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Quantitative Evaluation on Electric Motor Thermal Image for Comparison Hot Spot and Measuring Point Regions

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ABSTRACT

Inspection of the condition on industrial equipment becomes an urgent matter for industry. Infrared thermography inspection provides enormous benefits in preventive and predictive maintenance routines, especially for critical electrical equipment to prevent sudden damage to the equipment when the production process is underway, insofar that it impacts on the process. The result of inspection is in the form of thermal image which depicts the temperature of the electrical equipment. In general, thermal image evaluation is still analyzed manually by relying on visual reading by technicians. This would allow for errors in evaluating the image. Thus, this study used thermal images as the results of electric motor inspections, which are in hot spot and measuring point regions. Furthermore, this study aims to quantify the overheating resulted in electric motor by comparing those two regions using color entropy by Graphical User Interface (GUI) MATLAB. The study stages comprised of: zooming and object (region) cropping on color thermal image, color image histogram, calculating of color entropy (red, green, blue), and calculating of the color entropy average. The result of study on ten electric motor thermal images showed that the color entropy is higher in the measuring point region than the color entropy in the hot spot region. The average of color entropy in hot spot region were in the range of 2.9497 – 3.9578 and measuring point region were in the range of 5.1182 – 5.4489.

Keywords: Quantitative Evaluation, Electric Motor, Thermal Image, Color Entropy

1. INTRODUCTION

The utilization of infrared thermography is increasing significantly, especially in the inspection of condition of industry electrical equipment. Such as inspection finds hot spot caused by damage to the connections and components. In addition, infrared thermography is used to find overheating regions so that the problems can be corrected before component failure in the form of danger and loss of production [1]. Thermography is a non-destructive test that can be used to detect connection failure, load imbalance, deteriorating insulation, or other potential problems in electrical power components [2].

Inspection with correct infrared thermography will certainly affect the results of the analysis of the equipment condition. Thermal imager can only accurately calculate the surface temperature of an object if emissivity of the material is relatively high [3]. In general, thermal image evaluation on electrical equipment is still done manually, in which it is still relying on visualization when performing equipment temperature measurement. This of course allows for thermal image analysis errors, so needed quantitative evaluation to interpreting region of interest on the result of thermography inspection such as thermal image.

Some algorithms have been used to analysis of thermal image such as, breast cancer thermal image analyzing using fractal method [4], thermal imaging technique using image segmentation algorithm on banana fruit thermal image [5], thermal image processing using statistical parameter and image enhancement algorithm [6]. Thermal image processing by video peak store processing, region growing, and perceptual growing techniques in implemented within MATLAB [7], thermal image processing by template based tracking method [8], infrared thermography for assessment and monitoring of electrical components in the concrete structures that use a combination of image processing and artificial intelligence system to identify abnormalities of temperature on electrical equipment components [9]. Predictive maintenance of power substation equipment by infrared thermography to defect analysis in electrical power equipment using computer vision and machine learning approach [10], damage detection on composite materials with active thermography and digital signal processing in carbon fiber reinforced plastics applied two techniques with artificial cracks and internal delamination at known locations [11]. Therefore, this study is trying to develop color entropy algorithm for quantifying two regions of electric motor thermal image such as hotspot and measuring point regions implemented within GUI (Graphical User Interface) MATLAB.

2. THEORY

Every object that has a temperature above absolute zero (-273.15 degrees Celsius or 0 Kelvin) emits radiation in the infrared region. Very cold objects, such as ice cubes, emit infrared radiation. Heat from sunlight, fire or radiators is all infrared. Even though the eye can’t see it, the nerves in the skin can feel it as heat. The warmer the object, the more infrared radiation it emits. Thermal imaging can detect electromagnetic radiation in the thermal IR region, typically between the wavelengths of 3 and 15μm.

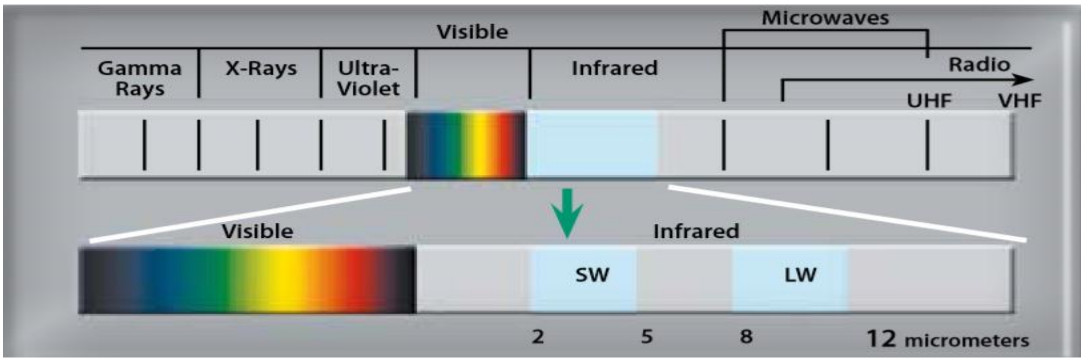

FIGURE 1. Infrared radiation [12][13]

The regions contain Near IR (NIR – 0.7 to 1μm), Short-Wave IR (SWIR – 1 to 3μm), Mid-Wave IR (MWIR – 3 to 5μm) and Long-Wave IR (LWIR – 8 to 12μm). Thermal imaging technology has become a very helpful tools in industry because it is able to detect abnormalities that are not visible to the eye so that preventive actions can be taken before a failure has a cost impact. Infrared camera has many

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applications specially in electrical area such as low voltage inspections and high voltage inspections. [12][13]. One of the thermal imaging applications in the industrial field is the thermographic inspection of electric motors. Motor failure such as brushes and armature shorts usually produce excess heat before failure but remains undetected by vibration analysis, because it often causes little or no extra vibration. Thermal imaging provides a comprehensive picture and makes it possible to compare different motor temperatures. The examples of thermography inspection on an electric motor are shown in the following Figure [12],

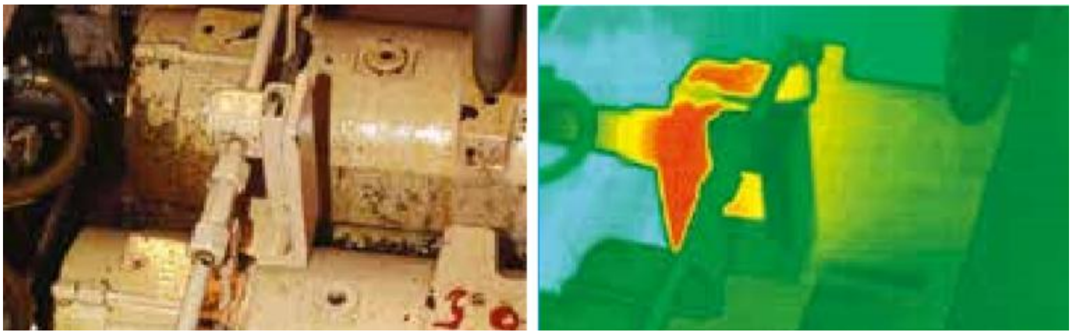

FIGURE 2. Bearing problem in electric motor [12]

2.1 THERMAL IMAGE PROCESSING

Image processing aims to improve image quality such as image quality, perceptual aspects, intelligence or visual appearance so that humans more easily interpret images. Digital thermal images captured by thermal cameras are stored in memory. These digital images are then processed and displayed for various applications such as remote sensing, medical image processing, robotics, industrial parts automatic inspection, infrared imaging and night vision systems for automatic target detection. Thermal image quality depends on the radiation pattern as well as the temperature difference between the object and the background [14]. Thermal image contains temperature values that giving information about condition of the object and it is represented by intensity level at each pixel location [15]. Colored thermal images have a composition of red, green and blue that describes the temperature values of an object. Therefore, quantifying evaluation on region of interest of image is very important to ensure measurement results.

2.2 ENTROPY OF IMAGE

The theory of entropy defined by Shannon is the theory used to measure information content or uncertainty from a random variable represented as a distribution. Shannon defined the entropy n-state system, it can be defined as [16]–[23],

$$H = -\sum_{i=1}^{n} p_i \, log\,(p_i) \qquad (1)$$

where pi is the probability of occurrence of the event i and the equation is defined as,

$$\sum_{i=1}^{n} p_i = 1, \qquad 0 \leq pi \leq 1 \tag{2}$$

Entropy of image is a measure of randomness information statistics that can be used to characterize the texture of an image object [21]. Entropy on image is calculated by the following equation [18],

$$H = -\sum_{i=0}^{L=L-1} - p_i \log (p_i), \qquad pi = N_i/N \tag{3}$$

Information theory is able to predict the relationship between the value of image intensity. The higher the entropy, the more variable information contained [16][23]. Entropy of image is closely related to the image histogram. Image histogram displays the probability of the occurrence of the intensity values of each pixel at the image intensity level [24][25].

3. METHODOLOGY

This study used thermal image of the infrared thermography inspection on electric motors. The quantitative evaluation was developed using GUI MATLAB. The stages of study were illustrated in Figure 2. The object to be evaluated consisted of two shown in Figure 3. Colored thermal image was zoomed using tools (*zoom*) and cropped the region: measuring point and hot spot using the tools (*imcrop*) with the size of rectangle crop of 8x8 pixels and then make image histogram using tools (*imhist*).

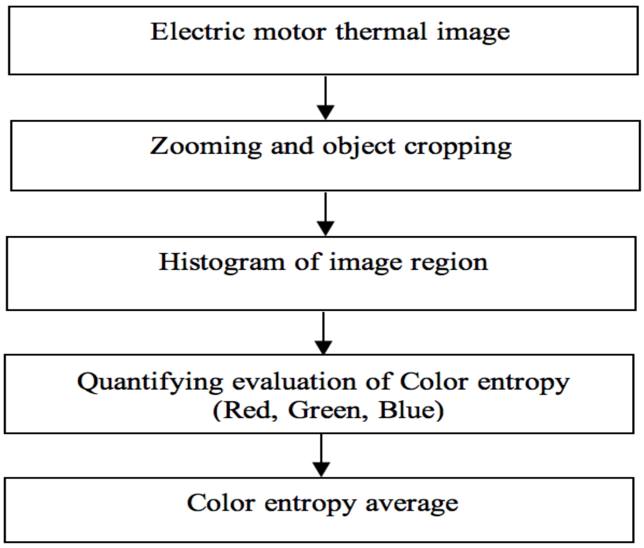

FIGURE 3. The Quantitative Evaluation Stages of Electric Motor Thermal Image

Quantifying [25] evaluation of each regions (the measuring point and the hot spot regions) to get the color entropy of red, green, blue colors using the tools (entropy) and

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then calculating the average of color entropy. The result of quantitative evaluation on each region are shown in the GUI such as Figure 4 and Figure 5.

4. RESULTS

The evaluation results on one of the electric motor thermal images in this study are shown in Figure 4 below:

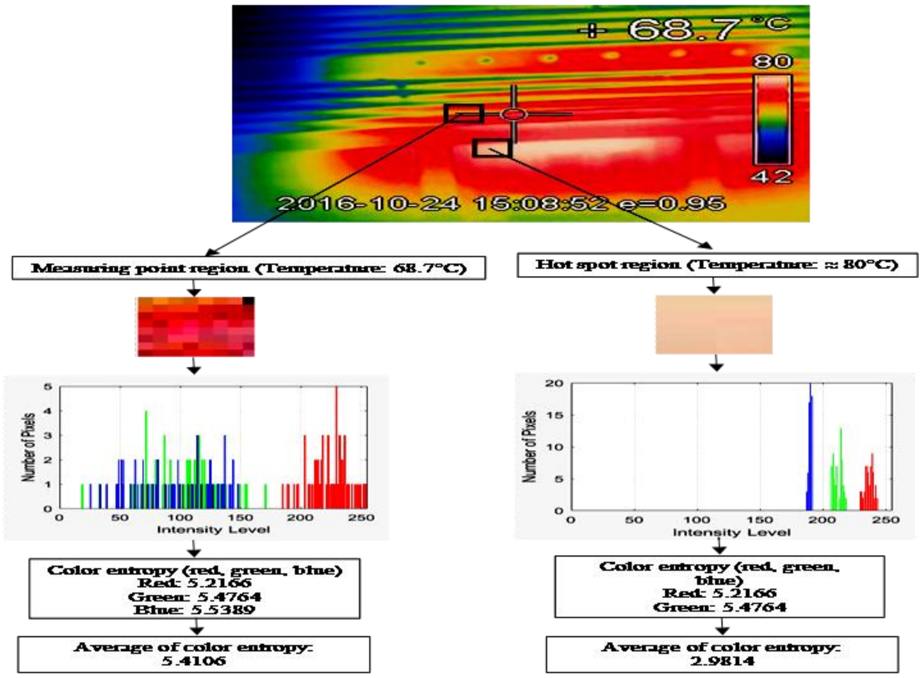

FIGURE 4. The comparison of study results on the measuring point region and the hot spot region

Evaluation of electric motor thermal image on the measuring point and hotspot regions using GUI MATLAB are shown in Figure 5 and Figure 6 below,

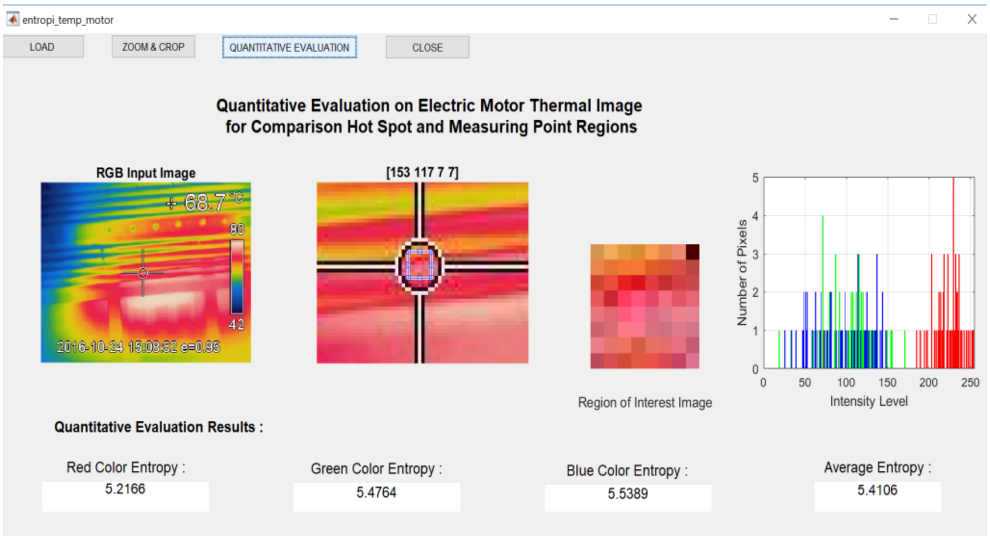

FIGURE 5. Quantitative Evaluation on Measuring Point Region

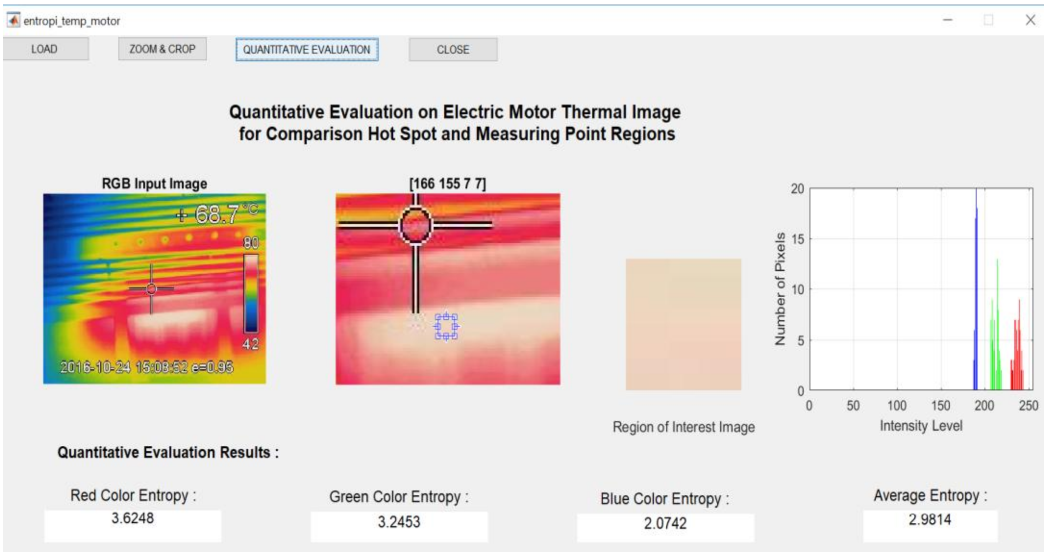

FIGURE 6. Quantitative Evaluation on Hot Spot Region

In this study, each color in the thermal image (red, green, blue) has a different entropy value so that the average color entropy value was used to quantify the measurement point and hot regions. The average color entropy can distinguish between two regions. This can provide information to the technician in analyzing the results of the thermography inspection of electric motor and make corrections about the exact location of the measurement point so that the measurement results describe the real condition of the electric motor. The overall results of quantitative evaluation on 10 images of electric motor are presented in the following table:

TABLE 1.
The result of quantitative evaluation electric motor thermography inspection

Electric motor thermal image	Color entropy on measuring point region			Color entropy on hot spot region			Entropy average of measuring point	Entropy average of hot spot
	Red	Green	Blue	Red	Green	Blue		
Image 1	5.2028	5.6209	5.1193	3.4351	4.0221	3.8002	5.3143	3.7525
Image 2	5.2166	5.4764	5.5389	3.0793	3.1618	2.8932	5.4106	3.0448
Image 3	5.1777	5.6327	5.5389	3.6392	2.9467	3.4952	5.4497	3.3604
Image 4	5.625	4.9605	5.4257	4.1927	3.5184	4.07	5.3371	3.927
Image 5	5.2402	5.5507	5.6757	3.574	3.5802	3.5516	5.4889	3.5686
Image 6	5.3945	5.1403	5.2417	3.4897	3.4721	3.6676	5.2588	3.5431
Image 7	5.2756	5.6563	5.5	3.8455	4.098	3.9301	5.4773	3.9578
Image 8	5.3945	5.6445	5.4098	3.4704	4.1771	3.9077	5.4829	3.8517
Image 9	5.2653	5.0855	5.6132	2.2544	3.0522	3.5423	5.3213	2.9497
Image 10	5.1716	4.9255	5.2577	3.4871	3.6188	3.7941	5.1182	3.6333

Based on the results of the study, we found that the color entropy is higher in the measuring point region than the color entropy in the hot spot region. This is caused by the measuring point region contains a lot of non-uniform information spread almost all the intensity level of the histogram (See. Figure 5), while in the hot spot

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region (high temperature) only spread uniformly in area of high intensity level with almost uniform color intensity values (See. Figure 6).

5. CONCLUSIONS

The quantitative evaluation of the thermal image of an electric motor using color entropy shows significant results to compare two regions of measuring point and hot spot and can provide a correction to the results of the measurement of the temperature of an electric motor. This will certainly help the technician in providing a monthly report on the thermography of electric motors inspection at the company, which so far only relies on the results of measurements and visualization.

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