2. Hu J., Chou Y. K. Characterizations of cutting tool flank wear-land contact // *Wear*, 2007, v. **263,** (7-12 SPEC), pp. 1454-1458;
3. Kozlov V. N. Flank Contact Load Distribution at Cutting Tool Wear // *Proceeding of the7th International Forum on Strategic Technology*, IFOAT2012, 2012, v. **2,** pp. 147-151.
4. Полетика М.Ф. Контактные нагрузки на режущих поверхностях инструмента. Москва: Машиностроение, 1969. – 148 с.
5. Развитие науки о резании металлов /В.Ф. Бобров, Г.И. Грановский, Н.Н. Зорев и др. – М. Машиностроение, 1967. – 416 с.
6. Васильев Д.Т. Силы на режущих поверхностях инструмента // Станки и инструмент. – 1954 – № 4. – с. 1-5.
7. Кравченко Б.А. Силы, остаточные напряжения и трение при резании металлов. Куйбышев: Куйбышевское книжное издательство. 1962. - 179 с.
8. Artamonov E.V., Chernyshov M.O., Pomigalova T.E. Improving the Performance of Composite Bits with Replaceable Inserts // Russian Engineering Research, 2017, v. **37**, No. 4, pp. 348–350.
9. Proskokov A. V. and Petrushin S. I. Chip Formation with a Developed Plastic-Deformation Zone // *Proceeding of the7th International Forum on Strategic Technology*, IFOST2012, 2012, v. **2.** pp. 173-177.
10. Afonasov A. and Lasukov A. Elementary Chip Formation in Metal Cutting // *Russian Engineering Research*, 2014, v. **3,** pp. 152-155.
11. Artamonov E. V., Vasil’ev D. V., Kireev V. V., and Uteshev M. Kh. Mechanics of Chip Formation in Cutting // *Russian Engineering Research*, 2017, Vol. 37, No. 5, pp. 450–454.


## CALCULATION OF TECHNOLOGICAL DIMENSIONS

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The designation of TP represents a multialternative task, the correct solution of which requires realization of a number of calculations. In the beginning of designation kinds of processing of blank surfaces and methods of achievement of their accuracy appropriate to the requirements of the drawing, type of manufacturing and equipment, existing in the machine shop, previously are defined or established.

At low accuracy of initial blanks TP begins with rough machining of surfaces having greatest stocks. Stocks are removed in first turn from those surfaces on which the defects are probable. This is done for the purpose of the prompt elimination of a spoilage.

The further manufacturing route is designed with a principle of machining at first rough, and then more accurate surfaces. The most accurate (precise) surfaces are machined in the last turn.

At drawing up of a TP route it is required previously to define quantity of machining of each surface. For this purpose it is better to take a surface with the most accurate (precise) size and to write a sequence of machining. Thus minimal allowances $2Z_{min}$ are consecutive "covered" on the final (design) size, which allows us to receive the intermediate technological dimensions.

In our task, for example, the most accurate outside size of a sleeve is Ø30h7 (Fig. 1). It should be machined with 7 grade of tolerance, before – with 9 grade of tolerance, and earlier – with 11 grade of tolerance. Initial workpiece is a rod with 14 grade of tolerance in condition of delivering.

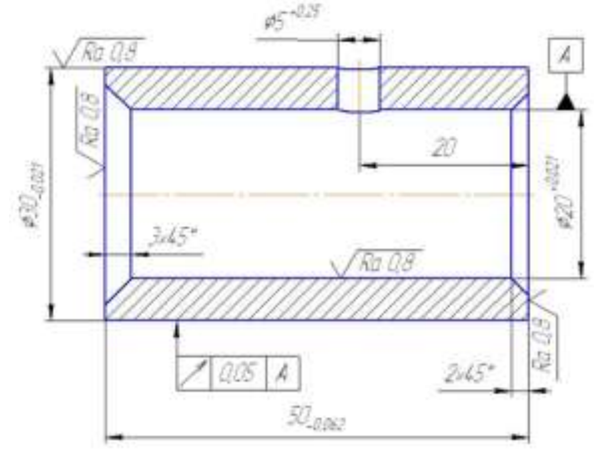

*Fig. 1. Sketch of a part "sleeve"*

We begin to write down the technological sizes from the end (design size is written first in a **right** position) and we go from the right hand to the left. In our example it is necessary to carry out heat treatment (quenching). The route of sleeve processing is written:

35h14 → 31.13h11 → 30.48h9 → Heat treatment → 30h7.

$2Z_{min} = 1.8$ mm   $2Z_{min} = 0.4$ mm   $2Z_{min} = 0.32$ mm

Allowance is a layer (thickness of a layer) of a material, removed in machining. Its minimal thickness $Z_{min}$ depends on many factors, but basics are:

1. Roughness of a machined surface received at the previous manufacturing (index ***i*-1**) – $Rz_{i-1}$;

2. Thickness of a defective layer of a machined surface received at the previous manufacturing – $h_{def\ i-1}$;

3. Warping of a machined surface received at the previous manufacturing – $\rho_{i-1}$;

4. Error of locating and clamping of a workpiece received at **considered** manufacturing (index ***i***) – $\varepsilon_i$.

If allowance is less minimal, the traces and defects from the previous machining will be on has machined surface, which is not allowable. Allowance is removed per one or several processing step, if the thickness is too large.

Minimal allowance for considered machining (on considered processing step) is defined from the tables or calculated by the formulas. If for calculation of minimal stock taking into account the seldom probability of occurrence in the same direction of warp of a surface received at the previous manufacturing ($\rho_{i-1}$) and error of locating and clamping received at considered manufacturing ($\varepsilon_i$) for rotation surfaces an equation is following:

$$2z_{i\min} = 2\cdot\left(R_{z.i-1} + h_{\partial ef.i-1} + \sqrt{(\rho_{i-1}^2 + \varepsilon_i^2)}\right), \quad (1)$$

where $2z_{i\ min}$ – is a minimal allowance of rotation surfaces for considered manufacturing.

It is better to calculate minimal allowance taking into account the probability of occurrence in the same direction of warp of a surface received at the previous manufacturing ($\rho_{i-1}$) and error of locating and clamping received at considered manufacturing ($\varepsilon_i$) for rotation surfaces:

$$2z_{i\min} = 2\cdot\left(Rz_{i-1} + h_{def.i-1} + \rho_{i-1} + \varepsilon_i\right). \quad (2)$$

In this case we avoid of an invalid (a penalized) workpieces due to very small allowance. Calculation of minimal allowances and technological sizes will be more suitable to do by filling a table. Following equations are used for calculation of minimal and maximal calculated technological size at the previous manufacturing ($d_{\min\ i-1\ calc}$ and $d_{\max\ i-1\ calc}$)

$$d_{\min\ i-1\ calc} = d_{\max\ i\ accepted} + 2z_{\min\ i}; \quad (3)$$

$$d_{\max\ i-1\ calc} = d_{\min\ i-1\ calc} + Td_{i-1}, \quad (4)$$

where $Td_{i-1}$ is tolerance of a surface machining at the **previous** manufacturing.

After these calculations it is necessary to round accepted basic technological size $d_{i\text{-}1\ accept}$ of “shafts” in the greatest value.

For “holes” following equations are used:

$$D_{max\ i\text{-}1\ calc} = D_{min\ i\ accepted} - 2z_{min\ i}; \qquad (5)$$

$$D_{min\ i\text{-}1\ calc} = D_{max\ i\text{-}1\ calc} - TD_{i\text{-}1}. \qquad (6)$$

where $TD_{i\text{-}1}$ is tolerance of a surface machining at the previous manufacturing.

After these calculations it is necessary to round accepted basic technological size $D_{i\text{-}1\ accept}$ of “holes” in the least value.

In order to avoid writing of equations and all calculation we suggest to use a table and carry out all calculations with the special order.

First of all it is necessary to write a sequence of a surface processing (for our example it is Ø30h7, Fig. 1), name of machining and grade of tolerance in a column No. *1* (Table 1).

Then it is necessary to write parameters of a surface machining for each processing step (fill in columns *2, 3, 4*), to write an error of a workpiece clamping *ε* (fill in a column *5* on the next stroke).

Table 1

*Calculation of minimal allowances and limit technological dimensions*

| **Technological transitions** | **Components of allowance, μm** | | | | **Calculated minimal allowance, $2z_{min}$, μm** | **Accepted technological size $d_{accept}$, mm** | **Tole-rance T, μm** | **Calculated limit sizes, mm** | |
|---|---|---|---|---|---|---|---|---|---|
| | ***$R_Z$*** | ***$h_{def}$*** | ***ρ*** | ***ε*** | | | | **$d_{min}$** | **$d_{max}$** |
| ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** |
| **External surface Ø30h7($_{-0.021}$)** | | | | | | | | | |
| Initial workpiece is a cold rolling rod (h14) | *160* | *250* | *500* | --- | | *35h14* | *620* | *33.22* | *33.84* |
| Turning: | | | | | | | | | |
| *rough* (h11) | *40* | *40* | *30* | *100* | *2·1010* | *31.2h11* | *160* | *31.01* | *31.17* |
| *semifinish* (h9) | *10* | *10* | *10* | *100* | *2·210* | *30.6h9* | *62* | *30.46* | *30.522* |
| Quenching | *20* | *100* | *100* | --- | --- | ---- | --- | --- | --- |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (HRC 42-46) | | | | | | | | | |
| Round grinding (h7) | *6* | *6* | *5* | *10* | *2·230* | *30h7* | *21* | *29.979* | *30* |
| **Internal surface (hole) Ø20H7($^{+0.021}$)** | | | | | | | | | |
| | | | | | | | | ***D**$_{max}$* | ***D**$_{min}$* |
| Center hole drilling (H18) | *40* | *40* | *51* | --- | Do not require of definition | *8H18* | *2200* | *8.0* | *10.2* |
| Drilling of a hole (H14) | *60* | *60* | 1076 | *90* | No prema-nufact. hole | *16.4H14* | *430* | *16.828* | *16.398* |
| Boring (H11) | *40* | *40* | *51* | *90* | *2·1286* | *19.4H11* | *130* | *19.54* | *19.41* |
| Heat treatment | *20* | *100* | *100* | --- | --- | ---- | --- | --- | --- |
| Internal grinding (H7) | *6* | *6* | *5* | *20* | *2·230* | *20H7* | *21* | *20* | *20.021* |
| **External surface (length of the sleeve) 50h9($_{-0.062}$)** | | | | | | | | | |
| | | | | | | | | ***l**$_{min}$* | ***l**$_{max}$* |
| Cut off a workpiece (quality of a **right** face end) (h16) | *80* | *80* | *500* | | | *56h16* | *1900* | *54.06* | *55.96* |
| Turning of a **right** face end (h14) | *40* | *40* | *24* | 500 | 1160 | *52.9h14* | *740* | *52.16* | *52.90* |
| **Quality** of a ***left*** face end (h16) | *80* | *80* | *500* | --- | --- | --- | --- | --- | --- |
| Turning of a ***left*** face end (h14) | *40* | *40* | *24* | 100 | *760* | *51.4h14* | *740* | *50.578* | *51.318* |
| **Quality** of a right face end (h14) | *40* | *40* | *24* | --- | --- | --- | --- | --- | --- |
| Flat grinding of a right face end (h11) | *6* | *6* | *5* | 74 | *178* | *50.4h11* | *190* | *50.154* | *50.344* |
| **Quality** of a ***left*** face end (h14) | *40* | *40* | *24* | --- | --- | --- | --- | --- | --- |
| Flat grinding of a ***left*** face end (h9) | *6* | *6* | *5* | 50 | *154* | *50h9* | *62* | *49.938* | *50* |

Calculation of minimal allowance is carried out by sum o component parameters Rz, hdef and ρ from the previous manufacturing and error of clamping ε from the considered manufacturing (see Table 2, upper and lower strokes).

Table 2. Calculation of minimal allowances

| Technological transitions | Components of allowance, µm | | | | Calculated minimal allowance, $2z_{min}$, µm | Accepted technological size $d_{accept}$, mm | Tolerance T, µm | Calculated limit sizes, mm | |
|---|---|---|---|---|---|---|---|---|---|
| | $R_z$ | $h_{def}$ | ρ | ε | | | | $d_{min}$ | $d_{max}$ |
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| **External surface Ø30h7(-0.021)** | | | | | | | | | |
| Initial workpiece is cold rolling rod (h14) | *160* | *250* | *500* | --- | | | | | |
| Turning: | | | | | | | | | |
| *rough* (h11) | *40* | *40* | *30* | *100* | *2·1010* | | | | |
| *semifinish* (h9) | *10* | *10* | *10* | *100* | *2·210* | | | | |
| Quenching (HRC 42-46) | *20* | *100* | *100* | --- | --- | ---- | --- | --- | --- |

Calculation of minimal size $d_{min}$ on the previous manufacturing is carried out by sum of maximal accepted size on the finish manufacturing $d_{max\ acc}$ ($d_{max\ acc}$ = 30.00 mm) and minimal allowance at this manufacturing $2{\cdot}z_{min}$ ($2{\cdot}z_{min}$ = 0.46 mm) (Table 3, lower stroke).

Table 3. Calculation of technological sizes

| Technological transitions | Components of allowance, µm | | | | Calculated minimal allowance, $2z_{min}$, µm | Accepted technological size $d_{accept}$, mm | Tolerance T, µm | Calculated limit sizes, mm | |
|---|---|---|---|---|---|---|---|---|---|
| | $R_z$ | $h_{def}$ | ρ | ε | | | | $d_{min}$ | $d_{max}$ |
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| **External surface Ø30h7(-0.021)** | | | | | | | | | |
| Initial workpiece is a cold rolling rod (h14) | *160* | *250* | *500* | --- | | *35h14* | *620* | *33.22* | 33.84 |
| Turning: | | | | | | | | | |
| *rough* (h11) | *40* | *40* | *30* | *100* | *2·1010* | *31.2h11* | *160* | *31.01* | *31.17* |
| *semifinish* (h9) | *10* | *10* | *10* | *100* | *2·210* | *30.6h9* | *62* | *30.46* | *30.522* |
| Quenching (HRC 42-46) | *20* | *100* | *100* | --- | --- | ---- | --- | --- | --- |
| Round grinding (h7) | *6* | *6* | *5* | *10* | *2·230* µm = 0.46 mm | *30h7* | *21* | *29.979* | *30.00 mm* |

Then calculation of $d_{max}$ on the previous manufacturing is carried out by sum of minimal size $d_{min}$ on the previous manufacturing and tolerance for this manufacturing T (column *8*) (Table 3). In our example: $d_{max}$ = 30.46 + 0.062 = 30.522 mm.

After this calculation it is necessary to round accepted basic technological size $d_{i\text{-}1\ accept}$ of "shafts" in the greatest value (30.522 ≈ 30.6). In accordance to 9 grade of tolerance (from column *1*) tolerance zone *h9* is written for a "shaft' without looking on the letter (fundamental deviation) of the design size. Accepted technological dimension is 30.6h9 (see column *7*, stroke "*semifinish* (h9)").

Then it is necessary to continue by the similar order. Diameter of initial workpiece is accepted to 35 mm as rods are manufactured only with the even digits or divisible to 5 digits (33.84 ≈ 35 mm) (see column ***7***, stroke "Initial workpiece is a cold rolling rod (h14)").

For calculation of longitudinal dimensions, it is necessary to take into account quality of surfaces on the **right** and **left** sides of a workpiece (face end **A** and **B**). In order to don't forget this quality it is better to write parameters of a machined surface **in a stroke under a stroke of calculation** (Table 4).

Table 4. Calculation of minimal allowances and limit technological dimensions for surfaces of manufacturing

| Technological transitions | Components of allowance, μm (mkm) | | | | Calculated minimal allowance, $2z_{min}$, μm | Accepted technological size $d_{accept}$, mm | Tolerance T, μm | Calculated limit sizes, mm | |
|---|---|---|---|---|---|---|---|---|---|
| | $R_z$ | $h_{def}$ | $\rho$ | $\varepsilon$ | | | | $d_{min}$ | $d_{max}$ |
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| **External surface (length of the sleeve) 50h9($_{-0.062}$)** | | | | | | | | | |
| | | | | | | | | $l_{min}$ | $l_{max}$ |
| Cut off a workpiece (quality of a right face end) (h16) and left face on previous cutt off operation | *80* | *80* | *500* | | | *56h16* | *1900* | *54.06* | *55.96* |
| Turning of a right face end (h14) | *40* | *40* | *24* | 500 | 1160 | *52.9h14* | *740* | *52.16* | *52.90* |
| **Quality** of a left face end (h16) | *80* | *80* | *500* | --- | --- | --- | --- | --- | --- |
| Turning of a left face end (h14) | *40* | *40* | *24* | 100 | *760* | *51.4h14* | *740* | *50.578* | *51.318* |
| **Quality** of a right face end (h14) | *40* | *40* | *24* | --- | --- | --- | --- | --- | --- |
| Flat grinding of a right face end (h11) | *6* | *6* | *5* | 74 | *178* | *50.4h11* | *190* | *50.154* | *50.344* |
| **Quality** of a left face end (h14) | *40* | *40* | *24* | --- | --- | --- | --- | --- | --- |
| Flat grinding of a left face end (h9) | *6* | *6* | *5* | 50 | *154* mkm | *50h9* | *62* | *49.938* | *50* mm |

## Conclusion

This format of a table and special order of calculation facilitates process of technological dimensions definition, do it more obviously.

REFERENCES

1. Косилова А.Г., Мещеряков Р.К Справочник технолога-машиностроителя Том 1. - Москва «Машиностроение», 2003. – 943 с.

## ПОЛУЧЕНИЕ ГРАНУЛИРОВАННЫХ КОМПОЗИЦИЙ ИЗ ТЕХНОГЕННОГО СЫРЬЯ

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Использование промышленных отходов в виде вторичного сырья – одно из главных направлений экономического развития и экологического благополучия страны. Согласно данным государственного доклада «О состоянии и об охране окружающей среды Российской Федерации в 2016 году» и федеральному классификационному каталогу отходов, утвержденным приказом Росприроднадзора № 242 от 22.05.2017, было выявлено, что ежегодно в России образуется около 30 тонн золошлаковых отходов (ЗШО). В связи с этим проблема использования техногенных материалов в производстве является актуальной.

Приблизительно 90% серы сегодня – побочный продукт нефтепереработки цветной металлургии. С экологической точки зрения соединения серы занимают одно из первых мест в мире по отрицательному воздействию на окружающую среду. Также, сера в виде пыли, может способствовать возникновению различных хронических заболеваний легких. Техническая сера устойчива к агрессивным средам и обладает высокой прочностью, а такие свойства, как водостойкость и гидрофобность, делают её идеальным материалом для использования в строительной промышленности [1 – 7].

Золошлаковые отходы являются достаточно дешевым продуктом. Применение ЗШО при изготовлении различного вида строительных материалов в существенной степени улучшает их физико-химические свойства. Кроме того, золошлаковые материалы по минералогическому и химическому составу практически идентичны минеральному природному сырью. Использование ЗШО в качестве основного сырья для