. To calculate the productivity value corresponding to a gun speed value, the blasting parameter selection module 103 may calculate a width of a single linear path of the blasting gun with the moving speed v first, and then calculate the productivity value corresponding to the gun speed value based on the width of the single linear path. It should be noted that the single linear path of the blasting gun satisfies the quality requirement of SA 2.5. Figure 4(b) shows two adjacent single linear paths of the blasting gun according to one example of the invention. In some embodiments, the width of a single linear path of the blasting gun may be calculated by solving the Equations (3) – (5) below;

$$\int_{t_1}^{t_2} Ae^{-Br(t)}\mathrm{d}t = 1 \qquad (3)$$

where t_1 and t_2 are the time instant when the blasting gun enters and exits the blasting spot, r(t) is radius of the blasting spot at time instant t;

where $r(t) = \sqrt{(L/2 - vt)^2 + w^2}$, (4)

where w is the half width of the single linear path of the blasting gun, v is the blasting gun speed value;

$$L = 2\sqrt{R_{\max}{}^2 - w^2} \qquad (5)$$

where L is the linear movement distance of the blasting gun; R_{max} is the upper limit value of the distance between point O and point P', which can be

obtained from the calibrated image of the work surface. No cutting power is generated out of the scope defined by R_{max}.

Once the coefficients A and B, the moving speed v of the blasting gun, and R_{max} are determined, by substituting all of the values into Equation (3), Equation (3) will have only one unknown, i.e. the half width of the single linear path of the blasting gun w. Accordingly, the value of w can be obtained by solving Equation (3).

Then, the productivity of the blasting operation corresponding to the gun speed value v may be calculated based on the value of w by using Equation (6).

$$P = 2wv\eta \tag{6}$$

where P is the productivity of the blasting operation, w is the half width of the single linear path of the blasting gun, η is the overlap rate, v is the blasting gun speed value. As shown in Figure 4(b), the overlap rate is used to indicate the overlapping part between two adjacent single linear paths of the blasting gun. It should be noted that in this embodiment, the blasting path is a zig-zag path, so the overlap rate η is used to calculate the productivity of a blasting operation to further improve the accuracy of the calculation. However, in some other embodiments of the invention, the overlap rate η may not be used for calculation of the productivity, e.g. if the blasting path is not zig-zag path and no overlap between blasting paths exists, or when the overlap between two adjacent linear paths is very small and may be omitted when calculating the productivity.

To validate the effectiveness of the functional relationship in Equation (1), and the accuracy of the calculation of the linear path width w through Equations (3) – (5), two sets of blasting experiments have been performed on a work surface covered with old paint. In the experiments, the blasting gun was mounted on a controllable mobile platform and invoked before the mobile platform moved.

In Experiment I, 15 valid blasting spots are obtained, and each blasting spot is blasted for a specific amount of time from 4s to 60s with an incremental step of 4s. Figure 5(a) shows the image captured by the camera 110 and input into the image calibration module 101 in Experiment I. Figure 5(b) shows the image calibrated by the image calibration module 101. In Figure 5(b), the right top spot is the starting point, and it is not valid since the blasting time is uncontrollable. In this experiment, eight points are selected for determination of the cutting power model and the remaining seven points are selected for validation of the ascertained cutting power model.

Figure 6(a) shows the cutting power model ascertained by the eight selected blasting spots in Experiment I. As shown in Figure 6(a), the two coefficients A and B associated with the cutting power model in Equation (1) are 40.438 and 121.3 respectively, and the value of R-squared, which is a statistical measure of how close the data to the fitted regression line, is 0.9953. Figure 6 (b) shows the validation results indicating the prediction errors corresponding to the seven selected blasting spots respectively when the ascertained cutting power model in Figure 6 (a) is used to predict the radius of each blasting spot.

As shown in Figure 6 (b), most of the prediction errors are less than 10%. The largest prediction error is around 20%, which may be caused due to fluctuation in air pressure or non-uniform paint thickness. Even if the largest protection error is counted, the average error is less than 7%. The experimental results shown in Figure 6(a) and 6(b) indicate that the proposed functional relationship in Equation (1) is very effective and accurate for ascertaining cutting power model of the blasting system.

In Experiment-II, a specially designed blasting process was carried out to test the accuracy of the calculation of the linear path width based on Equations (3)-(5). The experimental results are set out in Table 1 below.

Table 1

Gun speed [mm/s]	Measured width [mm]	Predicted width [mm]	Protection Error
10	85.19	86.6	1.63%
20	79.1	74.2	6.60%
30	62.72	66.8	6.11%
40	57.67	61.4	6.07%
50	57.01	57.2	0.33%
60	51.06	53.6	4.74%
70	53.58	50.6	5.89%
80	51.11	48.2	6.04%
90	44.56	45.8	2.71%
100	46.96	43.8	7.21%
110	43.18	41.8	3.30%
120	43.25	40.2	7.59%

Figure 7 (a) shows the actual measurement results of path width when the blasting gun speed values are 10 mm/s, 20 mm/s, 30 mm/s, 40 mm/s, 50 mm/s,

60 mm/s, 70 mm/s, 80 mm/s, 90 mm/s, 100 mm/s and 120 mm/s respectively. Figure 7 (b) shows a comparison between the actual measurement results in Figure 7 (a) and the corresponding prediction results obtained by using the method proposed by embodiments of the invention. From Figure 7 (b) and the results shown in Table 1, it can be seen that the prediction results are quite close to the actual measurement results, and the average prediction error is less than 5%. The results of Experiment II demonstrate the accuracy of the linear path width calculated based on the method proposed in embodiments of the invention.

In view of the above, since both the functional relationship between cutting power and radius of a blasting spot and the method for calculating linear path width of the blasting gun proposed by embodiments of the invention are effective and accurate, the method for predicting or calculating productivity value of a blasting operation corresponding to a specific blasting gun speed is effective and accurate accordingly.

An example is provided below to further explain the calculation process of productivity value corresponding to a specific gun speed value. In this example, the gun speed value is v = 60 mm/s, the ascertained coefficients A and B of the cutting power model are 40.438 and 121.3 respectively, and R_{max} *is* 0.0738 m. By substituting these values into Equations (3) to (5) as follows, the Equation (3') will only have one unknown variable *w.* Then, the value of *w* can be obtained by solving the Equation (3').

$$\int_{t_1}^{t_2} 40.438e^{-121.3\,r(t)}dt = 1, \qquad (3')$$

where t_1 =0, $t_2 = L/v = 2\sqrt{0.0738^2 - w^2}\,/\,0.06$,

$$r(t) = \sqrt{(\sqrt{0.0738^2 - w^2} - (60/1000)t)^2 + w^2} \qquad (4')$$

$$L = 2\sqrt{0.0738^2 - w^2} \qquad (5')$$

In this example, the half width of a single linear path w corresponding to the blasting gun speed 60mm/s is 0.0268 m. Then, according to Equation (6), the productivity corresponding to the gun speed value 60 mm/s is $P=2wv\eta=2\times(0.0268\text{ m})\times(60/100\times3600\text{ m/h})\times0.8 = 9.26\text{ m}^2/\text{h}$.

The predicted productivity results corresponding to different blasting gun speed values from 0 mm/s to the upper limit of the blasting gun speed value 100 mm/s are shown in Figure 8 (a). As indicated in Figure 8 (a), the maximum productivity value could be greater than $12\text{m}^2/\text{h}$. Figure 8(b) shows the work surface on which a blasting operation with the gun speed value corresponding to the productivity value of $12\text{m}^2/\text{h}$ is performed. As can be seen in Figure 8(b), the surface finish of the work surface satisfies the quality requirement SA2.5.

In the conventional manual blasting operation in a shipyard, the typical productivity of a blasting operation is $8\text{m}^2/\text{h}$, while with the solution provided in embodiments of the invention, the productivity of a blasting operation could be greater than $12\text{m}^2/\text{h}$. That is to say, the blasting parameter selection solution in

this invention can result in at least a 50% increase in the productivity of a blasting operation compared to the conventional manual blasting operation.

As will be appreciated from the above, the solution for selecting blasting parameter provided in embodiments of the invention includes two processes: (1) determination of a cutting power model and (2) selection of a blasting gun speed to be used in the blasting operation based on calculation/prediction of productivity values corresponding to a plurality of predetermined gun speed values respectively. As this solution accurately reveals the relationship between various blasting parameters of a blasting operation and the surface finish of SA2.5, the productivity of the blasting operation can be accurately predicted. Further, by selecting the blasting gun speed value corresponding to the maximum of the productivity value as the gun speed value to be used, the productivity of the blasting operation can be significantly improved.

In addition, the solution provided by embodiments of the invention is easy to implement and highly efficient since it does not need collect or measure the parameters of the actual blasting setup, e.g. particle properties, air fluid properties, workpiece properties, particle impact speed and angle, particle-particle interaction, etc.

It is to be understood that the embodiments and features described above should be considered exemplary and not restrictive. Many other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the invention. The scope of the invention should, therefore, be

determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and not to limit the disclosed embodiments of the invention.

5

Claims

1. A system for blasting parameter selection, the system comprising:

an image calibration module configured to calibrate an image of a work surface of a blasting operation, wherein the image is captured by a camera and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera;

a cutting power model determination module configured to ascertain a cutting power model based on at least two blasting spots in the calibrated image;

and

a blasting parameter selection module configured to select a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

2. The system according to claim 1, wherein the cutting power model determination module is further configured to ascertain the cutting power model by using a regression method.

3. The system according to claim 1, wherein the cutting power model determination module is further configured to ascertain the cutting power model based on a radius value of each of the at least two blasting spots, a cutting power value corresponding to each of the at least two blasting spots and a predetermined functional relationship between cutting power and radius of a blasting spot.

4. The system according to claim 3, wherein the cutting power model determination module is further configured to ascertain the cutting power model based on a predetermined functional relationship between cutting power and radius of a blasting spot defined according to the following Equation:

$$P_{cutting}(r) = Ae^{-Br}$$

wherein A and B are two coefficients associated with the cutting power model, $P_{cutting}(r)$ refers to the cutting power at radius r, which is equal to the reciprocal of blasting time required to obtain a blasting spot with the radius r.

5. The system according to claim 4, wherein the cutting power model determination module is further configured to determine the two coefficients A and B associated with the cutting power model based on the radius value of each of the at least two blasting spots and the corresponding cutting power value.

6. The system according to any one of claim 1 to claim 5, wherein the image calibration module is further configured to estimate the plurality of calibration parameters of the camera by using a predetermined calibration pattern.

7. The system according to claim 6, wherein the predetermine calibration pattern includes a checkerboard consisting of a plurality of squares.

8. The system according to any one of claim 1 to claim 7, wherein the blasting parameter selection module is further configured to calculate a productivity value corresponding to each of a plurality of predetermined gun speed values based

on the ascertained cutting power model; and select a gun speed value corresponding to a maximum productivity value as the blasting gun speed to be used in the blasting operation, wherein the plurality of predetermined gun speed values are determined based on the upper limit gun speed value of the blasting system.

9. The system according to claim 8, wherein the blasting parameter selection module is further configured to calculate the productivity value corresponding to each predetermined gun speed value based on a predetermined overlap factor.

10. The system according to claim 9, wherein the predetermined overlap factor is 0.8.

11. A method for blasting parameter selection, the method comprising:

calibrating an image of a work surface of a blasting operation, wherein the image is captured by a camera and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera;

ascertaining a cutting power model for the blasting operation based on at least two blasting spots in the calibrated image; and

selecting a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

12. The method according to claim 11, wherein the step of determining the cutting power model includes determining the cutting power model by using a regression method.

13. The method according to claim 11, wherein the step of determining the cutting power model includes determining the cutting power model based on a radius value of each of the at least two blasting spots, a cutting power value corresponding to each of the at least two blasting spots and a predetermined functional relationship between cutting power and radius of a blasting spot.

14. The method according to claim 13, wherein the predetermined functional relationship between cutting power and radius of a blasting spot is defined according to the following Equation:

$$P_{cutting}(r) = Ae^{-Br}$$

wherein A and B are two coefficients associated with the cutting power model, $P_{cutting}(r)$ is the cutting power at radius r, which is equal to the reciprocal of blasting time required to obtain a blasting spot with the radius r.

15. The method according to claim 14, wherein the step of determining the cutting power model includes determining the two coefficients A and B associated with the cutting power model based on the radius value of each of the at least two blasting spots and the corresponding cutting power value.

16. The method according to any one of claim 11 to claim 15, further comprising:

estimating the plurality of calibration parameters of the camera by using a predetermined calibration pattern.

17. The method according to claim 16, wherein the predetermined calibration pattern includes a checkerboard including a plurality of squares.

18. The method according to any one of claim 11 to claim 17, wherein the step of selecting a blasting gun speed to be used in the blasting operation comprises

calculating a productivity value corresponding to each of a plurality of predetermined gun speed values based on the ascertained cutting power model; and

selecting a gun speed value corresponding to a maximum productivity value as the blasting gun speed to be used in the blasting operation, wherein the plurality of predetermined gun speed values are determined based on the upper limit gun speed value of the blasting system.

19. The method according to claim 18, wherein the step of calculating the productivity value corresponding to each of the plurality of predetermined gun speed values comprises:

calculating the productivity value corresponding to each predetermined gun speed value based on a predetermined overlap factor.

20. The method according to claim 19, wherein the predetermined overlap factor is 0.8.

SYSTEM AND METHOD FOR BLASTING PARAMETER SELECTION

Abstract

Embodiments of the invention provide a system and method for blasting parameter selection. The system comprises an image calibration module configured to calibrate an image of a work surface of the blasting operation which is captured by a camera and includes a plurality of blasting spots, based on a plurality of calibration parameters of the camera; a cutting power model determination module configured to ascertain the cutting power model based on at least two blasting spots in the calibrated image by using a standard linear least square method; and a blasting parameter selection module configured to select a blasting gun speed to be used in the blasting operation based on the ascertained cutting power model and an upper limit value of the blasting gun speed.

(Figure 1)