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Wear Detection on Twist Drill Cutting Lips using Digital Microscope

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Abstract

Twist drill is normally used for hole making operation. It may vary in shape, size and composition depending on the application, size of the hole and also material of the workpiece. Drilling on a material with great hardness such as composite panels would be very challenging. The drill bit will experience greater fatigue and worn out faster. This will cause undesirable damage on the workpiece. Therefore, a regular human vision inspection and drill bit sharpness test are required to ensure the drill bit used is in a good condition and still able to produce a perfect hole without damaging the workpiece. The study on detecting the twist drill wear will contribute in solving the problem aforementioned. In this research, a method is proposed in detecting and measuring the presence of wear on the twist drill. The proposed method is done by comparing the images of both new and worn twist drill from the top view perspective in order to obtain a full image of the cutting lips. The top view images are acquired using digital microscope and processed through MATLAB using two different approaches which are Sum of Absolute Different (SAD) and Image Fusion. The percentage of wear for each method is calculate and compared. With photographic evidence, this research found that during the process of drilling, the twist drill not only losing its material due to friction but also experiencing a shape deformation which also contribute to the wear factor of the cutting lips.

Keywords: twist drill quality, wear detection, sum of absolute different, image fusion, MATLAB.

1. Introduction

Drilling is a major operation in aircraft manufacturing and assembly process where thousands of holes are drilled into the composite panel [1]. The composite material is known for its combination of high properties such as high strength to weight ratio, good damage tolerance, excellent fatigue and corrosion resistance. However, composite material have the worst machinability compared along with other materials due to its material discontinuity, inhomogeneity and anisotropic nature[2]–[5]. The most common problems reported are excessive tool wear and poor finish quality. Several damages usually occur due to excessive wear such as delamination and fiber pull-out. This undesirable damages reduces the strength of the composite structure and thus increasing the tendency of a structure failure[6].

The usage of the twist drill during the drilling process need to be monitored in order to avoid the problems mentioned. Practically in aircraft assembly, the condition of tool wear is monitored after several cycle used. A manual human vision inspection is conducted and a drilling test is carried out to ensure that the drill bit is still able to produce a good hole. A study on detecting wear of the twist drill would contribute in monitoring the twist drill efficiently

Recently, researchers are exploring the knowledge of machine vision and image processing innovatively to suit into their application especially in the context of tool wear monitoring and measurement. From literature study, this approach is not commonly used in detecting wear for drilling operation compare to other machining operation [7]. However, there are several researches on twist drill wear monitoring. A. Volkan Atli etc [8] used high speed CCD camera and proposed a fast approach in monitoring using the deviation from linearity (DEFROL) metric to measure the tool wear. Another research is done by Omid Saeidi etc [9]. The researchers evaluating wear of WC/Co cemented carbide bits in rotary drilling by using Gray level co-occurrence matrix (GLCM) texture analysis.

Other researchers also using the same approach but with different tool machining operation. S.P. Patil and D.M. Tilekar [10] measuring the cutting tool wear using MATLAB to investigate the performance of coated and uncoated ceramic cutting tool. T.Y. Lim and M.M. Ratnam [11] proposed a low-cost image acquisition for measurement system as they used scanned 2D images to measure and detecting edge of nose radii of cutting tool. Another good approach is done by H.H. Shahabi and M.M. Ratnam [12]. They used Wiener filtering, median filtering, morphological operations and thresholding in their algorithms for online tool wear monitoring to correct tool misalignment and measuring nose wear area using subtraction method. In other work [13], they extend the research in measuring the wear on surface roughness of the workpiece.

This research basically proposing a method in monitoring the condition of the twist drill through an imaging inspection. The main objective of this inspection is to detect and measure the presence of the wear on a twist drill in term of percentage. The major part of the twist drill that is affected most by the wear is the cutting lips. Hence, this is the best part to determine the wear in term of percentage using Sum of Absolute Difference (SAD) and Image Fusion method.

2. Methodology

This study starts with an experimental setup as shown in Fig. 1. This process included in preparing the devices required such as digital microscope and the computer. Further details regarding the experimental setup will be explained later in the next section. Next step is acquiring the image to undergo an image pre-processing stage before applying in image detection program developed in MATLAB. After the detection, the pixel of the image is counted in order to calculate the percentage of wear.

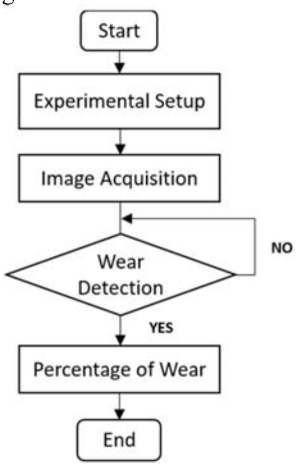

Fig. 1 Research process flow for the wear detection

2.1 Experimental Setup

Fig. 2 shows the experimental setup for the inspection process. The research requires a digital microscope to capture the images of the drill bit from the top in order to obtain a clear view of the cutting lips. A stable stand also important to keep the whole setup balance and maintain the height and alignment between the microscope and the tip of the twist drill. A computer with MATLAB R2016a installed is used to develop a detection program. In this research, the new and worn polycrystalline diamond (PCD) drill specimens are specially obtained from the industry to help in conducting the research. The worn specimen obtained was used to drill on a carbon fiber reinforced plastic (CFRP) panel.

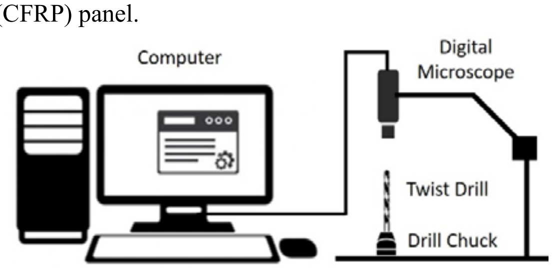

Fig. 2 Experimental setup for the inspection process

2.2 Image Acquisition

The images are taken through the digital microscope and went through a pre-processing stage. Fig. 3 shows a simple acquisition process which had been done. Starting from sample preparation, the twist drill is positioned below the microscope with a fix orientation set. After the preparation and configuring setting, the image is ready to be captured. The captured image is fixed to a square image with a resolution of 354 x 354 and 125 316 number of pixels.

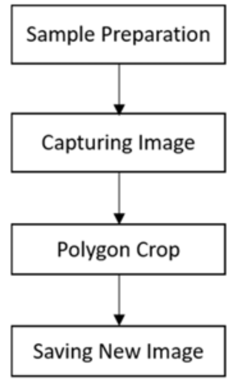

Fig. 3 Image acquisition process flow

As mentioned earlier, the inspection is focused on the cutting lips in order to measure the presence of wear. Hence, the captured image required a cropping function that is able crop the image according to the cutting lips boundary. In order to meet this requirement, polygon crop is developed which can be freely defined the cropping shape and area as shown in Fig. 4. It is a combination of polygon and mask function in MATLAB.

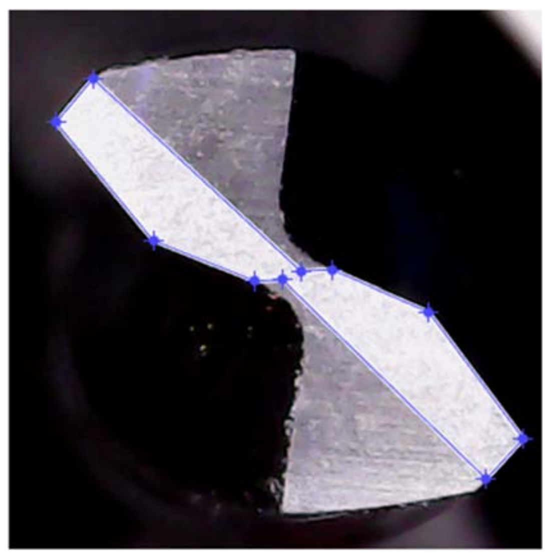

Fig. 4 User free-defined region in polygon crop

Final stage of the image acquisition is saving a new image. This part is also important as the image background is selected at this stage before it can be saved. The image background must be different in colour with the cutting tool. For example, if the twist drill is black, it is recommended to have a white background to differentiate the cutting lips region and to have a better inspection accuracy. Fig. 5 shows the results from polygon crop for both new (left) and worn

Fig. 5 Image cropped using polygon crop for both new and worn twist drill.

(right) twist drill image. The edge of the cutting lips is sharply cropped using the polygon crop. For this case, the image background is black as the cutting lips is white and the region of the cutting lips can be clearly seen and differentiated.

2.3 Wear Detection

The basic concept of the detection is by calculating the area of the cutting lips and area of wear from the number of pixel extracted from the images. A wear detection program is developed using MATLAB. Fig. 6 shows the detection flow program developed. From the flow, it is clear that the new and worn twist drill image will be processed separately for the cutting lips size calculation.

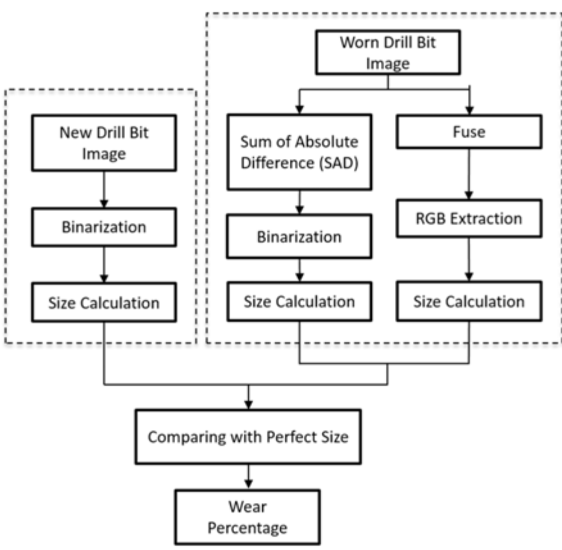

Fig. 6 Wear detection program flow chart

The new twist drill image is going through a binarisation process while for the worn twist drill image, there are 2 methods used in detecting the presence of the wear which is Sum of Absolute Difference (SAD) and Image Fusion. Both methods have pros and cons in interpreting acquired images. The images processed through both methods are compared with the original cutting lips size to obtain the value of wear percentage.

For the new or unused twist drill, the captured image is converted to binary image as shown in Fig.7. The total amount of the white pixels is calculated in order to measure the area of the cutting lips as the amount of the white pixel in the image is equal to the total area of the original cutting lips.

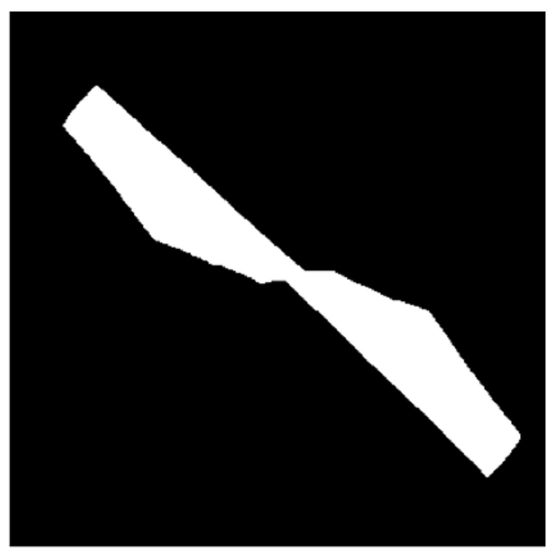

Fig. 7 Binarisation of image for new twist drill

Processing the worn twist drill image is more challenging. There are two methods used in detecting the presence of wear in the twist drill which is Sum of

Absolute Difference (SAD) and Image Fusion as mentioned earlier. SAD is a measure of absolute difference between each pixel in the original image and the corresponding pixel in another image being used for comparison. The result from absolute difference showed the amount of wear presence on the twist drill. The resulted image is then converted to binary image as shown in Fig. 8 before calculating the worn area.

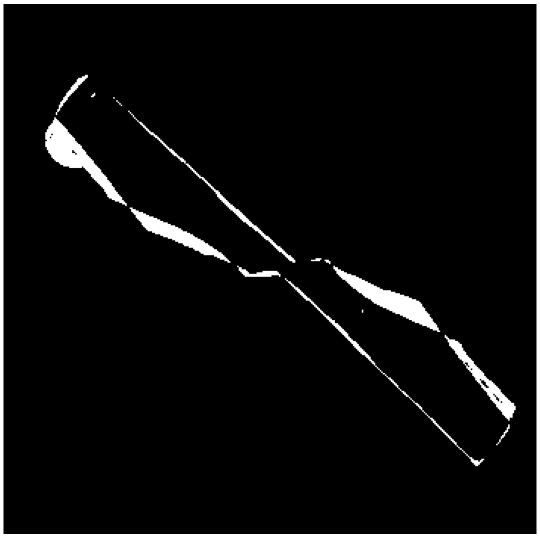

Fig. 8 Sum of absolute difference result after binarisation

Image fusion creates a composite image from two images. In this research, the fusion creates a difference image between new and worn twist drill image. The fused image resulted from the fusion created a RGB colour image. Fig. 9 shows the result of the image fusion that contains two colours of shading region which is green and magenta. The representation of these colours will be explained later in the discussion section.

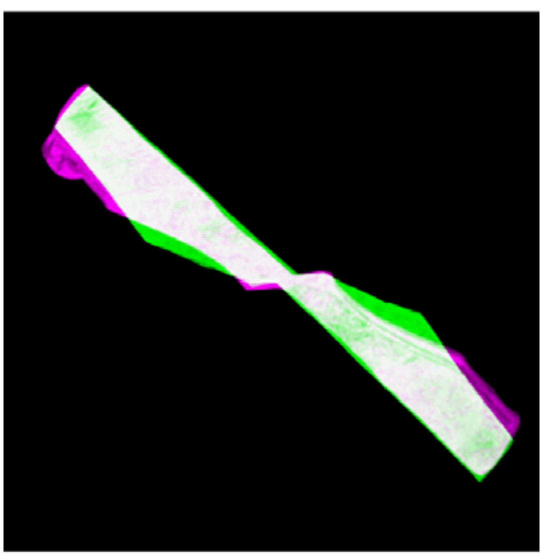

Fig. 9 Image fusion result ready for RGB values extraction

2.4 Percentage of Wear

This is the objective of this study which is to measure the presence of the wear of the twist drill in term of percentage. Before calculating the percentage of wear, a suitable threshold is needs to be determined. The threshold is very important for the inspection as it is affecting the accuracy of the detection. A good level of threshold will maximise the amount of the detection and thus increasing the accuracy of the inspection.

For the new twist drill image and also worn twist drill image from SAD method, the threshold is determined during the binarisation process. In this study, both images are converted to binary with default threshold value of 0.5 as it is the midpoint of the threshold that ranged from 0 to 1. Approaching to 0 values of threshold, the image turns brighter while approaching to 1 the images turns darker. This changes alter the original shape of the cutting lips and at the same time removed some important information from the SAD image. Therefore, the value of 0.5 is the best points as at this points, the changes are nominal. The binarisation process resulted a 2D binary image, hence the pixel value would be 0 and 1 which is between black and white colour only. The size of the original cutting lips area, $A_{cutting\ lips}$ and wear area, A_{wear} is then measured by calculating the total white pixel in the image. The percentage of wear is calculated based on the Eq. (1).

$$w = \left(\frac{A_{wear}}{A_{cutting\ lips}}\right) x100 \quad (1)$$

where:

w = Percentage of Wear (%)

A_{wear} = Wear area

$A_{cutting\ lips}$ = Cutting lips area

Image fusion method is slightly different from the previous method as it resulted a RGB colour image. There are two colours used in the image fusion for region shading which is green and magenta as shown in Fig 9. A pure green RGB values is Red = 0, Green = 255 and Blue = 0 (0,255,0) and a pure magenta RGB value is Red = 255, Green = 0, Blue = 255 (255,0,255). The range of threshold for this method very wide compared with the another method. The RGB values of the green and magenta colour is manually determined using MATLAB in order to find the lowest possible RGB range for both colours. This is to avoid any pixels or region of the wear area from being uncounted. The range of threshold is set to Red < 10, Green > 120 and Blue < 10 (R<10,G>120,B<10) for green colour while for magenta the threshold is Red > 120, Green < 10, Blue > 120 (R>120,G<10,B>120). The percentage of wear is calculated using the same Eq. (1) as the total area from the green and magenta section is considered as the wear area, A_{wear}.

3. Results and Discussion

The top view image taken is parallel to the drill bit but not to the surface of the cutting lips. This is because worn drill bit may not have the same angle as the new drill bit due to friction. The setup would be more difficult to find the correct projected angle that is parallel to the cutting lips. This will increase the chances of error as the projection for each image taken is not the same. Furthermore, the difference between both projections are very small and not significant. Therefore, the justification is made as the top view perspective is the best projection to capture the image. The result would not be affected as long as both images are compared using the same projected view.

The inspection is done 5 times for each part in order to get an accurate and consistent results. Table. 1 shows an average number of the white pixel in the new twist drill image from 5 trials. This average values will be used as the original cutting lips area, $A_{cutting\ lips}$ for the whole study.

Table. 1 Average original size of cutting lips (pixel) for new twist drill image

No. of Trial	Total Area (pixel)	**Average (pixel)**
1	14075	**14053**
2	14094	
3	14015	
4	13973	
5	14107	

In SAD method, the wear area is measured by calculating the number of white pixels in the image. The percentage of difference is then calculated as explained in the earlier section using the average values of the original cutting lips area from Table. 1. This process is repeated in 5 trials and the data are tabulated below in Table. 2

Table. 2 Percentage of Wear for Sum of Absolute Difference (SAD) method

No. of Trial	Percentage of Wear (%)
1	23.43
2	23.61
3	23.37
4	22.71
5	23.84

The percentage of wear for image fusion method is calculated after the threshold is determined. The results for the green and magenta region is calculated separately and tabulated along with the total percentage of wear for the green and magenta region combined as shown in Table. 3.

Table. 3 Percentage of Wear resulted from Image Fusion Method

No. of Trial	Percentage of Wear (%)		
	Green	Magenta	Green + Magenta
1	10.07	9.74	19.81
2	10.29	9.94	20.23
3	10.15	9.87	20.02
4	10.02	9.23	19.25
5	10.11	9.86	19.97

In Image Fusion method, the image resulted RGB colour image. The two shaded regions shown in Fig.9 representing the differences of each image compared. The green colour represent the difference of the new twist drill image from the worn twist drill image while the magenta colour represent the difference of the worn twist drill image from the new twist drill image. This research found that, the green shaded region is the material loss due to the friction during drilling operation and the magenta is the region increased detected from the original area. The magenta region could be define as the shape deformation region or as the adhesion of drilled material which is also cause by the friction during the same drilling operation.

During the drilling process, heat may produce due to friction between the twist drill and the surface of the carbon fiber reinforced plastic (CFRP) panel as the composite is very hard and tough. Frequent usage of the twist drill over a long period may cause the cutting lips to experience the deformation. Besides that, this region could be representing the adhesion of the drilled material on the cutting lips. However, in this research, the adhesion is hardly to occur as the material used is carbon fiber reinforced plastic (CFRP) which produce dust during drilling process. This requires the tip of the drill bit to be cleaned before testing to avoid any contaminant or dust affecting the result. Therefore, the magenta region is defined as the shape deformation region as the adhesion is likely not to happen.

The two regions represented by the green and magenta colour does affect the sharpness and performance of the twist drill as both are contributed to the wear factors. With these findings, this method provided more details information regarding the detection.

All results in Table. 2 and Table 3 are plotted together in Fig. 10 for comparison purpose. From the graph, the SAD method detected a higher number of wear percentage which is about 4% more than the total percentage of wear (Green + Magenta) in Image Fusion for all trials. The difference between the two methods is not identical as it is less than 5%. The amount of wear in the green and magenta region is almost similar with only small difference of 1%.

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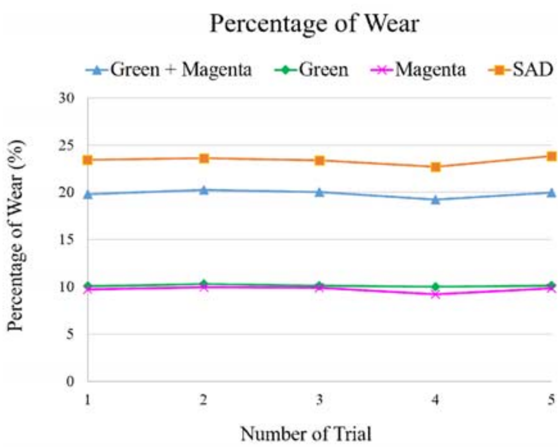

Fig. 10 Percentage of wear comparison for both Sum of Absolute Difference (SAD) and Image Fusion

Comparing both methods, Image Fusion method is able to classify the region of material loss and the region that experienced shape deformation. SAD method is able to detect and measure both area but unable to identify the region in details. This comparison gives advantages to the Image Fusion method to be recommended as a better approach. From the results recorded in Tables. 1-3, the consistencies of result in all trial provides a strong evidence that the detection used in this study is stable.

4. Conclusion

This study used two methods in detecting the presence of wear in twist drill. As discussed in previous section, both methods are able to detect the wear in term of percentage. However, this research proves that the Image Fusion method is a better approach than SAD method in providing more details information regarding the wear detected. With the information, this research found that the cutting lips of the twist drill not only losing it material during drilling operation but also undergo a shape deformation which changes the shape of the cutting lips. Therefore, the image fusion is recommended method in detecting the presence of wear at the twist drill. Besides than controlling and monitoring the condition of a twist drill, this approach also can be used to test the quality of new design twist drill.

5. Acknowledgement

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