www.s2is.org
International Journal on Smart Sensing and Intelligent Systems
ISSN 1178-5608

AUTOMATIC MEASUREMENT OF SHAPE PARAMETERS FOR HYDRAULIC TORQUE CONVERTER

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Submitted: Oct. 17, 2015 ***Accepted: Jan. 19, 2016*** ***Published: Mar. 1, 2016***

Abstract- ***In this paper, the automatic measurement method of the Hydraulic Torque Converter shape parameters is studied. Aiming at the defects of the traditional manual measurement method, the solution for measuring the shape parameters of Hydraulic Torque Converter with the automatic measurement system is proposed on the basis of in-depth analysis for the Hydraulic Torque Converter shape parameters’ characteristics. Automatic measurement system mainly contains two parts, the Hardware Measurement System and the Software Measurement System. The working principle of the automatic measurement system are as follows: firstly, as system starting, the arm upper Measuring Fixture put the Hydraulic Torque Converter work piece into the Measuring Fixture, and then the Measuring Fixture make the Pump Hub Axle and Cover Hub Axle of the measured work piece fixed; secondly, the measured work piece start to rotate, at the same times, s the work piece is measured by MARPOSS displacement sensor. The measuring stop as soon as the measured work piece completes rotating 360 degrees. Lastly, measurement data is collects by the Software Measurement System based on LabVIEW development platform using NI acquisition card. The Moving Average Filter and Butterworth approximation method is mainly used during processing the measurement data. The tolerance measuring value of each shape parameter can be obtained, after the measurement data processed. The external dimensions of the measured work piece have been qualified by the data obtained. Under practical test, this method fit the industrial production demand very well; it can help to improve the production efficiency greatly used in the industrial production.***

Index terms: Hydraulic Torque Converter; automatic measurement; shape parameters; data acquisition.

I. INTRODUCTION

Hydraulic Torque Converter[1] is a hydraulic element which is made up with a pump wheel, a turbine and a guide wheel. It takes the hydraulic oil as his working medium, and plays roles of the transmission torque, the torque variation, the speed change and the separation and reunion. As shown in Figure 1.

(1) Top

(2) Botoom

Figure 1 Hydraulic Torque Converter

The Hydraulic Torque Converter is a complex fluid solid coupling system, which consists of mechanical and hydraulic mechanism. The development of it can be divided into two stages:

(1) The first stage, is from 1930s to 1980s. This stage is called the development stage of the traditional Hydraulic Torque Converter;

(2) The second stage, is from 1990s to the present. This stage is called the development stage of the modern Hydraulic Torque Converter.

In early twentieth Century, the world's major industrial countries have put the Hydraulic Torque Converter into using. Take the United States as an example, since the seventy's , the ratio of the Hydraulic Torque Converter in the car was more than 90%, the production were more than 8 million units. In the bus which are in the urban area, the Hydraulic Torque Converter equipment rate is close to 100%. In terms of heavy vehicles, 30 - 80 tons of cargo heavy capacity dump truck almost all using hydraulic transmission. So far, in the heavy vehicles which power more than 735KW, carrying capacity more than 100 tons , hydraulic transmission has been applied. Such as the GLBT9680 series Hydraulic Torque Converter is applied in the power of 882.6KW, loading quality of 108 tons mine dump truck. In some non highway vehicles, in most tanks and military vehicles are also equipped with hydraulic transmission. In Europe and Japan, there is a significant increase in the hydraulic transmission of vehicles. Foreign large tonnage loader, bulldozer and other construction machinery all used hydraulic transmission.

China started to use the Hydraulic Torque Converter from 1950s. It is a kind of key industrial devices, with the use of it in our country; a new industrial development is officially opened. Some of the industries fall behind in the technology are improved, after the founding of new China; Some of the industries limited by the technology of Hydraulic Torque Converter, has made a great breakthrough; Some industrial machinery have changed from dependent on the original import into the current independent research and development, and it also could be continued to upgrade. The Hydraulic Torque Converter can make the performance of this machinery perfect, achieving it from making in China to creating in China. The development of industrial machinery, benefit all the industrial fields, greatly promote the development of the national economy. The development of industry and the promotion of economic gross have brought many blessings for our people, so that our country has taken a solid step in the road of industrial power.

Hydraulic Torque Converter is mainly used in the engineering industry, the petrochemical industry, the automotive and defense industries, as well as the related fields. As we see the most commonly used of it is in the automatic car. As one of the main carriers to realize the automation and intelligence of engineering machinery, it plays a most important role in every application field. With the rapid development of economy in our country, various application industrial of Hydraulic Torque Converter has put forward higher requirements to the external dimensions of Hydraulic Torque Converter. It will directly affect the working performance and service life of the machinery which used Hydraulic Torque Converter, if the external dimensions of Hydraulic Torque Converter are unqualified, and it also will hinder the sustained and rapid development of the economy greatly, if the product which external dimensions is unqualified come to apply in the relevant industrial areas.

In some major western industrial countries, the application measurement method to measuring Hydraulic Torque Converter shape parameters and then to determining whether the external dimensions of Hydraulic Torque Converter is qualified are more advanced. They have many obvious advantages, compared with the domestic same industry. In order to make the domestic production enterprises get a place in the market fierce competition, the measuring method of the Hydraulic Torque Converter shape parameters should be innovated，with the continuous development of the domestic Hydraulic Torque Converter market, as well as the entry of foreign enterprises. It can help enterprises to enhance the core competitiveness, under the premise of meeting the needs of higher industrial production.

Currently, some enterprises that produce Hydraulic Torque Converter often use the traditional measuring method for measuring the shape parameters of the Hydraulic Torque Converter to determine whether the external dimensions are qualified. Some even rely on the technical staff to use the three coordinate measuring instruments for all the shape parameters of the product to measure one by one. There are many deficiencies in this measuring method, such as: some shape parameters cannot be measured, the accuracy of the measurement tool is low, fewer data points were collected in measuring, artificial operation may bring a lot of error, and the time which is spending to measure the shape parameters of the Hydraulic Torque Converter is long, and so on. It not only spends a lot of manpower and material resources and gets the lower measurement efficiency, but also may lead the shoddy products appears among the outgoing ones in the production enterprises when using the traditional measuring method. Therefore, in order to ensure such phenomenon does not be appear, this paper focus on the automatic measuring method of Hydraulic Torque Converter shape parameter. It is a method of measuring the Hydraulic Torque Converter shape parameters with the automatic measuring system. The automatic measuring system contains the Hardware Measurement System and Software Measurement System which is designed by LabVIEW development platform. It can determine whether the external dimensions of the measured work piece is qualified through measuring the Hydraulic Torque Converter shape parameters. Comparing with the traditional manual measuring method, it can not only improve the measured level in accurate, automatic and intelligent for the shape parameters of Hydraulic Torque Converter, but also promote the development of Hydraulic Torque Converter industry. It can fit the industrial production demand very well and has important significance to the production and development of enterprises.

II. MEASURING PRINCIPLE

The shape parameters of Hydraulic Torque Converter mainly includes the Radial Run out, the Pump Hub Diameter, the Pump Hub Roundness, the Axial Dimension, the Leaf Litter Run out, the Panel Run out, the Cover Hub Diameter, and so on. In Figure 4, the Hydraulic Torque Converter shape parameters are indicated. To determine whether the external dimensions of Hydraulic Torque Converter is qualified is based on that if measuring the shape parameters of the work piece obtained all measured tolerances values are in the range which are given. If this condition is met, the external dimensions of the work piece is qualified [2].

A. Hardware Measurement System

The Hardware Measurement System is made up of many different parts. As shown in Figure 2, it is the schematic diagram for the core components of Hardware Measurement System.

The core components of Hardware Measurement System mainly includes the IPC(Industrial Personal Computer)[3], the Scanner, the Master Control Computer(The computer for real-time control of the measurement process), the Measuring Fixture ,the PLC(Programmable Logic Controller)[4][5], and so on.

The PLC is used to control the Measuring Fixture. The Measuring Principle are as follows:

First of all, the PLC makes the arm upper Measuring Fixture to put the Hydraulic Torque Converter work piece which is on the production line into the Measuring Fixture one by one.

Secondly, the PLC makes the Pump Hub Axle and Cover Hub Axle of the measured work piece to be fixed by Measuring Fixture.

Then MARPOSS displacement sensors which are in the Measuring Fixture start to move towards the measured work piece, until move to the position that the sensor's probe begin to contact with the measured work piece, the measured work piece will rotate after do these, when the measurement is begin. Simultaneously, the MARPOSS displacement sensors begin to measure its shape parameters. The measurement continues until the measured work piece completes rotating 360 degrees. As shown in Figure 3, the measured work piece is rotated in a clockwise direction.

At last, the PLC makes the MARPOSS displacement sensors to move away from the measured work piece, and release the fixing of the Pump Hub Axle and Cover Hub Axle. Then the PLC makes the arm to take the measured work piece out of the Measuring Fixture. If the external dimensions of the measured work piece are qualified, it will be put into the next production process. If unqualified, it will be removed from the production line.

All parts of the Hardware Measurement System contain accidental errors and systematic errors, the measurement data of seven Hydraulic Torque Converter shape parameters which is obtained from each measuring, contain the sum of the errors. Although, the application of such a measurement method is having errors, it still has a high precision. Compared with the traditional measurement technology, it has many significant advantages. When using Hardware Measurement System to measure the Hydraulic Torque Converter work piece, only the power supply and to turn on the Hardware Measurement System is connected to the operation, but not to the traditional measurement methods rely entirely on human operation. It will be great reduction in manpower and material resources, shorten the measuring time, and promote the improvement of the core competitiveness of domestic Hydraulic Torque Converter enterprises, when put the Hardware Measurement System into use.

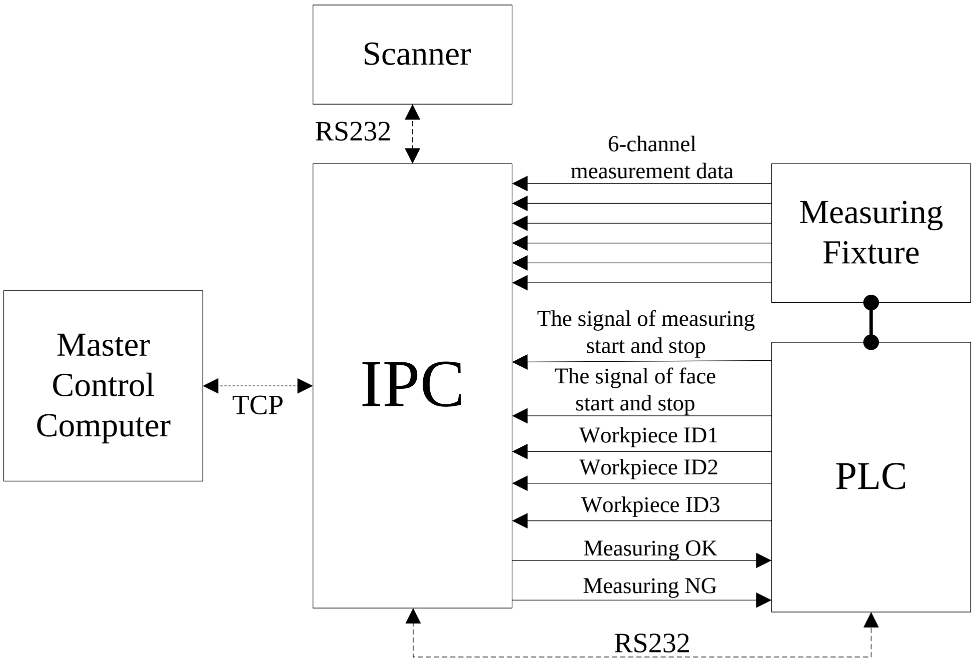

Figure 2 The core components of Hardware Measurement System

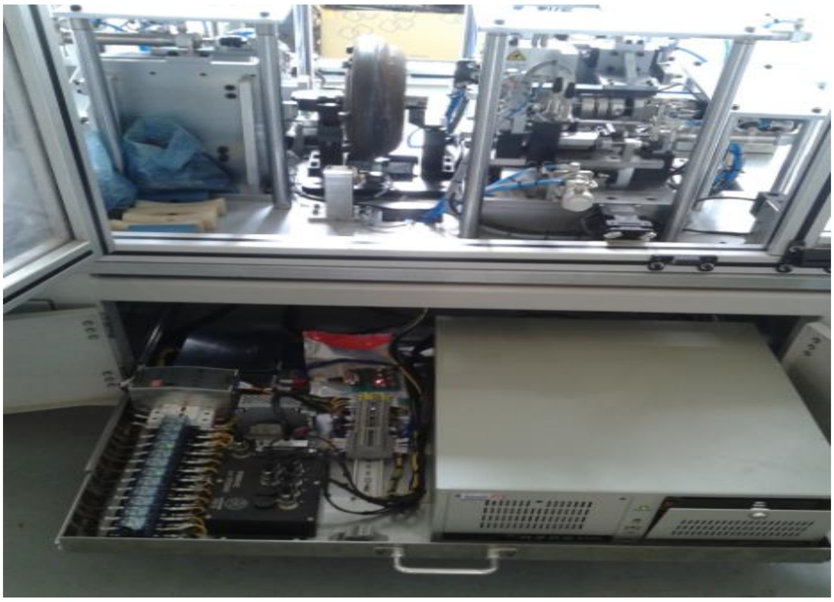

Figure 3 Measuring Fixture

Working principle of the core components:

(1)When the measurement is beginning, the first two-way real-time communication[6] is established between the IPC and Scanner via RS232. The IPC requires the scanner to measure the two-dimensional barcode of the measured work piece, and then the scanner sends the two-dimensional barcode which it has scanned to the IPC[7].

(2)The IPC collects 6-channel measurement data of the measured work piece shape parameters through the NI Acquisition Card and the MARPOSS displacement sensors.

(3)The PLC sends the signal of measuring start and stop, panel start and stop, work piece ID1, work piece ID2, work piece ID3 to the IPC. Meanwhile, when measurement is stopped, the IPC sends the signal of measuring OK(The external dimensions of the measured work piece is qualified) and measuring NG(The external dimensions of the measured work piece is unqualified) to the PLC.

(4)The second two-way real-time communication is established between the IPC and PLC via RS232.
(5)The third two-way real-time communication is established between the IPC and Master Control Computer via TCP.
The input values (Displacement Values) range of the MARPOSS displacement sensors which are in the Hardware Measurement System is -5mm-+5mm, the output values (Current Values) range is 4mA-20mA. A 250 ohm resistor is series connected in the external of each sensor, it can make the 6-channel measurement data, which are collected from the shape parameters of the measured work piece, in the range 1V-5V(Voltage Values). As shown in Figure 4, it is a schematic diagram for Hydraulic Torque Converter. The digital labels 1 to 6 in the figure are the distribution location of the six MARPOSS displacement sensors on the surface of Hydraulic Torque Converter.

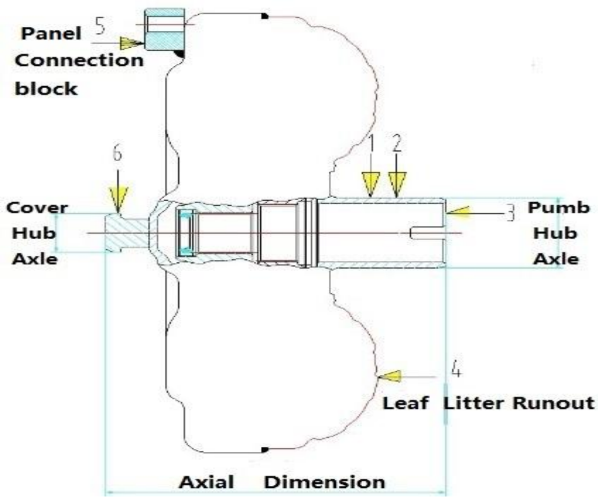

Figure 4 The schematic diagram for Hydraulic Torque Converter

Each displacement sensors[8] measures the shape parameters are as follows:
(1) The 1st displacement sensor measures the Radial Run out;
(2) The 2nd displacement sensor measures the Pump Hub Diameter and the Pump Hub Roundness;
(3) The 3rd displacement sensor together with the 5th displacement sensor measures the Axial Dimension;
(4) The 4th displacement sensor measures the Leaf Litter Run out;
(5) The 5th displacement sensor measures the Panel Run out;
(6)The 6th displacement sensor measures the Cover Hub Diameter.
In order to calibrate the measuring position of MARPOSS displacement sensor and improve the accuracy of measurement data which are obtained from the shape parameters of Hydraulic Torque Converter, The calibration component is used which is the same with it to calibrate the working machinery of Hardware Measurement System before measuring the Hydraulic Torque Converter work piece, when turned it on[9].
B. Measurement Method[10]
In the process of measuring the shape parameters of Hydraulic Torque Converter, the signal of measuring start and panel start are triggered by the rising edge, and the sampling frequency is $200\,Hz$. When the signal of measuring start arrival, the measured work piece will start to rotate, and the 1st , the 2nd , the 4th and the 6th sensors begin to collect the shape parameters' measurement data of Hydraulic Torque Converter which is measured. After a certain time delay, the signal of panel start arrival, the 3rd and the 5th sensors begin to collect

the shape parameters of Hydraulic Torque Converter measured. The signal of panel start is related to the panel connection blocks of the measured Hydraulic Torque Converter work piece. When all of the panel connection blocks are measured, the signal of panel stop coming. After another certain time delay from the signal of panel stop coming, when the measured work piece completes rotating 360 degrees in a clockwise direction, the measuring stop. As shown in Figure 5, they are the signal of measuring and panel.

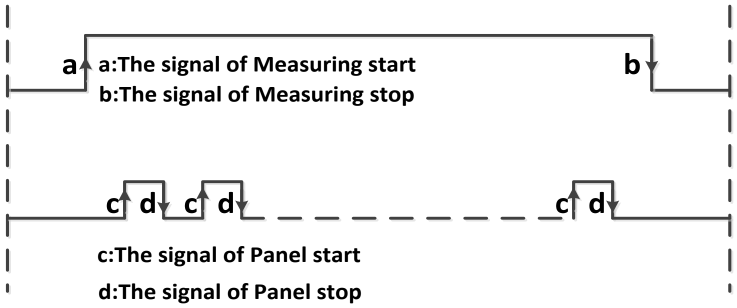

Figure 5 The signal of Measuring and Panel

Seven shape parameters tolerances measuring value (voltage values) of the Hydraulic Torque Converter can be obtained through processing the 6-channel measurement data which are collected by the MARPOSS displacement sensors. The 6-channel measurement data , which are collected from the shape parameters of the measured work piece, are in the range 1V-5V(Voltage Values), and the input values (Displacement Values) range of the MARPOSS displacement sensors are -5mm-+5mm. The relationship between the actual measured displacement value S and the voltage value U is as follows:

$$S = 2.5U - 7.5 \tag{1}$$

The 6-channel measurement data all are contained the rapidly changing high-frequency components. First, we use the moving average filter system[11] to filter out high-frequency components[12]. The equation of the moving average filter system is defined as follows:

$$y(\mathrm{n}) = \frac{1}{M+N+1}\sum_{K=-M}^{N} x(\mathrm{n}-\mathrm{k}) \tag{2}$$

N represents the N value before the first n value of the input sequence, M represents the M value after the first n value of the input sequence.

a.The Radial Run out, The Leaf Litter Run out, The Panel Run out

①The Radial Run out

The averaging data obtained from the two moving average filter for all the measuring data which the 1st sensor collected is U_1, the tolerance measuring value(displacement value) of Radial Run out is S_1, then can we get the following formula:

$$S_1 = 2.5U_1 - 7.5 \tag{3}$$

②The Leaf Litter Run out , The Panel Run out

The difference between the maximum and minimum of averaging data obtained from the two moving average filter for all the measuring data which the 4th and the 5th sensor collected are U_2, the tolerance measuring value(displacement value) of the Leaf Litter Run out and Panel Run out are S_2, then can we get the following formula:

$$S_2 = 2.5U_2 - 7.5 \tag{4}$$

b.The Pump Hub Diameter and Roundness, The Cover Hub Diameter

The Butterworth approximation[13] also should be used to do the smoothing filter[14] for the low-frequency components of all the measuring data , which the 2nd and the 6th sensor collected, after finishing the moving average filter.

When use the Butterworth approximation to do the smoothing filter for the low-frequency components, we should determine the pending parameter of the magnitude smoothing function ε and the order of Butterworth filter n.

The magnitude smoothing function and the attenuation equation of n order low-pass filter are respectively as:

$$\left|H(\lambda)\right|^2 = \frac{1}{1+\varepsilon^2 L_n^2(\lambda)} \tag{5}$$

$$A_{\mathrm{dB}}(\lambda)=10\left[1+\varepsilon^2 L_{\mathrm{n}}^2(\lambda)\right] \tag{6}$$

In the formula(5) and (6), $\varepsilon > 0$, $L_{\mathrm{n}}(\lambda)$ is the n-order polynomial. When designing the Butterworth low-pass filter, we choose $L_{\mathrm{n}}(\lambda)=\lambda^n$, then, the magnitude smoothing function and the attenuation equation are respectively become to:

$$\left|H(\lambda)\right|^2 = \frac{1}{1+\varepsilon^2\lambda^{2\mathrm{n}}} \tag{7}$$

$$A_{\mathrm{dB}}(\lambda)=10\left[1+\varepsilon^2\lambda^{2\mathrm{n}}\right] \tag{8}$$

In the formula(7), when $\lambda=0$, the first $2n-1$ derivatives of it is zero. Thus it has the maximally flat response.

According to the maximum attenuation of pass band:

$$a_p = A_{dB}(1) = 10\left[1+\varepsilon^2 L_n^2(1)\right] \tag{9}$$

The pending parameter can be obtained as;

$$\varepsilon^2 = 10^{0.1\alpha_{\mathrm{p}}} - 1 \tag{10}$$

According to the minimum attenuation of stop band:

$$\alpha_{\mathrm{s}} = A_{dB}\left(\frac{\Omega_{\mathrm{s}}}{\Omega_p}\right) = 10\left[1+\varepsilon^2 L_n^2\left(\frac{\Omega_{\mathrm{s}}}{\Omega_p}\right)\right] \tag{11}$$

The order of the filter can be obtained as;

$$n = \frac{\lg\sqrt{\left(10^{0.1\alpha_s}-1\right)/\left(10^{0.1\alpha_p}-1\right)}}{\lg\left(\Omega_{\mathrm{s}}/\Omega_p\right)} \tag{12}$$

From the formula (10) and (12) we can see, if ε is becoming smaller, the pass band of the Butterworth filter will become more flatness; if n is becoming bigger, the stop band attenuation will become greater. And n is an integer.

During the calibration and actual measurement, the Pump Hub Axle and Cover Hub Axle of the calibration component and the measured work piece are fixed in the right angles iron trough. The cross section diagram of the Pump Hub Axle or Cover Hub Axle of the calibration component and the measured work piece, are as shown in Figure 6. The cross section of the Pump Hub Axle or Cover Hub Axle of the measured work piece is the smaller radius circle in the Figure, and the bigger radius circle in the Figure is the cross section of the Pump Hub Axle or Cover Hub Axle of the calibration component. The smaller radius is R_1, the larger radius is R_2. The distance between the two circle center is M, the measurement data which are collected by the 2nd and 6th sensor are L.

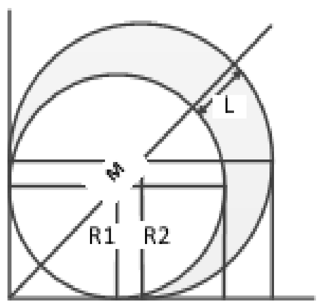

Figure 6 The cross section diagram

The angle in the Figure 6 is 45°, then we can get the distance between the two circle center:

$$M = \frac{R_2 - R_1}{COS45^{\circ}} = \frac{\Delta R}{COS45^{\circ}} \tag{13}$$

And from the Figure6 , we also can get:

$$M + R_2 = L + R_1 \tag{14}$$

That is

$$\frac{\Delta R}{COS45^{\circ}} + R_2 = L + R_1 \tag{15}$$

Then

$$\frac{\Delta R}{COS45^{\circ}} + R_2 - R_1 = \frac{\Delta R}{COS45^{\circ}} + \Delta R = L \tag{16}$$

So

$$\Delta R = \frac{L}{1 + COS45^{\circ}} = \frac{L}{1+\sqrt{2}} \tag{17}$$

If the tolerance measuring value(displacement value) of the Pump Hub Diameter and Roundness and the Cover Hub Diameter are D, then the relationship between D and L is:

$$D = 2\Delta R = \frac{2L}{1+\sqrt{2}} \tag{18}$$

① The Pump Hub Diameter and the Cover Hub Diameter

The averaging data obtained from the two moving average filter and Butterworth approximation of all the measuring data which the 2nd and the 6th sensor collected are U_3, the calibration value of each sensor is S^J, the tolerance measuring value(displacement value) of the Pump Hub Diameter and the Cover Hub Diameter is S_3, then,

$$S_3 = \frac{2\left(2.5U_3 - 7.5 - S^J\right)}{1+\sqrt{2}} \tag{19}$$

②The Pump Hub Roundness

It will take the most value of every 50 sub-groups data obtained from the two moving average filter and Butterworth approximation of all the measuring data which the 2nd sensor collected. The average of the most values is U_4, the calibration value of the 2nd sensor is S^J, the tolerance measuring value(displacement value) of the Pump Hub Roundness is S_4, then,

$$S_4 = \frac{2\left(2.5U_4 - 7.5 - S^J\right)}{1+\sqrt{2}} \tag{20}$$

c.The Axial Dimension

Axial Dimension is the length of the pump hub axle and the cover hub axle of Hydraulic

Torque Converter. As shown in Figure 2, the Axial Dimension is measured by the 3rd and the 5th sensor. When calibration, the measuring position of the 3rd and 5th sensor are calibrated, and the measurement of zero is determined. Also provides that if the measuring position of the sensor exceeds the measurement zero, the measurement data are positive, otherwise, are negative. When measuring, the following situations may occur,

① The measuring position of the 3rd and the 5th sensors all have exceeded the measurement zero, the distance are respectively a and b. Then the measuring value(displacement value) of the Axial Dimension should be $a+b$;

②The measuring position of the 3rd sensor has exceeded the measurement zero , and the 5th sensor has not exceeded, the distance are respectively a and b. Then the measuring value(displacement value) of the Axial Dimension should be $a-b=a+(-b)$;

③The measuring position of the 3rd sensor has not exceeded the measurement zero , and the 5th sensor has exceeded, the distance are respectively a and b. Then the measuring value(displacement value) of the Axial Dimension should be $b-a=(-a)+b$;

④The measuring position of the 3rd and the 5th sensors all have not exceeded the measurement zero, the distance are respectively a and b. Then the measuring value(displacement value) of the Axial Dimension should be $-a-b=(-a)+(-b)$.

So the tolerance measuring value of the Axial Dimension is the sum of data after processing which the 3rd and the 5th sensor collected.

When the signal of panel start arrival, the several groups measuring data which the 3rd and the 5th sensor collected should be taken out , then the averaging data after finishing the moving average filter twice for the middle half of each group measurement data are respectively U_5 and U_6, the calibration value of the 3rd and the 5th sensor are respectively S_3^J and S_5^J, the tolerance measuring value(displacement value) obtained from processing the measurement data which the 3rd and the 5th sensor collected are respectively S_5 and S_6,then,

$$S_5 = 2.5U_5 - 7.5 - S_3^J \tag{21}$$

$$S_6 = 2.5U_6 - 7.5 - S_5^J \tag{22}$$

So we can see, the tolerance measuring value(displacement value) of the Axial Dimension S_7:

$$S_7 = S_5 + S_6 = 2.5(U_5 + U_6) - (S_3^J + S_5^J) - 15 \tag{23}$$

c. Software Measurement System

According to the method to measure the shape parameters of the Hydraulic Torque Converter in the section B, we designed the Software Measurement System based on the LabVIEW development platform. It mainly includes the Calibration Mode, the Automatic Mode and some other working modes[15]. It's main function is to determine whether the external dimensions of the measured Hydraulic Torque Converter work piece is qualified through processing the measuring data of the shape parameters.

a. The Calibration Mode[16]

Before measuring the Hydraulic Torque Converter work piece, the calibration component which is the same with the measured one is used to calibrate the working machinery. The purpose of designing the Calibration Mode is to achieve this goal. The Calibration Mode mainly includes the acquisition program part of the measuring start signal and the measurement data, the program part of processing and saving the measurement data, and so on. To save and display the obtained ones which are from processing the measurement data, when the calibration component completes rotating 360 degrees, the measuring stop. As shown in Figure 7, it is the workflow of the Calibration Mode,

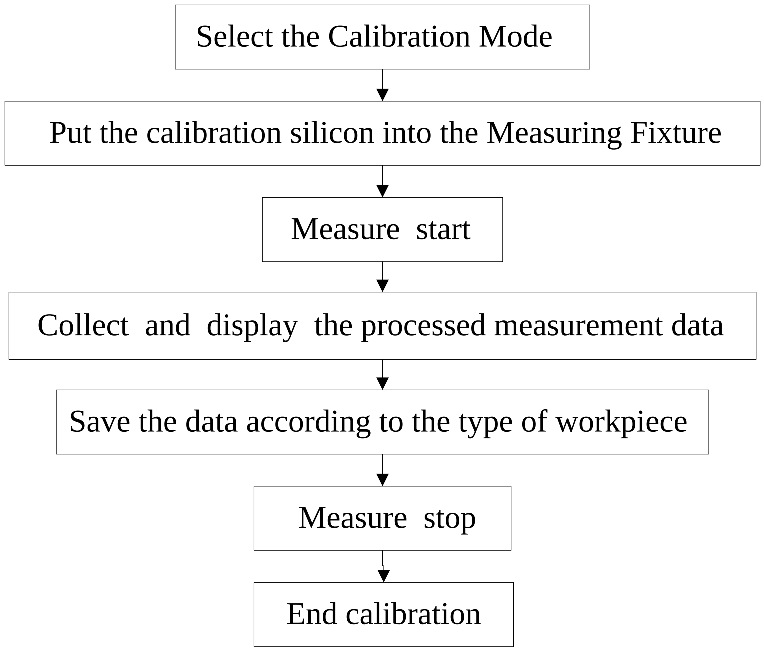

Figure 7 The workflow of the Calibration Mode

b. The Automatic Mode

The Automatic Mode is the mainly used mode in the Software Measurement System. It's main function is to determine whether the external dimensions of the measured work piece is qualified. The parts of Automatic mode mainly contains the acquisition program part of the measuring start and panel start signal, the acquisition program part of the measurement data [17][18] , the program part of processing and saving the measurement data, and the program part of determining the type of measured work piece, generating the detection number and time, and so on.

When got the signal of measuring start, each displacement sensor begins to collect the measurement data of the shape parameters of the measured Hydraulic Torque Converter work piece, and then those sensors can obtain seven tolerance measuring value(displacement value) of the measured work piece shape parameters after processing the measurement data. At last, the system save and display seven tolerance measuring value and determine whether the external dimensions of the measured work piece is qualified by checking seven tolerance measuring value[19]. The measuring continue until work piece completes rotating 360 degrees. Simultaneously, some other tasks also need to be completed by the Automatic mode, they are as follows:

① Receive the two-dimensional barcode of the measured work piece;

② Determine the type of the measured work piece with the work piece ID which are from the PLC;

③Generate the detection number and time， and so on.

After completing the tasks above, the data will be saved into the database with seven tolerance measuring value in order. As shown in Figure 8, it is the workflow of the Automatic Mode.

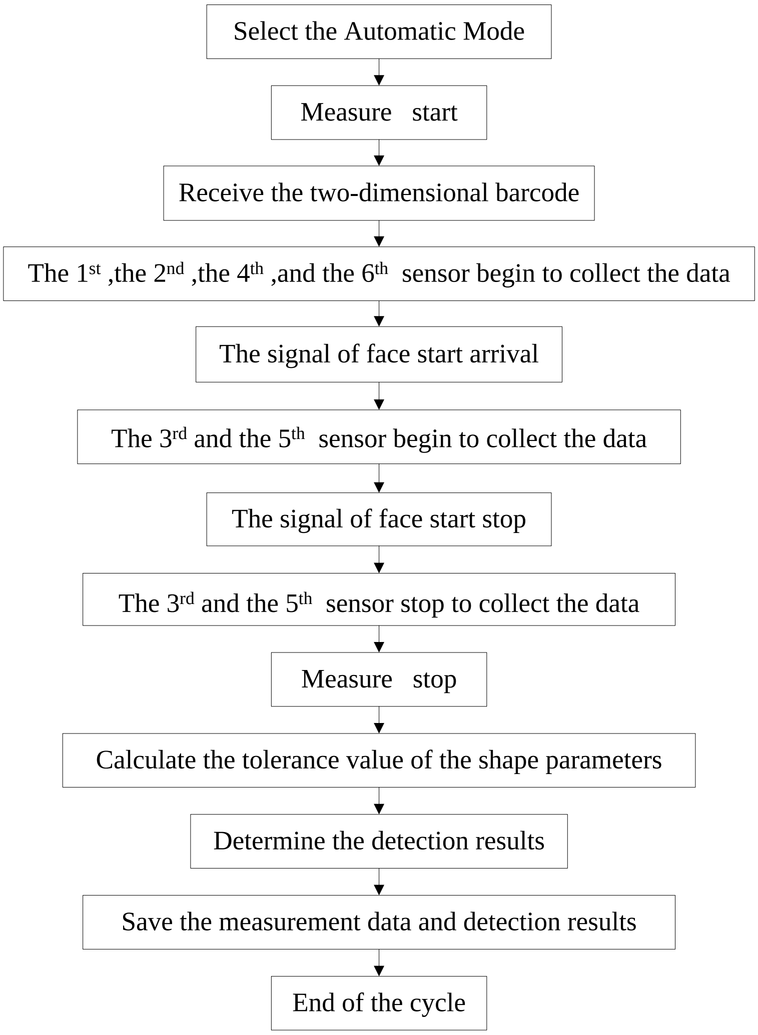

Figure 8 The workflow of the Automatic Mode

If seven tolerance measuring value(displacement value) of the measured work piece , which are measured by the Automatic Mode, all are in the tolerance measuring range of the respective work piece shape parameters which are given, then it can determine that the external dimensions of the work piece is qualified, otherwise, unqualified. The Measurement System can measure a variety of models of Hydraulic Torque Converter work piece. In this article, only set the three types— $YJH254$, $YJH236$, $YJH218$ —of the Hydraulic Torque Converter work piece as example. The tolerance measuring range of $YJH254$, $YJH236$, $YJH218$ is given as shown in Table 1.

Table 1 tolerance measuring range of $YJH254$, $YJH236$, $YJH218$

Work piece ID	Work piece Type	The Radial Run out (mm)	The Pump Hub Diameter (mm)	The Pump Hub Roundness (mm)	The Axial Dimension (mm)	The Leaf Litter Run out (mm)	The Panel Run out (mm)	The Cover Hub Diameter (mm)
001	YJH254	0~0.05	-0.025~ -0.009	0~0.03	-0.3~0.3	0~0.4	0~0.3	-0.061~ -0.04
010	YJH236	0~0.05	-0.034~ -0.009	0~0.01	0~0.4	0~0.4	0~0.3	-0.061~ -0.04
011	YJH218	0~0.05	0.043~ 0.068	0~0.03	-0.4~0	0~0.4	0~0.1	-0.073~ -0.05

c. Other Working Modes

There are also some other Working Modes in the Software Measurement System, in addition to the Calibration Mode and the Automatic Mode. The purpose of designing these Working Modes is to perfect the function of Measurement System, and meet the demands of industrial production better. The main functions of these modes are as follows:

① Add all the specification parameters and the given tolerance measuring range of the shape parameters of the measured work piece, and then to save these data to the database from these models;

② Query the data, which the Automatic Mode measured and saved in the database, according to the relevant conditions, and then to export the data which meet the conditions in EXCEL tabular form[20][21];

③ Statistics for the data, which the Automatic Mode measured and saved in the database, according to the relevant conditions, and then to show the average value, the standard variance and the distribution histogram of the data which meet the conditions;

④ Realize the real-time control of the whole measuring process of the Hydraulic Torque Converter shape parameters for using the corresponding program module to achieve two-way real-time communication with the Master Control Computer and the PLC.

III. CONCLUSIONS

As shown in Figure 9, it is the author in the field debugging. As soon as the automatic measuring system established, it is used to measure many Hydraulic Torque Converter work pieces of the types $YJH254$, $YJH236$ and $YJH218$. Some of the measured data are as follows;

Figure 9 Field debugging

①As shown in Table2, they are some of the measured data of the work piece $YJH254$.

Table2 The measured data of the work piece $YJH254$

Work piece Type	The Radial Run out (mm)	The Pump Hub Diameter (mm)	The Pump Hub Roundness (mm)	The Axial Dimension (mm)	The Leaf Litter Run out (mm)	The Panel Run out (mm)	The Cover Hub Diameter (mm)	Detection Results
YJH254	0.023	-0.013	0.006	0.024	0.113	0.144	-0.057	OK
YJH254	0.026	-0.024	0.006	-0.071	0.107	0.098	-0.052	OK
YJH254	0.029	-0.019	0.008	0.005	0.12	0.129	-0.059	OK
YJH254	0.031	-0.011	0.007	0.07	0.115	0.137	-0.05	OK
YJH254	0.028	-0.025	0.008	0.02	0.164	0.094	-0.058	OK
YJH254	0.026	-0.012	0.005	-0.007	0.121	0.11	-0.076	NG
YJH254	0.023	-0.023	0.006	0.108	0.098	0.073	-0.044	OK
YJH254	0.022	-0.018	0.004	0.095	0.151	0.084	-0.053	OK
YJH254	0.037	-0.011	0.005	0.018	0.074	0.126	-0.045	OK
YJH254	0.033	-0.014	0.011	-0.009	0.109	0.076	-0.053	OK
YJH254	0.032	-0.011	0.008	-0.009	0.136	0.121	-0.05	OK
YJH254	0.03	-0.023	0.004	0.009	0.144	0.065	-0.044	OK
YJH254	0.026	-0.014	0.006	0.016	0.169	0.123	-0.047	OK
YJH254	0.041	-0.013	0.011	-0.007	0.164	0.085	-0.052	OK
YJH254	0.04	-0.023	0.009	0.002	0.117	0.117	-0.048	OK
YJH254	0.026	-0.018	0.004	0.11	0.107	0.1	-0.043	OK
YJH254	0.025	-0.007	0.013	0.053	0.131	0.157	-0.054	NG
YJH254	0.037	-0.009	0.008	0.091	0.108	0.102	-0.044	OK
YJH254	0.033	-0.016	0.007	0.03	0.088	0.077	-0.047	OK
YJH254	0.028	-0.017	0.01	-0.032	0.185	0.053	-0.06	OK
YJH254	0.039	-0.009	0.013	0.044	0.176	0.059	-0.055	OK
YJH254	0.037	-0.011	0.009	0.021	0.165	0.088	-0.052	OK
YJH254	0.021	-0.01	0.009	-0.007	0.162	0.121	-0.048	OK
YJH254	0.028	-0.02	0.01	-0.011	0.109	0.116	-0.049	OK
YJH254	0.025	-0.022	0.007	0.029	0.132	0.111	-0.054	OK
YJH254	0.03	-0.025	0.004	0.037	0.147	0.099	-0.057	OK
YJH254	0.04	-0.021	0.008	0.032	0.134	0.087	-0.055	OK
YJH254	0.037	-0.019	0.006	0.04	0.159	0.106	-0.047	OK
YJH254	0.033	-0.012	0.012	0.018	0.178	0.129	-0.049	OK
YJH254	0.023	-0.017	0.008	0.021	0.161	0.131	-0.051	OK
YJH254	0.025	-0.021	0.013	0.023	0.183	0.087	-0.05	OK
YJH254	0.025	-0.018	0.005	0.029	0.154	0.095	-0.044	OK
YJH254	0.029	-0.013	0.007	0.032	0.167	0.101	-0.052	OK
YJH254	0.034	-0.017	0.01	0.043	0.134	0.112	-0.056	OK
YJH254	0.031	-0.018	0.009	0.005	0.123	0.099	-0.059	OK

②As shown in Table3, they are some of the measured data of the work piece $YJH236$.

Table3 The measured data of the work piece $YJH236$

Work piece Type	The Radial Run out (mm)	The Pump Hub Diameter (mm)	The Pump Hub Roundness (mm)	The Axial Dimension (mm)	The Leaf Litter Run out (mm)	The Panel Run out (mm)	The Cover Hub Diameter (mm)	Detection Results
YJH236	0.03	-0.021	0.006	0.323	0.261	0.038	-0.05	OK
YJH236	0.024	-0.019	0.005	0.292	0.225	0.045	-0.045	OK
YJH236	0.03	-0.026	0.009	0.275	0.256	0.039	-0.033	NG
YJH236	0.026	-0.024	0.006	0.329	0.215	0.044	-0.044	OK
YJH236	0.024	-0.02	0.008	0.307	0.289	0.041	-0.058	OK
YJH236	0.023	-0.024	0.009	0.253	0.298	0.058	-0.053	OK
YJH236	0.029	-0.018	0.008	0.277	0.237	0.064	-0.047	OK
YJH236	0.027	-0.023	0.011	0.339	0.278	0.055	-0.049	NG
YJH236	0.033	-0.02	0.008	0.286	0.263	0.065	-0.051	OK
YJH236	0.022	-0.021	0.006	0.292	0.239	0.037	-0.058	OK
YJH236	0.024	-0.019	0.009	0.218	0.22	0.065	-0.054	OK
YJH236	0.029	-0.02	0.004	0.292	0.387	0.049	-0.05	OK
YJH236	0.021	-0.025	0.006	0.265	0.287	0.082	-0.057	OK
YJH236	0.017	-0.025	0.005	0.237	0.293	0.077	-0.049	OK
YJH236	0.024	-0.017	0.01	0.226	0.214	0.051	-0.057	OK
YJH236	0.027	-0.016	0.007	0.259	0.289	0.049	-0.044	OK
YJH236	0.023	-0.023	0.008	0.235	0.237	0.069	-0.051	OK
YJH236	0.021	-0.024	0.006	0.267	0.278	0.088	-0.058	OK
YJH236	0.032	-0.027	0.009	0.242	0.286	0.075	-0.047	OK
YJH236	0.02	-0.018	0.009	0.332	0.225	0.062	-0.055	OK
YJH236	0.031	-0.029	0.007	0.312	0.234	0.074	-0.053	OK
YJH236	0.033	-0.021	0.005	0.317	0.252	0.082	-0.048	OK
YJH236	0.028	-0.017	0.008	0.249	0.269	0.061	-0.052	OK
YJH236	0.022	-0.019	0.009	0.258	0.287	0.044	-0.057	OK
YJH236	0.025	-0.018	0.006	0.277	0.291	0.058	-0.056	OK
YJH236	0.026	-0.02	0.005	0.281	0..251	0.063	-0.054	OK
YJH236	0.025	-0.018	0.01	0.264	0.235	0.054	-0.044	OK
YJH236	0.03	-0.016	0.006	0.273	0.277	0.084	-0.047	OK
YJH236	0.031	-0.019	0.009	0.262	0.268	0.066	-0.049	OK
YJH236	0.034	-0.022	0.007	0.265	0.259	0.049	-0.051	OK
YJH236	0.032	-0.025	0.005	0.243	0.275	0.053	-0.056	OK
YJH236	0.027	-0.021	0.008	0.321	0.289	0.047	-0.055	OK
YJH236	0.029	-0.018	0.006	0.307	0.293	0.062	-0.05	OK
YJH236	0.022	-0.017	0.005	0.257	0.264	0.073	-0.049	OK
YJH236	0.025	-0.021	0.009	0.264	0.273	0.052	-0.058	OK

③As shown in Table4, they are some of the measured data of the work piece $YJH218$.

Table4 Some of the measured data of the work piece $YJH218$

Work piece Type	The Radial Run out (mm)	The Pump Hub Diameter (mm)	The Pump Hub Roundness (mm)	The Axial Dimension (mm)	The Leaf Litter Run out (mm)	The Panel Run out (mm)	The Cover Hub Diameter (mm)	Detection Results
YJH218	0.02	0.046	0.011	-0.169	0.211	0.026	-0.043	NG
YJH218	0.025	0.06	0.014	-0.148	0.099	0.034	-0.058	OK
YJH218	0.029	0.049	0.017	-0.153	0.109	0.031	-0.061	OK
YJH218	0.027	0.057	0.015	-0.162	0.153	0.057	-0.062	OK
YJH218	0.031	0.047	0.017	-0.157	0.146	0.042	-0.059	OK
YJH218	0.026	0.052	0.013	-0.154	0.171	0.043	-0.053	OK
YJH218	0.023	0.053	0.018	-0.152	0.138	0.028	-0.063	OK
YJH218	0.031	0.052	0.021	-0.149	0.165	0.053	-0.068	OK
YJH218	0.025	0.054	0.016	-0.158	0.184	0.057	-0.066	OK
YJH218	0.029	0.059	0.019	-0.155	0.197	0.029	-0.058	OK
YJH218	0.031	0.045	0.014	-0.162	0.095	0.048	-0.062	OK
YJH218	0.03	0.048	0.013	-0.153	0.107	0.052	-0.054	OK
YJH218	0.031	0.046	0.017	-0.149	0.175	0.037	-0.052	OK
YJH218	0.022	0.056	0.011	-0.157	0.159	0.041	-0.057	OK
YJH218	0.026	0.053	0.015	-0.152	0.164	0.051	-0.064	OK
YJH218	0.024	0.054	0.013	-0.211	0.153	0.049	-0.059	OK
YJH218	0.024	0.047	0.016	-0.179	0.164	0.044	-0.063	OK
YJH218	0.027	0.052	0.021	-0.144	0.173	0.039	-0.06	OK
YJH218	0.028	0.047	0.023	-0.151	0.166	0.11	-0.055	NG
YJH218	0.025	0.055	0.025	-0.175	0.171	0.047	-0.061	OK
YJH218	0.027	0.049	0.014	-0.199	0.201	0.033	-0.062	OK
YJH218	0.029	0.051	0.022	-0.187	0.164	0.039	-0.058	OK
YJH218	0.022	0.052	0.024	-0.162	0.159	0.042	-0.055	OK
YJH218	0.025	0.048	0.019	-0.154	0.172	0.054	-0.061	OK
YJH218	0.031	0.055	0.021	-0.173	0.181	0.051	-0.064	OK
YJH218	0.029	0.052	0.018	-0.184	0.157	0.038	-0.054	OK
YJH218	0.025	0.047	0.015	-0.178	0.143	0.042	-0.059	OK
YJH218	0.027	0.056	0.021	-0.162	0.158	0.047	-0.061	OK
YJH218	0.026	0.05	0.025	-0.181	0.166	0.059	-0.058	OK
YJH218	0.026	0.055	0.02	-0.154	0.137	0.054	-0.057	OK
YJH218	0.024	0.056	0.018	-0.161	0.148	0.053	-0.066	OK
YJH218	0.027	0.054	0.019	-0.155	0.151	0.057	-0.064	OK
YJH218	0.028	0.052	0.024	-0.169	0.163	0.051	-0.062	OK
YJH218	0.023	0.048	0.015	-0.149	0.155	0.049	-0.065	OK
YJH218	0.026	0.053	0.021	-0.177	0.164	0.041	-0.059	OK

According to the data in table 2 , table 3 and table 4, it can verify the correctness for the automatic measuring method of the Hydraulic Torque Converter shape parameters. The automatic measuring system for the shape parameters of Hydraulic Torque Converter in this paper meets the enterprises production needs very well[22]. I believe it may give an important impact on the production and development of the Hydraulic Torque Converter production enterprises.

Compared with the traditional measurement method, it has many advantages, which can be divided into three parts as follows:

①Using the traditional measurement method to measure one work piece of Hydraulic Torque Converter needs about 5 minutes, while using the automatic measurement method which described in this paper only needs 16 seconds. So using the automatic measurement method can greatly shorten the measuring time.

②The traditional measurement method to measure the Hydraulic Torque Converter work piece , the data of shape parameters collected are not enough, the accuracy of measuring value are barely satisfactory, and there also may be a large measurement error existed; but using the automatic measurement method are opposite.

③ The status information, the barcode information which need to be measured and the various data instructions for controlling the process of measuring the Hydraulic Torque Converter shape parameters can be transmitted through RS232, a frame of data which is obtained after measuring can be transmitted through TCP, when using the automatic measurement system which described in this paper to measure the Hydraulic Torque Converter shape parameters. That is to say, the measurement process can be controlled in real time by using the automatic measurement system to measure the Hydraulic Torque Converter shape parameters.

④When using the automatic measurement system which described in this paper to measure the Hydraulic Torque Converter shape parameters, all measurement data can be summarized; The measurement data can be derived in the form of EXCEL table, according to the corresponding conditions; And it also can make the variance, standard deviation and data distribution histogram of the measurement data which meet the conditions. This can facilitate the production enterprises instant understanding the product release situation, then to improve the production plan further.

⑤The eligible and defective products can be reasonably distinguish， when using the automatic measurement system which described in this paper. This can facilitate the production and management of enterprises.

⑥The automatic measurement system which described in this paper has a high level of intelligence. It can help to save a lot of manpower and material resources, improve working efficiency. So the Hydraulic Torque Converter production enterprises can obtain a higher efficiency of industrial production with low cost.

The application of the automatic measuring method for the shape parameter of Hydraulic Torque Converter in the Hydraulic Torque Converter production enterprises, will make their industrial production line perfect and the implementation of the measuring technology which is used to determine whether the external dimensions of the Hydraulic Torque Converter is qualified becoming more convenient. Meanwhile, it can promote the development, the transformation and upgrading of these enterprises, enhance its core competitiveness, and narrow the gap with foreign enterprises. In further terms, it can also promote the development of Hydraulic Torque Converter industry in our Country, and help in-depth implementation of the industry 4.0.

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