Algorithm for calculating the time of thermal pulse processing of small-sized high-precision parts

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Abstract. The thermal impulse method of deburring is one of the most promising methods for removing unwanted liquids formed on the surface of small-sized high-precision parts of electronic equipment at the stage of blade machining. The thermal impulse method of deburring and rounding of sharp edges is characterized by constant processing time and quality, subject to the normalized size of liquids. Such qualities can significantly increase the stability of the release of parts in time, and, thanks to this, successfully implement a system of operational scheduling of production. This article describes an algorithm for calculating the time for thermal pulse processing of small-sized parts of coaxial radio components. An example of a basic generalized calculation of the time spent on thermal impulse processing of typical parts using a Pulsar-VKF thermal impulse installation of various configurations is given. Taking into account the peculiarities of thermal pulse processing of parts of coaxial radio components, a method for calculating the batch size and thermal pulse processing time, subject to algorithmization, is developed, conditions and restrictions, input and output information for the algorithm are described. Formulas for calculation are given.

1. Introduction

The thermal pulse method of deburring is one of the promising methods for removing unwanted liquids formed on the surface of parts at the stage of blade machining. Undesirable liquids include burrs and sharp edges, the presence of which is unacceptable for technical requirements. Parts of electronic equipment are small-sized and high-precision. Parts manufactured by blade processing on automatic lathes have overall dimensions of Ø0.4 ÷ 16mm × 80mm, on milling machining centers - dimensions of up to 400mm × 400mm. They require the execution of sizes according to 7 ÷ 10 accuracy grades. One of the main reasons for the failure of electronic devices is defects in the manufacture of parts resulting from the shaping of their surfaces. Burrs make it difficult to assemble products, lead to damage caused to mating surfaces and wires, and ultimately to a violation of the performance of the device. Sharp edges of parts of electronic equipment are stress concentrators and contribute to the destruction of the parts themselves and contacting surfaces [1]. According to international and industry standards [2, 3], all workpieces must be descaled, burrs removed, sharp edges blunted. Insufficient preparation of the surface
of parts before coating (burrs, sharp edges, the presence of contamination) leads to deterioration of adhesion, the formation of build-ups on the surface of parts.

The thermal pulse method is based on thermophysical processes in which burrs and other unwanted liquids are removed by reflow, followed by the discharge of combustion products from the working chamber, preventing the condensation of oxides. The advantages of the method include flexibility, high productivity, combination of cleaning and finishing of surfaces and edges, the ability to process high-precision parts, including parts of electronic equipment. The disadvantage is the limitation of the size of liquids depending on the material and design features of the parts [4]. So, the maximum size of burrs for parts made of metals with low thermal conductivity is 0.3 mm, for parts made of highly heat-conducting metals - 0.1 mm. Such design features of parts as the presence of thin-walled elements also limit the maximum size of burrs, it should be no more than 1/6 of the minimum thickness of the part.

The use of the thermal impulse deburring method eliminates manual metalworking of parts, which reduces the time and cost of manufacturing parts, and eliminates the element of uncertainty associated with the human factor inherent in manual processing of parts. The thermo-pulse method of deburring and rounding of sharp edges is characterized by constant processing time and quality, provided that the liquid size is normalized [5, 6]. Such qualities make it possible to significantly increase the stability of the production of parts in time, and, thanks to this, successfully implement a system of operational scheduling of production [7-9]. This article describes an algorithm for calculating the time for thermal pulse processing of small-sized parts of coaxial radio components.

2. An example of calculating the time spent on thermal pulse processing of typical parts when using a thermal pulse Pulsar-VKF installation of various configurations

For thermal pulse processing of small-sized parts of radio electronic equipment, it is advisable to use thermal pulse Pulsar-VKF installations of Russian production by Alfa Steel in St. Petersburg. The design of these units is well developed, and the quality of processing and reliability are confirmed by the experience of practical use at industrial enterprises. At the same time, the cost of these installations is several times lower than the cost of imported analogues [5, 6].

As a typical part for calculating the time of thermal impulse treatment in Pulsar-VKF installations, a part has been adopted that has the overall dimensions of a typical part of electronic equipment - the body of a coaxial radio component. Parameters of this part: cylindrical part Ø22 mm, H = 18 mm, $V_d = 6840$ mm (Figure 1).

![Figure 1. Schematic representation of a typical small-sized part - the housing of a coaxial radio component](image)

According to the operating conditions of the Pulsar VKF thermal impulse installation, the effective working volume of the chamber is 0.65 of the actual volume of the chamber (taking into account the fixing devices and containers, the free required volume for filling the space between the parts with gas, the geometry of a typical part).

The processing cycle of one batch of parts is no more than 30 minutes and it consists of:

- 5-10 minutes to start from cold off state;
- 5-10 minutes placing typical parts in containers and fixing them in the working area;
- 1.5 minutes automatic processing cycle;
- 5-10 minutes to cool down and remove containers with parts from the working area.

Table 1 shows the parameters for calculating the processing time of a batch of typical parts in Pulsar VKF thermal pulse units of various configurations.

**Table 1.** The parameters for calculating the processing time of a batch of typical parts in Pulsar VKF thermal pulse units of various configurations.

| Model   | Working chamber size, mm | Actual volume / Working volume, mm³ | The number of processed typical parts for 1 processing cycle | The number of processed typical parts per shift |
|---------|--------------------------|--------------------------------------|------------------------------------------------------------|-----------------------------------------------|
| VKF 3.150 Ø120 x H170 | Vf = 1 922 000 Vw = 1 249 300 | 182                                   | 4368                                                        |
| VKF 3.250 Ø220 x H250 | Vf = 9 500 500 Vw = 6 180 300 | 903                                   | 21672                                                      |
| VKF 3.350 Ø310 x H340 | Vf = 25 650 000 Vw = 16 672 500 | 2500                                  | 60000                                                      |
| VKF 3.450 Ø400 x H350 | Vf = 44 000 000 Vw = 28 600 000 | 4180                                  | 100320                                                     |

The calculations in Table 1 are made according to the following formulas:

The actual volume of the chamber of the thermal impulse installation, mm³:

\[ V_f = \pi r^2 \cdot H \]  

(1)

where \( r, H \) – radius, part height, mm.

The working volume of the chamber of the thermal impulse installation, mm³:

\[ V_w = V_f \cdot k \]  

(2)

where \( k \) – coefficient of the effective working volume of the chamber, \( k = 0.65 \).

The number of processed standard parts per 1 processing cycle, pieces:

\[ N_d = \frac{V_w}{V_f} \]  

(3)

The number of processed standard parts per shift, pieces:

\[ N_{ws} = N_d \cdot N_{ch} \cdot T_{ws} \]  

(4)

where \( N_{ch} \) – number of machining cycles per hour, \( N_{ch} = 3 \), \( T_{ws} \) – number of hours per shift, \( T_{ws} = 8 \).

In this example, the time of thermal pulse treatment was calculated based on the averaged data on the effective working volume of the chamber, taking into account the fixing devices and containers, the free required volume to fill the space between the parts with gas, and the geometry of a typical part. For a more accurate calculation of the batch processing time for thermal pulse processing, which is applicable when calculating the schedule of work centers in production, it is necessary to carry out additional formalization and supplement the calculation with updated data.

3. Algorithm for calculating the size of a batch of parts to be loaded into a thermal impulse installation and the time of thermal impulse processing of parts for a production program

The algorithm for calculating the batch size for loading parts into a thermal impulse unit and the time for thermal impulse processing of parts for a release program is designed to establish the size of the batch for loading parts into a thermal impulse unit in the operating chart, taking into account the permissible deviation, establishing the actual batch size for loading parts into a thermal impulse unit.
depending on the batch size parts coming from the previous operation, as well as determining the time of thermal impulse processing of parts to determine the output, the shift factor for this operation, as well as to calculate the schedule within the program for coordinating the production of products [10-14]. The calculation of the batch size for loading parts into a thermal impulse installation and the time for thermal impulse processing of parts for a release program can be performed using the formulas below. The calculation is based on the following conditions and restrictions:

- parts are high-precision, easily damaged, small-sized, so they will be placed in a tooling with a lid in one layer so as to provide gas access to all surfaces;
- placement of different parts in one load with separation by a partition is not provided, as this can increase the downtime due to waiting for the next parts for processing, reducing the size of the last batch of loading by more than 25% after evenly dividing the total amount into batches of acceptable size. It allows one to ensure the quality of processing; it is compensated by the placement of ballast, separated by a partition.

Input information is:
- overall dimensions of parts obtained from the CAD system, mm;
- diameter of the bottom of the chamber of the thermal impulse installation, obtained from the technical documentation of the thermal impulse installation, mm;
- wall thickness of the tooling for placing parts, obtained from the CAD system, mm;
- time for processing one batch of parts, obtained by the timing of the operation, minutes.

The output information is:
- maximum number of parts in a batch of loading into a thermal impulse installation, pieces;
- number of parts in the batch of loading into the thermal impulse installation, pieces;
- processing time of parts in a thermal impulse installation, minutes.

Since the parts are placed in one layer, it is necessary to calculate the area occupied by one part and the number of parts to be placed on the bottom area of the tooling, so as to provide access of the gas-air mixture to all surfaces of the parts.

The areas of parts occupied when placed on different surfaces are calculated using the formulas:

\[ S_{wl} = W \cdot L, \]  \hspace{1cm} (5) 

where \( S_{wl} \) – area of the part occupied when placed in width and length, mm\(^2\); \( W \) – part width, mm; \( L \) – part length, mm.

\[ S_{hl} = H \cdot L, \]  \hspace{1cm} (6) 

where \( S_{hl} \) – area of the part occupied when placed in height and length, mm\(^2\); \( H \) – part height, mm; \( L \) – part length, mm.

\[ S_{wh} = W \cdot H, \]  \hspace{1cm} (7) 

where \( S_{wh} \) – area of the part occupied when positioned in width and height, mm\(^2\); \( W \) – part width, mm; \( H \) – part height, mm.

The area occupied by one part in a thermal impulse installation, mm\(^2\), is calculated by the formula:

\[ S_d = \max(S_{wl}; S_{hl}; S_{wh}) \cdot (1 + k_{fs}), \]  \hspace{1cm} (8) 

where \( k_{fs} \) – coefficient of the inter-part space to ensure free access of the gas-air mixture to the surfaces of the part and loose fit; let us take \( k_{fs} = 0.05 \).

The maximum number of parts in a batch placed in a thermal impulse installation, pieces, is calculated by the formula:

\[ N_{dm} = \frac{\pi (D_{lu} - T_m)(1 - k_{fs})}{S_d}. \]  \hspace{1cm} (9)
where $D_{tu}$ – diameter of the bottom of the chamber of the thermo-impulse installation, mm; $T_{sn}$ – wall thickness of the tooling for placing parts, mm.

The number of parts in a batch placed in a thermal impulse installation, pieces, depends on the size of the batch of parts arriving for processing, and is calculated by averaging the size of the batch of loading parts, taking into account the permissible deviation of the size of the batch of loading by the formula:

$$N_d = \frac{N_{di}}{\max\left(\frac{N_{di}}{N_{dm}} - N_{dm \cdot 0.75}\right)},$$

where $N_{di}$ – number of parts arriving for thermal pulse processing from the previous operation, pcs.

The time of thermal impulse processing of parts for the release program is calculated by the formula:

$$t_{tp} = \sum_{i=1}^{n} \left(\frac{N_{pi}}{N_{di}}\right) \cdot t_1,$$

where $N_{pi}$ – planned number of parts of the $i$-type of the nomenclature, pieces; $N_{di}$ – number of parts of the $i$-type of the nomenclature in the batch placed in the thermal impulse installation, pieces; $t_1$ – processing time of one batch of parts in a thermal pulse installation, according to the results of the timing of the thermal pulse processing operation – $t_1 = 20$ minutes.

4. Conclusion
To calculate the number of parts placed in the thermal impulse installation and the time of thermal impulse processing of parts for the release program, a calculation method has been developed that is subject to algorithmization. Calculation of the batch size for loading parts into a thermal impulse unit and the time for thermal impulse processing of parts for the release program is intended to establish the size of the batch for loading parts into a thermal impulse unit in the operating chart, taking into account the permissible deviation, establishing the actual size of the batch for loading parts into a thermal impulse unit depending on the size of the batch of parts coming from the previous operation, as well as determining the time of thermal impulse processing of parts to determine the output, the shift ratio for this operation, as well as to calculate the schedule as part of the product coordination program.

The calculation is based on the following conditions and restrictions:
- parts are high-precision, easily damaged, small-sized, so they will be placed in a tooling with a lid in one layer so as to provide gas access to all surfaces;
- placement of different parts in one load with separation by a partition is not provided, as this can increase the downtime due to waiting for the next parts for processing, reducing the size of the last batch of loading by more than 25% after evenly dividing the total amount into batches of acceptable size. This allows one to ensure the quality of processing; it is compensated by the placement of ballast, separated by a partition.

Input information is:
- overall dimensions of parts obtained from the CAD system, mm;
- diameter of the bottom of the chamber of the thermal impulse installation, obtained from the technical documentation of the thermal impulse installation, mm;
- wall thickness of the tooling for placing parts, obtained from the CAD system, mm;
- time for processing one batch of parts, obtained by the timing of the operation, minutes.

The output information is:
- maximum number of parts in a batch of loading into a thermal impulse installation, pieces;
- number of parts in the batch of loading into the thermal impulse installation, pieces;
- processing time of parts in a thermal impulse installation, minutes.

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