

# Verifying practical implementation of QA process of mechanical component by using digital image processing

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**Abstract**—Manufacturing industry in need of a system to meet their quality assurance requirements specially when they have to produce quality and precise components which require to be used in mechanical machines. To reach this quality standard there is a need to solution which enable manufacturing industry to overcome speed and accuracy requirements. Inspection of quality parameters in mechanical components is very difficult and time consuming process. Computer vision / Image processing may contribute key role in developing solution through which quality assurance process become easy and fast.

**Keywords**—Quality assurance computer vision; DIP; Gear, involute curve; Manufacturing; Mechanical component; Matlab; Automation; Precision measuring.

## I. INTRODUCTION

Industrial revolution in manufacturing industry and complex process of producing mechanical components require state of the art procedures which can provide fast and precise quality assurance mechanism. The emerging technology of computer vision and digital image processing can be used for development of quality assurance system which can provide facility of inspecting quality parameters of mechanical components and this system can provide better inspection with fast and precise information about the component.

These systems can also fruitful in providing detailed data about components and same can be used to build database of information and may be utilized in different analysis about the components and also the production patterns and other related information which enable manufacturer to improve their processes and equipment to improve their quality and gain efficiency in their processes.

In this research we will be working for identification of problem which may occur in practical implementation of the system which was developed in our last research, in which we have some manual procedures and require to be automated. We have proposed different proposals to overcome these manual procedure with automated functions which may be helpful in automating the system.

### A. Gear

Gear is a part of machine have teeth which is also called cogs normally there are two parts one is to create power and another is to transmit torque. Normally small one is called pinion and larger one is called gear. Both the parts usually is of same shape regardless of size. There are different type of gears such as spur gear, helical gear which are most common.

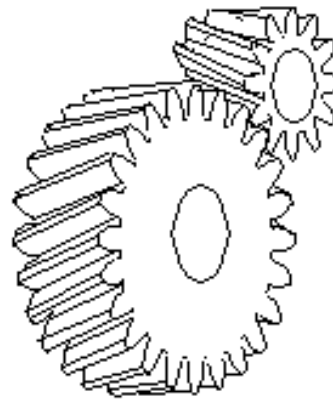


Fig. 1. Gear (Helical Gear)

Total number of teeth in a gear is directly proportional to the pitch circle and its radius, so angular velocity of is equal gear teeth & radii. This can be expressed with following equation:

$$\frac{w_A}{w_B} = \frac{r_B}{r_A} = \frac{N_B}{N_A}$$

### B. Involute

Involute is basically a curve generated through unfolding of string to a circular object. This involute curve is being used to produce involute profile in gear teeth.

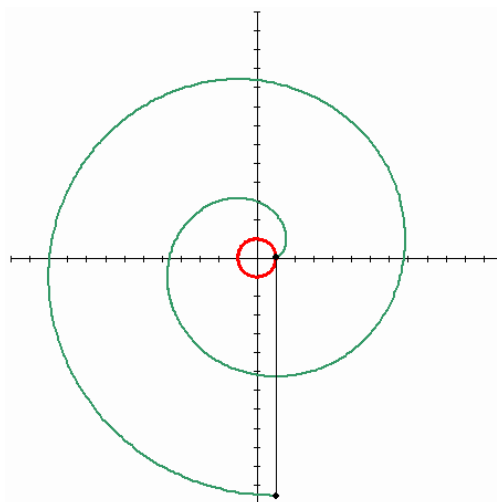


Fig. 2. Involute

### C. The Involute Profile

The commonly used involute gear profile is first designed by “Leonhard Euler” now a days almost every machine gear follow this design. This is called “Involute Gear Profile”. This design of gear provide smoothness in transmission of power between gears.

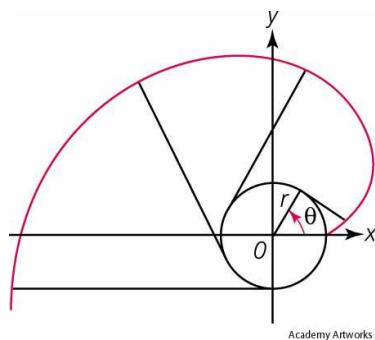


Fig. 3. Involute gear profile.

Expression for involute curve is as follows:

$$X[x, y] = x - \frac{x'}{\sqrt{x'^2 + y'^2}} \int_a^t \sqrt{x'^2 + y'^2} dt$$

$$Y[x, y] = y - \frac{y'}{\sqrt{x'^2 + y'^2}} \int_a^t \sqrt{x'^2 + y'^2} dt$$

There are different types in gear such as spur and helical, but in involute gears and these pair meet at common point.

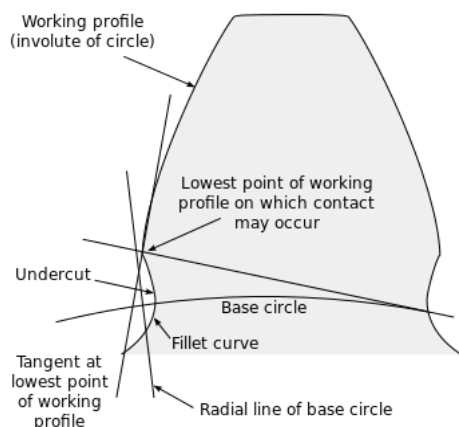


Fig. 4. Involute gear tooth profile

## II. PREVIOUS WORK

Different researchers worked on gears inspection through digital image processing but there work is limited to either measuring area or counting gear teeth and most of them worked on plastic gears. But we didn't find such work on this topic in which gear critical parameters especially involute profile is being check through digital image processing.

### D. Digital Image Processing

Digital image processing is basically a technique which is used to create system which is built on computer algorithms and provide functionalities such as creating image, process the image, and show the images.

Digital Image processing algorithms is used for:

- 1) Convert analog signals in to the digital image (bitmaps)
- 2) Remove any noise which may occur during the processing of conversion.
- 3) Improve the clarity of the object.
- 4) Calculate different aspects of the object such as:
  - a) Size of the object,
  - b) Scale of the object,
  - c) Counting of objects present.

### E. Image acquisition

In this technique / process analog information or signal is being converted into the digital form i.e. bitmap. In this process different input devices are used e.g. camera, scanner and other digital mediums. Usually image is acquired through these devices and then converted / stored in to digital form so that if can be further used in digital image processing system.

### F. Image enhancement

The process / technique of Image enhancement is used to acquire the best information about the region of interest, in this process different algorithms are used through which different features of the object is enhanced and these enhancement make it possible so it can be used in further processing of the digital image processing system.

### G. Segmentation

Segmentation process is used in digital image process to divide image into the portions according to the requirement. Through segmentation it is become more useful as the required information is picked up from the original one and its further processing become easy. Only meaningful and required information separated from the image so further processing become easy and efficient.

### H. Edge detection

Different techniques are being developed and complex algorithm are designed by the engineers which is used to process the image and extract the edges of the objects in the image which can better describe the object or our region of interest.

Some of the techniques are as under:

- 1) Sobel.
- 2) Laplacian of Gaussian.
- 3) Canny.

### I. Curve fitting

Mathematical function i.e. “Curve fitting” is used to draw curve on available data series which is best fit on the data points.

Interpolation is being used to construct curve fitting in which data is being plotted on approximation basis.

Polynomial		equation:
1st degree:	$y = ax + b$	
2nd degree:	$y = ax^2 + bx + c$	
3rd degree:	$y = ax^3 + bx^2 + cx + d$	

For curve fitting technique a built-in tool is available in matlab with the name of “curve fitting toolbox”. It is very easy to use with lot of options available in it. The tool can be used as a function and get desired results or it can be used with Graphical user interface (GUI) which provide WISIWIG facility to test your results and selection appropriate option for it.

### J. Overlaying

Technique of overlaying is used to check two different picture with combination of transparency in both and with this technique we can calculate the different / gape between two curves. This technique can be used to identify / calculate difference between the two curve lines which can be used to identify the deviation between them. These deviation figures are useful in decision making either the comparison is ok and the deviation is between the allowable limits ore deviation is higher than the allowable limit. With these deviation data decision can be made either it is ok or not.

Image processing tool box is a tool in Matlab which provide facility of overlaying and it can be used to calculate / overly the required images and perform desired results.

## III. METHODOLOGY

Theorem 1. *In this research we have use experimental research method and we will be working to develop algorithm to inspection different parameters of the gears using digital image processing.*

## IV. OBJECTIVE OF THE STUDY

The main objective of this research is to find mechanism of automating the process of mechanical component quality assurance. In our first research we worked on the possibility of using quality assurance using digital image processing in mechanical component manufacturing. Now in our research we will be working on finding gapes which may occur in developing system which can be used in production environment. Through this research we will not only identify the gapes but also provide their respective solutions which can be utilized in future work on the topic which may lead the

work to have comprehensive inspection system which will provide not only efficiency in quality control and inspection mechanism but also decrease cost of inspection which is incurred in traditional system used for gear inspection.

### K. Quality Control

The process of a quality control is of great importance in every type of manufacturing organization, the responsibility of this process is to make sure that the product which is being manufactured by the process is up to the mark and there is no deviation in it. Quality control process is being involve in every part of the process from raw material to finishing line. In mechanical manufacturing quality control is very critical as the quality control of mechanical components require very precise testing and minor deviation from the standard parameter can cause in great trouble.

## V. DESIGN AND IMPLEMENTATION

In this research we have selected a gear of type Helical which has 29 theeth. Material of the gear is Steel, and has pressure angle of 20 degree and diameteral pitch of 6.

The Details of gear parameters are as under:

Gear type:	Helical
Teeth count:	29
Diameteral pitch (DP):	6
Pressure angle (PA):	20°



Fig. 5. Showing gear and involute generated through program

### A. Image Acquisitioner

For image acquisition purpose we have experimented different designs to capture best image suitable for getting optimal results.

In this design we have used transparent sheet and a camera with a light bulb beneath of the sheet to provide only the required features. Camera was fixed over the tripod to get the clear picture.

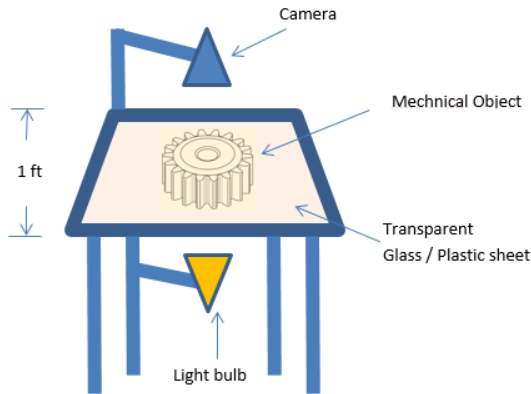


Fig. 6. Image acquisitioner.

**B. Image auto rotation**

The problem / gap identified in the research is that there is a need of a gear to be on the appropriate angle on which complete process can be started, for this purpose we have work on different experiments and after that we proposed solution which provided us proper results.

In this proposed solution we marked the gear with single colour line as a guide of perfect angle.



Fig . 6. Showing original scanned picture and cropped single tooth

**C. Image Scaling**

To get the proper scale of object and measurement accuracy we have performed different experiments such as through scale with the image, through coin, making of a square around the object. After different testing we observed that best results are provided by the square with complete black background.

Test 1: Using coin as a scale: First test which we have performed is by placing coin along with the gear, and calculate the scaling factor using the diameter of the coin, but due to camera alignment / aperture issue scale is there which is giving wrong scale for x and y axis.

Test 2: Using steel ruler: Second test we have tried is by using steel ruler along with the gear and try to calculate scale through this, but found same camera issue causing deviation in scaling.

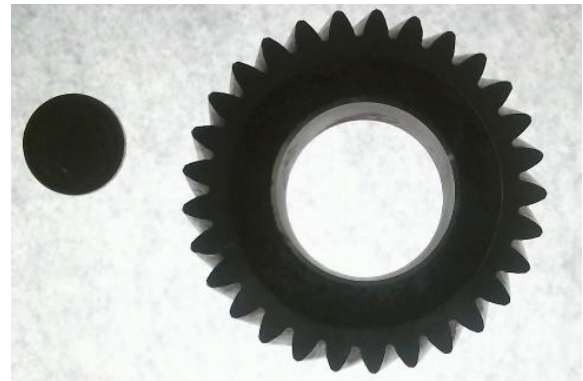


Fig. 8. Test 1 with scale of coin.



Fig. 9. Test 2 with steel ruler as scale.

Test 3: Using marked square box: Third test we have done by marking square box around the gear with pre-defined size which we have used for scaling, this removed the camera issue of scaling of axis but due to light in place causing problem in extracting clear boundaries.



Fig. 10. Test 3 with marked square box as scale.

Test 4: Square with black background: Forth test is basically is same as test 3 but there is an improvement which resolve the lighting issue which we were facing in the last test with simple draw square.

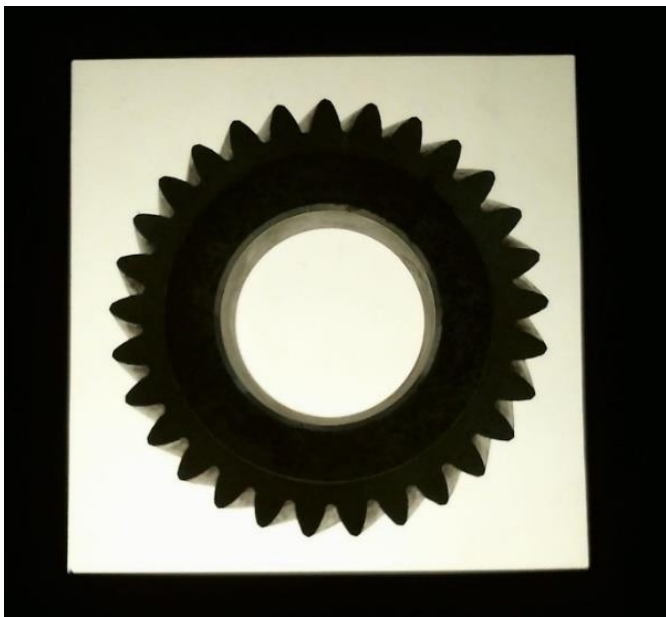


Fig. 11. Test 4 with black background square.

#### D. Scaling of the image

In first step we extracted the drawn rectangle with black background and crop complete image to this rectangle size and record the values of the rectangle i.e. pixel count of x axis and pixel count of y axis to make it a scale by calculating the pixels per inch ratio.

```

%scale conversions
in = 4;                % Square size in inches.
in2mm = 25.4;         % Inch to millimeter factor.
factor = in/in2mm;    % factor of conversion/
% get rectangle dimensions
xfactor = rec(3)-rec(1)/factor;
yfactor = rec(4)-rec(2)/factor;

```

#### E. Draw circle to extract each teeth

As gear has teeth around it in different angles to extract each teeth is a difficult and complex task, to extract each teeth accurately we have drawn two circles one which is outside the gear and second circle inside the gear but lower than the size of root circle. What we did is that we draw both the circles with the corners equal to the number of teeth we have counted in the code.

From these circles corners we selected each point of both circles and the next point of both circle and form a polygon to select the area of teeth to be extracted.

The problem is that there is no mechanism / function is available to crop the image using polygon shape as image supports only rectangle shapes so to overcome this issue we write a code which converts the polygon into the rectangle and this rectangle can be used to crop single teeth from the gear.

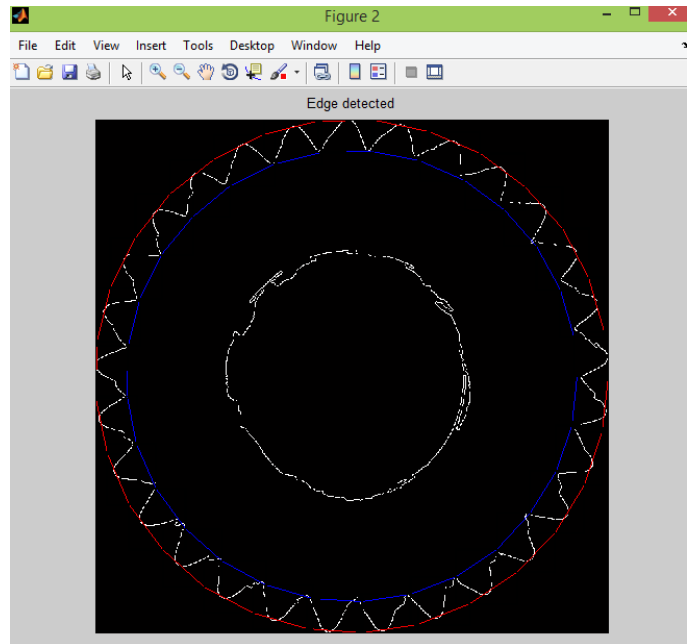


Fig. 12. Showing the both the circles and the generated rectangle for each teeth from cropping.

#### F. Teeth rotation

After extraction of teeth each teeth is rotated to the appropriate angle for overlying and comparison, for this purpose we have used the angles of each corner of the circle we created for cropping of the teeth and same value for each teeth is used to rotate it to the proper angle.

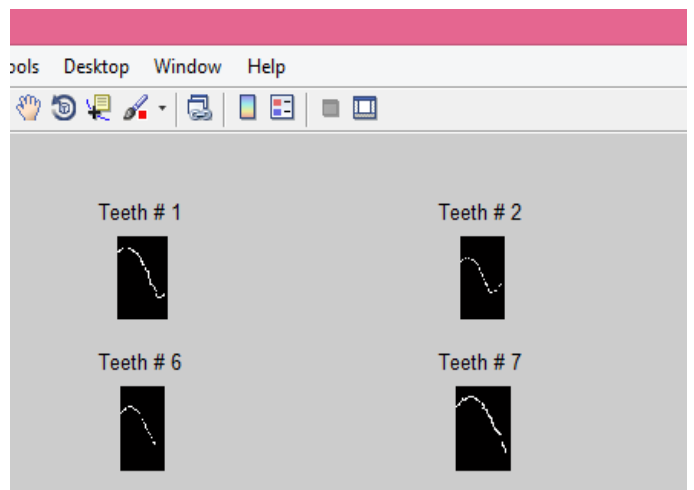


Fig. 13. Teeth extracted and rotated to appropriate angle.

#### G. Extracting outer circle diameter of gear

To extract the outer circle diameter of gear we have calculated the diameter of the outer circle through finding largest object and through its size we calculated the radius of the outer circle in this way we have extracted the outer circle diameter.

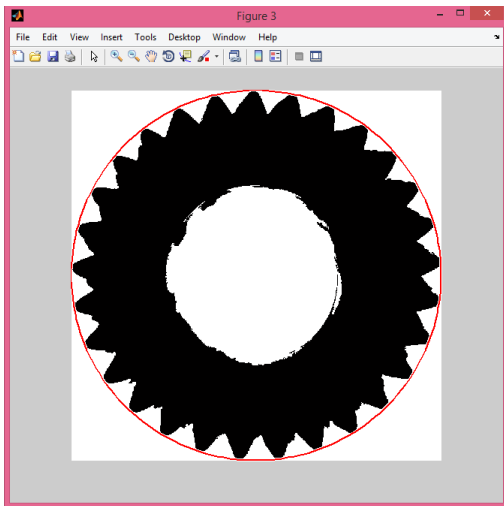


Fig. 14. Showing the outer diameter of the gear

#### H. Extracting Root circle diameter

To extract the root diameter of the gear we have identified the top teeth and the bottom teeth and after finding the top and bottom teeth we have calculated the minimum value of the available pixel from bottom teeth and maximum value of the available pixel from the top teeth and calculated the different using the cropping values available with us in the circles' x and y axis. After adding the minimum and maximum values to the cropping values we are able to calculate the distance between the two teeth and this is basically the diameter of root circle.

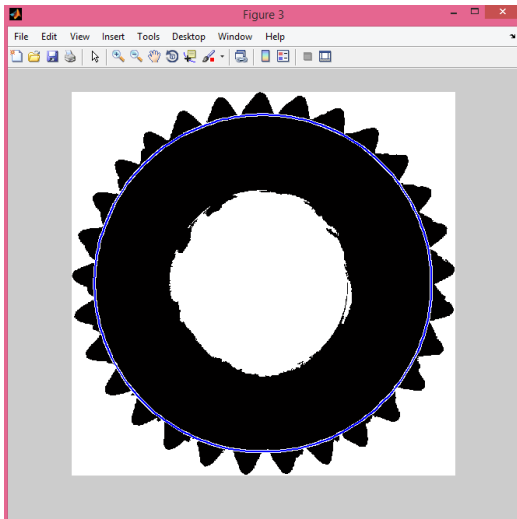


Fig. 15. Showing the root circle diameter of the gear

#### I. Extracting outer circle diameter of gear

To extract gear's 'outer hole' diameter we have cropped the image to the appropriate level and after cropping the shaft hole we get the size of the image through our function we have created for the scale getting, by using this function we are able to extract exact size of the shaft hole and with the size available we are able to calculate the diameter of the shaft hole.

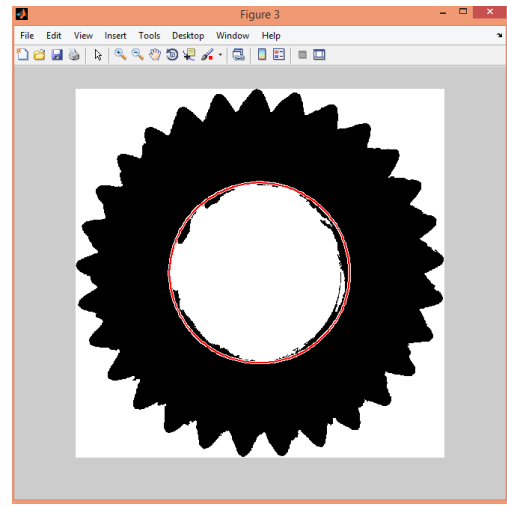


Fig. 16. Showing shaft hole.

#### J. Data collected

Parameter	Value (pixel)	Value (mm)
Conversion Factor	52.68	
Teeth count	29	
Shaft-hole diameter	180.50	34.27
Outer diameter	370.00	70.24
Root diameter	325.14	61.72

## CONCLUSIONS

This research was done to explore the use of digital image processing for quality assurance of mechanical components to provide better, efficient and less cost solution. The quality assurance of mechanical components is very critical and time taking job and the currently used solution is very expensive. So by using digital image processing techniques these problem can be solved and a system can be developed to provide inspection facility for gear manufacturing.

With our research study it is concluded that inspection is possible for mechanical components as we have done for the gear parameters.

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