INTERNATIONAL JOURNAL OF ELECTRONICS AND COMPUTER APPLICATIONS

ORIGINAL ARTICLE

Automatic Gear Error Detection System

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OPEN ACCESS
Received: 15-07-2025
Accepted: 17-11-2025
Published: 10-12-2025

Citation: Mahajan P, Phanse PS, Mogale SA, Dighe PR. Automatic Gear Error Detection System. 2025; 2(2):27-31. https://doi.org/10.70968/ijeaca.v2i2.E113

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Funding: None

Competing Interests: None

ISSN
Electronic: 3048-8257

Abstract

The present paper highlights the designing, implementation, and experimental study of the Automatic Gear Error Detection System for industrial gear inspection purposes. In the designed Automatic Gear Error Detection System, a conveyor belt system, camera sensor unit, Arduino Uno, and MATLAB image processing algorithms are employed for automated gear inspection and defect detection. The acquired gear image is processed in grayscale and binary form for precise measurement and detection of various gear parameters. Essential gear parameters like outer diameter, inner diameter, PCD, gear module, gear height, and the number of teeth are accurately measured and compared with their respective standard values. According to the comparison findings, defective gears are automatically segregated from good gears through an automated rejection mechanism. It was experimentally proven that the designed Automatic Gear Error Detection System performs reliable and non-contact gear inspection with high accuracy and minimum inspection time.

Keywords: Automatic Gear Inspection, Gear Error Detection, Image Processing, Conveyor Belt Mechanism, Defect Detection, Arduino Uno, MATLAB, Industrial Automation, Quality Control, Non-Contact Measurement

Introduction

Gears form one of the most critical components used in industries for transferring energy or motion between rotating shafts. Gears have multiple applications ranging from vehicles to robots. The efficiency and working period of any mechanical system rely on the quality and perfection of gears. Any flaw or mistake like breaking of teeth, incorrect dimensions, cracks on surfaces, or improper positioning affects their working, generates vibrations and produces noise which results in malfunctioning of machinery. Hence, checking gears is imperative before their utilization in industrial processes. However, some industries do manual or sampling inspection of gears. The process takes too long, requires manual work, and might not be able to identify any faulty gears within the batch of gears being inspected. In light of this, industries today need faster, more effective, and automatic inspection systems as their production speeds increase. To solve this problem, this study suggests an Automatic Gear Error Detection System. This system works with the help of a conveyor system for moving gears continuously, a camera to take pictures of the gears, and image processing that compares the gear measurements against the stored standards. Faulty gears will be sorted out from the accepted gears through rejection increases accuracy and supports industrial automation in mass production environments.

Novelty of Proposed Work:

The design of the Automatic Gear Error Detection System merges the processes of image processing, automated conveyor motion, and gear error rejection to form a cost-effective automated industrial gear inspection machine. While existing manual inspection systems analyze gears manually to detect defects, the proposed system offers real-time non-contact inspection of gears through MATLAB and rejection of faulty gears through a process of automated rejection. The system not only detects the defects present in gears but also provides accurate measurements of the tooth count, outer diameter, and pitch circle diameter of gears. The combination of automation technology and image processing technique in the proposed gear inspection system renders it applicable to be used in mass production industries. Current gear inspection machines either inspect or measure gears separately.

Literature Survey

Computer vision algorithms have been developed by Gadelmawla E. S. for measuring and inspecting spur gears. The paper shows that through computer vision systems, gears can be measured for their various parameters, such as pitch, tooth thickness, and diameter, using an automated method faster than doing so manually. But one drawback of the proposed vision system is that it does not include any automatic defect sorting system as well as does not automate the process within the industry(1).

A digital image processing algorithm for gear fault detection was presented by Mavi A. and Kaur M. This technique involved analyzing the captured images of gears and comparing them with normal images of gears to determine the faults. While the system was efficient in reducing the time consumed and minimizing manual work, its main focus was on detecting defects and not segregating the faulty gears automatically. The new system aims at improving this technique through an automation process(2).

Measurement system based on vision was designed for gear profile measurement by M. H. Ali, S. Kurokawa, and K. Uesugi. This method allowed accurate measurement of various parameters including tooth profile, pitch circle diameter, and alignment of the gears. Nevertheless, the arrangement suggested was more focused on dimensional analysis that had complex requirements for measurements. Unlike the system suggested, the proposed one is easier and more economical due to the combination of the described elements(3).

Hegde, *et al*. developed an image processing-based quality management technique for mechanical components. The investigation showed that the inspection process using computer vision techniques enhances the quality of products, decreases the rate of rejections, and eliminates human errors. The study, nevertheless, paid attention only to the inspection process and was not concerned with automatic gear parameter measurements and sorting defects. This study builds on their ideas by developing a system for automatic gear inspection, counting teeth, and rejecting faulty gears(4).

The same authors improved measuring accuracy utilizing a camera-based precise measurement technique(5).

An instantaneous angular velocity measurement method was devised by Y. Shao for the diagnosis of faults associated with planetary gears. This method proved useful in identifying any fault condition including tooth wear and misalignment. Even though the method was able to diagnose faults with greater accuracy, it involved complicated sensor systems and mainly concentrated on rotating gears. However, in the present study, the use of imaging techniques to diagnose faults makes the process easy, affordable, and viable for commercial applications(6).

A sub-pixel gear parameter measuring technique based on Zernike Moment was put forward by Y. Li *et al*., with high accuracy achieved in dimensional inspection. Measurement errors were minimized and edge detection was enhanced in noisy images. Nonetheless, the technique largely focused on precise measuring and lacked mechanisms of automatic sorting and fault rejection. The proposed system combines measurement, detection, and segregation into one system(7).

An enhanced industrial safety gear detection system was developed by M. Ravikiran and S. Sen through a Re-ID conditioned detector. In essence, their study was centered around the identification of the presence of safety gear worn by individuals in the industrial setup. Image processing and object detection techniques were applied to detect any violations with respect to the wearing of appropriate personal protective equipment. The system improved safety surveillance and minimized accident occurrences. Though the system was designed for safety reasons, it highlighted the application of intelligent vision systems in industrial automation(8).

In 2008, H. Nawaz and H. Ali designed a gear testing system based on MATLAB that utilized image processing techniques to measure parameters including pitch circle diameter, teeth spacing, and gear shape. Though inexpensive, the system had limited applications for use in laboratories but failed to address requirements for mass production in industries since it did not have any features of automation. The presented system addresses this issue and provides an automated method for measuring gears with the help of a conveyor(9).

A method of image processing was developed by C. Pengfei and F. Changyong that could effectively extract the characteristics of defects from the images of gears. These characteristics include cracks, scratches, and other damages that occur on gears. This process increased fault diagnosis efficiency and minimized human intervention. Yet, no effort was made to automate the process of gear inspection and sorting. Our proposed system is capable of accomplishing both tasks(10).

As can be seen from the literature review, it has been noticed that the present systems mostly concentrate on the parameters of the gears or detection of defects in them individually. There have been very few attempts to combine the use of image processing, automatic detection of defects, measuring the parameters, movement through the conveyor belt, and rejection of defective gears in one low-cost industrial setup.

Proposed System

A. Objective: The primary objective of the suggested Automated Gear Error Detection System is to analyze each gear automatically and detect any manufacturing faults in it with high precision. This would lead to saving time and effort in manual inspection, increase the quality of products, and help in automatically sorting the bad gears from good ones.

B. Basic Components: Conveyor belt, DC Motor, Camera, Arduino Uno, MATLAB, Pneumatic Rejecter, Power Supply, Frame.

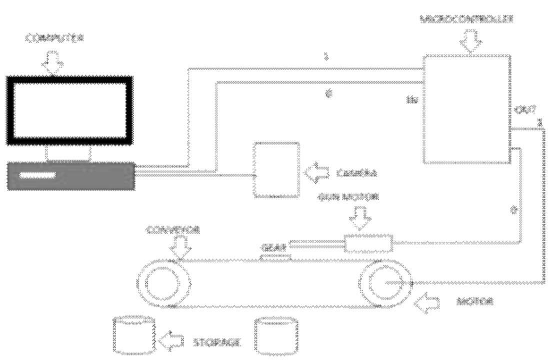

Fig. 1: System Block Diagram

C. Working Principle: The Automatic Gear Error Detection System is designed by employing MATLAB image processing algorithm to detect gears automatically. First of all, the image of the original gear is captured using camera as input of the system. The image is converted into the grayscale image. Next, a threshold value is generated, and the grayscale image is converted into a binary image. Furthermore, unwanted noise is detected and removed. Any hole existing inside the image of the gear is filled up in order to identify its exact shape. The surface area of the gear is calculated and the regions within the image are analyzed. Moreover, convex polygon processing is performed on the teeth region of the gear through the coloured boundary line. The parameters that include outer diameter or addendum diameter, inner diameter or dedendum diameter, pitch circle diameter or PCD, module, tooth height, and number of teeth are detected by MATLAB code. These values are compared with standard parameter values. If the gear meets the desired parameter values, it is considered acceptable and if not, it will be automatically rejected.

D. Benefits: There are numerous benefits offered by the suggested Automatic Gear Error Detection System. One benefit is that the inspection carried out using the proposed system will be faster and accurate, leading to reduced inspection time compared to manual inspection. The system eliminates human errors, leading to uniform quality inspection. Each gear is inspected separately, making the products more reliable and avoiding the rejection of entire batches of gears. Automatic sorting of faulty gears leads to lower labour costs. Moreover, image processing allows for non-contact inspection, thereby eliminating any potential damage caused during inspection.

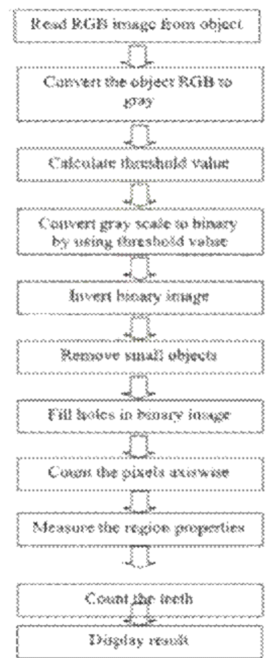

Fig. 2: Flow Chart of the System

The flow chart of the Automatic Gear Error Detection System depicts the process flow of the series of operations that are undertaken during automatic inspection of the gears by the help of image processing through MATLAB. The first step involves capturing the image of the gears from the camera, which is then taken as an input by the system. Next, the image is changed into a grayscale image to make image processing simpler. Further, a threshold level is established, after which the image is transformed into binary form. This makes it easier for the separation of the object from the background. In order to further improve accuracy, the binary image is inverted and noise or any other small objects in it are filtered out. Also, any holes within the gear image are filled to produce a perfect image. The next step entails the counting of the pixels in the object and calculation of region properties of the gear for dimensional inspection. Based on these images, the system accurately calculates the number of teeth.

Result and Discussion

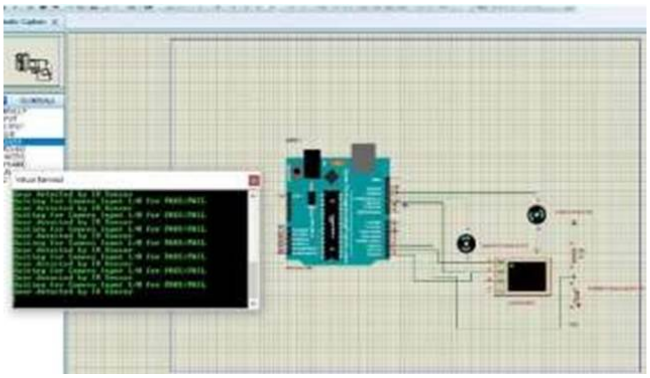

Fig. 3: System Result

(Fig. 3) demonstrates the simulation diagram for Automatic Gear Error Detection System implemented in Proteus software. The diagram represents the circuit design with Arduino Uno microcontroller interfaced with sensors, display device, and output devices. The Arduino Uno takes inputs from sensors that detect gears and then process these inputs as per the coding logic. The results of processing are displayed on the LCD display screen. Real-time measurements can be obtained from the serial monitor window. This simulation test is performed prior to the actual hardware implementation in order to save costs.

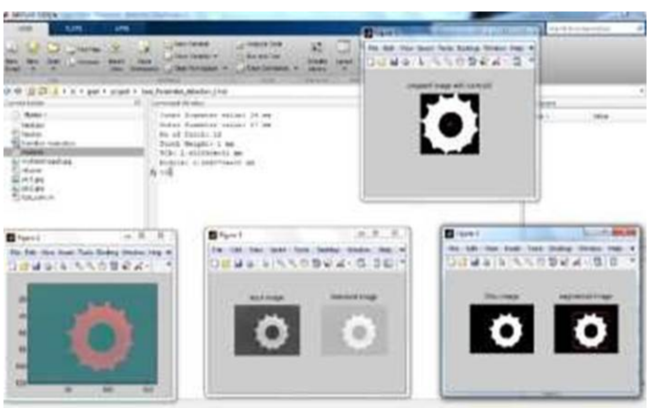

Fig. 4: Non-defective Gear Result

(Fig. 4) demonstrates the image processing output of MATLAB for a non-defective gear. The actual image of the gear is captured and converted into grayscale form for analysis. Following the threshold operation, a binary image is produced to distinguish the gear image distinctly. Boundaries of the gears and the region with teeth are detected by the system, which is marked with colored lines. All teeth in the image have proper alignment and uniform shape, indicating no defects in the gear.

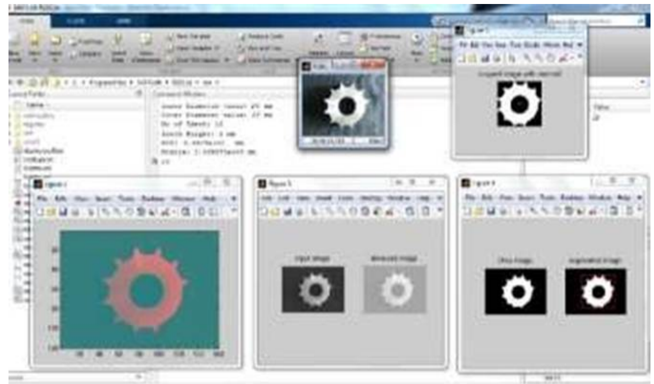

Fig. 5: Defective Gear Result

(Fig. 5) displays the image processing outcome in MATLAB for the defective gear. The image of the defective gear is obtained, and then it is converted to grayscale. The process of thresholding is carried out to get the binary image. The system identifies the gear along with its tooth boundary. In the segmented image, there is an irregularity in the tooth or teeth, which denotes that there is some defect in the teeth, such as damage or missing part in the tooth or teeth.

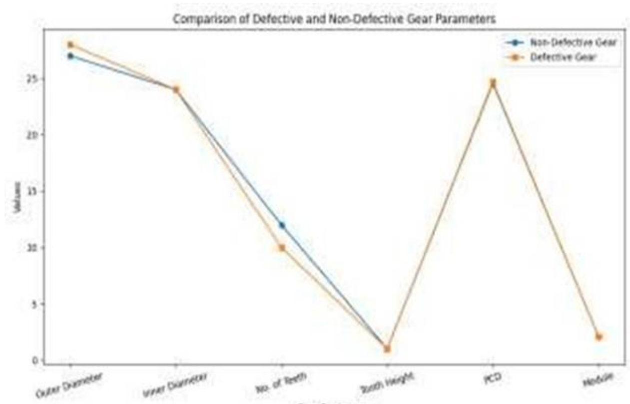

Fig. 6: Comparison Graph

As shown in (Fig. 6) Graphs are provided for the comparison between defective and non-defective gears in terms of their parameters, which were calculated using the image processing technique performed by MATLAB software. As seen from the graphs, the outer diameter of the non-defective gear is 27 mm, whereas its inner diameter is 24 mm. Furthermore, the gear has 12 teeth, with each one measuring 1 mm in height. The pitch circle diameter of the gear measures 24.52 mm, while its module is 2.06 mm. Similarly, the outer diameter of the defective gear is 28 mm, while its inner diameter is 24 mm. The gear has only 10 teeth with a height of 1 mm. Its pitch circle diameter is 24.67 mm, and the module is 2.06 mm.

Conclusion

The designed Automatic Gear Error Detection System has made it possible to automate the process of gear inspection through the use of image processing and MATLAB. The system is able to detect the presence of defects on gears such as broken teeth, dimensional errors, and shape errors accurately. Through the use of camera, which enables noncontact inspection, the problems associated with manual inspection such as human error, time taken, and inconsistency have been addressed. The addition of conveyor belts and automatic sorting mechanism enhances production speed and cuts down labour costs.

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