A review of methods on Condition Monitoring and Fault Diagnosis using IR Thermography – An Expert System approach

Ch. Vinay Kumar Reddy¹, K. V. Ramana²

¹Department of Mechanical Engineering, SR University, Warangal, Telangana, India
²Department of Mechanical Engineering, KL University, Vijayawada, India

Email ID: vinay_reddy_ch@srcwarangal.ac.in

Abstract. Condition Monitoring is a process of checking faults in machinery. The main goal of Condition Monitoring is to check the health of critical components of machines and systems. In real situations during operation of machines decisions to be taken on maintenance are considered based on the condition. It has the benefits such as decreasing catastrophic failures, minimize the maintenance, operational and logistical cost, maximize the system security, availability and increasing the reliability. Different researchers use different methods for fault diagnosis. Every method has its own shortcomings. In this paper a study has been done on the Expert system to do condition monitoring and fault diagnosis using IR Thermography.

Keyword: Condition Monitoring, IR Thermography, Expert system, Fault Diagnosis.

1. Introduction

Increased heat and resistance are the primary reasons for most of the mechanical and electrical components failure. Infrared cameras detect this heat. Infrared Camera detects the objects IR energy, transform to temperature, and shows as temperature distribution. IRT is a non-contact type condition monitoring technique, which can be used to identification of faults in the mechanical and electrical equipment. It also identifies system overloads, loose defective components, damaged switchgear etc. IRT can be used in electrical testing for finds hot, dangerous problems quickly.

IRT Benefits

IR Thermography is an expert system to diagnose condition monitoring system and it has so many merits to consider. This is non-contact type technique which reduces unscheduled breakdowns, increases life of equipment, no interruption during inspection and in-service time. Maintenance costs are low, very low risk in operating Technology, cost of repairs is low and increases profits by reducing labor cost. It helps to Prevent catastrophic failures; insurance premium will be low due to reduced losses. Minimizes risk of failure in equipment and increases safety, minimizes liability to the designers and installation team while erecting machinery. Increase overall System/Machine/component performance. It also identifies whether components and systems properly operating or not and design intent.
2. Methodology
Techniques of Condition Monitoring: Temperature measurement is classified into two types namely contact type and non-contact type. In this paper, the non-contact type of temperature measurement is discussed. IR Thermography is a non-contact type of condition monitoring technique.

3. Analysis
An analysis was done by the authors [1], to identify the fault on bearings using IRT Method, Vibration Analysis (VA) method and Airborne sound method. A specific rolling bearing is considered and tested by the experimental setup. Axial & radial loads applied on the ball bearing and tested in all three methods; authors observed relevant results in all these Methods. It is observed that IRT is cheaper than the other two methods. It is a known fact that VA is the effective & precise method in identifying faults on bearings but one replaces this method by the IRT method. Vibration analysis method needs experienced staff, the cost of processing is high and it requires great time to complete the process. The IRT method has both merits and demerits though it completes the process in less cost with low difficulties.
but results are less accurate. Many researches are working on this and still experiments are going on to identify the promising method to detect the fault on bearings.

Subramainam et. all [2] discussed about the failures of electrical and mechanical components related to misalignment of stator and Rotor, worn out components due to improper lubrication. It has been observed that 50% are bearing failures. Even though there are many different types of failure detection techniques but IRT is becoming a very promising tool these days with IRT to know the condition of bearings. All Infrared measurements are normally made in wavelength bands of 0.75 µm – 25 µm. According to Stefan Boltzmann Law.

\[ W = \varepsilon \sigma T^4 \]

\( W \) = Density of flux, \( \varepsilon \) = Emissivity, \( \sigma \) = Stefan-boltzmann constant, \( T \) = Absolute Temperature.

Unusual temperatures identified on bearing regions and impeller sides. Due to heat in gland packing impeller side is effected with hot spots. These IRT studies help in evaluating temperatures and prevent major breakdowns.

Lim. G et all [3] developed an intelligent fault diagnosis system, which they compared with the vibration signals and thermal images. Thermal imaging along with a Support Vector Machine (SVM) is used for fault diagnosis. Accuracy level is checked with vibration signals. This method is a novel intelligent method to apply for rotating machines in industrial areas to get probable accuracy. This method can be used for both thermal images and vibration. Above 90% of accuracy is obtained using thermal images with only three features whereas with vibration signals above 95% of accuracy obtained with four features.

Singh et. all [4] discussed identifying faults in Induction motors. Identified faults are Environmental, thermal, load stress and inter turn faults. Non-invasive technique called Infrared Thermography proposed in this paper. Transient and steady state analysis are the two categories mentioned in this paper. In 3 minutes of operation this method can identify the fault and its severity. By the rise of inter turn fault temperature rise. By this we can identify the faults at initial stage. Transient and steady state analysis is also presented in this paper.

Ranjith et all [5] tested stainless steel samples to identify artificial subsurface defects. Samples are analysed through experimentation and Finite Element Analysis. FEA results found to have good correlation with experimental results and thus identified subsurface defects. This LIT and image processing algorithms for identifying the subsurface defects in STS-304 material. The results show IRT is a reliable and non-destructive method for detecting subsurface defects.

Taheri-Garavand, Amin et. all [6] discussed intelligent fault diagnosis and condition monitoring using IRT. Authors identified six faults in the radiator. They are Tube blockage, Fins blockage, loose connection between Fins & tubes, radiator door failure, coolant leakage and normal conditions. Several procedures considered for the proposed system like thermal image acquisition, image processing etc.

Hui Zou et all [7] explained about the importance of IRT. Thermal defects of electrical equipments are identified using IRT. Authors suggested that IRT merits such as non-contact detection, electromagnetic interference, safety and, reliability. Manual analysis of IRT images very difficult, for avoiding those difficulties intelligent fault diagnosis methods are proposed. There may some more difficulties such as finding the region of interest and extracting features.

Garcia-Ramirez, et. all [8] discussed on thermo graphic analysis that can be a better technique to diagnose the fault with an additional merit. They also inform us Motor Current Signature Analysis (MCSA) and vibration is still preferred and should not be ignored. Authors suggest MCSA and Vibration techniques are detect only of specific faults. Thermographic analysis gives us detection of faults. This is very simple method. With this technique service time is reduced. In the future the author proposes this thermographic analysis is a smart instrument for fault identification. Jaffery et. all [9] discussed about IRT in agriculture, pharmaceutical, construction and manufacturing industries. In this paper the author proposed two systems real time and offline. By using these methods we can monitor the temperature variations and we can do analysis hot regions in the machinery. This technique helps to prevent catastrophic failures mechanical equipment. This system is simulated for big amount of thermo gram
images. The results obtained by comparing existing invasive type systems are very promising and satisfactory.

IRT technique[10] used in maintaining mechanical and Electrical machines over decades. Its use in Electrical machinery limited to identify faults in power transformers. In reference to predictive maintenance of rotating electrical machines it is very much limited. Due to this fact the capacity of this tool together with progressive decrease in price of IR cameras. Rubén et. al [11] worked on temperature measurement using IR and NDT. This paper gives us a review on IRT especially focused on two applications. One is temperature measurement and another one is NDT, in these two methods IR based sensors are used. Authors are reviewed and developments in these fields and recent advancement of technology. Dutta, Tamal et. al [12] said that high temperature rise impacts to failure of equipment. Ramana, K.V. et. al [13] developed an expert system for diagnosis of bearing faults of rotating machinery using vibrations. Babu, Ravi et. all [14] have studied the significance of modal analysis to detect and diagnose misalignment fault in turbine rotor. Duduku, M.R. et. all [15] have developed an expert system for condition monitoring of submarines using IR Thermography. Mohanty, A.R. et. all [16] have taken up fault diagnosis of pump motor set using condition monitoring and IOT technique. A critical review of condition monitoring parameter for fault diagnosis of rolling element in bearing has been taken up Jagdale, Manoj et. all [17]. Narayana, K.L. et. all [18] have investigated on condition monitoring of lubricants using wear debris analysis. Kondhalkar, Ganesh. et. all [19] has studied the effects of various defects in roller bearings and ball bearings due to vibrations. Now a days finite element analysis is also becoming a popular tool for design and simulation [20-28].

4. Expert System

Expert systems were introduced around 1965 by the Stanford Heuristic Programming Project led by Edward Feigenbaum, who is called as the "father of expert systems". Other contributors were Bruce Buchanan and Randall Davis. The Stanfordresearchers tried to identify domains where expertise was highly valued and complex, such as diagnosing faults. In the 1980s, expert systems proliferated. The first expert system to be used in a design capacity for a large-scale product was the SID (Synthesis of Integral Design) softwareprogram, developed in 1982 written in LISP. The block diagram of an expert system is shown in figures 1& 2 below.
Tools Used in Expert System
Artificial Neural Networks (ANN), Fuzzy Logic, Taguchi Method etc.

5. Conclusions
Infrared thermography (IRT) is a vital tool to recognize faults and it become an intelligent method in Mechanical and Electrical components/Machinery to do preventive maintenance due to its high...
precision and sensitivity imaging characteristics. Infrared thermography is used to identify over heating areas leads to high Friction/ resistance, so that problems can be identified before a component fails, causing damage to the component, creating safety hazards and reducing productivity loss. Because increased temperature is a sign of failure, infrared is the best diagnostic tool available for finding these hot connections in the early stages of degeneration, most importantly this is a non contact type technique. Some of possible faults are Loose/deteriorated connections, Overloads, Open circuits, unbalanced loads, Inductive heating, Harmonics and Defective equipment.

References

[1]. Athanasopoulos, Nikolaos and Botsaris, Pantelis, 2014. A Comparative Analysis of Detecting Bearing Fault, Using Infrared Thermography, Vibration Analysis and Air-Borne Sound. 10.1007/978-3-642-39348-8_14.

[2]. Subramainam, Bagavathiappan, Saravanan, Thangavelu, George N, Philip John, Jayakumar T and Raj Baldev, 2008 Condition monitoring of exhaust system blowers using infrared thermography. Insight - Non-Destructive Testing and Condition Monitoring. 50, 512-515. 10.1784/insi.2008.50.9.512.

[3]. Lim G Bae D and Kim J 2014 Fault diagnosis of rotating machine by thermography method on support vector machine. J Mech Sci Technol 28, 2947–2952.

[4]. Singh, Gurmeet, Kumar, Tulluri Chiranjeevi Anil, Naikan V, 2016 Induction Motor Inter Turn Fault Detection Using Infrared Thermographic Analysis, Infrared Physics & Technology. 77,10.1016/j.infrared.2016.06.010.

[5]. Ranjit Shrestha, Kang Kisoo and Kim Wontae, 2015 Investigation of Lock-in Infrared Thermography for Evaluation of Subsurface Defects Size and Depth. Int. J. of Prec. Eng. and Manuf. 16, 2255-2264. 10.1007/s12541-015-0290-z.

[6]. Taheri-Garavand, Amin, Ahmadi, Hojat, Omid, Mahmoud, Mohtasebi, Seyed, Mollazade, Kaveh, Smith, Alan, Carломagno, Giovanni. 2015 An intelligent approach for cooling radiator fault diagnosis based on infrared thermal image processing technique. Appl. Ther. Eng. 87, 434–443. 10.1016/j.applthermaleng.2015.05.038.

[7]. Hui Zou, Fuzhen Huang, 2015 A Navel Intelligent fault diagnosis method for electrical equipment using Infrared Thermography. Infrared Phys. & Tech. 73, 29-35.

[8]. Garcia-Ramirez, Armando, Morales-Hernández, Luis, Osornio-Rios, Roque, Benitez-Rangel, Juan, Garcia-Perez, Arturo, Romero-Troncoso, René. 2014 Fault detection in induction motors and the impact on the kinematic chain through thermographic analysis. Electric Pow. Sys. Res. 114, 1–9. 10.1016/j.epsr.2014.03.031.

[9]. Jaffery, Zainul, Dubey, Ashwani 2014 Design of early fault detection technique for electrical assets using infrared thermograms. Int. J. of Elec. Power & Ener. Syst. 63 753–759. 10.1016/j.ijepes.2014.06.049.

[10]. Lopez-Perez, David and Antonino-Daviu J.A. 2017 Application of Infrared Thermography to Failure Detection in Industrial Induction Motors: Case Stories, IEEE Transactions on Indust. Appl. PP. 10.1109/TIA.2017.2655008.

[11]. Usamentiaga R, Venegas P, Guerediaga J, Vega L, Molleda J, Bulnes F G 2014 Infrared thermography for temperature measurement and non-destructive testing. Sensors, 14(7), 12305-12348.

[12]. Dutta T, Sil J, and Chhotopadhyay P 2016 Condition monitoring of electrical equipment using thermal image processing. In 2016 IEEE First, Int. Conf. on Cont., Meas. and Instr. (CMI) 311-315. IEEE.

[13]. Ramana K V, Raghu Kumar, Bandlamudi, Kavuluru, Lakshmi 2014 An expert system for diagnosis of bearing faults of rotating machinery. Int. J. of Appl. Eng. Res. 9, 2591-2599.
[14]. Babu Ravi, Gupta Subham and Sri Dphaneendrasai Gautam, Kuldeep and Kumar, Chikkalameenu and Kumar Subham 2018 Significance Of Modal Analysis To Detect And Diagnose Misalignment Fault In Turbine Rotor. 10.13140/Rg.2.2.32278.45122.

[15]. Duduku M R, Kavuluru Lakshmi, Ramana K V, and Yesaswi C S 2017 Development of an expert system for condition monitoring of submarines using IR thermography, Int. J. of Mech. Eng. and Tech. 8. 26 -33.

[16]. Mohanty A R, Pradhan Prasanta, Mahalik Nitaigour, Ghosh Dastidar, Sabyasachi, 2012, Fault detection in a centrifugal pump using vibration and motor current signature analysis, Int. J. of Auto. and Cont 6, 261 - 276. 10.1504/IJAAC.2012.051884.

[17]. Jagdale Manoj, Garikapati, Diwakar 2018 A critical review of condition monitoring parameters for fault diagnosis of rolling element bearing. IOP Conference Series: Materials Sci. and Eng. 455. 012090. 10.1088/1757-899X/455/1/012090.

[18]. Narayana K L, Sandeepn V R K, Raghavendra T, Krishna V, Shankar Siva 2018 Condition monitoring of lubricants using wear debris analysis, Int. J. of Mech. and Prod. Eng. Res. and Development. 8. 803-808.

[19]. Kondhalkar, Ganesh. 2019 Effect of Various Defects in Roller Bearings On Vibration IJITEE Paper Vol 8 Issue 12. Int. J. of Innovative Tech. and Expl. Eng. 8. 5137-5141. 10.35940/ijitee.L2763.1081219.

[20]. Srivastava J P, Reddy G G and Teja K S 2020 Numerical investigation on vibration characteristics and structural behaviour of different go-kart chassis configuration Mater. Today Proc. 4–10 https://doi.org/10.1016/j.matpr.2020.06.488

[21]. Bhavani G, Srivastava J P and Mahesh V 2020 Characterization of used and virgin pearlitic rail steel Mater. Today Proc. https://doi.org/10.1016/j.matpr.2020.07.718

[22]. Srivastava J P, Chaithanya B K, Teja K S, Venugopal B, Vineeth S and Rajkumar M 2020 Numerical study on strength optimization of Go-Kart roll-cage using different materials and pipe thickness Mater. Today Proc. 1016–20 https://doi.org/10.1016/j.matpr.2020.08.217

[23]. Kumar P and Ashok G 2020 Design and fabrication of smart seed sowing robot Mater. Today Proc. https://doi.org/10.1016/j.matpr.2020.07.432

[24]. Srivastava J P, Sarkar P K, Kiran M V R and Ranjan V 2018 A numerical study on effects of friction-induced thermal load for rail under varied wheel slip conditions Simul. Trans. Soc. Model. Simul. Int. 95 351–62

[25]. Duhan N R, Srivastava J P, Anis M A and Sarkar P K 2018 Stress intensity factor for a semi-elliptical rail head crack under traction IOP Conf. Ser. Mater. Sci. Eng. 402 012132

[26]. Gope K D, Kumar U, Srivastava J P, Chattopadhyaya S, Das A K and Krolczyk G 2018 Experimental and Numerical Assessment of Temperature Field and Analysis of Microstructure and Mechanical Properties of Low Power Laser Materials (Basel). 1514 1–14

[27]. Mohanta M, Setu G, Ranjan V, Srivastava J P and Sarkar P K 2018 Indian railway track analysis for displacement and vibration pattern estimation Vibroengineering Procedia 21 71–6

[28]. Srivastava J P, Joshi D, Vivek L, Manish G S and Sravan G 2019 Design and fabrication of human-electric hybrid power tricycle IOP Conf. Ser. Mater. Sci. Eng. 653 012004 (1-7)