A GROUPING METHOD TO MINIMIZE SURPLUS PARTS IN SELECTIVE ASSEMBLY

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Abstract
Selective assembly is an assembly method that can achieve high accurate assembly even from the low level of accuracy of manufacturing parts; however, this always exists surplus parts, especially when the clearance or interference fit requirements vary in a given range. This paper presents a method in place of reducing surplus parts based on shifting the mean dimensional values and then grouping the mating parts based on their dimension tolerance and assembly characteristic. Examination case study of piston-cylinder assembly shows that by implementing this method, the percentage of surplus parts is reduced considerably (from 40.65% and 26.18% to 2.63%) and the clearance variation is minimized in comparison with the traditional ones. This method can be applied to manufacture and assemble products with high accuracy.

Keywords: Selective assembly; selective group; number of groups; mating part; surplus part.

1. Introduction
As a matter of fact, the quality and performance of an assembled product depends on the dimensional variation of the mating parts. The overall tolerance of the assembly is determined by the sum of the individual parts tolerances, that means the parts should be manufactured at a much higher level of precision in order to meet the requirement of assembly accuracy, but this is unfeasible and inevitable under economic considerations; therefore, selective assembly is a cost-effective alternative in these situations. This technique can be used to achieve high accurate assembly from relatively low accurate parts. D. Mease, V. N. Nair, and A. Sudjianto [1] described the statistical formulation of the problem and develop optimal classification strategies under several loss functions and distributional assumptions. This strategy showed to produce significant decreases in expected loss, however, they have not addressed the issue of limited buffer capacity. Ka Ching Chan & Richard J. Linn [2] proposed a method that it ensures the probabilities of the mating parts are equal in all corresponding groups, while maintaining the dimensional requirements in order to

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minimize total surplus parts. X. D. Fang and Y. Zhang [3] suggested a new algorithm to group the mating parts based on the ideas of balanced probabilities and unequal tolerance range in each group, thus can be reduced the surplus parts. Kannan and Jayabalan [4] proposed a method of manufacturing the mating parts for selective assembly. The parts with smaller standard deviations were manufactured with different means, so that the resulting population will have a standard deviation equal to the standard deviation of the mating parts. Pugh [5] had partitioned the mating parts into groups prior to random assembly. However, this method had been shown to produce poor results when the parts exhibit dissimilar variabilities.

The earlier proposed methods did not give direct solutions to determine the group tolerances and the number of selective groups for minimizing the total surplus parts, so that this article will analyze thoroughly a grouping method to solve this problem.

2. Problem description

We consider the variations in manufacturing process primarily follow the normal distribution, therefore the analysis in this article is restricted to the normal distribution. The methods can be also extended to cases with any distributional types.

Consider the assembly of the mating parts consist of a pair of assembly hole-shaft which has a clearance fit. This is the most common type of assembly such as piston and cylinder, ball bearing, and so forth. In these assemblies, the assembly clearance specifications cannot be gained by interchangeable assembly. The only solution to achieve is selective assembly. The model of the mating parts is in Fig. 1.

![Fig. 1. Modeling of assembling hole and shaft](image-url)
In conventional selective assembly, the number of groups and the tolerance range of groups are fixed [6-11]. In reality that performs well only for cases where both of the mating parts have identical or very similar standard deviation $\sigma$. However, in real-life situations, this is impossible and some parts in certain groups may be surplus due to the inequality of the mating parts, which are affected by the difference in standard deviation of the mating parts.

The corresponding probability distribution with hole dimensional distributions $6\sigma_h$ and shaft dimensional distribution $6\sigma_s$ are shown in Fig. 2. In selective assembly, both the holes and shafts are divided into the same number of smaller groups, and parts from their corresponding groups are mated interchangeably, so that closer tolerances could be achieved.

There is a paradox theory when divided the normal distribution into smaller groups. On the one hand, if the number of groups is small, when two parts assembly to form a product will not satisfy the given specifications. On the other hand, if the number of groups is large, there will arise some problems such as the precision of each group will be exceeded the capacity of measurement devices and the difficulty in managing, storing and utilizing. Thus, we should calculate and group the dimensional distributions of the mating parts to satisfy the given conditions.

3. Problem solution

In practice, the standard deviation of the hole $\sigma_h$ and shaft $\sigma_s$ is unequal; consequently, the number of parts in corresponding groups will be different. Suppose that the standard deviation of the hole is greater than the one of the shaft, as shown in Fig. 2. Due to the dissimilarity in standard deviations, the number of parts in each group is not the same as represented by the corresponding area under the normal curve. Thus, we have to calculate a set of holes and shafts into groups such that they meet the
clearance specifications as well as the number of parts in the corresponding groups should be nearly the same.

3.1. Theoretical base for determining the number of groups

In order to reduce the surplus parts as well as to enhance the effectiveness of assembly process, the process of determining the number of selective groups consists of two procedures:

Firstly, a method is proposed to manufacture the mating part with smaller standard deviation at shifted manufacturing means to satisfy the clearance requirements.

The difference between \((D_{\text{max}})_i\) and \((d_{\text{min}})_i\) is always smaller than the given maximum clearance. The difference between \((D_{\text{min}})_i\) and \((d_{\text{max}})_i\) is always bigger than the given minimum clearance.

\[
(D_{\text{max}})_i - (d_{\text{min}})_i = C_{\text{max}}(i) \leq C_{\text{max}} \quad (1 \leq i \leq n)
\]

\[
(D_{\text{min}})_i - (d_{\text{max}})_i = C_{\text{min}}(i) \geq C_{\text{min}}
\]

where \(i\) is group number, \((D_{\text{max}})_i\) is the maximum dimension in the \(i^{th}\) group of holes, \((D_{\text{min}})_i\) is the minimum dimension in the \(i^{th}\) group of holes, \((d_{\text{max}})_i\) is the minimum dimension in the \(i^{th}\) group of shafts, \((d_{\text{min}})_i\) is the maximum dimension in the \(i^{th}\) group of shafts, and \(C_{\text{max}}, C_{\text{min}}\) are given clearance, respectively.

From the 1st and \(n^{th}\) groups, we determine the new mean of shaft,

\[
d_m = \frac{(d_{\text{max}})_1 + (d_{\text{min}})_n}{2}
\]

Secondly, determining the number of selective groups by mathematical constraints.

The probability of appearance of parts in \(i^{th}\) group of shaft is equal to the probability of appearance of parts in \(i^{th}\) group of holes.

Suppose that the probability density function for the distributions of hole and shaft dimensions are \(f(x_h); f(x_s)\),

\[
f(x_h) = \frac{1}{\sigma_h \sqrt{2\pi}} e^{-\frac{1}{2} \frac{(x_h - \mu_h)^2}{\sigma_h^2}}; f(x_s) = \frac{1}{\sigma_s \sqrt{2\pi}} e^{-\frac{1}{2} \frac{(x_s - \mu_s)^2}{\sigma_s^2}}
\]

where \(\sigma_h\) and \(\sigma_s\) are the standard deviation of the dimensions of holes and shafts; \(x_h\) and \(x_s\) are the dimensions of holes and shafts; and \(\mu_h, \mu_s\) are the mean or expectation of the dimensional distribution of hole and shaft.

The probability of appearance of parts in \(i^{th}\) group of holes,
\[(P_i) = \int_{(\mu_i, \sigma_i)}^{(\mu_h, \sigma_h)} \frac{1}{\sigma_i \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{x - \mu_i}{\sigma_i}\right)^2} \, dx_i\]  

(4)

The probability of appearance of parts in \(i^{th}\) group of shafts,

\[(P_i) = \int_{(\mu_i, \sigma_i)}^{(\mu_h, \sigma_h)} \frac{1}{\sigma_i \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{x - \mu_i}{\sigma_i}\right)^2} \, dx_i\]

(5)

The probabilities of shafts and holes expected in the corresponding group must be equal. Thus, the following relation can be derived,

\[(P_i) = (P_i)\]

\[\Leftrightarrow \int_{(\mu_i, \sigma_i)}^{(\mu_h, \sigma_h)} \frac{1}{\sigma_i \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{x - \mu_i}{\sigma_i}\right)^2} \, dx_i = \int_{(\mu_h, \sigma_h)}^{(\mu_i, \sigma_i)} \frac{1}{\sigma_i \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{x - \mu_h}{\sigma_i}\right)^2} \, dx_i\]

(6)

Modeling for calculating the number of groups is shown in Fig. 3.

Because the standard deviation of the mating parts is the different and the rounding values during calculations. Therefore, those results in the surplus parts, and these values are calculated as below:

\[
\text{Surplus parts (i)} = \left| (P_i) - (P_i) \right|
\]

(7)

3.2. Case study

In order to demonstrate how the grouping method works, an example below will be analyzed.
The mean diameter for manufacturing piston and cylinder is planned before manufacturing the parts for selective assembly. It is more convenient to make correct holes of fixed sizes, since the standard drills, taps, reamers and branches etc. are available for producing holes and their sizes are not adjustable. On the other hand, the size of the shaft produced by turning, grinding, etc. can be very easily varied, so that the manufacturing mean for the hole is taken as the reference.

The allowable clearance $C_{\text{max}}, C_{\text{min}}$ are designed to satisfy the functions of products. In piston-cylinder assembly, if the clearance is too small, the oil film between the cylinder wall and piston becomes too thin and piston scuffing occurs. If the clearance is too large, the piston vibrates in the cylinder and abnormal noise occurs. Analyzing the performance, maintenance and value of product, in the design step we take $C_{\text{min}} = 0.003; C_{\text{max}} = 0.015$.

Assume that the process capability of the workshop can be able to manufacture the mating parts with the fit $\Phi50 H^7 h^6$. The specifications and tolerances of piston and cylinder diameters are shown in Fig. 4. Tolerance of piston and cylinder diameters are $\sigma_p = 0.016, \sigma_c = 0.025$, respectively.

![Fig. 4. Specifications and tolerances of piston and cylinder](image)

If the mating parts are picked and interchangeably assembled, then the minimum and maximum clearances are 0.000 and 0.041, respectively. These values exceed the range of allowable clearance, that is $[0.003, 0.015]$. Therefore, we have to apply the selective assembly by dividing the dimensional distributions into n smaller groups then they are assembled to gain the clearance within allowable range as well as to reduce the surplus parts. The procedures consist of two steps as bellow:

**Step 1.** Shift the mean piston diameter

From equation (3), at the mean value of piston and cylinder diameters,
As seen in Fig. 5, the actual mean value of piston diameter is $50.000 - 0.008 = 49.992$ mm. Now, we have to calculate the new one to meet the allowable clearance.

It is easy to determine the dimension range of cylinder and its mean value:

$$D_m = 50.013; \quad D_{\min} = 50.000; \quad D_{\max} = 50.025$$

From Fig. 3, the maximum diameter of the first group of piston,

$$\left(d_{\max}\right)_1 = (D_{\max})_1 - C_{\min} = 50.000 - 0.003 = 49.997 \text{ (mm)}$$

The minimum diameter of the $n^{th}$ group of piston,

$$\left(d_{\min}\right)_n = (D_{\max})_n - C_{\max} = D_{\max} - C_{\max} = 50.025 - 0.015 = 50.010 \text{ (mm)}$$

The new mean value of piston diameter,

$$d_m = \frac{(d_{\max})_1 + (d_{\min})_n}{2} = \frac{49.997 + 50.010}{2} = 50.004 \text{ (mm)}$$

The limits of piston diameter,

$$d_{\min} = d_m - \frac{6\sigma_p}{2} = 50.004 - \frac{0.016}{2} = 49.996 \text{ (mm)}$$
When manufacturing the mating parts, the mean value of cylinder diameter is kept constant. The mean value of piston diameter is moved from the actual value 49.992 to the calculated one 50.004 (mm).

The dimensional distributions of piston and cylinder after shifting the mean of piston diameter is presented in Fig. 6.

Step 2. Determine the number of groups

It is clear that the frequency of mating parts is high near the mean and reduce on both sides of the normal distribution; thus, we will divide and number the normal distribution as in Fig. 7.

From the inequations (1), for the \( \frac{n}{2} + 1 \) group,

\[
(C_{\text{max}})_{\frac{n}{2}+1} = (D_{\text{max}})_{\frac{n}{2}+1} - (d_{\text{min}})_{\frac{n}{2}+1} \leq C_{\text{max}}
\]

\[
\Rightarrow (D_{\text{max}})_{\frac{n}{2}+1} \leq (d_{\text{min}})_{\frac{n}{2}+1} + C_{\text{max}} = 50.004 + 0.015 = 50.019 \text{ (mm)}
\]

So,

\[
(D_{\text{min}})_{\frac{n}{2}+1} = 50.013 \text{ (mm)}
\]

\[
(D_{\text{max}})_{\frac{n}{2}+1} = 50.019 \text{ (mm)}
\]
Due to dimensional distributions of cylinder are follow normal distribution, so that it is easy to determine the probability in the $\frac{n}{2} + 1$ group by equation (5),

$$
(P_{n})_{\frac{n}{2}+1} = \int_{50.019}^{50.013} \frac{1}{0.025} e^{-\frac{1}{2} \left( \frac{x-50.013}{0.025} \right)^2} \, dx \approx 0.4066
$$

For equating the probability under the normal curve, from equation (6) the maximum diameter of piston in the $\frac{n}{2} + 1$ group is calculated as follows:

$$
(P_{\frac{n}{2}+1}) = \int_{50.004}^{50.016} \frac{1}{0.016} e^{-\frac{1}{2} \left( \frac{x-50.004}{0.016} \right)^2} \, dx = (P_{\frac{n}{2}+1}) = 0.4066 \Rightarrow (d_{\text{max}})_{\frac{n}{2}+1} \approx 50.00702 \text{ (mm)}
$$

The maximum diameter of piston in the $\frac{n}{2} + 1$ group is $(d_{\text{max}})_{\frac{n}{2}+1} \approx 50.00702 \text{ (mm)}$. It will be very difficult if trying to measure this value with the measuring devices in the workshop. There is a method to solve the above issue is that we will round off this value to three decimal digits, so that we are able to measure that value and accept the number of surplus parts. Thus, the maximum diameter of piston in the $\frac{n}{2} + 1$ group is $(d_{\text{max}})_{\frac{n}{2}+1} = 50.007 \text{ (mm)}$.
The probability in the \( \frac{n}{2} + 1 \) group of piston,

\[
(P_p)_{\frac{n}{2} + 1} = \int_{\frac{50.007}{6}}^{\frac{50.013}{6}} \frac{1}{\sqrt{2\pi}} e^{-\frac{(x-50.016)^2}{6}} \, dx_p \approx 0.4053
\]

The surplus parts in the \( \frac{n}{2} + 1 \) group is the absolute value of the difference between the probability of cylinder and piston,

\[
\text{Surplus parts} \left( \frac{n}{2} + 1 \right) = \left| (P_p)_{\frac{n}{2} + 1} - (P_p)_{\frac{n}{2} + 1} \right| = |0.4066 - 0.4053| = 0.0013
\]

The minimum clearance is obtained using this value,

\[
(C_{\text{min}})_{\frac{n}{2} + 1} = 50.013 - 50.007 = 0.006 > C_{\text{min}}
\]

So that, for the \( \frac{n}{2} + 1 \) group,

\[
(D_{\text{max}})_{\frac{n}{2} + 1} = 50.019; \quad (D_{\text{min}})_{\frac{n}{2} + 1} = 50.013; \quad (d_{\text{max}})_{\frac{n}{2} + 1} = 50.007; \quad (d_{\text{min}})_{\frac{n}{2} + 1} = 50.004
\]

The tolerances of the rest of groups are calculated until the maximum diameter of piston and cylinder are reached. In the same way, group tolerances on the left of the mean diameters are calculated with the same procedures. Fig. 8 shows the procedures of the calculating process.

The range diameter of groups, probabilities, assembly clearances and surplus parts are tabulated in Tab. 1.

**Tab. 1. The range of diameters, assembly clearances and surplus parts**

<table>
<thead>
<tr>
<th>Selective Group</th>
<th>Piston</th>
<th>Probability</th>
<th>Cylinder</th>
<th>Probability</th>
<th>Assembly clearance</th>
<th>Surplus parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.996</td>
<td>50.000</td>
<td>0.0062</td>
<td>0.003</td>
<td>0.006</td>
<td>0.0051</td>
</tr>
<tr>
<td>2</td>
<td>49.997</td>
<td>50.002</td>
<td>0.0112</td>
<td>0.003</td>
<td>0.007</td>
<td>0.0059</td>
</tr>
<tr>
<td>3</td>
<td>49.999</td>
<td>50.004</td>
<td>0.0780</td>
<td>0.003</td>
<td>0.008</td>
<td>0.0029</td>
</tr>
<tr>
<td>4</td>
<td>50.001</td>
<td>50.007</td>
<td>0.4066</td>
<td>0.003</td>
<td>0.012</td>
<td>0.0013</td>
</tr>
<tr>
<td>5</td>
<td>50.004</td>
<td>50.013</td>
<td>0.4066</td>
<td>0.006</td>
<td>0.015</td>
<td>0.0013</td>
</tr>
<tr>
<td>6</td>
<td>50.007</td>
<td>50.019</td>
<td>0.0780</td>
<td>0.010</td>
<td>0.015</td>
<td>0.0029</td>
</tr>
<tr>
<td>7</td>
<td>50.009</td>
<td>50.022</td>
<td>0.0112</td>
<td>0.011</td>
<td>0.015</td>
<td>0.0059</td>
</tr>
<tr>
<td>8</td>
<td>50.011</td>
<td>50.024</td>
<td>0.0022</td>
<td>0.012</td>
<td>0.014</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Total surplus parts: 0.0263
Fig. 8. Flow chart of the grouping method for selective assembly
4. The traditional grouping methods

In order to compare the grouping method to the traditional methods we analyze two conventional methods: the equal group tolerance method and equal probability as follows:

4.1. Equal group tolerance method

This technique relies on both distributions being separated into groups that have equal widths.

\[ \Delta = \Delta_p = \Delta_c \]  

(8)

In this technique, the groups’ width is the same for both distributions, this is expressed mathematically in equation (8). According to [11-13] the dimensional distributions were divided into 6 groups.
Tab. 2. The result of the assembly using equal width method

<table>
<thead>
<tr>
<th>Selective Group</th>
<th>Piston</th>
<th>(P_i)</th>
<th>Cylinder</th>
<th>(P_i)</th>
<th>Assembly clearance</th>
<th>Surplus parts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(d_{min}^i), (d_{max}^i)</td>
<td>(D_{min}^i), (D_{max}^i)</td>
<td>(C_{i_{min}}), (C_{i_{max}})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out of limit</td>
<td>50.000</td>
<td>50.004</td>
<td>0.0254</td>
<td></td>
<td></td>
<td>0.0254</td>
</tr>
<tr>
<td>1</td>
<td>49.996</td>
<td>49.998</td>
<td>0.0122</td>
<td>50.004</td>
<td>50.007</td>
<td>0.0595</td>
</tr>
<tr>
<td>2</td>
<td>49.998</td>
<td>50.001</td>
<td>0.1181</td>
<td>50.007</td>
<td>50.010</td>
<td>0.1608</td>
</tr>
<tr>
<td>3</td>
<td>50.001</td>
<td>50.004</td>
<td>0.3697</td>
<td>50.010</td>
<td>50.013</td>
<td>0.2642</td>
</tr>
<tr>
<td>4</td>
<td>50.004</td>
<td>50.007</td>
<td>0.3697</td>
<td>50.013</td>
<td>50.016</td>
<td>0.2642</td>
</tr>
<tr>
<td>5</td>
<td>50.007</td>
<td>50.010</td>
<td>0.1181</td>
<td>50.016</td>
<td>50.019</td>
<td>0.1608</td>
</tr>
<tr>
<td>6</td>
<td>50.010</td>
<td>50.012</td>
<td>0.0122</td>
<td>50.019</td>
<td>50.022</td>
<td>0.0595</td>
</tr>
<tr>
<td>Out of limit</td>
<td>50.022</td>
<td>50.025</td>
<td>0.0154</td>
<td></td>
<td></td>
<td>0.0154</td>
</tr>
<tr>
<td>Total surplus parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.4065</td>
</tr>
</tbody>
</table>

In this method, the probability under the normal curve of the mating parts in the corresponding groups is dissimilar, those results in the number of parts in the corresponding groups will be different, leading to surplus parts.

4.2. Equal probability method

In this method, the dimensional distributions of the mating parts are divided into nearly an equal number of parts, then the corresponding groups are assembled interchangeably. Modeling for this situation is shown in Fig. 11. The surplus parts of this method are approximately 26.18%.

![Fig. 11. Equal probability method](image)
Tab. 3. The result of the assembly using equal probability method

<table>
<thead>
<tr>
<th>Selective Group</th>
<th>Piston $(d_{\text{min}})$</th>
<th>$(P_i)$</th>
<th>Cylinder $(d_{\text{max}})$</th>
<th>$(P_i)$</th>
<th>Assembly clearance $(c_{\text{max}})$</th>
<th>Surplus parts $(d_{\text{min}})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.996</td>
<td>0.1377</td>
<td>50.000</td>
<td>0.1473</td>
<td>1</td>
<td>49.996</td>
</tr>
<tr>
<td>2</td>
<td>50.002</td>
<td>0.1550</td>
<td>50.010</td>
<td>0.2065</td>
<td>2</td>
<td>50.002</td>
</tr>
<tr>
<td>3</td>
<td>50.003</td>
<td>0.2073</td>
<td>50.012</td>
<td>0.1462</td>
<td>3</td>
<td>50.003</td>
</tr>
<tr>
<td>4</td>
<td>50.004</td>
<td>0.2073</td>
<td>50.013</td>
<td>0.1462</td>
<td>4</td>
<td>50.004</td>
</tr>
<tr>
<td>5</td>
<td>50.005</td>
<td>0.1550</td>
<td>50.014</td>
<td>0.2235</td>
<td>5</td>
<td>50.005</td>
</tr>
<tr>
<td>6</td>
<td>50.006</td>
<td>0.1377</td>
<td>50.016</td>
<td>0.1303</td>
<td>6</td>
<td>50.006</td>
</tr>
</tbody>
</table>

Total surplus parts: 0.2618

5. Conclusions

The main conclusions from the research results of the current work can be drawn as follows. Firstly, the mating parts with dissimilarity between the standard deviations have been studied. Secondly, analyzing a grouping method to shift the mean of the distributional dimension of shaft, then determining the number of selective groups, so that this helps to reduce an amount of surplus parts, in the case study the surplus parts are roughly 2.63%. This value is compared to approximately 40.65% and 26.18% surplus parts to the equal width and the equal probability method, respectively. However, in the equal width method the surplus parts are too large, and at the groups 1 and 6 of the equal probability method, the clearance assembly does not meet the clearance specifications. The results are showed in Tab. 2 and Tab. 3. In addition, the result of this paper may be applied into practice to manufacture the products with high precision.

References


MỘT PHƯƠNG PHÁP CHIA NHÓM ĐỂ GIẢM THIỂU PHẾ PHẨM TRONG LẮP CHỌN

Tóm tắt: Lắp chọn là phương pháp lắp có thể đạt độ chính xác cao ngay cả khi độ chính xác của các khâu thành phần thấp, tuy vậy thường gặp nhiều phế phẩm, đặc biệt khi yêu cầu kẽ hở hoặc độ do đối với lắp biến thiên trong một khoảng cho trước. Bài báo này trình bày một phương pháp phân nhóm để giảm tỷ lệ phế phẩm đó là dịch tinh phân bố kích thước và chia nhóm các chi tiết dựa trên yêu cầu mỗi lắp cho trước và dung sai cặp chi tiết lắp trong điều kiện cụ thể. Nghiên cứu trường hợp lắp ráp pít tông - xi lanh chỉ ra rằng nhóm được phương pháp phân nhóm này, tỷ lệ phần trăm phế phẩm giảm thiểu đáng kể (từ 40,65% và 26,18% xuống 2,63%) và biến thiên về kẽ hở khi lắp nhỏ hơn so với các phương pháp chia nhóm truyền thống. Phương pháp này có thể ứng dụng tốt vào sản xuất và lắp ráp các sản phẩm yếu cầu độ chính xác cao.

Từ khoá: Lắp chọn; nhóm chọn; số nhóm chọn; cặp chi tiết lắp ráp; phế phẩm.

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