Proceeding of the 8th North American International Conference on Industrial Engineering and Operations Management, Huston, Texas, USA, June 13-16, 2023

Visual Inspection System Using Image Sensor in Manufacturing Industry

Nisarg Ishvarbhai Patel
Department of Mechanical Engineering,
school of Technology,
Pandit Deendayal Energy University,
Gandhinagar, Gujarat

Dr.M.B.Kiran
Associate Professor
Department of Mechanical Engineering,
School of Technology,
Pandit Deendayal Energy University
Gandhinagar, Gujarat

Abstract

Quality inspection is a very important aspect of manufacturing industries. It satisfies some important objectives of manufacturing industries such as decreasing human labour, during subjective judgment destruction of human error, increasing overall profit of the industry and improved quality of the workpiece. To overcome the constraints of conventional inspection system which were very time consuming and lengthy and cost effective; quality inspection using image based sensor is the system for getting maximum product quality in such lesser time. In this paper we focus on quality inspection using image sensor. we will be focusing on how image based sensor inspection is a very efficient solution for conventional non-efficient inspection systems. The results will offer an overview different approaches of visual inspection using image based sensor, its perks and constraints and specific applications in manufacturing industry.

Keywords

visual inspection, Quality Inspection, Image Sensor, Industry 4.0, Modern Manufacturing.

1. Introduction

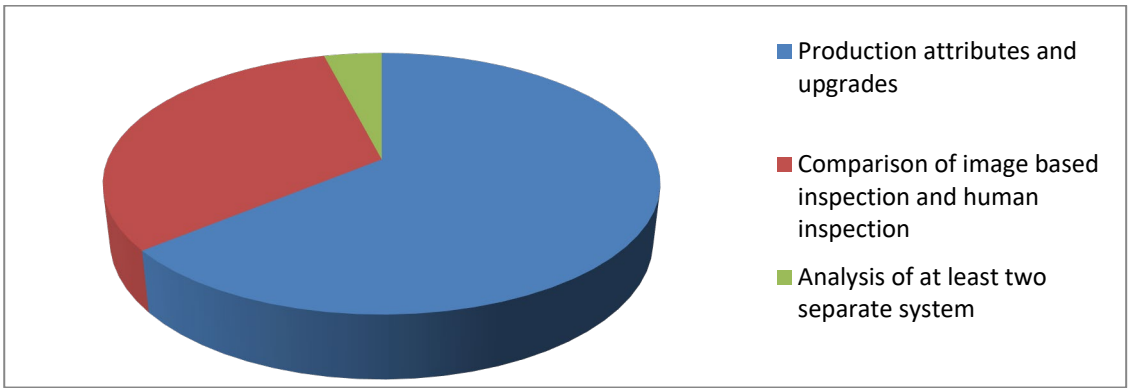
In manufacturing industries; inspection of the machined part is a procedure of measuring, To determine whether a machined parts features correspond to the design give by client company, one can examine surface flaws, conduct testing, or use optical gauging. This is crucial since it entails avoiding the possibility of providing customers with subpar goods. Conventionally, inspection of machined parts was done by a human comparing it with blue prints or design given by customer and if it they matched, the workpiece is accepted. which was considered for a big amount of scrap from redundant product. As production turn out to be sophisticated and effective, to conclude; clearly result could never exactly match the sketch(design given by customer) because there would always be some variation based on the level of security. Tolerance restrictions became increasingly common and computer vision system are replacing human inspectors as a solution to this problem Because of greater rivalry. As a result, concepts like mass production, automation, total quality management, and lean manufacturing were developed. Furthermore, there has been a recent surge in the adoption of the industry 4.0 paradigm, which is fuelled by the digital transformation of the manufacturing sector. However, these advancements can also result in increased potential for human error as it becomes more challenging for human operators to keep pace with inspection tasks.. Even tiny workplaces may afford to adopt such technology to improve their present systems and products for quality control and inspection. Operators now have more time to focus on tasks that call for higher levels of creativity, such complex process improvement and complex problem-solving.

1.1 Objectives

Traditional methods to inspect the machined part is expensive, labour-intensive, and take a lot time; they do not meet the needs of the modern manufacturing sector very efficiently. These techniques are ineffective because they can only effectively sample either a very small area or a very tiny percentage of the total items. But in image sensor based quality inspection method; there is a reduction of labour costs, during subjective judgment removal of human error and the real-time visualisation of product data for labelling, documentation and traceability.

2. Literature Review

An summary of prior research projects, known as a literature review, helps shape current and upcoming studies. The rationale behind earlier studies is crucial to comprehend since it offers essential information about which areas have received extensive research and which still require contributions. For the purpose of this review, have analysed all studies published between 2010 and 2020, and we found that machines are more accurate at identifying products defects. In contrast to operators who have numerous tasks to complete during their limited workdays, image-based inspection system have a single 24/7 responsibility (Diesing, 2020). The outcomes of a comprehensive paper review of around 160 paper's main points are covered in pie chart below.



The majority of the research publications analysed were concerned with assessing a new or current image based inspection system setup. Which shows that subjects that demand more research and improvement. In this paper, Elmasry, G. et al. give an overview of conventional methods for evaluating the quality of meat used in the food sector before introducing hyper spectral imaging as a non-destructive alternative. They note how expensive, labour-intensive, and time-consuming traditional processes are, and how the current food processing sector. These techniques are ineffective because they can only effectively sample a very tiny percentage of the total items. The "medical industry" has made intriguing usage of visual inspection systems, and the application can be quite interesting, in addition to applying them in manufacturing(Hoshikawa et al.2019).

The fact that a human operator is a part of the majority of computer-focused solution is intriguing and adds to industry 4.0's emphasis on this. According to the data, only 4% of the paper compared currently implemented system to those that had just been designed. From this, We can infer that a lot of business may not yet have adopted this type of inspection system, and that just a few of them working more closely with these systems. Which addresses that there are more of a development is needed in this type of systems. According to a recent survey, 23% of quality control measure are erroneous due to human error, and 70% of the organisations admit they are unaware of the importance of equipment management (General Electric 2016).

In order to verify that the product fulfils the industry-established quality standards, visual inspection is an essential phase in the manufacturing process. The use visual inspection systems has gained popularity through times as a result of its capacity to record high-resolution images, process massive amounts of data, and deliver precise and reliable conclusions.

A lot of research has been done recently on the creation and application of visual inspection system using image sensors in manufacturing sectors like the automobile, electronics, and food industry. To check car bodies for flaws like scratches, dents and crack, researchers have created image sensor-based devices. These system take pictures of

the car's body using high-speed cameras and specialised illumination, the analyse the pictures using algorithms to find flaws.

The same is true for the electronics sector, where researchers have created visual inspection devices that use image sensors to find flaws in printed circuit boards (PCBs). These systems use high-resolution cameras and image processing methods to spot flaws including soldering faults, components placements mistakes, and other flaws that could impair the PCB's operation. Another industry where visual inspection system with image sensors have made considerable strides is food processing impurities in food products like plastic, metal fragments, and other foreign materials, researchers have created system that use image sensors. These systems use near-infrared sensors, colour cameras, and other imaging technologies to get rid of impurities in the food products.

In addition to these fields, the manufacturing of semiconductors, medicines and aerospace products have all used image sensor-based visual inspection systems. These system use cutting-edge imaging technologies including x-ray, hyper spectral, and fluorescence imaging to find flaws and guarantee product quality.

With concluding all these, image sensor-based visual inspection systems have grown to be crucial components of the industrial sector since they consistently and accurately identify faults and guarantee the quality of products. Image sensor-based visual inspection systems are predicted to become even more advanced and effective in the future as image technologies evolve, which will boost productivity and enhance product quality.

3. Methods

Quality inspection using image sensor starts with acquirement of an image using a monochrome camera with an illumination depending on the application, a sensor, and a computer. Based on the extracted image the processor will take decision if it is either Acceptable or Not Acceptable. that's why a component, which is not acceptable will be rejected in an assembly line utilising an actuator or blower as the ejection mechanism (Figure 1).

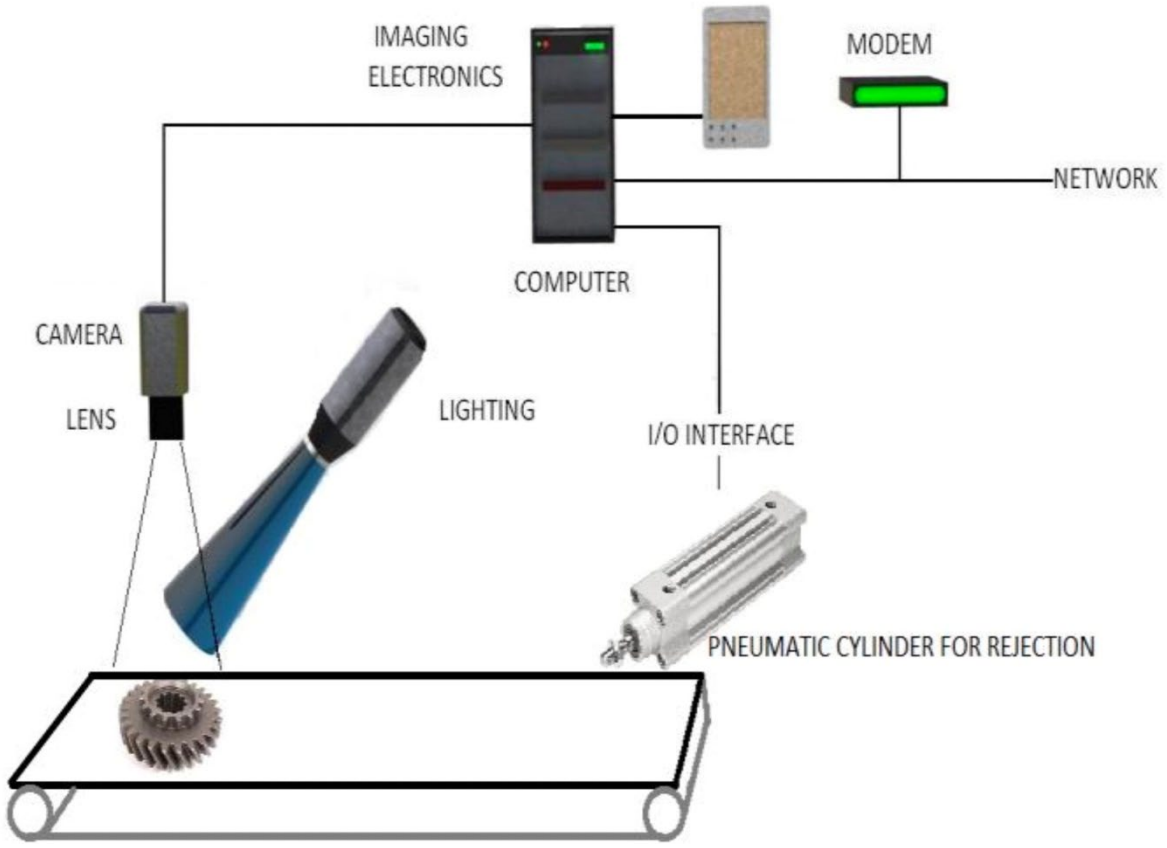


Figure 1. Machine vision inspection (Sathiyamoorthy, 2014)

3.1 Optical Gauging Measurement of Rotogravure Printing Machine Head-plate

During inspecting the rotogravure printing machine head-plate important areas to measure are the surface finishing, depth & distance between every and each hole. which should have tolerance according to the designs customer gave(i.e. tolerance of hole should be +_0.5 mm). If the tolerance is more than +_0.5 mm in each and every hole. So before sending machined parts to customers; it is certified using image sensor based quality inspection. In this, the requirement is to detect surface defects and dimensions of each & every hole on the plate with confirming if it matches customer's required design or not by below classifications:

I. Accept Product
II. Reject Product

Rejected product goes to rework or as scrap if it is not curable by filling the hole with booze. The operator choose the model from the display for a certain model. The machined part is put on the spot. The operator then depresses the leg pedal, activating the camera and light. The image is then taken by the cameras and transferred to the software (Zhang et al. 2008). Results are visible on monitor screen.

4. Data Collection:

This technique was created to count the pixels of the machined plate that fall within the required design of the plate given by the customer gives acceptance level of that plate. the value of particular pixel is graduated to reflect the real environment. By computing the amount of pixels that cover all the ages of the plate on one axis, with the difference in grey scale, the measurements of the item are formed (Hsu et al. 2010). after that the value of pixels are graduated and transform into real time value. and then the monitor shows weather the product is acceptable or not.

5. Results and Discussion:

Visual Inspection system using image sensor have yielded promising outcomes in several industries. Likewise, in the automotive sector, these systems have been implemented to detect flaws like scratched and dents on car bodies. According to Li et al. (2019), a visual inspection system utilizing image sensors achieved a remarkable 99.8% accuracy rate in detecting faults on car bodies. Similarly, in the electronics industry, these systems have been used to detect misplaced components on circuit boards. Sun et al. (2020) reported an accuracy rate of 98.5% for a visual inspection system utilizing image sensors to detect faults on circuit boards.

In the manufacturing sector, visual inspection systems with image sensors are becoming more and more common since they have several advantages over manual inspection techniques. We will talk about the outcomes and potential effects of deploying such systems in production in this section:

- Increased Accuracy and Consistency

  Utilising visual inspection system has a number of benefits, including improved accuracy and consistency. Human error can frequently result in inconsistent inspection results with traditional manual examination, However, image sensors are able to capture image with high degree of precision and accuracy, allowing manufacturers to quickly and consistently detect flaws. This lessens the possibility of product recalls and raises consumer satisfaction by ensuring that only top-notch products are made and released onto the market.

- Reduced Inspection Time:

  Systems for visual inspection can quickly and efficiently analyse huge numbers of products, speeding up examination and boosting output. It is no longer necessary to undertake manual inspections outside of business hours because automated inspection systems can analyse photographs in real-time and operated continuously. In the long term, this can help manufacturers save a sizable amount of time and money.

- Improved Data Collection and Analysis:

  During the inspection process, visual inspection systems can gather enormous amounts of data, which can give important insights into the manufacturing process. Manufacturers can utilise this data to make data-driven decision to enhance their operations by identifying trends, patterns, and potential problems.

- Cost Savings:

  The labour expenses associated with manual examination can be greatly decreased by automated visual inspection systems. These devices can also spot flaws early in the production cycle, lowering the like hood of pricey recalls and raising the calibre of the final product. For manufacturers, this may result in cost reductions and elevated profitability.

- Limitations:

  Despite the facts visual inspection methods have many advantages, they do have certain drawbacks. For example, it's possible that these algorithms can't find flaws that are too minute or intricate to be seen with the naked eye. Additionally, the price of putting these systems in place can be high, which limits their usability for smaller manufacturing operations.

  Visual inspection system is among the most often used since, ability to be put into place very quickly and for less money (Figure 2). Even small workshops can afford to use these solutions and enhance their current quality inspection and control procedures. These days, industrial-grade camera system with excellent resolution are generally accessible at a competitive price. They can also be connected onto the virtual shop floor and managed remotely in a smart manufacturing system.

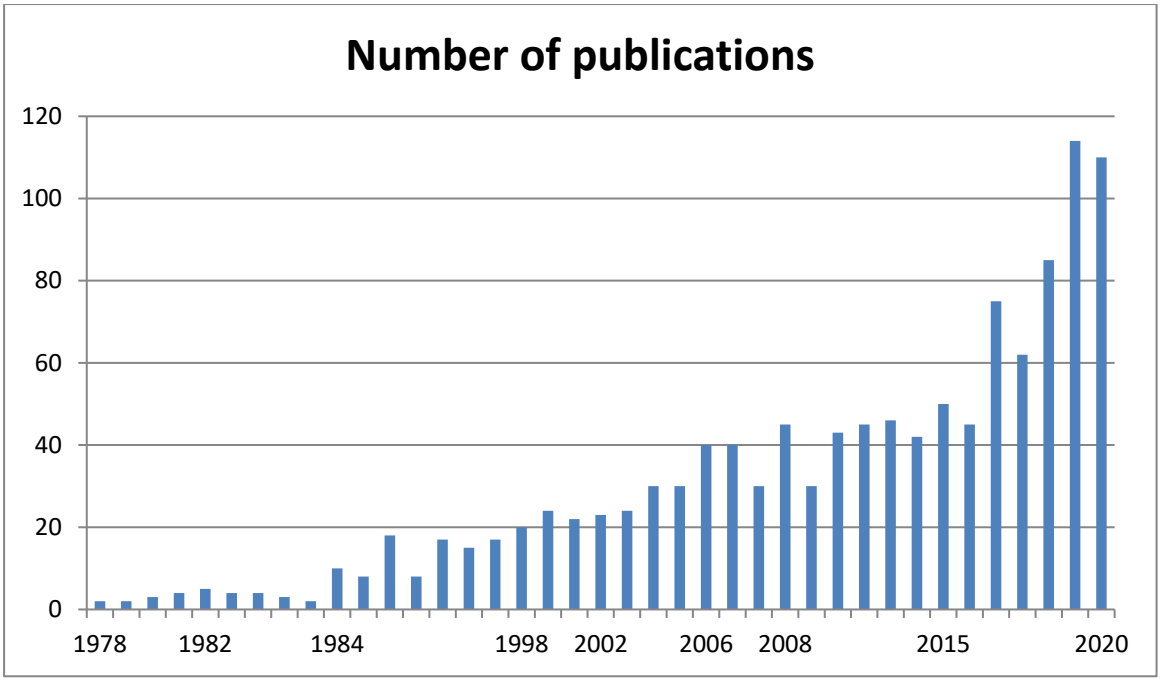


Figure 2. Histogram: number of publications connected to visual inspection using image sensor (Shen et al., 2012.)

Many issues arise with image-based inspection systems. For instance, an excessive quantity of picture pixels might cause overload of data or an erroneous image overlap can lead to flawed flaws analysis. Other software that was mentioned used image analysis to show where defects were located and to provide statistical information about them, including their size, colour, and location on an axis.

In order to quickly identify all surface flaws on a can's bottom surface, (Chen et al. 2016) introduced a machine vision method for circular car-end inspection The focus is on utilising image processing techniques to find surface faults at various points on a can's end. To do this, the scientists used a multistep image analysis method that entailed identifying flaws in various areas of the can end surface using a light source and a monochrome camera. An entropy rate clustering algorithm and a prior shape restriction are used to locate the can end in the first stage. The authors suggested using a super pixel clustering and selection approach to identify problems in the middle panel (Chen et al., 2016).

He Z. et al. came up with a control charting method that can identify specific visual defect clusters in images of industrial objects. This approach is appropriate for products that are characterized by consistency, such as identifying defects in LCD monitors or adhering to a predetermined pattern. The authors employed this technique to locate and classify visual faults in such products., it is feasible to identify several faults as well as to gauge the size and extent of the fault. to gather the necessary photos, they set up a single camera system and used gray scale photographs (He et al., 2016)

In addition to these pieces, 86% of the articles used a single camera as their setup, 20% of papers had cameras that could be operated by people, while the remaining cameras had to be mounted or fastened to a surface because they were taking pictures automatically. In our collection of papers, 14% concentrated on talking pictures of objects from all angles to finish 3D inspection, whereas the remaining 86% concentrated primarily on particular sides. This choice was made since the object issue's principal focus was the product's dimensions, which are often seen from one or two sides. This suggests that the majority of study was devoted to the analysis of a certain kind of product rather than the development of a system that could look at a whole thing.

78 "Defect Detection" approaches were used in 224 articles on image-based inspection and control. To find flaws in two-dimensional input data used in the manufacture of semiconductors, Maggipinto et al. applied a deep learning methodology. The creation of a phone app that enables employees to take pictures with their mobile phones' cameras

to inspect defects was the subject of one research that deserves special mention. Due to the software's ability to rectify picture problems without the requirement for a reference image, this ground-breaking idea may be applied in Industry 4.0.

6. Conclusion

Clearly, during the past ten years, quality control has seen significant advancement. As a result of the fact that machine can only be as intelligent as the human who designed them, a large body of study on the fourth industrial revolution came to the conclusion that human inspector should be replaced with visual inspector. High levels of weariness are brought on by repetitive tasks, particularly those that demand a great deal of attention to detail. This results in a faster decline in a human operator's cognitive abilities (Lughofer et al, 2009).

The emphasis of industry 4.0 is on automated system that simplify an operator's job and increase its dependability. It is evident that the research community is making a concentrated effort to develop fully AI methods for product inspection (Huang et al. 2015). Although automation is a goal in this area, there is still room for significant advancement. Industry 4.0 and automation are intertwined, but there is a narrow line between them that needs to be handled with greater caution.

It is obvious that industry 4.0 has fostered the development of automated processes based on the aforementioned data, which show that the majority of study designs used human operators. Consequently, there has been an increase in the application of visual inspection systems to modify image-based inspection and control (Shen et al, 2012, Manish et al. 2018, Manzano et al. 2020).

To wrap up the discussion, I would like to mention that to maintain product quality and lower manufacturing costs, the visual inspection system utilising image sensor has become a crucial instrument in the manufacturing sector. The system can function at fast rates and is capable of detecting flaws like cracks, scratches, and dents that are not visible to the human eye, making it an effective quality control method. The system has become even more dependable and efficient as a result of improvements in image sensor technology, Which have increased accuracy, resolution, and speed. There are still issues to be resolved, such as image analysis algorithms and system integration with other manufacturing processes, despite the technology's many advantages. Generally speaking, the visual inspection system incorporating image sensors is a significant and promising technology that can greatly enhance the manufacturing process.

References

Chen, T., Wang, Y., Xiao, C. & Wu, Q.M.J., A machine vision apparatus and method for can-end inspection, IEEE Transactions on Instrumentation and Measurement, 65(9), pp. 2055-2066. 2016.

De Mitri, O., Stahl, S., Jauch, C., Distante, C., Image acquisition, evaluation and segmentation of thermal cutting edges using a mobile device, Multimodal Sensing: Technologies and Applications, 11059, p. 110590U, 2019

Diesing, G., How to Automate your Inspection Process, Quality Magazine-online, retrieved from: https://www.qualitymag.com/articles/96009-how-to-automate-your- inspection-process, 2020.

General Electric, The Impact of Digital on Unplanned Downtime, retrieved from: https://www.ge.com/digital/sites/default/files/download_assets/ge- the-impact-of-digital-on-unplanned-downtime.pdf, 2016.

He, Z., Zuo, L., Zhang, M. & Megahed, F.M., An image-based multivariate generalized likelihood ratio control chart for detecting and diagnosing multiple faults in manufactured products, International Journal of Production Research 54(6), pp. 1771-1784. 2016.

Hsu, R.C.; Ping-Wen Kao; Wei-Jie Lai; Cheng-Ting Liu, "An initial edge point selection and segmental contour following for object contour extraction," Control Automation Robotics & Vision (ICARCV), 2010.

Huang, S.-H. & Pan, Y.-C., Automated visual inspection in the semiconductor industry: A survey, Comput. Ind., 66, pp. 1–10. 2015

Hoshikawa E., Sato T., Kimori Y., Suzuki A., Haga K., Kato H., Tabeta K., Nanba D., Izumi K., , Noninvasive measurement of cell/colony motion using image analysis methods to evaluate the proliferative capacity of oral keratinocytes as a tool for quality control in regenerative medicine, Journal of Tissue Engineering, 10, 2019. doi: 10.1177/2041731419881528.Zhang Z., Chen Z., Shi J., Jia F., Dai M.: Surface roughness vision

measurement in different ambient light conditions. 15th Int. Conf. Mechatronics and Machine Vision in Practice, Auckland (New Zealand), 2-8 December 2008.

Lughofer E., Smith J., Tahir M., Caleb-Solly P., Eitzinger C., Sannen D., Nuttin M.,, Human–Machine Interaction Issues in Quality Control Based on Online Image Classification, IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, 39(5), pp. 960-971, 2009, doi: 10.1109/TSMCA.2009.2025025.

Manish, R., Venkatesh, A., & Ashok, S. D., Machine vision based image processing techniques for surface finish and defect inspection in a grinding process, Mater. Today, Proc., 5(5), pp. 12792–12802. 2018.

Manzano J.E.M., Bolaños T.A.H., Muñoz M.Á.O., Arenas V.E.P., Orozco H.P., , Evaluation of a machine vision system applied to quality control in a liquid filling, lid and labelling line for bottles, Communications in Computer and Information Science, 1280, pp. 140-154. 2020

Maggipinto, M., Beghi, A., Susto, G.A., A deep learning-based approach to anomaly detection with 2-dimensional data in manufacturing, IEEE International Conference on Industrial Informatics (INDIN) 8972027, pp. 187-192, 2019.

Sathiyamoorthy. S, INDUSTRIAL APPLICATION OF MACHINE VISION. International Journal of Research in Engineering and Technology. Volume: 03., 2014. 10.15623/ijret.2014.0319120.

Shen, H., Li, S., Gu, D., & Chang, H., Bearing defect inspection based on machine vision, Measurement: Journal of the International Measurement Confederation, 45(4), pp. 719–733. 2012.

Schmitt R., Fürtjes T., Abbas B., Abel P., Kimmelmann W., Kosse P., Buratti A., Real-time machine vision system for an automated quality monitoring in mass production of multiaxial non- crimp fabrics, 15th IFAC Symposium on Information Control Problems in Manufacturing, 28(3), pp. 2393-2398. 2015

Zhou, W., Fei, M., Zhou, H. & Li, K., A sparse representation based fast detection method for surface defect detection of bottle caps, Neurocomputing, 123, pp. 406-414. 2014