

Punched belt hole position deviation analysis of float type water level gauge

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Abstract. The key parts of the float type water level gauge instrument is perforated belt, The size and tolerance requirements of its aperture is: (1) alternation of $100+0.2$ and $100-0.2$, (2) 200 ± 0.1 , (3) 1000 ± 0.15 , (4) 10000 ± 0.2 . The single hole position: alternation of $100+0.2$ and $100-0.2$; double: 200 ± 0.1 , and ensure the best hole position error avoidance tends to be one-way, that is to say: when the punched belt combined with a water wheel rotating line moving, The hole position error to single direction increase or decrease, caused the water level nail gradually and close to the edge of the hole, and then edge and final punched belt was lifted. This paper uses the laser drilling process of steel strip for data collection and analysis. It is found that this method cannot meet the tolerance requirements and the double stamping processing method with adjustable cylindrical pin is feasible.

1. Introduction

As shown in Figure 1, standard float type water level gauge is mainly composed of water wheel, water wheel Fixed plate, Handwheel retainer, Pedestal support, ROQ425 encoder, arc top cover, screws and Stainless steel perforated steel strip (Hereinafter referred to as perforated steel strip) and other components.

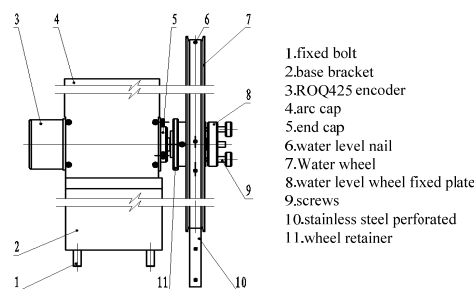


Figure 1. Standard float type water level gauge structure diagram.

In the standard water level gauge design, usually use the thickness of 0.2mm stainless steel belt, the material is 1Cr18Ni9Ti (linear expansion coefficient of $16.6 \times 10^{-6} / ^\circ\text{C}$)^[1], can ensure that the perforated steel and water level wheel due to water level mutation, So as not to cause perforated steel

belt and water wheel slip, then the perforated steel strip and the water pin nail accurate and reliable engagement is the key to ensure the accuracy of measurement^[2], so this paper focuses on Figure 1-2 water level gauge perforated steel hole tolerance design. The depth of the perforated steel strip is analyzed in depth, and the stainless steel strip is required to be punched at room temperature of $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ ^[3] to reduce the temperature and cause manufacturing errors. The water level gauge perforated hole position tolerance design diagram is shown in Figure 2.

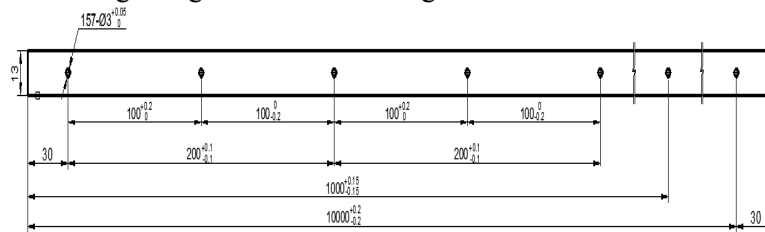


Figure 2. Water level gauge perforated hole position tolerance design diagram.

2. Perforated steel hole error data acquisition

2.1. Data collection principles

Data collection of laser drilling of steel strip is carried out in this paper. When carrying out the data collection, vernier caliper (0.02mm) within the card measuring head on the outside of the two measured data is used and divided into single hole (hole center distance of 100mm) and double hole (hole center distance of 200mm) two types.

Single hole position measurement value: in order to facilitate the read and reflect the error, take the standard value of 103mm to statistical error value.

Double hole position measurement value: in order to facilitate the reading and reflect the error, take the standard value of 203mm to statistical error value.

2.2. Statistical charts of hole deviation

Statistical charts of hole deviation are shown in Figure 3-8. As the two laser perforated steel strip data collected the same trend, limited space, this article only one of the strip measurement data as an example for statistical analysis. In the lines shown in Figure 3-8, the abscissa represents the single/double hole, and the ordinate reflects the difference between the measured value and the standard value (103 mm/203 mm).

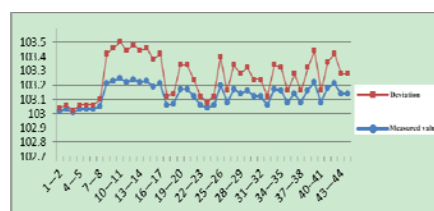


Figure 3. 1-44 single hole position deviation statistical chart.

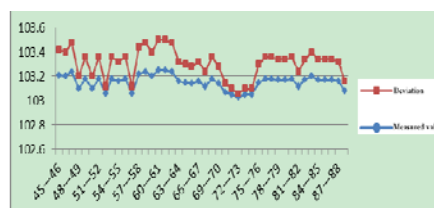


Figure 4. 45-88 single hole position deviation statistical chart.

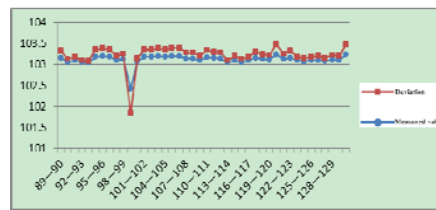


Figure 5. 89-130 single hole position deviation statistical chart.

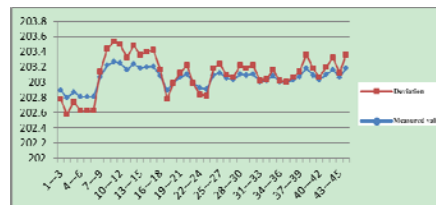


Figure 6. 1-45 double hole position deviation statistical chart.

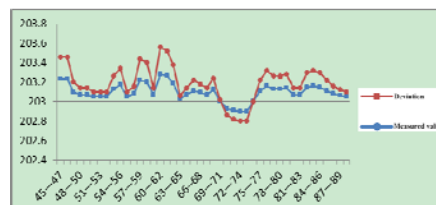


Figure 7. 45-89 double hole position deviation statistical chart.

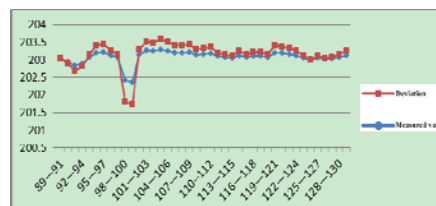


Figure 8. 89-131 double hole position deviation statistical chart.

3. Analysis of hole deviation of perforated steel strip

The error in the statistics table, including the measurement of the measurement error, due to the attention of this problem, has been tried to control, about no more than $\pm 0.02\text{mm}$ ^[4].

3.1. The maximum tolerance processed

From Figure 5 and Figure 8 (single and double hole deviation statistical line graph), it can be obtained from the maximum tolerance hole, combined with perforated steel hole pitch measurement data record table can be obtained in Table 1 marked # The data, that is 99-100, 99-101, 100-102 error is too large (a total of 3), after analysis is due to the location of the first 100 holes caused by errors.

Table 1. Punched belt hole distance measurement data record 3 (part data).

Serial number	Single hole	Measurement data	Deviation	Double hole	Measurement data	Deviation
89	89-90	103.16	0.16	89-91	203.03	0.03
90	90-91	103.06	0.06	90-92	202.95	-0.05
91	91-92	103.09	0.09	91-93	202.83	-0.17
92	92-93	103.05	0.05	92-94	202.90	-0.1
93	93-94	103.04	0.04	93-95	203.07	0.07
94	94-95	103.18	0.18	94-96	203.20	0.2
95	95-96	103.19	0.19	95-97	203.22	0.22
96	96-97	103.18	0.18	96-98	203.13	0.13
97	97-98	103.10	0.1	97-99	203.07	0.07
98	98-99	103.13	0.13	98-100	202.41	# -0.59
99	99-100	102.42	# -0.58	99-101	202.36	# -0.64
100	100-101	103.07	0.07	100-102	203.14	0.14
101	101-102	103.18	0.18	101-103	203.26	0.26
102	102-103	103.18	0.18	102-104	203.24	0.24
103	103-104	103.19	0.19	103-105	203.29	0.29
104	104-105	103.18	0.18	104-106	203.25	0.25
105	105-106	103.20	0.2	105-107	203.20	0.2
106	106-107	103.20	0.2	106-108	203.20	0.2
107	107-108	103.14	0.14	107-109	203.21	0.21

3.2. Connected tolerance analysis

From Figure 4, 5 and Figure 7, 8, single and double hole deviation statistical chart, and combined with perforated steel hole pitch measurement data record table, can be obtained Table 2 and 3 table in the mark # data (2 groups, 13) also exceeded the error.

Table 2. Punched belt hole distance measurement data record 1 (part data).

Serial number	Single hole	Measurement data	Deviation	Double hole	Measurement data	Deviation
1	1-2	103.02	0.02	1-3	202.89	-0.11
2	2-3	103.03	0.03	2-4	202.79	-0.21
3	3-4	103.01	0.01	3-5	202.87	-0.13
4	4-5	103.03	0.03	4-6	202.81	-0.19
5	5-6	103.03	0.03	5-7	202.81	-0.19
6	6-7	103.03	0.03	6-8	202.81	-0.19
7	7-8	103.05	0.05	7-9	203.07	0.07
8	8-9	103.21	0.21	8-10	203.22	# 0.22
9	9-10	103.23	# 0.23	9-11	203.27	# 0.27
10	10-11	103.25	# 0.25	10-12	203.25	# 0.25
11	11-12	103.22	# 0.22	11-13	203.16	0.16
12	12-13	103.24	# 0.24	12-14	203.24	# 0.24
13	13-14	103.22	0.22	13-15	203.18	0.18
14	14-15	103.23	0.23	14-16	203.20	0.2

Table 3. Punched belt hole distance measurement data record 2 (part data).

Serial number	Single hole	Measurement data	Deviation	Double hole	Measurement data	Deviation
59	59-60	103.20	0.2	59-61	203.07	0.07
60	60-61	103.25	# 0.25	60-62	203.28	# 0.28
61	61-62	103.25	# 0.25	61-63	203.26	# 0.26
62	62-63	103.24	# 0.24	62-64	203.19	0.19
63	63-64	103.16	0.16	63-65	203.03	0.03
64	64-65	103.15	0.15	64-66	203.07	0.07
65	65-66	103.14	0.14	65-67	203.11	0.11
66	66-67	103.16	0.16	66-68	203.09	0.09

3.3. Independent tolerance analysis

From Figure 5 and Figure 8, single and double hole deviation statistical line graph can be inferred in Table 4 marked # (total of 4), mostly relatively independent, although the error, the basic can accept^[5].

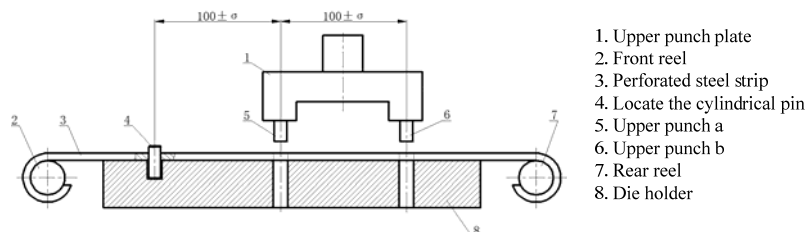
Table 4. Punched belt hole distance measurement data record 2 (part data).

Serial number	Single hole	Measurement data	Deviation	Double hole	Measurement data	Deviation
45	45-46	103.21	0.21	45-47	203.23	# 0.23
46	46-47	103.20	0.2	46-48	203.23	# 0.23
47	47-48	103.24	# 0.24	47-49	203.10	0.1
48	48-49	103.10	0.1	48-50	203.07	0.07
49	49-50	103.18	0.18	49-51	203.07	0.07
50	50-51	103.10	0.1	50-52	203.05	0.05
51	51-52	103.18	0.18	51-53	203.05	0.05
52	52-53	103.06	0.06	52-54	203.05	0.05
53	53-54	103.18	0.18	53-55	203.13	0.13
54	54-55	103.16	0.16	54-56	203.17	0.17
55	55-56	103.18	0.18	55-57	203.05	0.05
56	56-57	103.06	0.06	56-58	203.08	0.08
57	57-58	103.22	0.22	57-59	203.22	0.22
58	58-59	103.24	# 0.24	58-60	203.20	0.2
59	59-60	103.20	0.2	59-61	203.07	0.07

In summary, the laser drilling cannot meet the accuracy requirements of the perforated steel hole, and the perforated steel strip should be processed with double hole stamping die.

4. The principle of eliminating the error process of stamping die

The stamping die designed specifically for the water level gauge perforated steel strip, punching die structure diagram shown in Figure 9.

**Figure 9.** Punching mold structure sketch diagram.

The serial number 5 is the upper punch a, the serial number 6 is the upper punch b, the difference between the two punch after the basic size 100 is fixed, the serial number 4 is fine-tunable positioning

cylindrical pin, through which you can adjust the processing error. If the distance between the two punches is positive (+0.05) and the positioning pin is adjusted to a negative deviation (-0.05), the errors of the two dimensions 100 are offset from each other, and the other is adjusted in the opposite direction.

From the statistical knowledge, the standard deviation calculation formula is:

$$\sigma = \sqrt{\frac{1}{n} \cdot \sum \Delta_i^2} = \sqrt{\frac{1}{n} \sum (x_i - x_0)^2} \quad (1)$$

The x_0 represents the ideal truth. Usually the small sample measurement theory is used to infer the overall characteristics, that is, using the experimental standard deviation to characterize the dispersion of the measurement results. For the same measured x_i (under repeated conditions) for n measurements, the experimental standard deviation can be solved as:

$$s = \sqrt{\frac{1}{n-1} \cdot \sum v_i^2} = \sqrt{\frac{1}{n-1} \sum (x_i - \bar{x})^2} \quad (2)$$

The deviation is calculated by Formula 2, and the result is close to the normal distribution.

In this case the number of measurements $n \geq 6$, is the use of the maximum residual value look-up table and statistics for the line graph processing data. For a measured x_i (under repeated conditions) for n measurements, the measurement results are x_1, x_2, \dots, x_n , calculate the residual method v_1, v_2, \dots, v_n . The unbiased estimate of the s value is obtained by $|v, \max|$. Then the “maximum residual method” to calculate the experimental standard deviation is according to Formula 3:

$$s = c_{1,n} |v_{i,\max}| \quad (3)$$

Here, $c_{1,n}$ is residual error coefficient which can be found in the above table; $v_{i,\max}$ is the i -th maximum residual error value.

5. Conclusion

From the analysis of the error data collected in Tables 1 to 4, the strip hole is essentially a one-way error, which is very unfavorable. There is the risk of watering nails from the top, it can be seen, laser drilling cannot meet the perforated steel hole accuracy requirements. Need to specifically design punching die processing perforated steel strip, in order to meet the requirements of the drawings, so that the length of the perforated strip of any adjacent two holes between the “+” and “-” error alternately, so that the hole distance error can offset each other, the water level nail and steel Hole always maintain accurate positioning (water level on the circumference of the two water level nail spacing of 200), and will not interfere with the water hole and the water nail.

Acknowledgments

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