Computer Reverse Engineering for Reproducing Spur Gears using Digital Image Processing (DIP) Technique

Mohanad Qusay Abbood
Production Engineering and Metallurgy Department, University of Technology/Baghdad
Email:mohanaduot@gmail.com

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ABSTRACT

Reverse Engineering (RE) is a technique that uses different approaches to obtain characteristic data of a physical object for which no drawings, documentations or computer models are available. This paper presents an experimental approach of reverse engineering for reconstructing the spur gears. 3D CAD model is made using digital image processing (DIP). Gears have been scanned using a single digital camera. The digitized data of spur gears was collected and processed using MATLAB package with Digital image processing (DIP) technique. It is worth mentioning that the accuracy of the modeling process of given piece depends on the number of points that are captured on the work piece surface. This proposed method is the best tool used in reverse engineering because it is faster and more accurate than the method used the coordinate measurement machines (CMMs). To confirm the effectiveness of the proposed method a comparison is made using image processing between the first data of spur gears and the data from the manufactured gears. The obtained results indicated that the proposed digital image processing system is an accurate and reliable reverse engineering for reproducing Spur gears using inexpensive equipment.

Keywords: Reverse Engineering, Spur Gear, Digital Image Processing (DIP), Reconstruct of 3D CAD Model.

INTRODUCTION

The reverse engineering under the mechanical engineering environment is an extremely important methodology for geometric design and manufacture applications. Revere engineering is usually undertaken in order to re-design or to re-produce design details in the form of CAD model for better maintainability, reparability, interchangeability and overhauling of exiting physical models[1].

The reverse engineering process is utilized as a part of a huge mixture of areas, for example, car industry, airplane industry, pharmaceutical, structural planning and expressions [2]. The reverse engineering process is important in configuration stage as a result of taking after perspectives [3, 4, and 5]:

- Some physical objects are available but there design or manufacturing documentations are not available.
- A product is working but its geometry has to be improved because it gained some bad features after usage.
- Manufactured product is compared to its CAD model.
- Analyzing the competitors' products.

Related Works

Maysaa Hameed Al-Hamdani [6] described the enhancement in the behavior of the 2D PCA (Principles Component Analysis) based on recognition algorithm that recognize face images by adding noise removal filter before and after the recognition stage. PCA algorithm based on information theory concept, seeks a computational model that best describes a face by extracting the most relevant information contained, and compare the Eigen face with the Eigen faces in the gallery database, the Euclidean distance check the face image acceptance with noise removal filter added as an additional step to modify the performance of classic PCA algorithm to get better recognition.

Ivan Klimek, et al [7] presented trials to give a review of a portion of the genuine utilization situations of reverse engineering, examines what abilities and methods for intuition are produced by reverse engineering and gives cases how reverse engineering could be taught by functional critical thinking, presenting imaginative deduction models and techniques. They concentrated on the significance of reverse engineering as an instrument to light the self-inspiration of understudies and efficiently manufacture their legitimate deduction capacities and scientific aptitude.

N. Y. Louis Lee and P. N. Johnson-Laird [8] presented a theory of the process, which postulates that individuals rely on an initial strategy of either focusing on the outputs of a system one by one, or on the components of the system one by one. They then try to assemble the system guided by both local and global constraints. The theory predicts that three main factors should affect the difficulty of reverse engineering: the number of variable components in the system, the number of their settings that yield an output, and, most importantly, the interdependence of components on one another in yielding outputs. Five experiments corroborated these predictions, using a test bed of electric light circuits and water-flow systems based on Boolean logic.

Ira D. Baxter and Michael Mehlich [9] delivered a conceivable formal transformational design instead of the first creators' real design. A repercussion of the transformational reverse engineering procedure is a design database for the system that then can be kept up to minimize the requirement for further reverse engineering amid the remaining lifetime of the framework. An outcome of this viewpoint is the conviction that arrangement acknowledgment routines are not adequate for reverse engineering. As a sample, a little section of a constant working framework is reverse-engineered utilizing this methodology.

Hayder Hadi Abbas [10] presented an algorithm to select the desired shape individually even if there are different shapes in the image (multi-shapes image). The algorithm is software implemented using Mat lab programming language and then implemented program is used to recognize any of the following shapes (the shapes must be distinct and not overlapped): Seven types of triangle; pentagons, hexagons, squares, rectangles, circles, ellipse shapes, rhombus, and parallelogram. The recognition capability of the implemented software is tested for different cases.

Tahseen Fadhil Abbas and Ahmed Abdullah Ebraheem [11] presented another test methodology in reverse engineering for quick reproduction, displaying and assembling of products with complex free shape surfaces. The proposed methodology disposes of the prerequisite for camera adjustment and postures estimation. Utilizing planar segmenting, they create an arrangement of even parallel planes slicing the article to an arrangement of parallel cross-areas. For every item slice, they caught a picture utilizing single advanced camera. The test item is set in a cubic holder loaded with a dull fluid and the convergences between the fluid level and the genuine article are created by bringing the versatile base up in regulated way, and for every stride a picture has been caught. The profundity of every cross area can be specifically acquired for each of the caught picture. Subsequent to getting all the profundity data of the genuine article, the information has been incorporated to recreate the 3D free shape surface.

Oancea Gh., Ivan N.V., and Pescaru R. [12] presented a Computer Aided Reverse Engineering system configured in the department of Manufacturing Engineering of Transylvania University. A few case studies developed in the system for industrial and non-industrial products. The system consists of 3D scanners used for parts digitization, software systems for point clouds handling, customized software tools for automation part recognition, CAD systems used for parts designing or redesigning and equipment with associated software tools for part manufacturing.

Spur Gear

Spur gear is a machine component concerned with transmission of power and movement between parallel shafts as indicated in figure (1). The phrasings of good rigging teeth are outlined in figure (2). Spur gears have the lion's share among a wide range of rigging being used accordingly. Investigation of spur gear utilizes reverse engineering turns into a persevering target [13].

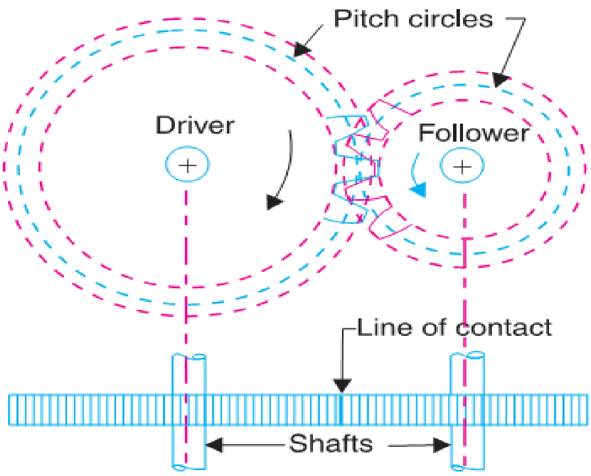


Figure (1) Spur Gear [13]

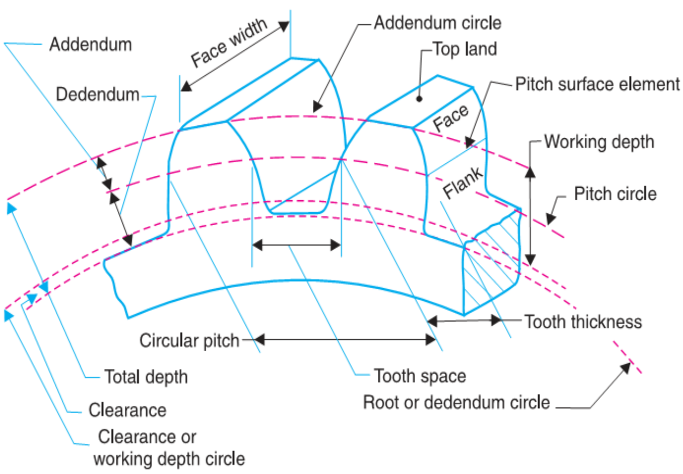


Figure (2): Spur gear terminology [13].

Digital Image Processing (DIP)

Computerized Image Processing (DIP) includes the adjustment of advanced information for enhancing the picture qualities with the guide of PC. This aides in expanding the clarity, sharpness and points of interest towards data extraction and further investigation [14].

Digital image processing is a broad subject and frequently includes systems which can be scientifically intricate; however focal thoughts behind advanced picture handling are very straightforward. The advanced picture is encouraged into a PC and PC is modified to control this information utilizing a comparison, or arrangement of comparisons and afterward store the consequences of the processing for every pixel (picture component). These outcomes shape another advanced picture that may be shown or recorded in pictorial organization or may it be further controlled by extra PC programs. The conceivable types of the advanced picture control are truly endless. The crude computerized information when seen on the presentation will make it hard to recognize fine highlights. To specifically upgrade certain fine highlights in the information and to uproot certain noise, the advanced information is subjected to different picture handling operations [15].

The goal of noise evacuation is to distinguish and expel undesirable noise from computerized picture. The trouble is in figuring out which includes in a picture are honest to goodness and which are brought on by noise. In general, it is expected that varieties in picture intensity and color will be progressive in a picture, so focuses that are altogether unique in relation to their neighbors can frequently be credited to noise. Thus, the focal thought behind numerous noises an evacuation algorithm is to supplant irregular pixels with qualities got from adjacent pixels [16].

Reconstruction of 3D CAD Model

The paragraph is explaining how to generate digital data of spur gear. This process is done using a digital camera (SONY) with high resolution (18.2 Mega Pixels) which was facing perpendicularly to gear using a mechanism enables a suitable gripping of the camera and facilitates with flexibility the setting of the camera position, height and viewing direction as shown in figure (3).

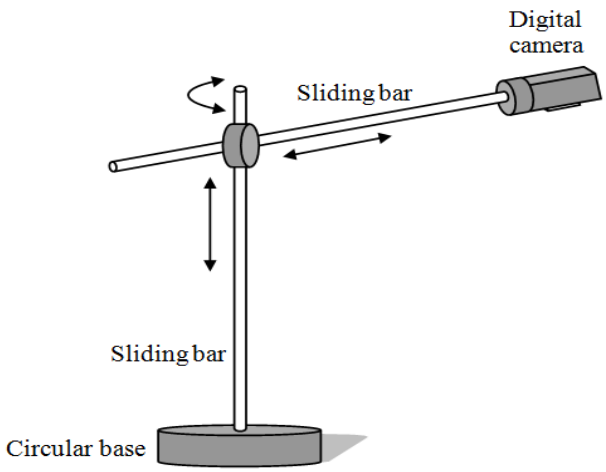


Figure (3) Schematic diagram of the Cartesian mechanism

A color image of the gear is captured, because of the large size of information of the colored image; it is converted to gray scale image and then to binary image for reducing the computation time and focusing on the object of interest. The digital image data usually contain some noise therefore some image preprocessing are required to remove overlapped points data and data

filtering to be carried out to reduce the noise of the captured image and calculating the data point of gear.
Camera calibration is necessary to convert the measurement with pixel unit into metric. The ratio between pixel counts corresponding to the gauge length on the image and the actual length of the gauge is used as the scale factor, which is found by using the following equation.

$$Sc = \frac{\text{No. of Pixels}}{L_o} \quad \dots 1$$

S_c: Scale Factor
L_o: Original Length

Proposed Algorithm

The proposed algorithm in this work greatly depends on the reading of the colored images captured by using digital camera, and then reducing image information by converting them into gray-scale images. Gray-scale images are converted to binary image for reducing the computation time and focusing on the object of interest. The process of converting gray scale image to binary image, has only two values (0) and (255) i.e. black and white, is called thresholding. Where, each pixel in gray scale image is checked if its intensity is above or below (160) threshold value. Applying this technique will divide the image into two regions, one is white and the other is black.

The adopted edge detection method in this work is based on seeking for the first pixel that has a (0) intensity (black) then check the intensities of its 8-neighborhood. If any neighborhood pixels has (255) intensity, then the first pixel belongs to the boundary, otherwise this pixel does not belong to boundary and its intensity value is changed from 0 to 255. Thus the idea of adoptive edge detection method is to move 8-neighborhood mask over the entire binary image to locate the object boundaries. Figure (4) presents results of the edge detection method as applied to different images using the developed system.

X-1, Y+1	X, Y+1	X+1, Y+1
X-1, Y	X, Y	X+1, Y
X-1, Y-1	X, Y-1	X+1, Y-1

Figure (4) Image 8-neighborhood mask [17]

Some problems may rise when contour tracing is applied, such as discontinuity of one contour into many parts. This case may occur due to inaccurate setting of threshold value in thresholding process. Hence a proposed method is developed to reduce the effects of the above problem, where the proposed method is based on erosion, and dilation operation.

Dilation is defined as the maximum value in the window hence the image after dilation will be brighter or increased in intensity. It also expands the image and is mainly used to fill the spaces. Dilation process expands the image objects by changing the pixels with value of (0) to (1) [18].

Erosion is just opposite to dilation. It is defined as the minimum value in the window. The image after dilation will be darker than the original image. Erosion process shrinks the objects or images by changing pixels with a value of (1) to (0)[19]. Dilation operator is used to eliminate dark regions in image, whereas the bright region can be used to enhance edges in image. However, erosion operator can be used to eliminate weakens region of edges [20]. In the last part of this proposed algorithm a comparison will be done between the images of spur gear which applied it the above process with the image of manufactured spur gear. Consequently, the proposed algorithm is shown in figure (5).

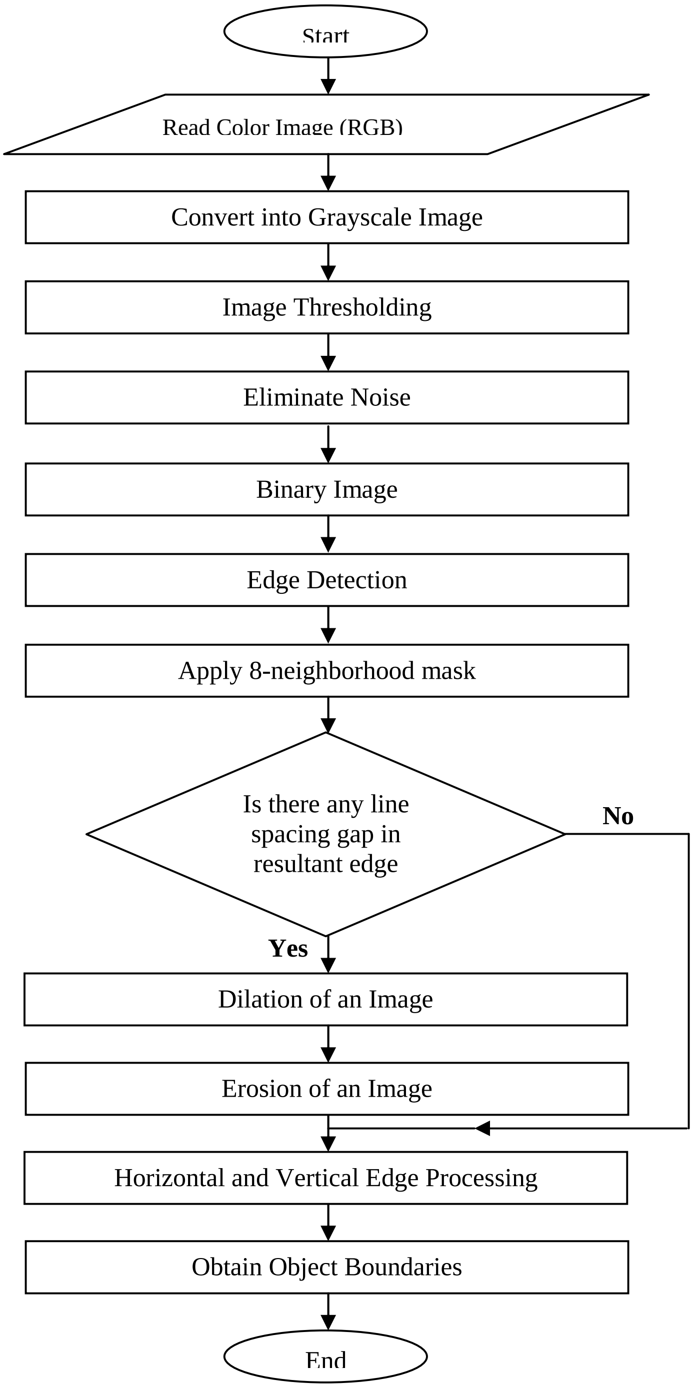


Figure (5) The flow chart of the proposed algorithm

Experimental Work

The collected data of the four spur gears using the algorithm shown in figure (6) is then used to manufacture the new spur gears by CNC machines shown in figure (7) by the G-code programming of the data extracted from the Mat lab software. In this research, Teflon material is used to manufacture the spur gears because of its availability, as shown in figure (8). After manufacturing process is performed, an image of the manufactured gears will be captured. The last image must be compared with the first images. This process will be performed using digital image processing technique in Mat lab software.

Figure (9) shows applying of overlapping process to spur gears before manufacturing and gears after manufacturing; this process is applied to confirm the effectiveness of the proposed method for manufacturing Spur gears using reverse engineering process.

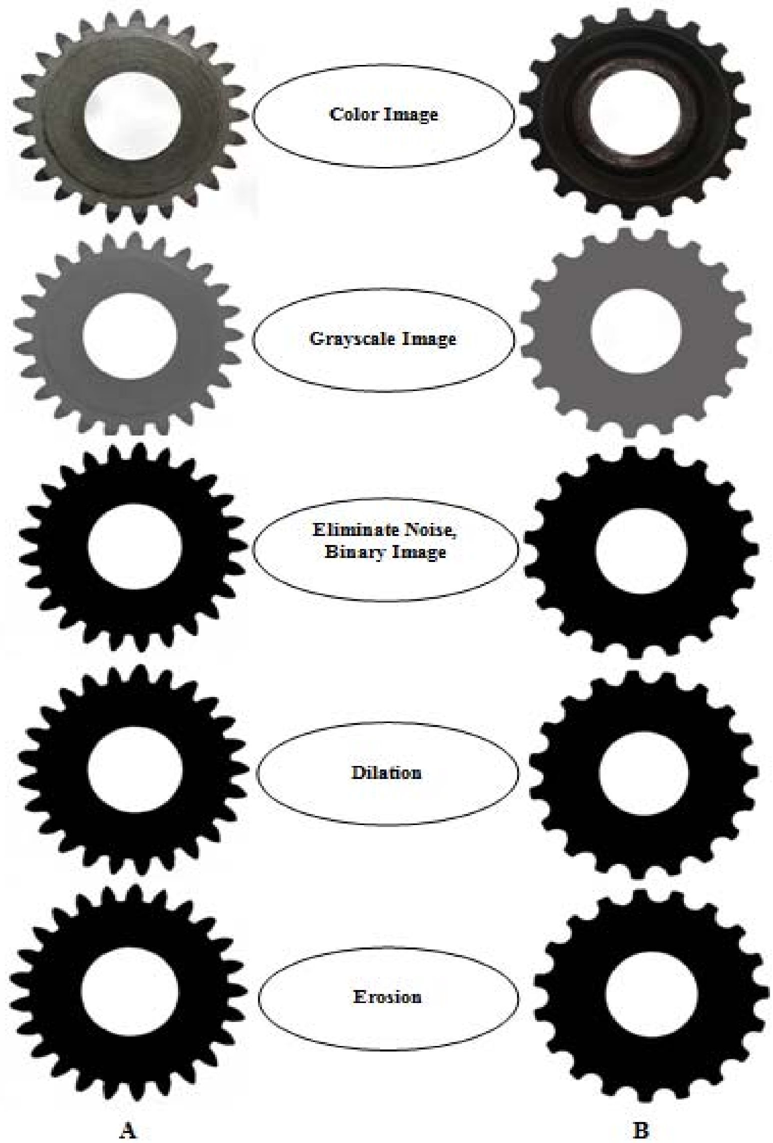
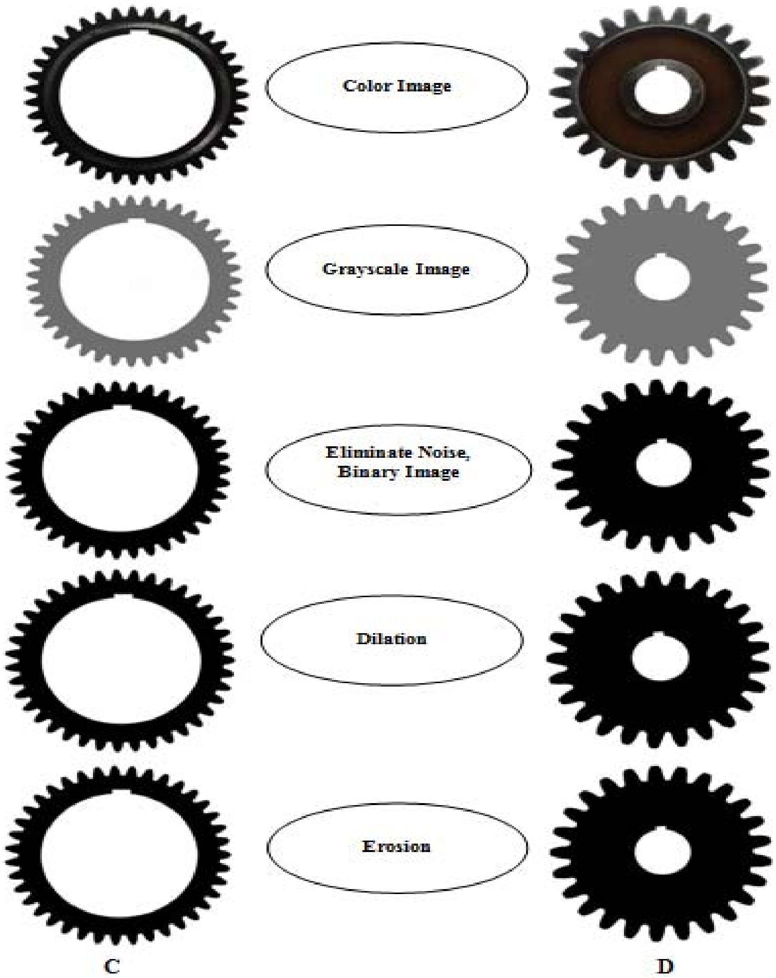


Figure (6) Samples (A, B) of Spur Gears



Figure(6) Samples (C, D) of Spur Gears

Figure (7) CNC milling machine

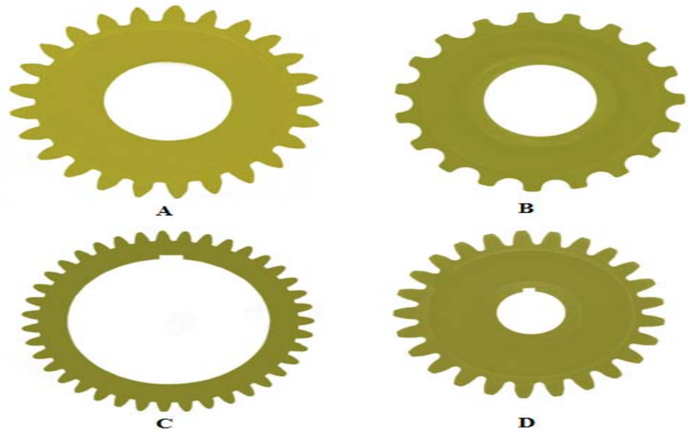


Figure (8) Spur Gears Manufactured

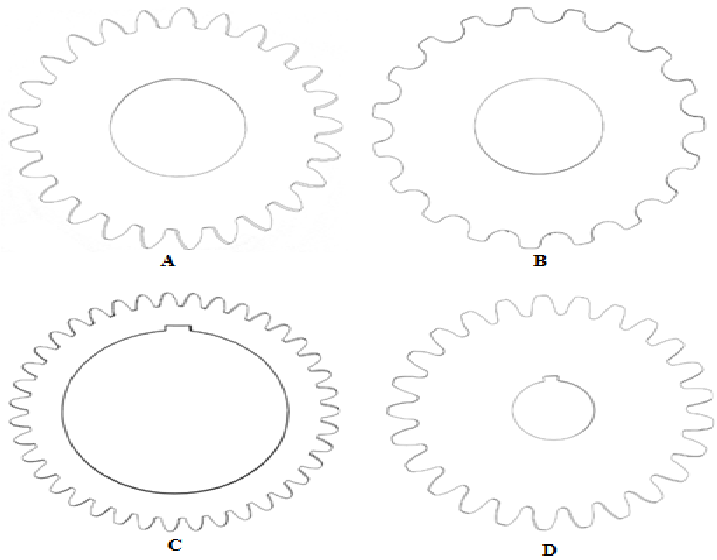


Figure (9) The Overlapping Process of Spur Gears

CONCLUSIONS

The proposed method incorporates the automatic technique of spur gear reconstruction using digital image processing in Mat lab software. This work concentrates on overcoming some of the difficulties of capturing images with more than enough information. The proposed algorithm is able to process this information through the use of image processing methods to reconstruct 3D spur gear model.

This work presents the use of reverse engineering to manufacture the spur gear and to confirm the effectiveness of digital image processing technique using overlap process between the captured image of gears before and after the manufacturing. The results proved the efficiency of the proposed method and the accuracy of the experimented gears.

This work presents a simple, low-cost method comparing with coordinate measurement machines (CMMs) or the other methods in reverse engineering of spur gear manufacturing.

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