STUDY ON THE INFLUENCING FACTORS OF THE HYSTERESIS ERROR OF SENSOR

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Summary – as one of the important characteristic parameters of the sensor, the improvement of the hysteresis error has the direct impact on the overall error of the sensor. Firstly, it should be known what factors played a role if you want to be able to accurately control. In this paper, the influence factors of the sensor hysteresis were analyzed from the hysteresis effects on the precision of the sensor point of view.

Key words – sensor, hysteresis, factors, control.

The definition and significance of hysteresis. With the development of society, more and more sensors are applied. The measurement accuracy will be affected because of the influence of environment and the sensor's index. Take the strain sensor for example. The strain sensor gains more and more attention because of the wide range of measurement and the high accuracy. But in using, due to various factors, the precision of measurement results is affected to a certain extent. In the evaluation of strain sensor, the influence of hysteretic index can not be ignored.

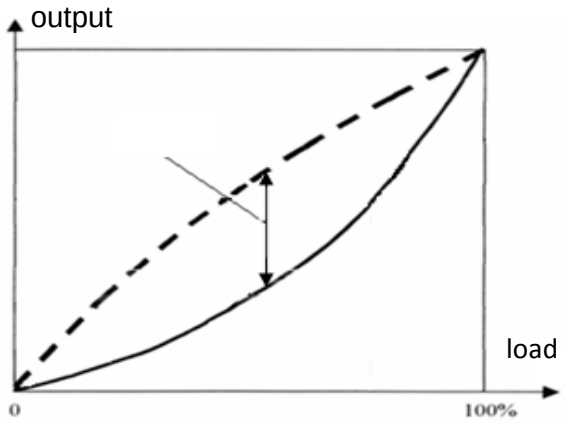
As one of the important static index of sensor, hysteresis has a great influence on the test precision of sensor. In the calibration process, the output signal of the sensor is not equal, even though the input value has the same size but different direction. The degree of not coincide of the input-output characteristic curve in the sensor’s positive, reverse stroke was called the hysteresis. As shown in Figure 1.

The value of the hysteresis error can be determined by experiment. It can be expressed with the percentage of the maximum output difference Δmax and full-scale output YFS.

$$\delta_H = \pm\frac{1}{2}\frac{\Delta_{\max}}{y_{FS}} \times 100\% \qquad (1)$$

The hysteresis error is also called the return error. The return error is mostly expressed by absolute value.

The definition of hysteresis can be introduced through Figure 1: horizontal for load, vertical axis for the sensitivity output. The specified load will be rated at least equally divided into five parts in general when testing output characteristics of the sensor, from 0 to 100% step loading and record the output values, each recorded points into smooth curves, called the loading curve, also called process curve, such as the thick solid line in diagram. From 100% to 0 step load shedding, and record the corresponding data, the data into smooth curves, called load curve, also known as the return curve, such as the thick dotted lines. The maximum error between the load curve and the loading curve is called the hysteresis error.



The hysteresis error is one of the main indexes of the sensor's precision. The hysteresis error affects the accuracy of measurement. Various factors affecting the hysteresis must be strictly controlled in the production process of the sensor. At the same time, try to avoid the influence factors of hysteresis existence when the sensor is installed under the different conditions.

The analysis on influence factors of hysteresis. In addition to unavoidable defects of the mechanical such as bearing friction, clearance, loose fasteners, material internal friction, dust and other strain aging, the reasons for hysteresis phenomenon of strain sensor are the following factors.

The material of sensor. The elastic: Any kind of metal material, because of the complexity of its internal organization structure relation, the micro strain occurs between the tiny grains by the external pressure, the micro strain disappears when the external force disappears. But different materials have different performance whether the materials could be restored to the original state. In Figure 1, we can see the strain curve ε1 during loading does not coincide with the strain curve ε2 in unloading process. The difference is mainly determined by stability, from material composition uniformity, the microstructure of after heat treatment. As the key element, the elastic limit of the elastic can be improved by different heat treatments, in order to reduce hysteresis. The material commonly used

is 40CrNiMo in the present, this kind of material can achieve the ideal comprehensive mechanical properties after reasonable heat treatment.

The sensitive element: The sensitive element of the strain sensor is a strain gauge. The typical structure of metal strain includes the sensitive gate, the basement, the composition of coating layer and lead. The change of the elastic transformed into the change of resistance, be the resistance strain effect of the sensitive gate when the sensor was using. The strain gauge itself has the hysteresis according to the hysteresis of material itself. The current world famous meter factories consider the self compensating of hysteresis in the process of production, to make the influence minimum in the application of sensor. Such factors should be considered when choice the strain gage.

The quality and thickness of sealant: It needs a mount of sealant to fix line and seal in the production process of strain sensor. The sealant is soft and the strength almost can be neglected compared with elastic body. But for a small range of products, it must be taken into account. The small range of products, the deformation zone is relatively weak, the influence degree of thickness of sealant increased significantly.

Figure 2 shows the variation between hysteresis and range when the thickness of adhesive layer is determined. The approximate function as below:

$$Y=K*e-X_a \quad (2)$$

Type: Y - the hysteresis of sensor

K - the hysteresis of the fully cured sealant

X_a - the rated load of sensor

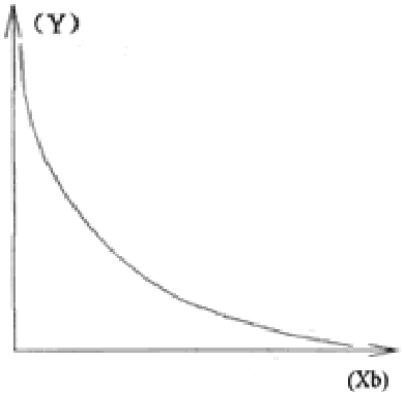


Figure 2

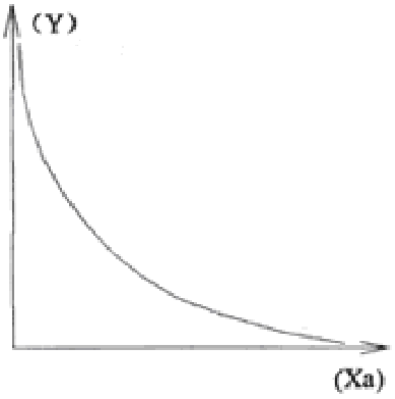


Figure 3

The adhesive layer when the range is determined. The approximation function as below:

$$Y=K*(1-e- X_b) \quad (3)$$

Type: Y - the hysteresis of sensor

K - the hysteresis of the fully cured sealant

X_b - the thickness of adhesive layer

The adhesive layer with different qualities has different performance. If the hardness of adhesive layer increases with time layer, the hysteresis of products will also change. It's better to choose the high stability adhesive.

The conditions of installation.

The strain sensor is widely used in weighing and measuring field. As sensitive element, it is directly used for measuring the strain of test pieces. As the conversion element, it can constitute sensor in use of the elastic element to test other physical quantities. The structure and installation conditions are different for the different application. The installation conditions refer to the boundary conditions when the sensor is installed special accessories (such as the base of bridge sensor). For example, the condition of surface, the torque of installation is the biggest factor. On the other hand, it refers to the installation conditions of the sensor using at the scene. According to the analysis and research of customer application, some factors such as surface condition, the contact area, the mounting torque, the intensity of bolt, the hardness of surface will affect the hysteresis sensor and the test precision of sensor. The weighing sensor is analyzed as an example.

The contact area: It refers to the fixed contact area of the sensor and the weighing platform. As shown in Figure 4(a), the contact area is too small, in Figure 4(b), the contact area is too large. The contact surface of different types of products is slightly different, because of the different structure and process. So, it must be determined during the installation of sensor.

Figure 4(a)

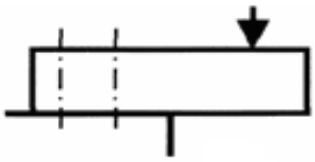


Figure 4(b)

The mounting torque: The mounting torque has some influence on the hysteresis of sensor. Generally speaking, when the mounting torque is changing greater or smaller, the hysteresis is changing smaller or greater if the contact surface is determined. The regular pattern of mounting torque is not the same for different structure products. For example, the cantilever beam sensor can get the best hysteresis when the mounted torsion reaches 100N• m. The hysteresis will be worse when the mounting torque is too large or too small.

The intensity of bolt: It has the same influence compared with the mounting torque. The locking force will become loose to influence precision if insufficient strength when the product is used for a period of time.

The hardness of mounting surface: Take the cantilever beam sensor for example, if the hardness is too low, because the contact surface on fixed end is small, the stress point will move with the increase in the frequency of use. As shown in Figure 5, the stress point moved from point a to point b, then the accuracy would change with different degree.

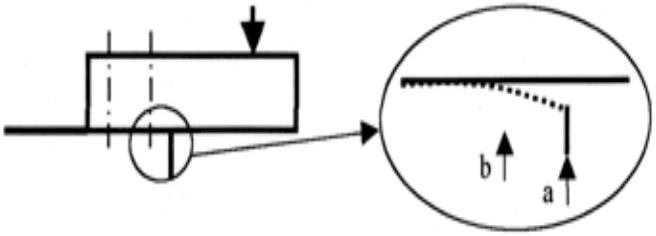


Figure 5

The surface condition: It refers to the quality of the contact surface of the weighing platform and sensor, such as roughness, parallelism, etc.. It will cause the looseness of the fastening bolt and affect performance if the surface is too rough and the using time is too long. If parallelism is high, the sensor will produce a force after it was loaded and directly affect the product precision, also can not reflect the real accuracy of the sensor. In order to reduce costs in some enterprises, the certain thickness steel plate is cut into the appropriate size of welding to the weighing platform, without any processing. The accuracy will be getting worse with the extension of time although there is no problem during the early time.

Effect of intensity of working face.

Taking the weighing platform for example, the four cantilever weighing sensors are installed in four angles, as shown in Figure 6 (a):

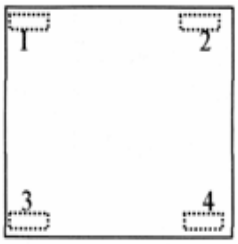


Figure 6(a)

Figure 6(b)

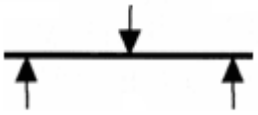


Figure 6(c)

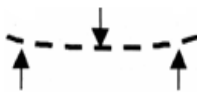


Figure 6(d)

Side-view schematic and stress model as shown in Figure 6(b) shows, If the strength of table is big enough to resist the external load, as shown in Figure 6(c) of the ideal situation, so that the sensor can reflect the real weight of the measured object. If the strength of table is not enough, the scale central will depression, as shown in Figure 6(d), the lateral force will influence the sensor. And the lateral force increases with the increase of the weight of the object to be measured, but the increasing amplitude is nonlinear relationship. Take Figure 6(d) as the simplified model of stress,

the relationship between stress and load sensor can be estimated by using the following formula:

$$F=G/2\cos\alpha \quad (4)$$

Type: F - the force of loading terminal of sensor

α - the stress and deformation of the weighing platform

From the formula shows that, if the scale and intensity is strong enough, the weighing platform deformation can be ignored, let α =0, cosα=1, F=G/2, if the scale strength is poor, α becomes larger with the increase of load, the nonlinearity of F and G gets worse.

In the practical application process, there is two types of the installation anchor, one is the fixed anchor and the other is the movable anchor. The fixed anchor is composed of the screw, the base and the vibration damping rubber composition, as shown in figure 7(a). The movable anchor is composed of the screw, steel ball, the base and the anti-skid pad, as shown in figure 8. The lateral force has no influence to the movable anchor because of its structural characteristics. If the installation anchor of platform scales is the fixed anchor, the impact of changes need to be considered when the anchor was tilt in the force structure, as shown in Figure 7(b). The negative influence caused by the deformation of foundation can be reduced if the movable anchor is used.

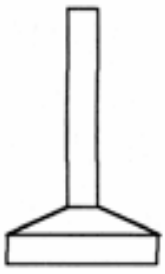


Figure 7(a)

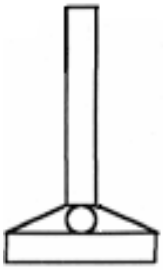


Figure 8

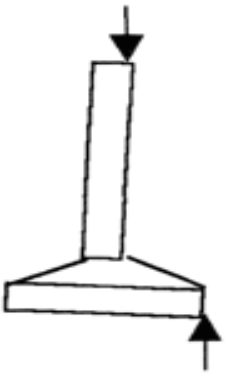


Figure 7(b)

Influence of dust and water.

These two factors will have no influence in the better maintenance of conditions, but special attention should be paid to the sensor used in the open air, such as automobile, sensor track scale. The dust on the surface of the sensor and the clearance of accessories would be harden for a long time. The harden dust can make the activities of the part become fixed that result in the linear and hysteresis of the sensor significantly get worse. On the other hand, from the water or moisture, is the main corrosion sensor surface, the contact point changes, especially with accessories products,

rust will cause parts of the sensor " rust " together, and the effect of hysteresis.

The effects of dust, experienced manufacturers will adopt the appropriate protective measures, such as increasing sealing cover, coated with butter appropriate protection.

Conclusion. The strain sensor is widely used now. It acquired the industry's favor due to its wide measuring range, stable performance, high quality characteristics of frequency response. But the accuracy of the sensor will be affected because of the hysteresis error. If the attention was paid on the above analysis, it would be engendered the profound significance to improve the accuracy of the sensor and the development of using in the process of producing or using sensor.

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ИЗУЧЕНИЕ ФАКТОРОВ ВЛИЯЮЩИХ НА ГИСТЕРЕЗИСНЫЕ ОШИБКИ СЕНСОРА

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Аннотация **– одной из ключевых идей статьи, является усовершенствование точности в показаниях сенсора за счет гистерезиса, который имеет прямое влияние на общую ошибку показания сенсора. В статье проанализированы факторы, которые имеют влияние на гистерезис точности показания сенсора**.

ВИВЧЕННЯ ФАКТОРІВ, ЩО ВПЛИВАЮТЬ НА ГІСТЕРЕЗИСНІ ПОМИЛКИ СЕНСОРУ

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Анотація

Однією з ключових ідей статті, є удосконалення точності у свідченнях сенсора за рахунок гістерезису, який має прямий вплив на загальну помилку показанньь сенсору. У статті проаналізовано чинники, які мають вплив на гістерезис точності показанньь сенсору.