Uncertainty Analysis of Chamber Pressure Measurement Based on Standard Copper Cylinder

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***Abstract* -- The copper cylinder is often used to measure chamber pressure in weapon test. Due to differences in primary pressure datum, uncertainty of height measurement, inconsistent individual deformation, inconsistent sensitivity and difference of temperatures, these five evaluated values have a certain degree of uncertainty, which reduces the accuracy of the measurement. Since the decrease of uncertainty is at the expense of higher measurement cost, optimization of test for acceptable uncertainty becomes a significant issue. This paper describes selection process of copper cylinder. According to usage characteristics and selection of copper cylinder, five compositions of the uncertainty will be discussed. On the basis of these arguments, a model has been proposed to calculate the uncertainty that meets the requirement of measurement uncertainty. The analysis and model result in lower error, in comparison with the evaluation of self-adaptive weight algorithm.**

Keywords - uncertainty of measurement; copper cylinder; chamber pressure; dynamic discrepancy

I. INTRODUCTION

Peak chamber pressure is one of the important parameters which must be measured in the firing weapons design, manufacture and acceptance [1]. In general, there are two options for measuring the chamber pressure: electrical measuring method and plastic deformation method. Pressure measuring holes are needed to be drilled on the barrel to install the sensor for the electrical measuring method, so it is seldom used for range acceptance tests. The plastic deformation method has been the main technical means of measuring chamber pressure in the practical ballistic fields with its advantages of reliability, convenience, no damage to tested weapons and low price as well [2].

The standard copper cylinder plays an important role in plastic deformation method. Current measurement error theory suggests that the measurement should not only give the result, but also contain the measurement uncertainty [3]. A standard copper cylinder, as a pressure transmission element during selection and calibration of internal crusher gauge, has a measurement uncertainty directly affecting performance of the all levels of internal crusher gauge. Many researchers have tried to resolve this issue. Liu and Kong analyzed the relationships between deformation and pressure [4]. Hang investigated the formula between the pressure and distortion [5]. A comparatively satisfactory result based on the performed static formula of mathematics and physics was obtained, which was verified by the tests. Kong and Zhu pointed out temperature errors [6]. Means of forming the unitary temperature correction equation were also discussed. Zhang, Kong, and Jia introduced the importance of standard copper cylinders in the plastic pressure-measuring calibration system and the way to select standard copper cylinders from general ones [7]. It was developed into a data fusion method of self-adaptive weight estimation to calculate the deformation. Kong, Zhang, Zhu, et al devised the change law of dynamic-static error for a vertical copper cylinder 3.5mm high by 8.75mm diameter [8]. However, few people considered uncertainty of measuring.

In this work, we consider five main contributors related to chamber pressure measurement uncertainty. Certain dynamic-static discrepancy will be introduced, when the statically calibrated copper cylinders are used to measure dynamic chamber pressure, as illustrated in Fig.1. To decrease or eliminate the error，some technical methods are taken, such as primary preloading and secondary preloading. Copper cylinders should be pressed on working-level press machine, which needs calibration of standard copper cylinders. Therefore, measurement uncertainty of standard copper cylinders can affect the accuracy of statically calibrated copper cylinders [9]. As a result, the decrease of uncertainty becomes a key engineering problem. With this in mind, based on the study of usage characteristics and selection methods of a standard copper cylinder, to control the uncertainty, this paper systematically discusses influencing factors and evaluation methods of measurement uncertainty of standard copper cylinders.

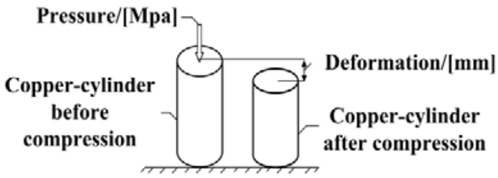

Figure 1. The measuring process of chamber pressure on copper cylinders.

The organization of the paper is as follows. In Section II, the method of selecting copper cylinders is introduced. Five factors influencing the uncertainty are analyzed in Section III. The computation model for each uncertainty and the overall model are given in Section IV. And in Section IV, a case study on a vertical copper cylinder 8mm high by 13mm diameter is also presented to demonstrate the application of the derived uncertainty model on measuring chamber pressure. In section V, the results of the overall model and evaluation of self-adaptive weight algorithm are compared. Finally, conclusion remarks and potential applications of the proposed model are discussed in Section VI.

II. SELECTION OF COPPER CYLINDERS

According to GJB 1735A-2005[10,11], the copper cylinder, as a sensor in chamber pressure measurement, should be selected from a lot of produced copper cylinders. The selection process should be divided to four steps: preselect test, prejudgment test, and final determination test and recheck test. However, only those copper cylinders meet all requirements, they can be used to chamber pressure measurement.

The preselect test of standard copper cylinders should be conducted during the process of picking copper cylinders. The main purpose is to evaluate surface strength, and consistency of deformation of copper cylinders. In addition, the measurement accuracy should be checked, which requires standard uncertainty of copper cylinder less than 1%. The preselect test, in accordance with the method of parallel compression, lasts for one working day and it should be conducted on the working-level press machine. During the test, it presses 10 copper cylinders on pressure point of each one and respectively records the height ε_{tij} before and after as well as the deformation of each copper cylinder, where ε_{tij} is deviation of number *j* copper cylinder's in pressure point *i*, on the *t* day.

The prejudgment test, with the method of parallel compression, is conducted on the working-level press machine and lasts for three working days. In order to get copper cylinders to meet the requirements, 10 of them are selected from qualified batches of copper cylinders daily. Then 10 copper cylinders are compressed under a setting pressure load, and the surface strength, and consistency of deformation should be considered during this progress. Also accuracy of pressure measurement is important for final evaluation of uncertainty. In short, this step requires standard uncertainty less than 1% in the prejudgment test.

The final determination test is conducted on a testing-level press machine and lasts for five working days, which is the same as the prejudgment test [11]. The copper cylinders are compressed continuously under a given pressure on testing-level press machine, whose accuracy level is better than 0.1%. The deformation of copper cylinders under different pressures is recorded on each working day. The range is also a significant parameter used to estimate the selected copper cylinders. The relative uncertainty of copper cylinder from all working days is better than 0.7%.

The recheck test is conducted on testing-level press machine one month after the final determination test. 10 standard copper cylinders are selected randomly, sealed, and loaded under pressure, low to high [12]. 10 deformations of copper cylinder on pressure point p_i are recorded, where p_i means pressure on each point *i*. The average deformation of each copper cylinder should be in the range of double standard deviation. In this step, maximum deviation of the 10 rechecking copper cylinder deformation on pressure point p_i should be less than or equal to the maximum deviation of 10 copper cylinder deformation of all days.

III. FACTORS INFLUENCING MEASUREMENT UNCERTAINTY

Throughout production or the selection process of standard copper cylinders, either from preselect test, prejudgment test, final determination test or recheck test, measurement uncertainty of standard copper cylinder relates to primary pressure datum and inconsistent individual deformation of a standard copper cylinder [13,14]. Therefore, factors that affect pressure measurement uncertainty of copper cylinder can be divided into the following categories: difference in primary pressure datum, uncertainty of height measuring, inconsistent individual deformation, inconsistent sensitivity and difference of temperature.

A. *Uncertainty of Pressure Datum*

During selection of the standard copper cylinder, accuracy of various press machines affects the accuracy of the standard copper cylinder directly [15]. Therefore, uncertainty of primary pressure datum is an important factor that cannot be ignored.

B. *Uncertainty of Height Measuring*

According to the working principles of copper cylinder, the chamber pressure is reflected by the size of plastic deformation of the copper cylinder. Therefore, height measurement uncertainty is introduced by different operators, unevenness of copper cylinder on two end faces and different measurement times [16].

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C. *Uncertainty of Individual Deformations*

Inconsistent individual deformations of standard copper cylinder demonstrate random fluctuations of surface strength, and consistency of deformation of the same batch [17]. This factor is reflected not only by the comprehensive mechanical properties of copper materials, but also by production and operation process and heat treatment, which influence the comprehensive performance of copper cylinder [18]. Therefore, this uncertainty component can be quantitatively reflected by individual fluctuations of copper cylinder during selection tests.

D. *Uncertainty of Sensitivity*

Copper cylinder reflects pressure and accuracy of standard copper cylinders on calibrating working-class press and classifying internal crusher gauge. Pressure of copper cylinder is derived from corresponding pressure gauge or pressure sensitivity of copper cylinders. However, copper cylinder appears non-linear during measuring range when pressure sensitivity varies from low to high. As a result, there is a principal error when using linear or linear interpolation method.

E. *Uncertainty Caused by Temperature*

The mechanical properties of copper cylinder relate to temperature, when the temperature is different to the selection test and usage of copper cylinder. As a result, this is bound to introduce some errors. A number of literatures [19] have investigated that measurement error can be controlled within ± 0.1%, if the measurement is located in a temperature-controlled environment of 20 ± 1°C. Therefore, in the analysis of pressure measurement uncertainty of copper cylinder, temperature is very essential.

IV. UNCERTAINTY EVALUATION

A. *Experimental Set-up*

To evaluate each uncertainty of each progress, 10 standard cylindrical copper cylinders are used in this experimental test. The working pressure range in test is in the range pressure 150 - 400MPa. Also, in the experiment, the size of them is 8mm high by 13mm diameter, and the material is of course copper. One of standard cylindrical copper cylinders is shown in Fig.2. In whole test, these copper cylinders are pressed under the pressure machine, which can produce setting pressures.

Figure 2. Standard cylindrical copper cylinder

Here in the test, these standard cylindrical copper cylinders are press with pressure machine in 14 different pressures, which are in the range pressure 140- 400MPa. However, each 20MPa take a point. Original test results are show in Table 1. Ten standard cylindrical copper cylinders are pressed on 140MPa, 160MPa, 180MPa, 200MPa, 220MPa, 240MPa, 260MPa, 280MPa, 300MPa, 320MPa, 340MPa, 360MPa, 380MPa, and 4000MPa in a continues process. Since there are 10 copper cylinders, 140 heights after pressing data are obtained, as shown in Table.1. The following uncertainty evaluation is based on these data.

Table 1. Ten groups original results of 8mm high by 13mm diameter standard copper cylinders

Setting pressures [MPa]	1	2	3	4	5	6	7	8	9	10	Mean value of height after pressing[mm]
	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	Height after pressing [mm]	
140	11.158	11.146	11.150	11.144	11.145	11.169	11.154	11.167	11.164	11.161	**11.156**
160	10.688	10.695	10.696	10.695	10.709	10.721	10.720	10.721	10.714	10.712	**10.707**
180	10.207	10.221	10.205	10.204	10.189	10.229	10.217	10.230	10.229	10.229	**10.216**
200	9.689	9.692	9.713	9.699	9.682	9.693	9.717	9.710	9.715	9.710	**9.702**
220	9.203	9.199	9.195	9.187	9.198	9.217	9.198	9.200	9.202	9.199	**9.200**
240	8.699	8.680	8.683	8.672	8.718	8.717	8.703	8.694	8.696	8.735	**8.700**
260	8.260	8.241	8.228	8.238	8.249	8.220	8.225	8.227	8.217	8.213	**8.232**

280	7.789	7.775	7.791	7.797	7.801	7.801	7.780	7.798	7.783	7.786	**7.790**
300	7.429	7.430	7.434	7.434	7.431	7.418	7.414	7.409	7.410	7.435	**7.424**
320	7.085	7.085	7.091	7.078	7.080	7.082	7.078	7.078	7.101	7.069	**7.083**
340	6.790	6.783	6.789	6.779	6.780	6.796	6.795	6.790	6.826	6.794	**6.792**
360	6.526	6.518	6.506	6.529	6.522	6.546	6.524	6.560	6.526	6.513	**6.527**
380	6.268	6.268	6.260	6.261	6.262	6.267	6.270	6.263	6.269	6.267	**6.266**
400	6.050	6.048	6.037	6.025	6.029	6.045	6.051	6.042	6.043	6.041	**6.041**

B. *Uncertainty of Pressure Datum u_1*

Uncertainty of primary pressure datum is regarded as a type B uncertainty. This component is determined by accuracy of testing-level press machine. According to theory of uncertainty in measurement, evaluation of type B uncertainty is achieved with the use of estimates from previous measurements, specifications from the manufacturer, hand-books, calibration certificates etc. Since the press machine in the experiment is chosen according to GJB 3196. 27A-2005[2], it requires uncertainty of testing-level press machine should be better than 1%. As a result, uncertainty of pressure datum u1 can be expressed as: u_1=0.1%.

C. *Uncertainty of Height Measuring u_2*

Uncertainty of height measurement is in accordance with the following four items [14, 15]:

(1) Height measuring instruments

A normal micrometer, which resolution ratio is 0.001mm, is chosen to measuring height data in Table.1. According to the hand-books of the micrometer, uncertainty of this height measurement, including instrumentation system repeatability and linearity, can be controlled within 0.1% or less. Therefore this uncertainty can be denoted as: u_{21}=0.1%.

(2) Personal errors

When using a digital instrument, influence of this component can be ignored. However, a micrometer is used in experiment, personal error contributed uncertainty in height measurement of copper cylinders in Table.1. In view that the resolution ratio of micrometer is 0.001mm, it is possible to obtain the uncertainty on personal error u22 as follows: u_{22}=0.1%.

(3) Unevenness of the copper cylinder on two measuring ends u_{23}

This component depends mainly on two options: one is ending unevenness of crusher gauge after being compressed on piston rod; the other one is the anvil's end unevenness of crusher gauge. According to design drawings and detect tests of crusher gauge, this component can be controlled within 0.1%.

(4) Influence of the height measuring time u_{24}

Indeed, the elastic recovery of copper cylinder takes some time after unloading. According to reference [4], through the numerical simulation analysis, this recovery time is usually milliseconds or seconds in practical use or in the process of selection. In general, Height measuring of copper cylinder lasts one minute after unloading it from the press machine in general. So this component does not affect the results. As a result,

$$\begin{aligned} u_{2h} &= \sqrt{u_{21}{}^2 + u_{22}{}^2 + u_{23}{}^2 + u_{24}{}^2} \\ &= \sqrt{(0.1\%)^2 + (0.1\%)^2 + (0.1\%)^2} \\ &= 0.17\% \end{aligned} \tag{1}$$

Through the above analysis u_2 can be obtained as follows:

$$u_2 = \frac{u_{2h} \cdot \Delta\varepsilon_{\max} \cdot k_{p_{\Delta\varepsilon_{\max}}}}{p_{\Delta\varepsilon_{\max}}} \times 100\% \tag{2}$$

Where $\Delta\varepsilon_{\max}$ is the maximum deformation, $p_{\Delta\varepsilon_{\max}}$ is the pressure at $\Delta\varepsilon_{\max}$, $k_{p_{\Delta\varepsilon_{\max}}}$ is the sensitivity of copper cylinders at $p_{\Delta\varepsilon_{\max}}$.

On basis of data on Table.1, the maximum deformation is 0.536mm, that is to say the largest decrease of height in pressure 20MPa. It is occurred on the sixth copper cylinder pressure point 200MPa, and pressure sensitivity $k_{p_{\Delta\varepsilon_{max}}}$ on this point is evaluated as

$$k_{p_{\Delta\varepsilon_{max}}} = \frac{20MPa}{0.536mm} = 37.31MPa/mm$$

Then there is

$$\begin{aligned} u_2 &= \frac{u_{2h} \cdot \Delta\varepsilon_{max} \cdot k_{p_{\Delta\varepsilon_{max}}}}{p_{\Delta\varepsilon_{max}}} \times 100\% \\ &= \frac{0.0017 \times 0.536 \times 37.31}{200} \times 100\% \\ &= 0.0169\% \end{aligned} \tag{3}$$

D. *Uncertainty of Individual Deformations u_3*

$\{\varepsilon_{tij}, p_i\}$, obtained from final determination test, is the analyzed object. Deformation of 10 copper cylinders on pressure point p_i is obtained on each working day. As a result, a total of 50 results are obtained from *t* working days (here, *t*=5).

(1) Consistency component $u_{p_{ti}}$ is deformation (or height of copper cylinders after pressure) of the calibrated copper cylinder in point Pi from each working-day. $u_{p_{ti}}$ has been estimated according to the following formulas:

a. Calculates mean deformation $\overline{\varepsilon_{ti}}$:

$$\overline{\varepsilon_{ti}} = \frac{1}{10}\sum \varepsilon_{tij} \tag{4}$$

Where ε_{tij} is deviation of each point, *t* means the number of days, $i = \{1, 2, ..., 14\}$ is the number of pressure point. And $j = \{1, 2, ..., 10\}$ is the number of copper cylinder

b. Calculates maximum deviation $\Delta\varepsilon_{i\max}$ of deformation from 10 calibrated copper cylinders in point Pi from all working days, according to

$$\Delta\varepsilon_{i\max} = \left|\varepsilon_{ij} - \overline{\varepsilon_i}\right| \tag{5}$$

c. Therefore, relative uncertainty $u_{p_{ti}}$ can be expressed as

$$u_{p_{ti}} = \frac{\Delta\varepsilon_{ti} \cdot k_{p_{ti}}}{p_i} \tag{6}$$

Where $k_{p_{ti}}$ is the pressure sensitivity of p_i on t working day, it can be obtained from the model of the pressure of one day's test.

(2) Combined uncertainty u_{p_i} on press point p_i from working day t is derived as

$$u_{p_i} = \sqrt{\frac{\sum u_{p_{ti}}^2}{t}} \tag{7}$$

u_{p_i} of the vertical copper cylinder 8mm high by 13mm diameter is given on Table 2 as follows. The maximum value of u_{p_i} is 0.019, which meets the requirements in GJB3196. 27A- 2005 [2].

Table 2. Calculation of u_{p_i} from mean value of copper cylinder 8mm high by 13mm diameter

p_i [MPa[	$\overline{\varepsilon_i}$ [mm[	$\left\|\varepsilon_{i\max}\right\|$ [mm[	**k_{pi} [MPa/mm]**	u_{p_i}
140	11.156	0.013	-39.227	**0.015**
160	10.707	0.019	-39.222	**0.010**
180	10.216	0.027	-39.580	**0.014**
200	9.702	0.020	-40.322	**0.009**
220	9.200	0.017	-41.492	**0.005**
240	8.700	0.035	-43.164	**0.009**
260	8.232	0.028	-45.454	**0.010**
280	7.790	0.015	-48.548	**0.011**
300	7.424	0.015	-52.736	**0.006**
320	7.083	0.018	-58.506	**0.004**
340	6.792	0.034	-66.720	**0.013**
360	6.527	0.033	-79.054	**0.017**
380	6.266	0.005	-99.237	**0.004**

400	6.041	0.016	-137.551	**0.019**

(3) Inconsistent individual deformation of standard copper cylinder u_3

According to selecting progress of standard copper cylinder, both cylindrical and tapered standard copper cylinders are selected on specified pressure point [16]. Setting n as pressure points on test one working day, a number of n u_{p_i} can be obtained based on above analysis and calculation. Taking the simplest method to reflect random fluctuations of overall deformation of a standard copper cylinder, u_3 can be obtained from

$$u_3 = \sqrt{\frac{\sum u_{p_i}^2}{n}} \tag{8}$$

Calculated data on Table 2 according to Eq. (8), there is $u_3 = 0.48\%$.

E. Uncertainty of sensitivity u_4

According to function of standard copper cylinder, this component doesn't appear in the calibration of working-class press machine because the calibration is conducted on prescribed pressure point. The regulated pressure is the same as the pressure from the identification test of a standard copper cylinder. Therefore, measurement uncertainty of u_4 can be considered as 0 when the standard copper cylinder was used to calibrate the press machine [17].

However, u_4 should be considered when standard copper cylinder is used to classify internal crusher gauge. The common classifying method is secondary preloading, while the main problem of that method is principal error [18]. In general, the copper cylinder is regarded as a linear sensitive element, which means that deformation and pressure of copper cylinder change linearly in a range of 245MPa to 295MPa. Therefore, u4, the main component affecting uncertainty component, is a nonlinear-output characteristic of copper cylinder during this. Consequently, by definition of nonlinear [5], u_4 is given by:

$$u_4 = \frac{\Delta L_{\max} \cdot k_{p_{\Delta L \max}}}{Y_{F \cdot S}} \times 100\% \tag{9}$$

Where $\Delta L_{\max}$ represents the remaining height of copper after pressed twice on 245MPa and 295MPa. $k_{p_{\Delta L \max}}$ is pressure sensitivity on $\Delta L_{\max}$. $Y_{F \cdot S}$ is the measurement range, which is for sure calculated as 295MPa in this experiment.

Results of fitting curve for 8mm high by 13mm diameter copper cylinders' deformation after pressure are shown on Fig.3, where *y* is deformation and *R* is error.

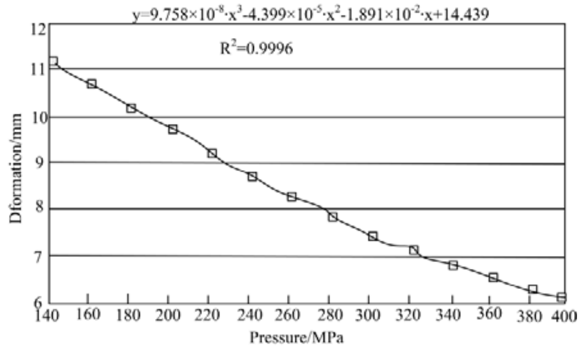

Figure 3. Results of fitting curve of $\phi 8mm \times 13mm$ copper cylinders.

On the basis of calculation results of Fig.3, $\Delta L_{\max}$ on this experiment is 0.015mm in about 270MPa pressure point, $k_{p_{\Delta L \max}}$ is the sensitivity in 270MPa, where the maximum deformation is 0.471mm. It is occurred on the first copper cylinder pressure point 270MPa, and pressure sensitivity $k_{p_{\Delta L \max}}$ on this point is evaluated as

$$k_{p_{\Delta L \max}} = \frac{20MPa}{0.471mm} = 42.46MPa / mm$$

As a result, u_4 is calculated by Eq. (9), there is Eq. (10)

$$u_4 = \frac{\Delta L_{\max} \times k_{p_{\Delta L \max}}}{Y_{F \cdot S}} \times 100\% = \frac{0.015 \times 42.46}{295} = 0.216\% \tag{10}$$

F. Uncertainty of Temperature u_5

This component, Uncertainty of temperature has been analyzed in reference [6]. And it is a previous study from our research group. It is proved in reference [6] that since calibration of working-level press machine by standard copper cylinder is carried out at about 20±4°C, while selection of the internal crusher gauge is carried out in the range 15℃~25°C. Selection test of standard copper cylinder is conducted in a range of 20±1°C. Clearly, the extreme relative deviations will reach 0.5% if temperature has not been corrected [16]. Actually, the worst precision can be controlled within 10% in practical usage. That is, influence of temperature can be derived as:

u_5=0.5%×10%=0.05%.

G. Combined Uncertainty

(a) The combined uncertainties of 8mm high by 13mm diameter standard copper cylinder on calibrating working-level press machine, u becomes now

$$
\begin{aligned}
u &= \sqrt{u_1^2+u_2^2+u_3^2+u_5^2}\,(u_4=0)\\
&=\sqrt{(0.1\%)^2+(0.0174\%)^2+(0.48\%)^2+(0.05\%)^2}\\
&=0.49\%
\end{aligned} \tag{11}
$$

(b) However, The overall expanded uncertainty of 8mm high by 13mm diameter standard copper cylinder using for selecting internal crusher gauge, u turns to be

$$
\begin{aligned}
u &= \sqrt{u_1^2+u_2^2+u_3^2+u_4^2+u_5^2}\\
&=\sqrt{0.1\%^2+0.0174\%^2+0.48\%^2+0.26\%^2+0.05\%^2}\\
&=0.56\%
\end{aligned} \tag{12}
$$

V. DISCUSSION

This section compares the results of combined uncertainties and the results from self-adaptive weight algorithm.

Fig.4 shows the standard deviations by self-adaptive weight algorithm [7]. As can be seen, the maximum and minimum standard deviation of a copper cylinder 8mm high by 13mm diameter is 1% and 0.62%. With the method of above analysis, we reduced the overall expanded uncertainty of standard copper cylinder 8mm high by 13mm diameter using for selecting internal crusher gauge and selecting internal crusher gauge to 0.49% and 0.56% separately, in Eq. (11) and Eq. (12). The uncertainty of this paper is slightly greater than for the previous one.

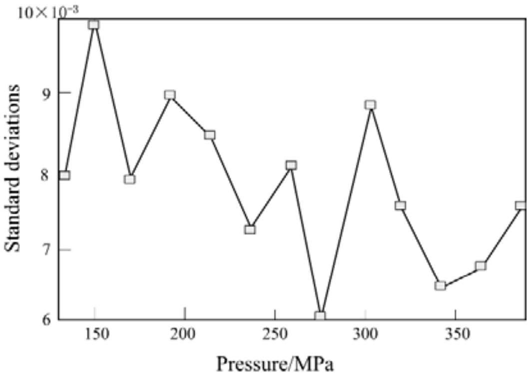

Figure 4. Standard deviations of measuring with method self-adaptive weight algorithm.

The main reason for increase of uncertainty with copper cylinder pressure measuring is the inclusion of differences in primary pressure datum, height measuring, inconsistent individual deformation, inconsistent sensitivity and temperature. All components are important factors that cannot be ignored. With improvement in five main options mentioned above, the achievement of future process is expected.

VI. CONCLUSION

This paper describes a selection method of standard copper cylinder and discusses steps and related criteria of preselect test of standard copper cylinder. Selection process is simple and feasible. Different from the traditional methods, this paper divides the measurement uncertainty into five parts, which are the difference in primary pressure datum, difference of height measuring, inconsistent individual deformation, inconsistent sensitivity, and difference of temperature.

By analyzing those five parts of overall uncertainty, a model on measurement uncertainty was established. Inconsistent individual deformation is the main contributor to uncertainty of pressure measuring by copper cylinder. Take data of copper cylinder 8mm high by 13mm diameter for example, measurement uncertainty is 0.49% when calibrates working-level press machine and 0.56% when selects internal crusher gauge. The measuring accuracy of pressure increases, compared with standard deviation, which calculated by the self-adaptive weight algorithm. This method of analyses can also be applied to other kinds of pressure measurement about uncertainty and errors. For instance, shock wave pressure is an effective characteristic parameter in evaluation of explosion. Since the electrometric measurement results is affected by test method itself, dynamic performance and calibrations of measurement system, environment, and the sensors used. To improved reliability of measurement results, measurement uncertainty can refer to the method suggested in this paper, more or less.

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