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DIMENSIONAL ANALYSIS OF A MANUFACTURING PROCESS

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Projection of a manufacturing process of a part requires to ensure manufacturing of design sizes [1]. The diametrical sizes in a manufacturing process are ensured directly but ensuring of the linear sizes depends on locating in an axial direction.

If a technological locating (a technological datum) in longitudinal direction does not coincide with a design datum it is required to determine a dimensional chain, which includes the required design size (it is denoted by a symbol K_i) and a technological size, which is ensured on the given manufacturing operation (it is denoted by a symbol $A_{j.m}$).

In the specified denoting i – is a number of the design size on a sketch or executive drawing; j – is a number of manufacturing operation on which a technological size $A_{j.m}$ is ensured; m – is a number of processing step of j manufacturing operation. Use of such denoting allows easily to define, when the required technological size is ensured.

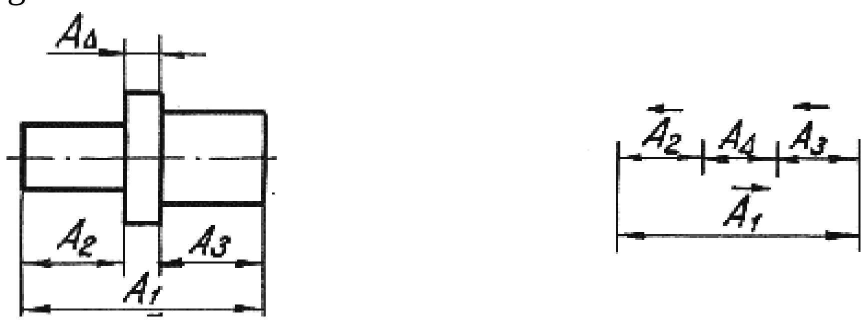
Closure of a dimensional chain [the closed consecutive arrangement of sizes (links)] is the first obligatory condition for calculations. Before calculations the next condition is checked – only one resulting (closing) dimension should be in a dimensional chain. Usually it is denoted by a symbol A_Δ. Resulting dimension is not ensured (is not manufactured) directly and can be fulfilled only as a result of execution (manufacturing) of other sizes in a circuit.

If for a resulting dimension its maximum permissible values (A_{max} and A_{min}) are known and it is necessary to fulfill these requirements – this resulting dimension is called as initial dimension, i.e. proceeding from it, it is necessary to calculate nominal (basic) sizes and deviations of all component dimensions of a chain.

Following stage of calculations is definition of character of all dimensions. As an increasing dimension understand a size, at which increase of it, the resulting or initial dimension is increased too.

As a decreasing dimension is named a size, at which increase of it, the resulting dimension is decreased on the contrary.

For simplification of procedure of definition of character of a component dimension any component dimension near to a resulting dimension (in Fig. 1 it is the size A_Δ) is analyzed, its character is defined (for example, in Fig. 1 the component size A_2 is decreasing size), and over a size an arrow is drawn, directed to the right (→) for increasing size, and to the left (←) – for decreasing.



a *b*

Fig. 1. The designer sketch (a) and the circuit of a dimensional chain for this sketch (b)

Then it is necessary to go in a direction of this arrow, and over other sizes arrow is drawn on their stroke. Their direction will tell to us character of other dimensions.

In an example in Fig. 1 the analyzed size A_2 is a decreasing link, therefore the arrow is drawn from right to left **(**←**)**. Direction of an arrow over sizes A_1 and A_3 shows character of other sizes: the size A_1 – is an increasing dimension, the size A_3 – is a decreasing dimension.

Calculation of a dimensional circuit consists of calculation of basic sizes and their limit deviations (upper and lower deviations) for all component dimensions, proceeding from construction or technological requirements. Two tasks distinguish:

1. Calculation of basic size and limit deviations of a resulting link in accordance to known basic sizes and limit deviations of component sizes – is inverse task (or checking calculation).

2. Calculation of limit deviations of all component dimensions in accordance to known basic sizes of all component dimensions of a circuit and the given (known) limit sizes of an initial link ($A_{\Delta\,max}$ and $A_{\Delta\,min}$) – is a direct task (design calculation of a dimensional circuit).

Last task is most often solved in technological calculations.

Let's consider a sketch of a part “pulley” (Fig. 2). On this sketch there are axial designer sizes, which are necessary for ensuring.

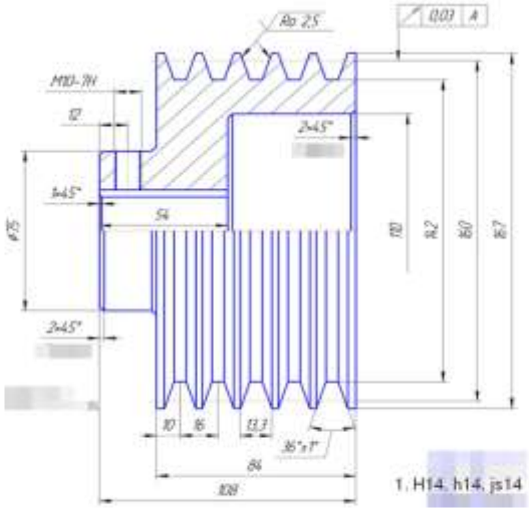


Fig. 2. Sketch of a part “pulley”

At master schedule execution the technological sizes $A_{j.m}$, which are ensured directly, are denoted in the lower part of a dimensional diagram of a manufacturing process (Fig. 3).

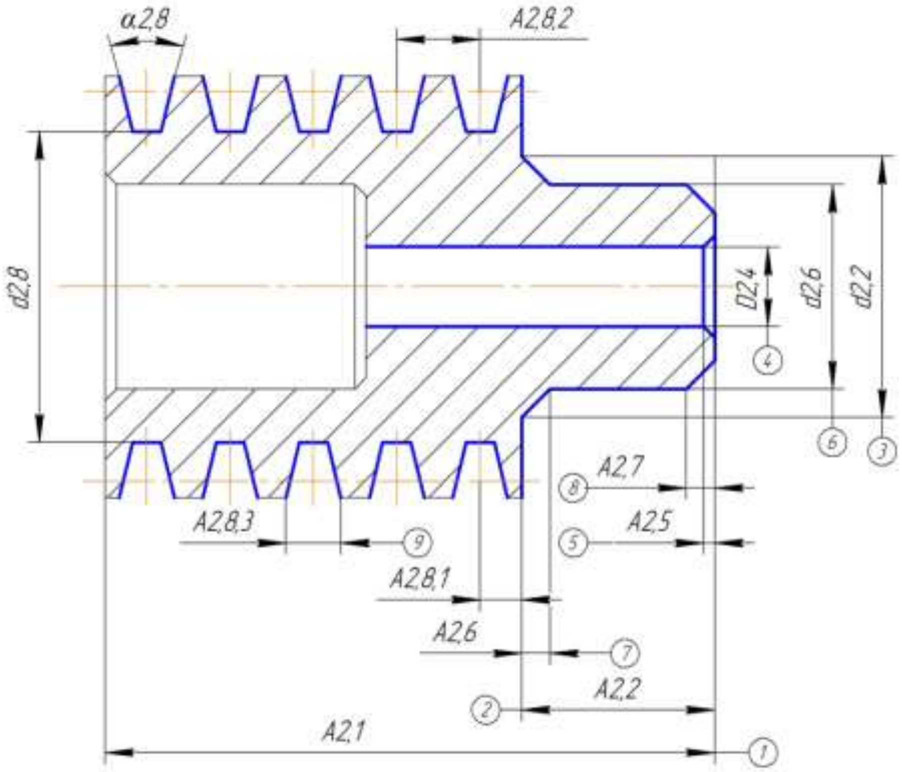


Fig. 3. Technological sizes ensured directly during machining of a part "pulley"

A dimensional diagram of a manufacturing process is drawn (Fig. 4). The axial designer sizes (K_i) from a sketch of a part (see Fig. 2) are denoted in the upper part, below – the technological sizes ($A_{j.m}$) which are ensured directly (see Fig. 3).

In the complex circuit it is visible that some designer sizes are not ensured directly, i.e. a technological size does not coincide with a designer size.

For example, for the designer size K_2 any technological size does not correspond. Therefore, it is necessary to select a dimensional circuit which includes this design size K_2 and technological sizes.

It should be satisfied two conditions: 1) the determined dimensional chain should be closed; 2) the determined dimensional chain should contain the least amount of sizes.

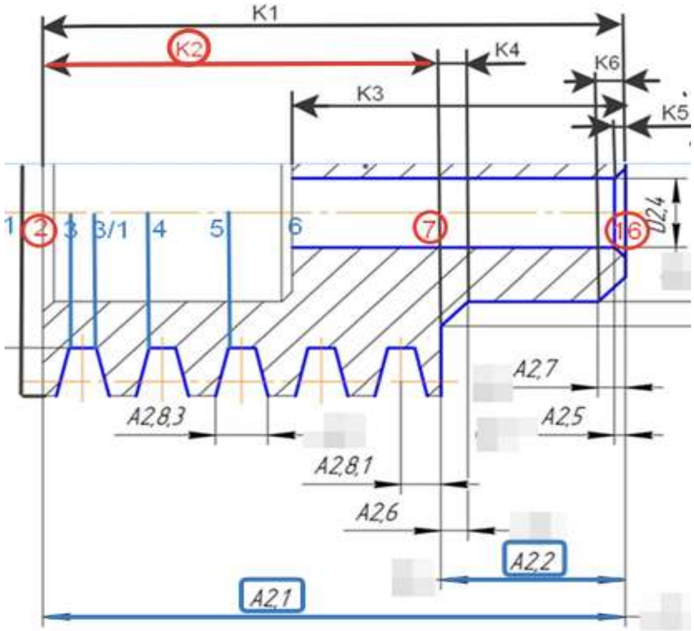


Fig. 4. Dimensional diagram of the manufacturing process of a part "pulley"

In the Fig. 5 the determined dimensional diagram for calculation of the technological sizes concerning the designer size K_2 is presented. Technological sizes A2.2 and A2.1 are denoted with its tolerances in the brackets.

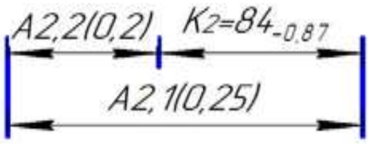


Fig. 5. Dimensional diagram containing the designer size K_2

In the determined dimensional chain character of each component link (of the technological sizes $A_{2.1}$ and $A_{2.2}$) is defined and possibility of the decision of a task is defined, i.e. how much precisely it will be necessary to ensure sizes $A_{2.1}$ and $A_{2.2}$.

For this purpose it is necessary, that the sum of tolerances of all component sizes ($\sum T_{A\,j.m}$) was less or equal the tolerance of a resulting link ($T_{A\Delta}$) (in our case of the designer size K_2 [T_{K2}]).

$$T_{K\,2} \geq T_{A\,2.1} + T_{A\,2.2}, \tag{1}$$

where $T_{K\,2}$ – is the tolerance of designer size K_2; $T_{A\,2.1}$ – is the tolerance of technological size $A_{2.1}$; $T_{A\,2.2}$ – is the tolerance of technological size $A_{2.2}$.

In a reference book the technologically permissible tolerances of sizes $A_{2.1}$ and $A_{2.2}$ in their machining are defined [1, 2], from the detail drawing – the tolerance of the designer size K_2. These tolerances are substituted in an inequality (1): $0.87 \geq 0.25+0.2$.

The inequality (1) is executed, therefore the problem is solved. If the inequality (1) is not executed, it is necessary to change the scheme of locating or to search a possibility for increase accuracy of machining of one or several technological sizes which are going into a dimensional chain. It will lead to increase of the cost price of a workpiece machining and to increase of probability of occurrence of invalid parts.

For more obvious execution of the dimensional analysis it is offered to use a method of graph of the technological sizes [1]. On the dimension diagram all surfaces of a part in an axial direction from left to right are numbered without passes and repetitions (Fig. 4, below of an axis of a part).

In the field of the graph-tree (Fig. 6) we plot digits of these surfaces in circles which are connected by the corresponding technological sizes (are specified by straight lines with designations $A_{j.m}$), by the designer sizes (are specified by curves lines with designations K_i), by the allowances (are specified by wavy lines with designations $z_{j.m}$,), where indexes specify number of manufacturing process and technological processing step of this process on which this allowance is removed.

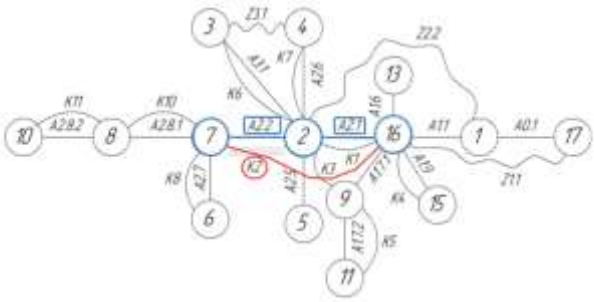


Fig. 6. Graph-tree of sizes and allowances of technological process

At correct assignment of the technological sizes on the graph-tree should not be the digits connected only by straight lines or only by curves.

If any circles are connected only by curves (in the Fig. 7 it is designer size K_8) – it means that such designer size is not ensured in a manufacturing process. It means that a technologist (a process man) has forgotten about necessity of its execution, therefore it is required to add a technological size.

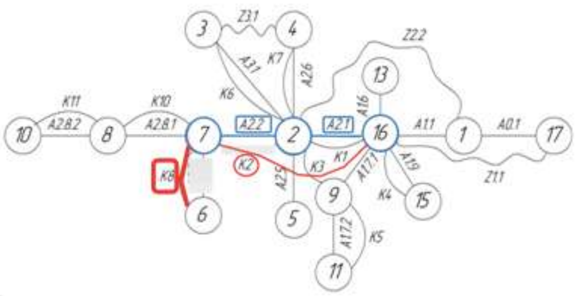


Fig. 7 Graph-tree of sizes of technological process with unensured designer size K_8

For above considered designer size K_2 in the graph-tree it is required to pass from number *16* to digit *7* through number 2.

On the left of main equation of a dimension chain the symbol of a resulting link A_Δ is written (in our example it is the designer size K_2). On the right in the equation symbols of component dimension (of technological sizes) (in our case of the technological sizes $A_{2.1}$ and $A_{2.2}$) are written.

If at go of graph-tree in direction of *counter-clockwise* a value of digit decreases, for example from *16* to *2***,** the plus sign is written, if it is vise versa, for example from *2* to *7* – the minus sign is written.

For the designer size K_2 the equation of a dimensional chain will be written:

$$K_2 = A_{2.1} - A_{2.2}.$$

Links of a dimensional chain with a plus sign are increasing links, with a minus sign – decreasing.

Change of locating is, very often, a difficult problem because of a configuration of a detail and its sizes, features of used attachments (clamping devices). Therefore it is necessary to define criterion on which it is possible to use originally assigned locating.

For this purpose it is offered to calculate the average tolerance for the technological sizes, using an inequality (1). For this case it is supposed equality of tolerances of all technological sizes, i.e. $T_{Aj.m} = \text{const} = T_{Ai}$. In this case

$$TA_i. = TK / n, \qquad (2)$$

where n – is an amount of component links in a dimensional circuit.

Calculated tolerance it is necessary to compare with a tolerance for a size corresponding to a basic value of the greatest technological size. If this calculated tolerance T_{Ai} in the table of tolerances corresponds to the eleventh (11) or lager grade of tolerance the task can be solved.

If calculated tolerance T_{Ai} corresponds to the ninth (9) or more exact grade of tolerance it is necessary to change locating (technological datum) without attempts to solve a dimensional circuit since in a workpiece machining the probability of deriving of reject (invalid part) is great.

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CONTACT LOADS ON SURFACES OF WORN OUT CUTTER IN STEEL MACHINING

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For calculation of a cutting tool strength, it is necessary to know not only component forces of cutting, but also distribution of contact loads on rake and flank surfaces [1-5]. This task is especially important for rough cutting by the worn out cutting tool. Wear on a flank surface leads to appearance of a chamfer on a flank surface (flank-land) and the big contact loads leading to a tool failure.

The method of a “section tool” is used for research of contact stresses distribution [1-5]. It is very labour-consuming and demands the use of rigid, special four-component dynamometer. Therefore research was carried out for defining the parametres of contact loads distribution which can be used for loading of cutting tool for calculation of cutting tool strength.

Research of force dependences was executed in turning a workpiece made from a steel 40X with hardness HB 220 and ultimate tensile stress