Development of Brittle Material Machined Surface Quality Image Detection System and Application

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Abstract. The brittle graphite machined surface quality cannot be completely evaluated only by surface roughness $Ra$ measured by profilometer, owing to its 3D surface defects. This paper developed an image detection system for brittle material machined surface quality based on Matlab and VB seamless interface mixed programming. The system hardware setup, software constitution and system programming principle are emphatically elaborated. Finally, the application of this system to detect brittle graphite surface quality proved its good feasibility.

1. Introduction
In recent years, graphite electrode material has been used more and more in EDM applications of die & mould manufacturing in automobile, home appliances, electronic industries, communication, et at. It becomes the prevailing electrode material over copper in EDM, especially for manufacturing complicated mould cavities with narrow and deep slots and micro holes [1-4].

In high speed machining of graphite, micro fractured cracks always occur to graphite machined surfaces. Some cracks are almost parallel with the free surface of material, but others go deep into the subsurface and cause brittle fracture surface in the form of fracture craters [5-6]. Therefore, the graphite machined surfaces are some kind of 3D micro fracture coarse surfaces with irregularly distributing defects. The $Ra$ values of surface roughness is measured at any section vertical to the cutting direction by profilometer, so $Ra$ is a 2D evaluation indicator of surface quality, which is not enough to sufficiently evaluate the 3D graphite machined surface quality.

Image detection technology is more and more applied to automatically detect surface quality in many areas, such as component surface imperfection and damage detection [7-8]. This paper developed an image detection system for brittle material machined surface quality. The constitution of system hardware and software and are elaborated, the system programming principle is put forward, and finally the application of this system to detect brittle graphite surface quality is presented to verify the system feasibility.

2. Constitution of Brittle Material Machined Surface Quality Detection System
Brittle Material Machined Surface Quality Detection System is made up of a hardware system for image acquisition and a software system for image processing and calculation. These two parts are designed in details as follows.

2.1. Hardware system setup
The hardware system is a platform for target surface image acquisition and digital transformation, which consists of a set of stereoscopic microscope, lighting system, camera, and computer as shown in figure 1. The image can be observed and enlarged by the stereoscopic microscope, captured by the camera, and saved and processed by the computer.

![Figure 1. Hardware system.](image1)

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2.2. Software system functions and constitution

Software system design is the core studied in this paper, which is the carrier to deal with image processing and material surface quality parameter calculation.

2.2.1. Software system functions. The overall functions frame of the software system are shown in figure 2, which includes the following functions:

- Read and save image
- Preprocess and...

![Figure 2. System functions overall frame diagram.](image2)
segment image;(c) Extract feature texture and geometry parameters;(d) Calculate surface roughness and surface damage ratio according to texture and geometry features;(e) One key process and cancel.

2.2.2. Software system module constitution. The software system consists of several following program modules, so its functions are convenient to expand in favour of software development. The software workflow diagram is shown in figure 3.

(a) Image acquisition module: The image is read, opened and saved by VB dialog box control, and displayed by image box control.

(b) Image preprocessing module: First of all, M file is compiled by Matlab function, then COM Builder is used to convert M file to Dynamic link library (DLL) file, and finally VB is used to call DLL file. Therefore, the function of using VB to call MATLAB image processing toolbox is realized. This module is applied to enhance image contrast and remove image noise, providing foundation for image segmentation later.

(c) Image segmentation module: The surface damage is highlighted in the image, and the target area and the background area are distinguished using image segmenting algorithm. Image segmentation quality will influence following feature parameter extraction and surface roughness and damage ratio calculation.

![Software workflow diagram.](image)

Figure 3. Software workflow diagram.

(4) Texture feature extraction module: Apply some kind of texture feature extraction method to quantify the gray level variation characteristics and extract feature parameters.
3. System programming principle

Visual Basic 6.0 and MATLAB 2016A are selected as the main development tools of the system. The mixed programming of VB and MATLAB is used to design the software of the surface image detection system for brittle materials, which is the core part of image processing system for hard and brittle materials. Active X, Dynamic data exchange (DDE), Dynamic link library and Matrix VB are the most commonly used methods of VB and MATLAB interfaces. However, the first two methods cannot completely get rid of the restriction of MATLAB environment, the greatest disadvantage of Matrix VB is that the functions contained are limited and the scope of use is not large. Using MATLAB Add-in to generate DLL technology is a programming method of seamless interface programming method between VB and MATLAB.

Seamless interface programming enables software to function completely out of the MATLAB working environment. DLL generation, calling and debugging is the key to this method. The Seamless interface programming principle is shown in figure 4. MATLAB Com Builder tool is used to convert M files into COM components, which are in-process components existing in the form of DLL dynamic link library, and can be called in the VB integrated development environment.

![Figure 4. Seamless interface programming principle.](image)

4. Application of surface quality detection system to brittle graphite material

The system was used to detect graphite machined surface quality to verify system feasibility. The graphite work piece was observed by stereo microscope. The graphite surface photos were taken by image acquisition camera and saved in the computer (as shown in figure 5). The surface images were processed by system software to extract surface texture feature parameters so as to evaluate the surface quality. The software was seamless interface programming of VB and MATLAB. The images were processed by Matlab using Gray-level Co-occurrence Matrix method to extract two texture feature

![Figure 5. Graphite surface images corresponding to different roughness values listed in table 1.](image)
parameters Entropy ENT and Second moment ASM as listed in table 1 (this part of research will be published in another paper). From the values of ENT and ASM, it can be found that the values of ENT and ASM are in good linear correlation to surface roughness Ra. Therefore, ENT and ASM values can be good characterization of surface quality besides Ra. Therefore, the above application of this system approved that it could be used very well to detect brittle graphite machined surface quality. This system will also be a good exploration to develop machine vision detection system to automatically evaluate brittle material surface quality by digital image processing.

![Surface image processing](image)

**Figure 6. Surface image processing: (a) Original image; (b) After image segmentation.**

| No. | Surface Roughness Ra | Entropy ENT | Second Moment ASM |
|-----|-----------------------|-------------|-------------------|
| 1   | 1.738                 | 0.2869      | 0.7210e+07        |
| 2   | 2.420                 | 0.3441      | 0.8645e+07        |
| 3   | 2.517                 | 0.3447      | 0.8630e+07        |
| 5   | 3.041                 | 0.3822      | 0.9601e+07        |
| 7   | 4.557                 | 0.4621      | 1.1610e+07        |
| 8   | 6.639                 | 0.5974      | 1.5007e+07        |

### 5. Conclusions
A brittle material surface quality image detection system was developed by means of Matlab and VB seamless interface mixed programming. This system includes image acquisition, image preprocessing, image segmentation and texture feature extraction modules. The application of this system to brittle graphite material verifies that graphite surface images can be processed by this system.

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