A Novel Non-Contact Thread Surface Detecting Syetem based on Machine Vision Technology

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Abstract

Based on the principle of the machine imaging technology, a novel non-contact thread surface detecting system was presented. The system is efficient and simple to implement. By analyzing the contour characteristics of the screw, the main parameters of thread detection are selected, which can be obtained directly from the two-dimensional figure of the screw thread. Such an operation can avoid the need for image Mosaic due to the acquisition of three-dimensional objects to be measured, which leads to a large and complex image processing process with large data volume. This system can greatly optimizing the efficiency, and is very suitable for the rapid detection of a large number of threads. Besides, the subsequent ductility of this system is very good, which can be used for different sizes of threads. The test results show that the accuracy of thread detection by this method can reach over 98%.

Keywords

Surface, Machine Vision Technology.

1. Introduction

With the continuous development of China's industrial economy, the quality requirements for industrial products are becoming more and more stringent in recent years. China, as a big exporter of fasteners, needs to export a large number of fastener products every year, especially screw products. As we known, product quality inspection is a very important link in the production process. The improvement of detection technology is the foundation of the improvment the manufacturing industry and the breakthrough of improving the level of processing and manufacturing in China. Therefore, the identification and detection of screw threads is of great significance in modern industry [1-3].

At present, the detection methods of non-destructive identification and screening for screw threads are basically as follows:

(1)Contact detecting method. Usually, this kind of detection method uses univeral microscope for manual measurement or thread gauge for contact measurement [4-5]. This measurement method can’t guarantee the measurement accuarcy and the efficicency is very low. Besides, in the contact measurement, the cost of changing measurement tools like the thread gauges is high.

(2)Non-contact detecting method. Magnetic flux leakage testing (MFL) is a method to determine the location of defects according to the change of magnetic field of the detected workpiece [6]. But the result of this method is not accurate, and it is only valid for metal workpiece whose shape is simple. Ultrasonic inspection testing (UI) is another kind of non-contact method, which is based on the same type of workpiece ultrasonic reflection is basically the same. However, this method needs to add couplers on the surface of the tested object, which increases the complexity of the measurement.

Another non-contact detcting method is mainly based on machine vision system [7-9], this system uses industrial camera to take photos of the measured objects, and processes the image through various image recognition algorithms, then compares the information with measured objects. In this paper, an automatic thread detection system is designed by using machine vision technology. This system can collect the key data of screw thread quickly, realize the comparison of key data, and classify the measured screws automatically.

2. The Design of the Detection System

The thread detective machine vision system contains the following modules: light source、camera lens、camera、image processing unit、execution unit[10], as shown in figure 1. CCD high-speed camera acquires image signals, and the image signals can be shown on the monitor. The image processing unit preprocesses the image signal, and determine whether the measured threads meet the requirements. Finally, the output results are given to the execution unit, and the measured threads are classified.

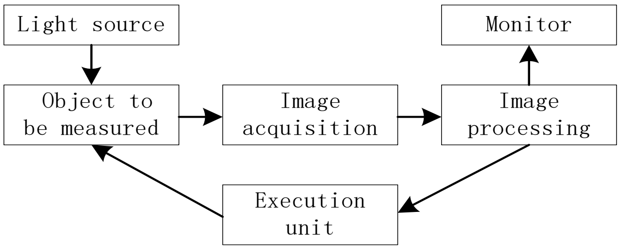

Fig1 the detective machine vision system

Functionally, the thread detection system can be divided into three parts in further: image acquisition unit、screw drive unit and algorithm control unit. The image acquisition system consists of lens, industrial camera and light source. The screw drive unit is composed of vibration plate, screw clamping device, transmission guide rail and air nozzle. Algorithm control unit consists of computer, identification algorithm, controller, air pump, electromagnetic valve, screw classification unit, etc. The system structure is shown in figure 2.

This detection system works as follows：A large number of screws are arranged on the conveyor belt after passing through the vibration plate. The industrial camera acquires thread images from the side and sends them to the computer for image processing. After the processment, the computer start qulification judgment algorithm, then the controller is activated to carry out srew classfication system. The screws are divided into two categories by the quality and putted in different places.

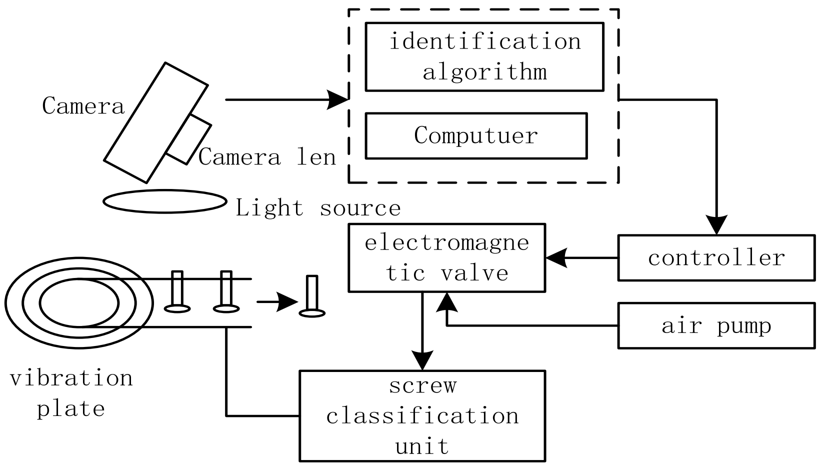

Fig 2 the structure of the thread detetive machine vision system

3. The design of Image processing algorithm

3.1 The parameter of the thread detection

On the surface of a cylinder or cone, a curve formed by a moving point rotating uniformly around its axis and moving rapidly along its axis, this curve is so called a spiral line. When a plane geometric figure rotates along the helix, the corresponding thread is obtained by keeping the plane geometric figure through the axis of the cylinder or cone. The figure 3 is the trace of the thread.

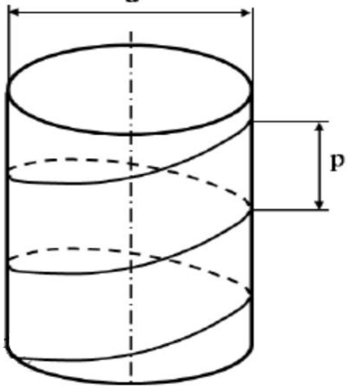

Fig 3 The trace of the thread

Take the center of the lower surface of the cylinder as the coordinate origin, we set a rectangular coordinate axes of space, and the coordinate equation of thread curve can be obtained as follows.

$$X = \frac{d}{2}\cos\theta$$
$$Y = \frac{d}{2}\sin\theta \quad (1)$$
$$Z = \frac{\theta}{2\pi}p$$

Where d is the diameter of the cylinder, p is the pitch of thread. θ is the angle of rotation along the helix of the cylinder's plane figure.

As the screw thread is a 3-D model, multiple set of the images should been taken from different angles to get the entire 3-D model data. For the assembly of automatic batch detection, the image data involved in this method is too large. In fact, for the common triangulation external thread detection, if the external spacing, internal spacing and screw pitch meets the requirements, the quality of thread would be up to standard. In this way, only the main view image of the triangular thread is collected. After image processing, the quality of the thread can be judged. Figure 4 shows the main geometric parameters of thread.

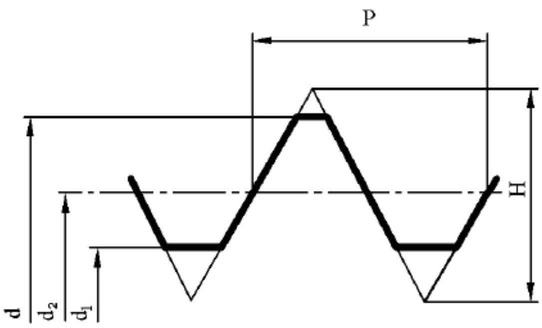

Fig 4 The main geometric parameters of thread

Where d is the full diameter of thread, d1 is the minor diameter of thread, d2 is the pitch diameter of thread, P is the pitch of thread. The angle of the standard thread is 60 degrees.

The pitch diameter d2 and full diameter d1 of the standard thread can be calculated according to the following formula.

$$d_2 = d - 2\times\frac{3}{8}H = d - 0.6495P \tag{2}$$

$$d_1 = d - 2\times\frac{5}{8}H = d - 1.0825P \tag{3}$$

$$\text{Where } H = \frac{P}{2}\times\tan^{-1}\frac{\pi}{6} = \frac{\sqrt{3}}{2}P \tag{4}$$

3.2 The research of algorithm

The description of the algorithm is shown in figure 5.

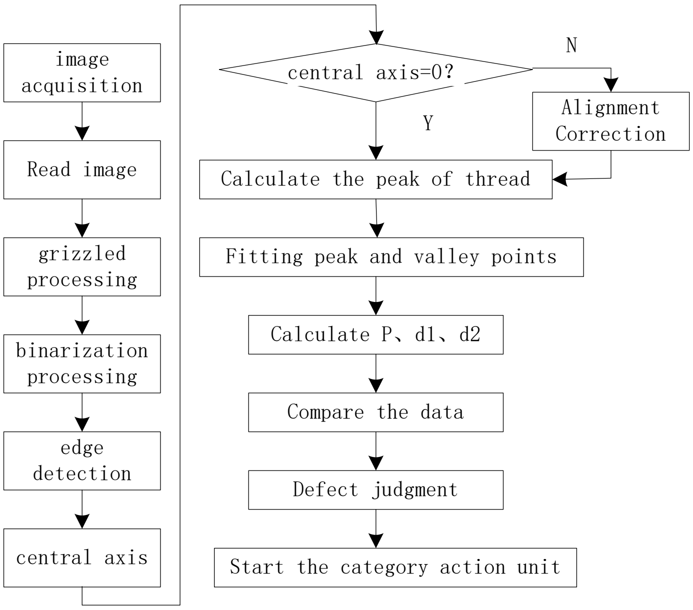

Fig 5 Description of algorithm

The whole process of the algorithm can be roughly described in the following three parts.

Image acquisition part. In this process, an image of screw thread is collected through the CCD camera. Then collected image data is then transmitted to the computer [11].

Image processing part. The computer starts the image processing part when the image data transmission finished. The image data is grayed and then binarized to reduce the amount of data. The image after binarization is shown in figure 6(a). Then start the edge detection algorithm to detect the edge of thread data. The Canny operator for edge detection is used in the edge detection algorithm [12]. The input image is smoothed and filtered through the two-dimensional gaussian function to remove the image noise, the gaussian is shown below.

$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \tag{5}$$

Where σ is the standard deviation of the gaussian curve.

The extraction results of screw edge data are shown in figure 6(b). In order to calculate the pitch equivalence better and ensure the low error rate of subsequent detection, the central axis of the image needs to be detected. If the central axis angle is not 0, the image should be calibrated. The calibrated image is shown in figure 6(c). Then, the parameters like the screw peak, the peak and the valley point are calculated. The result of fitting is shown in figure 6(d).

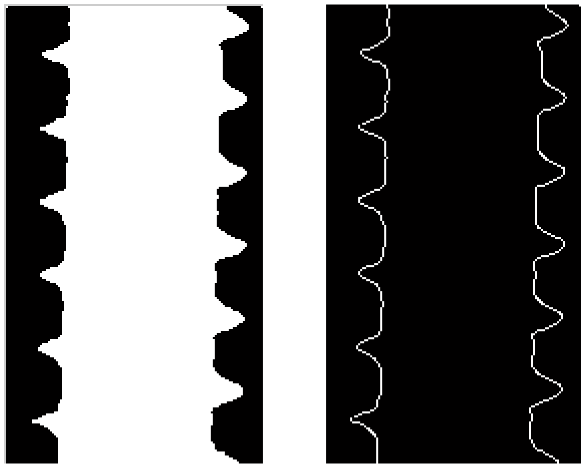

Fig 6(a) binarization result Fig 6(b) screw edge data

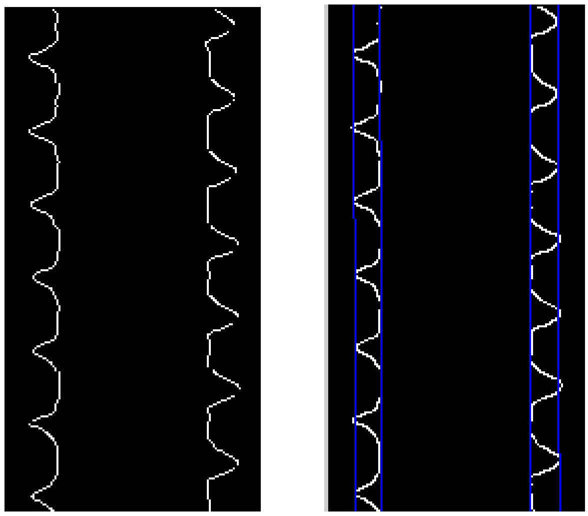

Fig 6(c) calibrated result Fig 6(d) fitting result

Fig 6 Comparison of image processing results

Judgement part. This part calculate the parameters like P, d1, d2 etc. according to the results of image processing. Compare with the standard data stored in the computer, and start the action switch to classify the screws into qualified and unqualified.

4. Analysis of experimental results

To verify the quality of system, 100 screw threads of different sizes were tested on site. The following parameters are selected as the standard screw thread: d is 20mm, P is 2.5mm, d2 18.376mm, and d1 is 17.294mm.The size and number of screw threads in 100 screws selected on site are shown in the following table1.

Table 1 Dimension of screw thread to be measured

No.	d/mm	P/mm	d2/mm	d1/mm	quantity
1	20	2.5	18.376	17.294	80
2	1	0.25	0.838	0.729	5
3	64	6	60.103	57.505	5
4	20	2	18.701	17.835	5
5	18	2.5	16.376	15.294	5

A total of 5 tests were conducted, and the test results are shown in table 2.

Table 2 Test result of screw thread

Test No.	test the correct number of threads for each serial number					accuracy
	No.1	No.2	No.3	No.4	No.5	
1	79	5	5	5	5	99%
2	80	5	5	5	5	100%
3	79	5	5	5	4	98%
4	80	5	5	4	5	99%
5	79	5	5	5	5	99%
accuracy	99.25%	100%	100%	96%	96%	

It can be seen from the data in the table that the recognition accuracy of the thread of standard no. 1 can reach more than 99%, with high accuracy. For threads with large data difference, such as samples no. 2 and no. 3, the accuracy can reach 100%. And for the thread with a relatively close difference, such as no. 4, no. 5, the accuracy rate can also reach above 96%.5 test results showed that the overall screw thread recognition accuracy was above 98%.

5. Conclusion

To sum up, this study builds a Thread Surface Detecting system based on Machine Vision Technology. The system structure is simple and easy to implement. Screw thread is a 3-D structure, the collection of three-dimensional graphics involves a lot of image processing and Mosaic, this result in a huge volume of image data. In this paper, the external characteristics of screw threads are analyzed, the basic external features of a thread can be determined by comparing the parameters of D, d1, d2 and P. In this way, the corresponding parameters can be obtained directly by collecting two-dimensional image measurement and calculation. Then compare these data with the thread data in the database and draw a conclusion. This method can greatly reduce the data volume and improve the speed.

The test results show that the system is reliable and with high accuracy. By changing the thread parameter values in the database, the identification and judgment of multiple screw threads are made, which provides important reference for future research.

Acknowledgments

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References

[1] Lu Dong-Fang, Ding Zhen-Liang; Yuan Feng. Measurement of inside screw curve surface by laser probe[J], Guangxue Jingmi Gongcheng/Optics and Precision Engineering, Vol.15, No. 2, 2007, p186-191.

[2] S.D.Cook,S.L.Salkeld,T. Stanley, A. Faciane, S.D. Miller, Biomechanical study of pedicle screw fixation in severely osteoporoticbone[J], The Spine Journal 4 (4) (2004) 402–408.

[3] N.A. Ebraheim, J.R. Misson, R. Xu, R.A. Yeasting, The optimal transarticular c1-2 screw length and the location of the hypoglossalnerve[J],Surgical Neurology 53(3), 2000, 208–210.

[4] Li YuShan. Thread measurement method and error analysis[J], Fastener technology,2007(2): 29-35.

[5] Zheng Jiang，Yang Chunfeng，Thread measurement[M]，Beijing：China metrology press，1998.

[6] REN Zhifeng, The Application of Magnetic Particle Testing Method in Testing the Welding Seam of Spheroidal Container[J], Journal of Jiamusi University（NaturalScienceEdition）,2010, 28(004):557-559.
[7] WU W Y, WANG M J, LIU C M. Automated inspecion of printed circuit boards through machine vision[J]. Computers in Industry, 1996,28(2):103-111.
[8] GUO Feng-lin, GUAN Shu-an. Research of the machine vision based PCB defect inspection system[C]. Internation Conferenc on Intelligence Science and Information Engineering, Wuhan: IEEE, 2011.
[9] Liu Chunxiao, Hu Peng. Design of Digital Servo Precision Detection of Certain Type Reconnaissance Vehicle[J].Ordnance Industry Automation,2015,34(10):15-17.
[10] Shen Shao-Wei, Yan Shu-Hua, Zhou Chun-Lei, Tong Hui-Peng, Research of automatic detection technology of thread parameters based on CCD vision[J]. Bandaoti Guangdian Semiconductor Optoelectronics, Vol. 28, No. 6, 2007, p 865-869.
[11] SUZUKI K, HORIBA I,SUGIE N. Linear-time connected-compent labeling based on sequential local operations[J]. Computer Vision and Image Understanding, 2003,89(1):1-23.
[12] T.F. Coote, G.J.Page, C.B.Jackson, C.J.Taylor. Statistical grey level models for object location and identification. Image and Video Computing, 1996, (14):533-540.