

Research on the Method of Identifying the Collapsed Angle Surface of Fine Punching Small Gear

Lingzhi Tang^{1,2,3}, Yitao Chen^{1,2,3}, Zhifeng Song^{1,2,3}, Zhen Cai¹

¹School of Mechanical Engineering and Automation Wuhan Textile University, Wuhan 430200, Hubei, China

²Three dimensional textile engineering research center of Hubei Province, Wuhan 430200, Hubei, China

³Hubei Key Laboratory of Digital Textile Equipment, Wuhan 430200, Hubei, China

Abstract: Aiming at the requirement of automatic assembly of automobile rear wiper for automatic identification of the collapsed corner surface of finely-punched pinion, this paper proposes a method based on the mean value of the area of multi-toothed region of finely-punched pinion as the characteristic parameter, which can better identify the collapsed corner surface. Firstly, the industrial camera is used to obtain the pinion image, and the Halcon operator is used to fit the circle in the pre-segmented region to obtain the pinion circle position parameter, and the parameter is used as the reference to accurately segment the toothed annulus ROI, and then carry out the dynamic thresholding of the region, merging the regions, shape convex package transformation, and the conditional filtering to obtain the multiple toothed regions, and then rank the toothed regions, and the maximum top three toothed regions area mean value is the feature parameter to achieve the fine blanking pinion surface automatic identification of the collapsed corner surface. The mean value of the area of the first three tooth-shaped areas is used as the characteristic parameter to achieve the identification of the collapsed angle surface of the fine blanking pinion gear. The application on the assembly line shows that the recognition accuracy of this method reaches 99.9%, with good robustness and stable operation, which meets the production requirements, and also provides a method for the recognition of collapsed corner surfaces of other fine blanking parts.

Keywords: Fine punching gear; Collapsed angle; Image identification; Halcon; Feature.

1. Introduction

Rear windshield wiper is the standard configuration of two-box cars, SUVs, MPVs and other passenger vehicles, and the annual demand is as high as 12 million sets in China alone. The transmission assembly is the core functional part of the rear wiper assembly, which consists of a step pin, a large gear, a small gear, an output shaft, a plastic cap and a connecting plate. In order to reduce the cost of parts manufacturing, improve production efficiency and ensure product consistency, pinion production mostly adopts fine blanking molding technology. Parts in the fine blanking molding process, will form the collapse angle. The existence of fine blanking parts collapsed angle will make the working area of the part is reduced, affecting the use of parts performance, in the output shaft through the pinion gear station, the process requires the pinion reverse (non-collapsed angle surface for the front, collapsed angle surface for the reverse) must be in the output shaft of the small head side (threaded side), so the fine blanking pinion gear has the positive and negative side identification requirements. With the development of automation and Informa ionization, the assembly line has been transferred from manual assembly line to automatic assembly line, and the identification of the positive and negative faces of fine blanking pinion gears from manual identification to automatic identification has become an important and imminent task. In recent years, non-contact image recognition technology is widely used in the detection

of the surface of the parts, Zhou Dinghe [1] used an industrial camera to obtain images of automotive plate-like painted parts, using defect extraction algorithms based on morphology Blob well classified defects identified; Wang Dongsheng [2] used machine vision technology to detect defects on rotary class toothed painted parts, for its rotary class parts size irregularities, the Developing a new inspection equipment for rotary toothed parts; Priyanka Khandelwal [5] achieved noise removal and extraction of crack defects on the surface of automotive parts by using the similar gray value filling method; Yuan Xiao Cui [4] proposed the interclass variance defect segmentation method with target variance weighting, which weights the target variance of the interclass variance of an image to ensure a high detection rate of the defects and a low misdetection rate, the Sohail Akhtar, Tatsuya Yamazaki, Jyotismita Chaki, Adarsh Tandiya, M Dhivya, BLAYVAS I, Carsten Steger and others [5-14] have done a lot of research in the detection of defects on surfaces such as circuit boards, metals, and so on, and have done a lot of research in the areas of image enhancement, region segmentation, edge extraction, Blob detection etc. many algorithms are proposed.

This paper centers on the research of non-contact image recognition method of the front and back faces of the fine blanking pinion gear of the transmission assembly in the industrial environment, which provides the technical basis for the automatic assembly of the rear wiper transmission assembly.

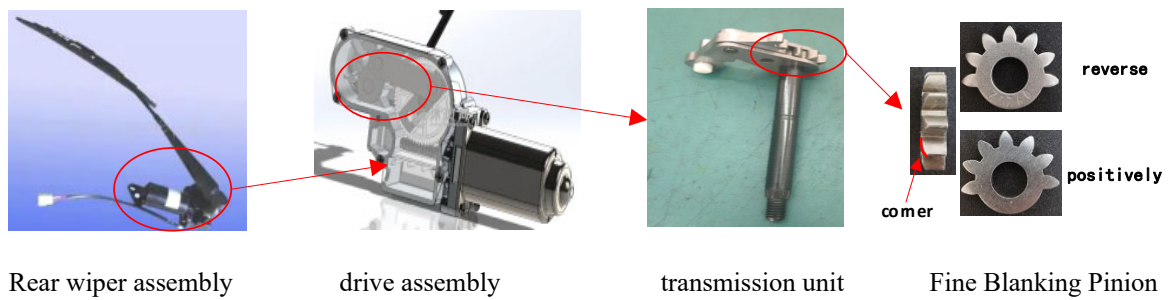


Figure 1. Schematic diagram of rear wiper

2. Acquisition of Images and Analysis of Fine Blanking Pinion Gear Positive and Negative Recognition

On the automatic assembly line of the rear wiper transmission assembly, the image acquisition equipment for the fine blanking pinion gear positive and negative identification station is shown in Table 1, which adopts a black-and-white camera from the domestic Dahua Company to acquire images, and a ring-shaped blue light from the domestic Comet as the light source to overcome ambient light interference and ensure image stability.

The image acquisition system is shown in Figure 2, with the misalignment cylinder and push rod cylinder installed at

right angles, the misalignment cylinder pushes the pinion in the magazine to the photo position, the camera takes a picture, the vision system recognizes the front side of the pinion, the push cylinder extends out, and if it is the front side, the reverse storage cylinder does not move, and the push cylinder pushes the pinion into the robotic pickup position; if it is the reverse side, the reverse storage cylinder extends out, and the push cylinder pushes the pinion into the robot pickup position; if it is the reverse side, the reverse storage cylinder extends out, the reverse storage cylinder extends out. If it is the front side, the reverse storage cylinder extends, the reverse storage door opens, and the pushing cylinder pushes the pinion to the reverse storage box, ensuring that the pinions on the line are all front side.

Table 1. Image acquisition equipment

Name	factory	model	quantities	clarification
cameras	Da Hua	A3600MG18	1	Industrial Camera Black and White Camera
footage	Wallace	WL0615M14-3M	1	3MP, 6-15mm manual aperture
light	Comet	KM-2rND8040A90-B	1	Circular direct 90 degree blue light source

As can be seen from Figure 1 fine blanking fine blanking pinion diagram, fine blanking pinion is a completely symmetrical part, relying on the shape and geometric dimensions can not be distinguished between the front and back of the pinion. Pinion by fine blanking process, fine blanking parts fine blanking process, sheet material into the concave die when the material near the edge of the concave die plastic deformation and flow and produce a collapse phenomenon, the formation of the collapse angle, so the fine blanking parts in the convex die surface without collapse angle (front), in the concave die surface has a collapse angle (reverse), fine blanking pinion of the collapse angle is the intrinsic characteristics of all fine blanking parts (Fig. 1 in the fine blanking pinion pinion on the reverse side of the number, not all). (Fig. 1 shows a number on the reverse side of the fine-punching pinion, not all pinions have a number and cannot be

used as an identifier). The fine blanking pinion image acquisition system is shown in Fig. 2, and the image of the fine blanking pinion is a black-and-white image of 3072*2048 pixels. It can be seen from the images of the front and back sides of the fine blanking pinion that there is a clear difference between the front side of the pinion and the back side of the pinion with or without the collapse angle of the seven teeth. In Figure 2, the surface of the pinion has scratches, spots, stains, and poor color, mainly because the fine blanking pinion gear assembly before the fine blanking molding, grinding and deburring, oiling and rust prevention, storage, and other processes, each process will affect the pinion affects the quality of the image; the camera to obtain the image, but also by the dust and ambient light noise, which further increases the difficulty of identification and stability.

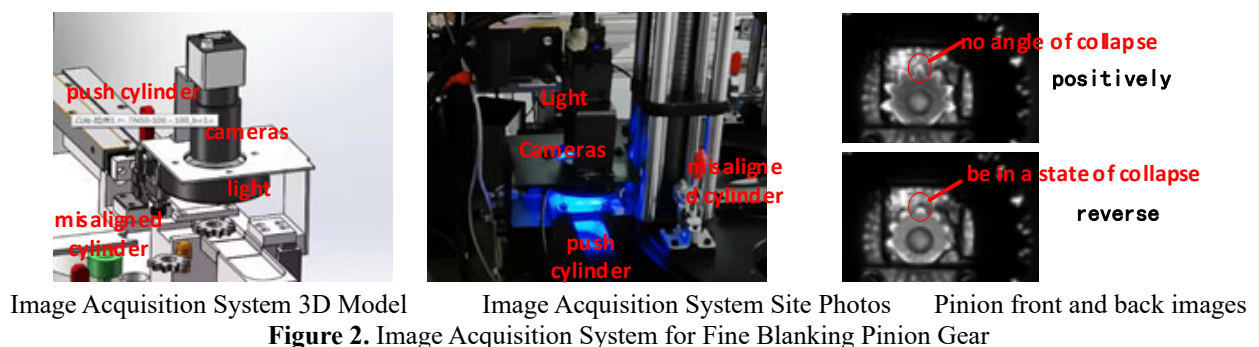


Figure 2. Image Acquisition System for Fine Blanking Pinion Gear

3. Fine Blanking Pinion Gear Positive and Negative Recognition Process

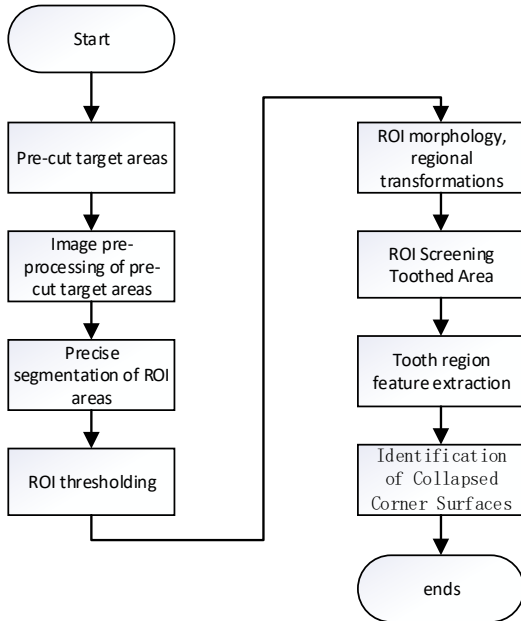


Figure 3. Flow chart of identification of collapsed angle surface of fine blanking pinion gears

As shown in the front and back images of the pinion in Fig. 2, the background of the camera-obtained fine blanking pinion image is complex, and most of the acquired image is useless except for the target region, which must be pre-segmented to focus on the target region. Pre-processing such as image enhancement, smoothing and filtering of the pre-segmented target region, and then accurate segmentation of the ROI of interest of the ring containing seven teeth, further focuses on the information region and also shortens the subsequent processing time. Then the ROI is thresholded, the thresholding must overcome the above process, light and other effects on the image, then the ROI is transformed, multiple tooth-shaped regions are screened from the ROI region, the tooth-shaped region feature parameters are extracted, and the fine blanking pinion front and back

recognition model is applied to identify the collapsed corner surface of the fine blanking pinion, and the fine blanking pinion collapsed corner surface recognition flowchart is shown in Fig. 3.

3.1. Image preprocessing and ROI segmentation

As can be seen in Fig. 2, in the front and back images of fine blanking pinion gear, the region with no information accounts for a relatively large proportion, and it is necessary to reduce the complexity of processing and the subsequent processing time, and it is necessary to focus on the target region. In order to ensure the smoothness of mechanical movement, the designed pinion gear has a gap around it, so the pinion gear position and attitude will change within a certain range in the pinion gear image acquired by the fine blanking pinion gear image acquisition system. Considering the influence of the above factors, this paper firstly defines a rectangle region in HALCON through the construction of the operator `gen_rectangle`, which covers all the pinion change regions, and then carries out the initial segmentation of the original image to get the first segmented image, as shown in Fig. 4. Using the `equ_histo_image` operator and `median_image` operator in Halcon to enhance and smooth the histogram equalization of the segmented image, the preprocessed image is obtained, the `edges_sub_pix` operator then filters and extracts the edges of the preprocessed image, and the operator `union_cocircular_contours_xld` for radian merging of contours, `select_shape_xld` operator for contour filtering, and finally `fit_circle_contour_xld` operator for circle fitting to obtain the parameters of the fitted circle (coordinates, radius), the parameters of the fitted circle are used to construct an accurate annular region by using `gen_circle` and a rectangular region by using `gen_rectangle`, and a rectangular region is constructed by using `gen_circle` and the operator `gen_xld_rectangle` to construct a rectangular region, and the precise segmentation region is constructed by morphological transformation, based on which the precise ROI is segmented from the enhanced and smoothed preprocessed image. The flow of the fine blanking pinion image preprocessing and precise target region segmentation is shown in Fig. 4.

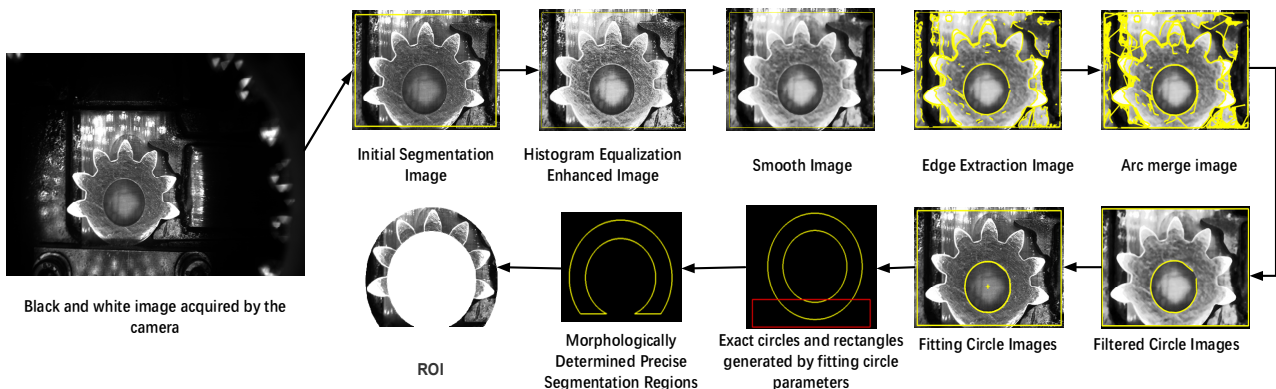


Figure 4. Schematic diagram of image preprocessing and precise target area segmentation of fine blanking pinion gears

3.2. Feature extraction for ROI

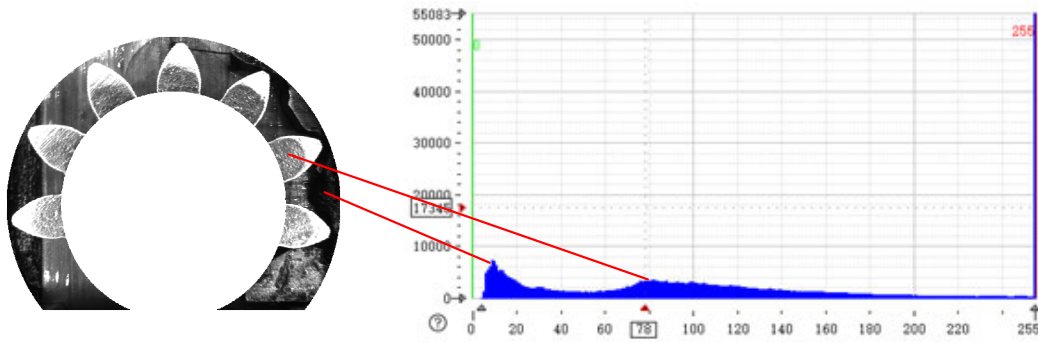


Figure 5. Histogram of ROI with areas corresponding to wave crests

Thresholding segmentation method is one of the most widely used methods in image processing, the histogram of ROI with the corresponding region of the wave peaks is shown in Fig. 5, as can be seen from the histogram, the wave peaks in the histogram do not correspond to the collapsed corner region. Since the background image of the pinion is non-uniform, determining a global threshold to segment the tooth shape is difficult. From Fig. 5, it can be seen that the difference between the tooth shape and the background contrast is large, so this paper adopts dynamic thresholding for tooth shape segmentation, first of all, image smoothing is carried out for ROI mean filtering, and the average gray value of ROI is computed as the background estimation value, and then the value is used to compare with the image to segment the tooth shape region, as the average gray value of ROI of the annulus is used as the background estimation value, and

the external ambient light changes, the background estimation value also changes along with it, and it can be used to segment the tooth shape region. As the average gray value of the ring ROI is used as the background estimation value, when the external ambient light changes, the background estimation value also changes, which can overcome the influence of the external ambient light. Set the original image gray value as g_o , smooth image as g_t , offset for the deviation value, using formula 1, to obtain the fine blanking pinion gear tooth-shaped region, the offset of this paper many tests to determine the estimated value of 150.

$$g_o \geq g_t + offset \quad (1)$$

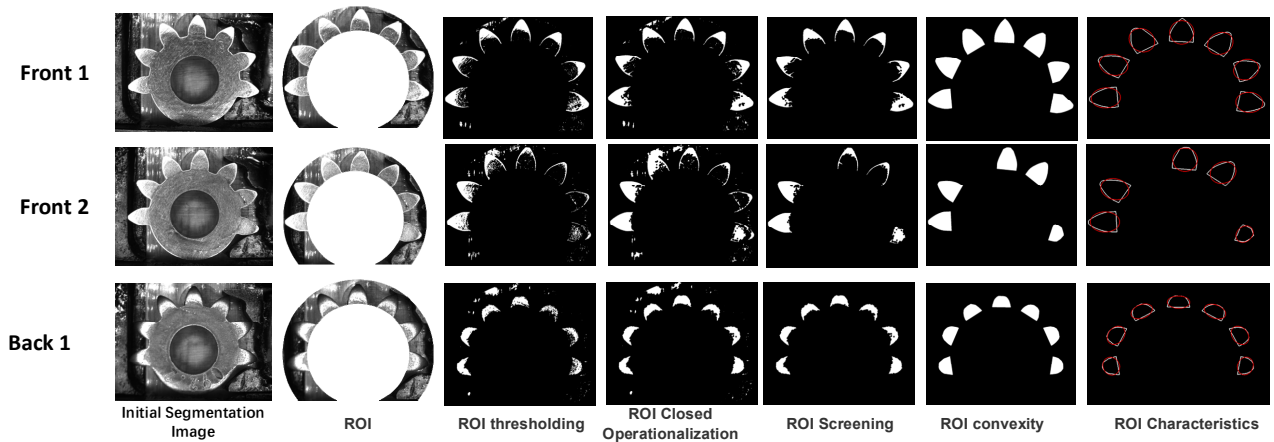


Figure 5. Comparison of image processing for identification of collapsed angle surfaces of fine blanking pinion gears.

After obtaining the toothed region through dynamic threshold segmentation, the closed operator `closing_circle` is used to fill the gap, the operator `fill_up` fills the punch region, the operator `opening_circle` removes the burr, and the operator `select_shape` screens the region. The selection of parameters for regional feature screening is crucial, this paper adopts the long semi-axis (ra), short semi-axis (rb) and area ($area$) feature parameters of the regional equivalent ellipse for screening, and the final parameters are determined as follows in many tests: $50 < ra < 100$, $40 < rb < 100$, $3000 < area < 96000$, and it can be seen from the front and back screening images in Fig. 5 that if the front and back tooth-shaped region for convex operation, will expand the positive and negative teeth

area difference, so this paper adopts the regional shape transformation operator `shape_trans` to screen the region of convex transformation, the effect of processing is shown in Figure 5 fine blanking pinion collapsed angle surface aliasing image processing comparison of the convex transformation of the teeth area sorting, statistics of positive and negative convex teeth area of the largest area of the front 7 areas. The situation is shown in Table 2. From the table, it can be seen that the difference between the area of the positive and negative sides of the ratio is very large, which can be used as a recognition parameter, due to the image effect is not good, the image filtering after the front 2 images only 5 tooth-shaped areas.

Table 2. The front and back feature value

name	area1	area2	area3	area4	area5	area6	area7
Front 1	15850	15763	15588	14969	14851	14702	14254
Front 2	15792	15759	15747	15733	9328		
Back 1	9857	9535	9431	9412	9339	9239	9084

3.3. Precision punched pinion gear positive and negative criteria and recognition

In order to obtain accurate evidence, according to the above method of image processing, to obtain the convex tooth-shaped region, and then the convex tooth-shaped region in accordance with the size of the area is sorted, take the area of the largest seven areas, sampling the front and the reverse side of each of the 500 images, processed to obtain the largest seven areas of the scatterplot shown in Figure 6. From the front and reverse side of the seven teeth area scatter plot know, due to the process, environment, environmental light source, etc., to obtain the image effect is not ideal, after image processing, screening the remaining teeth area many less than seven. The front and back of the largest area of the three regions together, the reverse side of a small number of the

largest point in the front of the point group, the front of a small number of the smallest point in the reverse point group, so just based on a single area can not be completely differentiated between the front and back. From Figure 6, the area of the first three areas of the front and back of the map can be seen, the vast majority of the front below 19,000, the vast majority of the reverse side of the more than 3,000, based on the data to eliminate the dissimilarity of the region, and then take the area of the largest three areas to take the average, the dissimilarity of the region to screen the largest area of the front and back of the first three averages are shown in Figure 6 scatterplot, can be seen from the figure, the average of front and back of the average value is completely separate, so that the average value So the average value can be used as a criterion to distinguish the positive and negative sides of the fine blanking pinion.

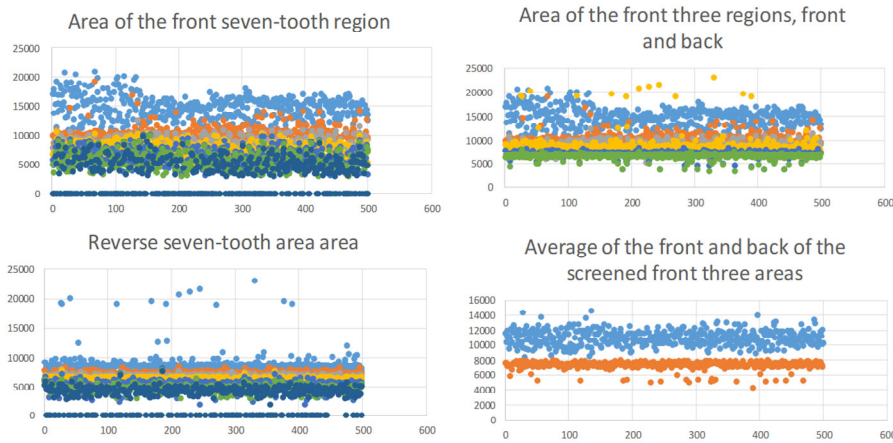


Figure 6. Area statistics of the positive and negative tooth area of the fine blanking pinion gears

In order to obtain an accurate criterion, after several trials, the recognition model is determined as in Equation 2, and a_1 , a_2 , a_3 , and a_4 in this paper are 19,000, 8,700, 8,000, and 4,200, respectively

$$.g(x) = \begin{cases} \text{inconclusive} & a_1 \ll x \\ \text{front} & a_2 \ll x < a_1 \\ \text{inconclusive} & a_3 \ll x < a_2 \\ \text{back} & a_4 \ll x < a_3 \\ \text{no part} & x < a_4 \end{cases}$$

4. Tests and Applications

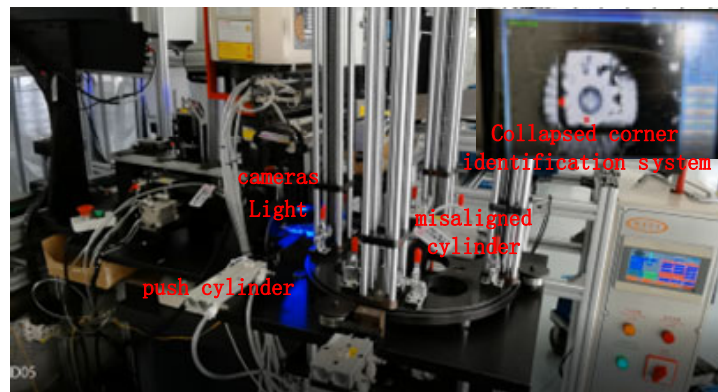


Figure 7. Application site of fine blanking pinion collapsed angle surface identification system

Table 3. Hardware and software

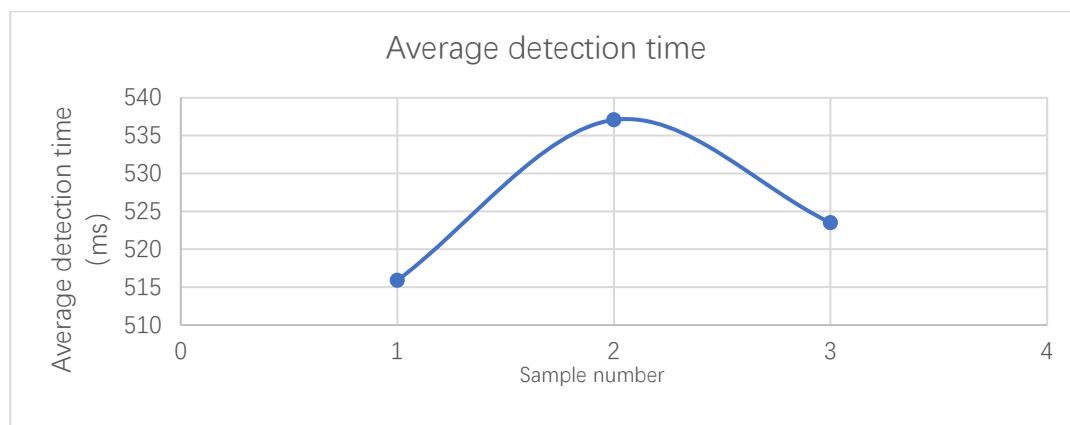
name	factory	Versions	quantities	instructions
computer	Guan Yi	PX1502	1	Industrial Touch All-in-One
CPU	Intel	i7-7700HQ	1	Core(TM) 2.80GHz
RAM	4.1.1. Samsung	PC3-12800U	2	16G
hard disk	Intel	pro 250	1	360G SSD
systems	Microsoft	Win10 V22H2	1	64-bit, Professional Edition
software	MVTec	Steady V20.11	1	HALCON x64 win64

The application site situation is shown in Figure 7, fine blanking pinion collapsed angle surface identification system hardware and software components are shown in Table 3. in order to further test the detection of the algorithm correctness, stability and reliability. 30 consecutive days of production, the production of parts every 10 days as a test sample, numbered

1, 2, 3. 40,000 pieces of each sample, the test results are shown in Table 4, the average detection of front and back face accuracy of 99.95%, the average detection of each piece of time for 525.5ms, as shown in Figure 8, to meet the assembly requirements of the production line.

Table 4. Algorithm correctness test table

serial number	Detection type	Number to be inspected	quantities	Detection accuracy
1	front	20117	20115	0.99990
1	back	19883	19871	0.99940
1	inconclusive		65	0.00163
1	void	55	55	1.00000
2	front	20215	20214	0.99995
2	back	19785	19772	0.99934
2	inconclusive		98	0.00245
2	void	72	72	1.00000
3	front	19989	19986	0.99985
3	back	20011	19989	0.99890
3	inconclusive		88	0.00220
3	void	64	64	1.00000

**Figure 8.** Statistical chart of detection time

5. Conclusion

Collapse angle is an inherent feature of precision punched pinion gear, this paper adopts industrial camera to obtain the image of precision punched pinion gear, and carry out circle fitting in the initial positioning segmentation region to determine the center of precision punched pinion gear, and then take this as the benchmark to carry out rectangular region accurate segmentation, and further accurately segment the toothed torus ROI through morphological transformation; carry out image dynamic threshold segmentation of ROI, regional shape transformation, and screening of regional area conditions. To obtain the tooth shape region of fine blanking pinion gear; extract the area characteristics of the tooth shape

region, statistically determine the range of the front and back face feature parameters of the tooth shape region, eliminate the abnormal areas of oversize and over small, and take the average value of the area of the top three tooth shape regions with the largest area as the feature parameter for identifying the collapsed corner surface. The application on the assembly line shows that the recognition accuracy of this method reaches 99.9%, with good robustness and stable operation, which meets the requirements of production, and can also be used as a method to recognize the collapsed surface (front and back) of fine blanking parts.

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