

Thermal Image-Based Disc Pads Diagnosis System in Grab Crane

Yeon-Jae Oh*, Kyoung-Wook Park **, Eung-Kon Kim*

*Department of Computer Science, Sunchon National University,
255 Jungang-ro, Suncheon, Jellanam-do, Republic of Korea

** Division of Culture Contents, Chonnam National University,
50 Daehak-ro, Yeosu, Jellanam-do, Republic of Korea

*oksug10@sunchon.ac.kr, **zergadiss73@chonnam.ac.kr, *kek@sunchon.ac.kr

Abstract — Grab cranes are used for multi-purpose when the sand and soil are deposited into harbor wharf or the undersea construction is performed. Among the components of crane grab, the wire drum and disc brake pad are key expendables and have disadvantages that lot of heat is generated and very expensive when replacing them. In this study, the thermal image analysis for the disc brake, which works with wire drum of the crane is suggested. The suggested system performs the pad thermal diagnosis through the thermal image using the characteristics that the disc and pad surface temperatures are distributed abnormally before the brake failure and the disc pad damage. Therefore, the damage by the failure can be prevented by discovering the abnormality of the machine parts before failure and the life cycle of the pad and the cost can be extended and saved by operating the crane performing constant checkup for the overload.

Keywords— Thermal image camera, Thermal Image Diagnosis, Disk Pad Diagnosis

I. INTRODUCTION

Recently, the importance of the thermal image camera is being increased in the diverse areas such as the industry, chemical engineering, semiconductor, shipbuilding, etc. In addition, by the development of smart devices, diverse mobile monitoring solutions are needed[1].

The continuous growth of our economy has been made by the navigation and port technologies and the shipbuilding industry together with the development of cutting edge technologies. Particularly, the marine transportation handles more than 98% of the world cargo volume and to deal with the cargo volume, the ships are growing bigger and faster[2], for which the navigational equipment and additional equipment[3] are installed in the ships. Among them, the grab cranes is used for multipurpose when the sands and soils are deposited in the port wharf or performing the undersea construction. Among the components of grab crane, the wire drum and disc brake pad are the key expendables and have disadvantages that lot of heat is generated and very expensive when replacing.

In this paper, the thermal image analysis for the disc brake, which works with wire drum of the crane is suggested. The

suggested system performs the pad thermal diagnosis through the thermal image using the characteristics that the disc and pad surface temperatures are distributed abnormally before the brake failure and the disc pad damage.

Although, in the existing diagnosis system, the checkup and maintenance are made after occurring the failure symptoms, since the disc pad diagnosis system grafted with the thermal image camera can identify the failure symptoms before occurring the failure, it can prevent the accident in advance and save the time to find the cause of problem by stopping the system. In addition, since the temperature of the monitored component is collected, it can predict when the failure may occur based on the database made for the past.

II. PAGE LAYOUT

Temperature measurement through the thermal image camera All objects having temperature emit those heat with the infrared. All the objects having higher than absolute temperature of 0 (-273°C) radiate the rays of infrared domain. The infrared is radiated even to the ice, the object having very low temperature. The higher the temperature of the object, the more the infrared is radiated. Using such principle, diverse diagnoses are made using the thermal image equipment[4].

Infrared is the electromagnetic wave having the wavelength between 0.72~1000μm, from the long wavelength of visible rays to the short wavelength of microwave. Since the infrared has close relation with the temperature of the objects, all the objects having the temperature higher than 0°C of absolute temperature are radiating the infrared constantly. These imaging devices are filming the thermal image on the surface of the object and use it as examining the state of the object by analyzing the temperature distribution and changes. According to the Planck's law, the radiant intensity (homogeneous radiant existence) of the black body can be obtained from Equation (1) [5].

$$\omega_{\lambda} = \frac{c_1}{\lambda^5} \left(\frac{c_2}{\lambda T} - 1 \right)^{-1} (W/cm \cdot \mu m) \quad (1)$$

where, λ is wavelength(μm), T is the absolute temperature of the black body (K), C_1 is $3.7402 \times (10^{-12} \text{W} \cdot \text{cm}^2)$, and C_2 is $1.4388 (\text{cm} \cdot ^\circ\text{C})$.

As an object, which absorbs the infrared projected into it completely, the black body is the object having greater radiant energy at certain temperature than any other objects.

Electromagnetic wave domain of infrared thermal image The infrared is a form of electromagnetic radiation having long wavelength than visible rays. For the other radiant waves, there are X-rays, ultraviolet rays, radio waves, etc. The range of the electromagnetic radiation is determined by the frequency or wavelength. The range of the infrared detector or system is determined by the wavelength. The system, which detects the radiation in the band of $8-12\mu\text{m}$, is generally referred to as 'long wavelength' and that can detect the radiation in the band of $3-5\mu\text{m}$ is referred to as 'short wavelength'. The visible range of the electromagnetic spectrum is $0.4-0.75\mu\text{m}$ [6].

Image subtraction method Image subtraction is the method of processing the image and has 3 characteristics. First, it helps to identify small changes in the temperature. Second, it helps to suppress the influences of the heat reflection. Third, in case of applying consecutively, it helps, for example, visualizing the time derivative by the transient phenomena.

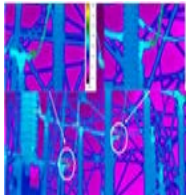
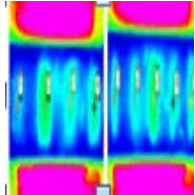
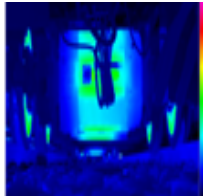
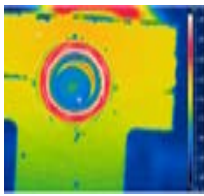
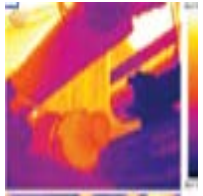
The image subtraction can be performed mainly by two methods. One is to subtract reference image from the each image in the recorded sequence and the other is the continuous process, that is, to subtract the each image from the previous image. The first method forms a new order as a result and shows the difference in the temperature between each image and the reference image. The comparison between the reference image and resulted image, in fact, is not helpful to find the location of hot spot but the subtracted image can indicate the location of abnormal heat source exactly. In the second method of image subtraction, the consecutive image subtraction is made, in which case, the difference signal of the n th image pixel (c, y) at the sequence $\Delta S(x, y, n)$ is calculated by following equation[4]. Since the image n and $n-1$ are separated by the time interval Δt , all of which are defined by the recording frame speed, the consecutive image subtraction refers to calculate the first derivative in the time domain. If the consecutive subtraction algorithm is applied to the image sequence consecutively subtracted second time, the second derivative of the temperature within the time domain will be calculated, which can provide the additional information of the time-based temperature action of the object to be examined and, for example, is used in the pulse thermography.

The consecutive image subtraction can be used to extract the characteristics of the moving objects in real-time when the object and the background are static or does not have characteristics.

Cases of infrared diagnosis system If the infrared camera is used, the performance or the state of the object can be evaluated by examining the condition of the object using non-

contact method. Therefore, it is actively used in diverse areas. Table 1 is shown the cases used the thermal image diagnosis system using thermal image camera[7-12].

TABLE 1. CASES OF THERMAL IMAGE DIAGNOSIS SYSTEM

Power board/ substation diagnosis using time series data of thermal image camera [7]	Inspect the aging and tearing of the apartment with the thermal images [8]	Detect the defects in the thin wall piping with small calibre in the nuclear power plant [9]
		
Detect and analyze the abnormal heat generation at the substructure of railway car [10]	Diagnose and measu re the dynamic load of ball bearing [11]	Inspect the industri al plant condition u sing the thermal im age camera [12]
		

III. DISC PAD DIAGNOSIS SYSTEM USING THERMAL IMAGE CAMERA

Grab cranes are used for multi-purpose when the sand and soil are deposited into harbor wharf or the undersea construction is performed. Among the components of grab crane, the wire drum and disc brake pad are key expendables and have disadvantages that lot of heat is generated and very expensive when replacing them. In this paper, the disc pad diagnosis system using thermal image is suggested. The suggested system performs the thermal image monitoring for the pad thermal analysis using the characteristics that the disc and pad surface temperatures are distributed abnormally before the brake failure and the disc pad damage. Figure 1 is shown the system layout for the brake and disc diagnosis and monitoring using thermal image.

The image of the disc pad of the grab cranes are fed into the thermal image control and diagnosis server using thermal image camera. The thermal distribution chart of the thermal disc pad fed is compared with the existing data and can be verified through the smart phone, tablet PC or control PC of the user. In this moment, if the overheating may occur above than designated temperature, the notification message will be sent to the controller. Figure 2 is shown the screen fed the

images using thermal image camera, wireless image transmission module.

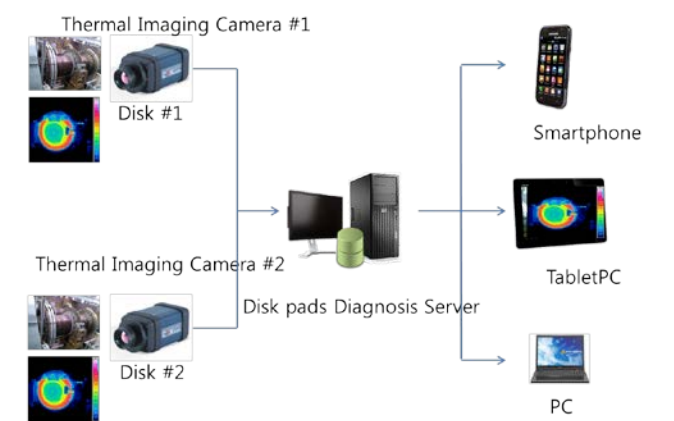


Figure 1. System structure

The disc pad diagnosis system using thermal image us basically composed with the thermal image camera to monitor the heating condition of the disc pad and surrounding components and the communication equipment to transmit the thermal image data to control/diagnosis server. The thermal image control server receives the images of the thermal image camera installed at each disc through TCP/IP, stores them with the disc No. operator, time information, and at the same time, performs the streaming service that transmits the images to the smart phone or tablet PC, which request the monitoring.



(a) Screen Fed Images from Thermal Image Camera



(b) Wireless Image Transmission Module

Figure 2. Screen Fed Images from Thermal Image Camera, Wireless Image Transmission Module

To analyze the thermal image, the software module to extract the feature point of the temperature distribution was developed. Figure 3 shows the screen performed the login, select disk, transmission test of the thermal image camera's image for the disc and pad of current grab crane.

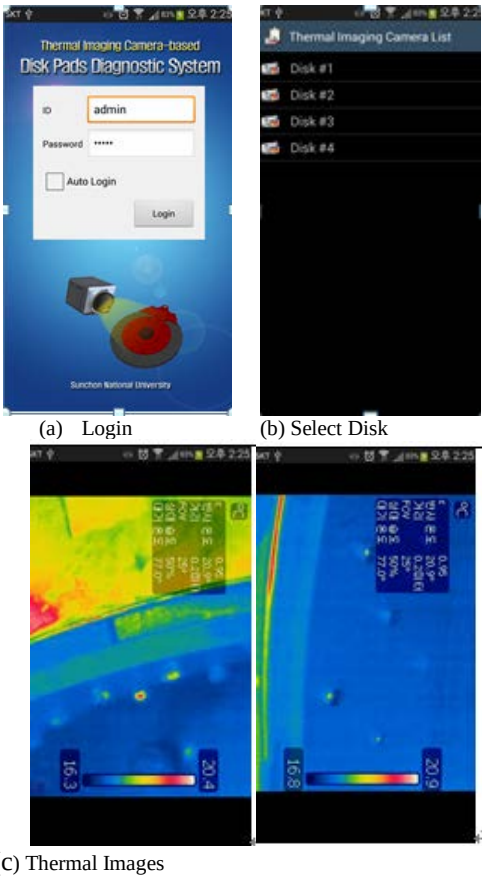


Figure 3. Screen shots of login, select disk and thermal image transmission test

The detailed specification of the thermal image camera used in the thermal image monitoring system is shown in Table 2.

TABLE 1. DETAILED SPECIFICATION OF THERMAL IMAGE CAMERA

Description	Specification
Resolution	320×240
Detector type	LWR <80mK@f/1, 60Hz, 300K
Spectral Range	8 to 14μm
Measurement Range	-20°C to 120°C, up to 650°C
Frame Rate	NTSC(60Hz), PAL(50Hz)
Ethernet	10/100base, TCP/IP
Lens	20mm Motorized Focus lens

The detailed specification of the thermal image camera used in the thermal image monitoring system is shown in Table 2.

TABLE 2. DETAILED SPECIFICATION OF THERMAL IMAGE CAMERA

Description	Specification
Resolution	320×240
Detector type	LWR <80mK@f/1, 60Hz, 300K
Spectral Range	8 to 14μm
Measurement Range	-20°C to 120°C, up to 650°C
Frame Rate	NTSC(60Hz), PAL(50Hz)
Ethernet	10/100base, TCP/IP
Lens	20mm Motorized Focus lens

It determines the abnormality of the thermal distribution of the disc and pad by performing image analysis according to the designated rules for the images transmitted from the thermal image control server. Table 3 is shown the rule for the image analysis.

TABLE 3. RULES FOR IMAGE ANALYSIS

Rule	Explanation
Disc Overheat Temperature (300°C)	Designate the maximum disc temperature
Disc pad thermal distribution (100°C)	Designate range between maximum and minimum values of the measured temperature on the disc surface
Pad overheat temperature (300°C)	Designate the maximum temperature of the pad surface
Abnormal pad thermal distribution (100°C)	Designate the difference between the maximum and minimum temperature of the pad surface

TABLE 4. TYPE OF NOTIFICATION MESSAGE

Notification Message	Explanation
Disc Overheat	Detect the higher value than designated temperature from the disc surface
Abnormal disc thermal distribution	Detect the unusual pattern of thermal distribution from the disc surface
Pad Overheat	Detect the higher value than the designated temperature from the pad surface
Abnormal pad thermal distribution	Detect the unusual pattern of thermal distribution from the pad surface

The thermal image analysis of the disc and brake pad compares and analyzes the difference between the maximum temperature and the minimum temperature from the thermal image of the disc and the brake pad area and the distribution of the temperature by time and determines as abnormality if they may out of the rules. It analyzes the thermal image according to the rules established and if determines abnormal situation, sends the notification message to the relevant controller. The notification message is composed with the contents of the message, time of occurrence, disc No. and thermal image and the types of notification messages are shown in Table 4.

The application for the smart phone and tablet PC was developed in order for the operator to monitor the thermal images of the disc and disc pad easily during the operation. Table 5 is shown the functions of the smart phone application

TABLE 5. FUNCTIONS OF SMART PHONE APPLICATION

No	Description	Function	Explanation
1	Log-in	User Log-in	Function to authenticate the user
2		User Registration and Modification	Register user ID and password
3	Monitoring	List of thermal image camera	Display the list of thermal image cameras
4		Thermal image monitoring	Visualize the images of the thermal image camera selected by user
5	Notification Service	Notify abnormal situation	Display the notification message if the abnormal situation is transmitted from the server

IV. CONCLUSIONS

All the machine parts or electric components have characteristics that the temperature is rising before they are failed or damaged. Since the thermal image camera detects the area occurred the heat and display it with images, it has advantage that finds such machine parts and electric components before they may be failed. Therefore, the thermal image camera displays the out-of-order signal of the key components such as bearing shaft, gear, brake, pad, etc., immediately with high reliability and allows performing preventive maintenance or replacing the relevant component in advance.

In this paper, the thermal image diagnosis system for the disc brake pad, which works in the wire drum of grab crane was suggested. The suggested system performs the pad heat diagnosis analysis through the thermal images using the

characteristics that the disc and pad surface temperature is distributed abnormally before they may be failed or damaged. Particularly, by sending the notification message to the controller when the overheat or overload occurs in the disc and brake pad, it always can extend the life cycle and save the cost by performing the checkups for the overload and operating the crane

ACKNOWLEDGMENT

“This research was financially supported by the Ministry of Education (MOE) and National Research Foundation of Korea(NRF) through the Human Resource Training Project for Regional Innovation (No. 2013 H1B8A2032217).”

REFERENCES

- [1] A. Gleiter, G. Riegert, T. Zweschper, G. Busse, “Ultrasound lockin thermography for advanced depth resolved defect selective imaging,” in European Conference on Nondestructive Testing, ECNDT conference Proceedings (Berlin, Germany), 25-29 September, 2006.
- [2] Y. S. Lee, Y. J. Ahn, “A Study on the Standard Ship’s Length of Domestic Trade Port”, Journal of the Korean Society of Marine Environment & Safety, Vol. 19, No. 2, pp. 164-170, 2013.
- [3] K. Y. Jeong, E. K. Kim, “Image Guidance System for Working with Abalone Park”, Journal of The Korea Institute of Electronic communication Sciences, Vol.9, No.3, pp.369-376, 2014.
- [4] J. Y. Kim, “Thermo-analysis of machining center main-axis thermo-displacement for infrared rays thermo-image camera,” Proceedings of the Korean Society of Machine Tool Engineers Conference, Vol.2001, No.-, pp. 125-130. 2001.
- [5] D. Y. Kim, D. P. hong, C. H. Yu, “Concdtion Monitoring under In-situ Lubrication Status of Bearing Using Infrmed Thennography”, Journal of the Korean Society for Nondestnktive Testing, Vol. 30, No. 2, pp. 121-125, 2010. 4.
- [6] P. O. Moore, "Nondestructive Testing Handbook," Infrared and Thermal Testing, Vol. 3, 3rd ed., ASTM, pp. 223-246, (2001)
- [7] S. S. Hwqng, Y. C. Bae, “Diagnosis of power supply using time-series of infrared camera”, Journal of The Korea Institute of Electronic communication Sciences, Vol. 7, No. 6. pp. 144-147, 2012.
- [8] C. H. Cheong, “Study on External Wall Surface Temperature Pattern of Old Residential Building in Jinju City”, Architectural Institute of Conference Proceedings published, Vol. 34, No.1, pp. 265-266, 2014.
- [9] K.W. Yun, D. L. Kim, H. C. Jung, “Application Defects Detection in the Small-Bore Pipe Using Infrared Thermography Technique“, Journal of the Korean Society for Nondestructive Testing, Vol. 33, No. 1, pp. 34-39, 2013.
- [10] B. B. Kang, J. G. kim, C. M. Jimg, “Thermal image analysis method for the detection of the abnormal heat under the railway vehicle“ Vol.13, No. 1, pp.1347-1360, 2013.
- [11] D. P. Hong, H. J. Kim, W. T. kim, “On Diagnosis Measurement under Dynamic Loading of Ball Bearing using Numerical Thermal Analysis and Infrared Thermography“, Journal of the Korean Society for Nondestructive Testing, Vol. 33, No. 4 pp. 354-359, 2013.
- [12] B. J. Jeon, T. W. Kim, S. G. Kim, “Panorama Image Processing for Condition Monitoring with Thermography in Power Plant”, Journal of the Korean Society for Nondestructive Testing, Vol. 30, No. 2, pp. 98-103, 2010.



Yeon-Jae Oh

She received the B.S. degree from Korea National Open University, Korea, in 2007, her M.S. degree from department of computer science, Suncheon National University, Korea, in 2009. She is currently a Ph.D. student in computer science at the Suncheon National University, Korea, Her current research interests include augmented reality, image processing, computer graphics.



Kyoung-Wook Park

He received the B.S. degree from Suncheon Na-tional University, Suncheon, Korea, in 1997, his M.S degree from department of computer sci-ence and statistics, Chonnam National Universi-ty, Gwangju, Korea, in 1999, his Ph.D. degree from department of computer science, Chonnam National University, Gwangju, Korea, in 2004. His current research interests are parallel and distribution processing, graph theory, theory of



Eung-Kon Kim (M’76–SM’81–F’87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author’s educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year degree was earned. The author’s major field of study should be lower-cased.