Simulation research on measurement method of geometric parameters of non-contact pipe thread

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Abstract. In order to ensure that the pipe thread exerts its good sealing and transmission performance in the oil and gas pipeline, it is essential to judge the geometric parameters of the pipe thread. The experiment uses the 60° standard sealed pipe thread of model NPT1/2 as the research target, the machine vision technology is used to make non-contact measurement of the pipe thread geometry, LABVIEW is used as the software development platform to analyse the processed thread image. Finally, the parameters such as pitch, thread angle, taper, and thread height are simulated and measured to obtain the qualification conclusion.

1. Introduction
Pipe thread often refers to the thread for preventing leakage. The pipe thread is divided into 55° unsealed pipe thread (G), 55° sealed pipe thread (PT) and 60° tapered pipe thread (NPT). The traditional method of measuring the thread parameters has problems such as slow detection speed and low precision. We use the machine vision system to capture the actual thread pattern online, and then use the LABVIEW software to simulate the pipe thread geometry parameters and determine the pipe thread qualification according to the tolerance requirements. This method improves the accuracy and efficiency of thread detection and has high feasibility.

2. Identification system of pipe thread geometry
The equipment we use to acquire the images of pipe threads is realized by a laboratory-modified universal tool microscope. As shown in Figure 1, the operator clamps the pipe thread to the workpiece table, opens the universal tool microscope power supply, makes the light source shine on the pipe thread, adjusts the X and Y workbench to display the image in the camera field of view, and realizes the progressive scan of the pipe thread[1], start the simulation software to display the edge information of the entire pipe thread profile.
3. Research on image edge feature extraction

3.1. Image preprocessing
The graying process of the original image collected by the system will make the calculation of the subsequent image simple. Figure 2(a) shows the original image acquired for the system.

First, calculate the uniformity of gray distribution in the neighborhood where each pixel \([i, j]\) of the gray image is located. Then, using the weighted average method, different weights are assigned to the color components R, G, and B of the pixels in the original image, namely:

\[ V_{gray} = 0.299R + 0.587G + 0.114B \]  

At this time, a reasonable gradation image can be obtained, and Figure 2(b) shows the thread image after graying.

Under the influence of camera and surrounding environment, the image will produce noise that degrades the image quality. In this paper, the median filtering method is used to eliminate the noise in the image, as shown in Figure 2(c). Firstly, the gray scales of the pixels are sequentially arranged, then the median value after sorting is selected, and use it to replace the original gray value, which is expressed by the formula as follows:

\[ G(m,n) = \text{Media}\{f(m-k,n-l)\} \quad (k,l) \in W \]  

3.2. Edge extraction of threaded images
Image edge detection is the key to measuring thread parameters. The Canny operator is an optimal edge detection operator because of its high accuracy in locating boundary points \cite{2}. The specific implementation method of Canny edge detection operator is: first-order filtering with Gaussian function for image smoothing, differential operation to obtain amplitude and direction, finding gradient amplitude local maximum point, and double threshold detection. Figure 3(a) shows the edge point position information detected by the canny operator. After the edge point position information is detected, the least squares fitting method is used \cite{3}\cite{4}, as shown in Figure 3(b). The curve trend is used to reflect the data trend and make the boundary information more accurate.
The Newton interpolation function can achieve sufficient smoothing of the profile of the pipe thread and facilitate the precise positioning of the secondary sub-pixel \[5\]. Figure 4 shows the final extracted thread profile.

4. Simulation experiment on geometric parameters of pipe thread

4.1. Pitch
Pitch is the distance between a point on the helix and the corresponding point on an adjacent thread. As shown in Figure 5, L3 is the pipe thread centerline, we select 3 thread teeth for calculation. L1, L2 and L3 intersect at points A and B, and the coordinates of points A and B are obtained. At this time, the distance between A and B is divided by 2, which is the pitch.

4.2. Thread angle
In the axial section of the thread, the angle between the two sides of the thread profile is the thread angle. As shown in Figure 6, firstly, straight-line fitting is carried out on the two flanks of the measured pipe thread, and the tooth form angle parameters can be calculated through the equations fitted on both flanks.
of the tooth form. Let one side fit the line as L1 and the other side fit the line as L2. Then the angle of the thread is:

$$\alpha = \tan^{-1} \left[ \frac{k_2 - k_1}{1 + k_1 k_2} \right]$$

(3)

In the above formula, $k_1$, $k_2$ are the slopes of the two lines respectively.

4.3. Thread height
Thread height refers to the distance from the crest to the bottom of the tooth in the direction perpendicular to the axis of the thread. The measurement process of the tooth height is shown in Figure 7, it is assumed that a tooth apex and a tooth bottom point are respectively A, B, and C, and the line connecting the two points of B and C, that is, the minimum square fitting line of the bottom is $L_1: y = k_1 x + b_1$, the thread height is:

$$h = \frac{|k_1 x_A - y_A + b_1|}{\sqrt{1 + k_1^2}}$$

(4)

4.4. Taper
The pipe taper is defined as [6]: the amount of increase in the pitch diameter of the thread in the axial length. We take the connection of the bottom of the tooth as the measurement object, for the midpoint sampling of the bottom of the tube thread in the image, as shown in Figure 8, the fitting line of the upper tooth bottom is $L_1$, the parallel line of the thread axis is $L_2$, and the fitting line of the lower tooth bottom is $L_3$.

The inclination angle is expressed as:

$$2\varphi = \tan^{-1} k_2' - \tan^{-1} k_1'$$

(5)
Among them, the diameter of the small end face and the diameter of the large end face, respectively. While the increment of pitch diameter changes as follows:

\[
\Delta d = 2 \tan \left( \frac{\tan^{-1} k_2 - \tan^{-1} k_1}{2} \right)
\]

(6)

![Figure 8 Taper measurement](image)

5. Qualification judgment of pipe threads

For NPT1/2 60° standard sealing pipe thread, the qualification condition of the pitch\(^7\): 1.814±0.034 mm, the qualification condition of the thread angle: 60°±0.5°, the qualification condition of the thread height: 1.451±0.043 mm, the qualification condition of the taper: 3.58°±0.074°. From our simulation results of the 60° standard sealed pipe thread of NPT1/2 (Figure 8), it is seen that the results of the four sets of data are within the specified range. Therefore, the thread is qualified.

6. Conclusion

In this paper, it is feasible to use non-contact measuring pipe thread geometric parameters by applying machine vision and LABVIEW virtual software platform, mechatronics and other technologies. It not only realizes the rapid detection of pipe thread pitch, thread angle, thread height and taper. Moreover, the system also uses LABVIEW virtual software to greatly improve the accuracy of data processing. It provides the market with high cost performance, easy operation and accurate measurement.

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