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Manufacturing Technology of Multilayer Metal Filters

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Abstract. The article presents methods for obtaining micro-holes in the manufacture of fine metal filter elements. The analysis of the results of experimental studies of filter samples with holes made by electron beam and electroerosion perforation methods is carried out. The advantages of using multilayer structures in the manufacture of filters are substantiated. The research works carried out contribute to improving the manufacturability of products of new generations of technology, which is important for mechanical engineering.

Introduction

In modern conditions, the machine-building industry is everywhere switching to flexible structural production based on competitive designs and technologies with a high level of adaptation to consumer needs. This principle is used in the manufacture of complex products in the aviation and space industries, where the production program refers to small-scale (and in pilot production - to a single) production.

In the aerospace industry, the main criterion for the quality of a product is its reliability. One of the key factors ensuring the required level of reliability of liquid rocket engines is the cleanliness of internal cavities and hydraulic paths. The ingress of foreign particles in the fuel components (in some cases cryogenic) into the engine units often leads to abnormal situations in the operation of the rocket engine, the occurrence of high-temperature harnesses, fires and accidents of aircraft. The most effective way to protect internal cavities and aggregates from contamination is to install metal filters in front of critical elements of the rocket engine design, such as automation and control units, a gas generator, a combustion chamber, etc. Structurally, filters are, in most cases, cylindrical, conical, spherical parts with a large number of holes up to 1 mm in diameter. Examples of fine metal filters are shown in Fig. 1.

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Fig. 1. Typical designs of fine metal filters

During operation as part of aircraft filters are subjected to significant dynamic and temperature loads. In order to achieve the required level of strength characteristics, filter elements are made mainly of hard-to-process metal sheet materials. The thickness of the sheet determines not only the mechanical strength, but also the resistance of the filter to vibration loads. However, with increasing thickness, such indicators as the mass of the product, its overall dimensions, and the hydraulic resistance of the element grow[1; 2; 3].

In aircraft engines, it is necessary to achieve a minimum mass of parts. In this case, the filter element must provide the maximum filtering capacity, estimated by the ratio of the cross-sectional area of the channels to the total area of the working surface of the filter. In the manufacture of parts installed in the fuel lines of aircraft, high requirements are imposed on the accuracy of the holes and the quality of the surface layer. This limits the use of traditional methods of obtaining holes.

To solve the problem of obtaining high-quality filters of heat engines with a high consumption of gas-liquid (in some cases cryogenic) media, the development of new technological modes and methods of high-tech combined processing is required. At the same time, it is necessary to find a solution to the problems of ensuring high technological performance of the process with resource-saving firmware of a large number of small diameter holes.

Methods of manufacturing filter elements

Traditional drilling is impractical for holes with a diameter of less than 1 mm due to the considerable complexity of the process, which allows to obtain only a circular cross section. When using this method, burrs form on the edges of the holes, an error in the arrangement of channels is possible.

Promising methods of manufacturing solid metal filters are electroerosion and combined group processing, which make it possible to obtain holes of any cross-section shape with a curved axis, with a minimum width of the bridge, high accuracy of the location and geometry of the holes. Also, the advantage of the methods is the possibility of simultaneously obtaining up to 500 deep holes. The disadvantages of the methods are:

- tool electrode wear;
- high complexity and complexity of manufacturing the electrode-tool;
- high profile roughness (Ra = 1.25-2.5 microns);
- small productivity [4; 5; 6].

There are known methods of electrochemical processing and combined stitching of thin metal plates (up to 0.8 – 1.0 mm) using dielectric templates, which provide high performance and the possibility of obtaining holes of any cross-section. The advantages of these types of processing are:

- no burrs and deburring;
- the ability to adjust the geometry of the edge;
- high accuracy of the location and quality of the surface layer of the holes (Ra = 0.32 – 0.63 microns);
- the possibility of making holes at an angle.

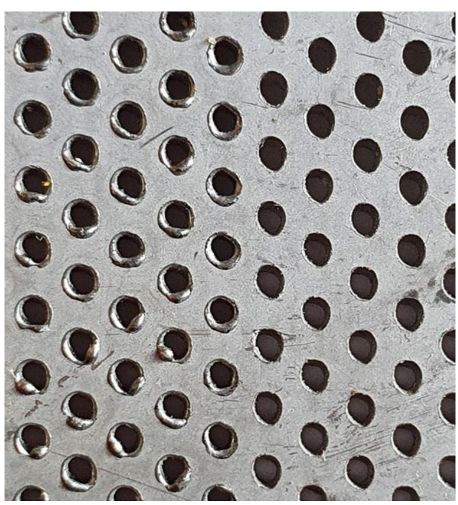
The disadvantages of the methods are:

- restrictions on the possible thickness of the workpiece (optimally no more than 0.8 mm);
- the need to introduce additional operations to delete templates;
- the complexity of applying and combining templates;
- with a two-way approach, errors in the alignment of the oncoming channels [5; 6; 7].

In the aerospace industry, in the manufacture of solid filters, high-performance beam methods have become the most widespread, allowing up to 3000 holes with a minimum diameter of 0.15-0.2 mm per minute, with high positioning accuracy. The disadvantages of the method are:

- the possibility of obtaining holes only of circular cross-section with a straight axis;
- the presence of an error (taper) in the depth of the hole;
- melting of the edge of the holes due to the impact of beam pulses;
- uneven radius of rounding of the edges of the hole;
- the process of electron beam processing takes place in a vacuum, the creation of which takes a long time (30-40 minutes) in the absence of a gateway, which increases the manufacturing cycle of the part;
- the appearance of splashes of molten metal on the treated part of the holes – the so-called burr, the removal of which is not guaranteed and is dangerous during the operation of the product [8].

Figure 2 shows a sample filter with holes made by electron beam processing.



a b

Fig. 2. A fragment of the filter wall from 12H18N10T steel after an electron beam treatment with a thickness of 1.0 mm. The diameter of the hole is 0.6 mm
a) from the side of the beam entrance; b) after removal of the burr by chemical-mechanical treatment with metal granules

Fig. 3 shows the results of measurements of the burr value obtained after piercing round holes with a diameter of 0.4 mm with several pulses at different filter wall thicknesses.

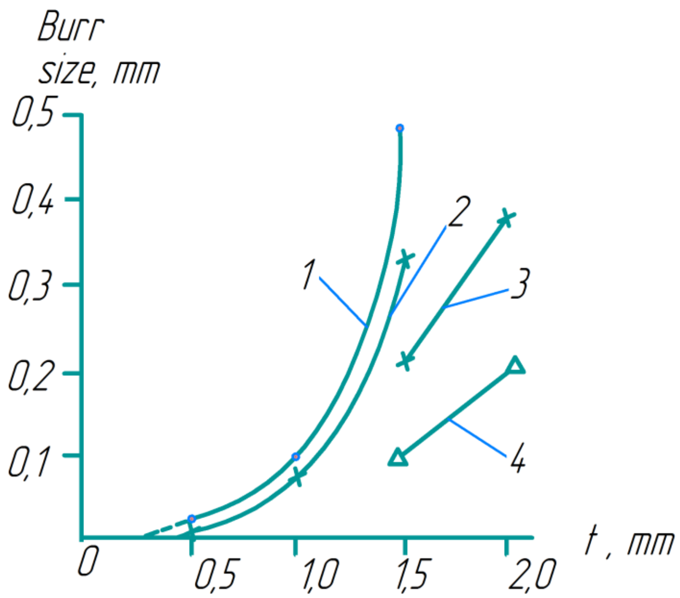


Fig. 3. The change in the size of the grate from the thickness (t) of the walls after flashing the electron beam for 12H18N10T steel
1 – the average width of the burr layer at the entrance of the beam; 2 – the average height of the burr layer at the entrance of the beam; 3 - the average width of the burr layer at the output of the beam; 4 - the average height of the burr layer at the output of the beam.

Fig. 3 clearly shows the dependence of the burr value on the thickness of the processed material. During the experiments, the burr was not guaranteed to be observed with a layer thickness of less than 0.35 – 0.4 mm, which can be considered the boundary value of the thickness of the initial sheet in the manufacture of a multilayer filter.

The formation of deburring affects the hydraulic characteristics of filters, which are a critical parameter. The separation of molten metal particles during operation can negatively affect the performance of the product as a whole. Various types of combined treatment, such as the chemical-abrasive method, are traditionally used to remove the deburring. The use of finishing operations increases the overall labor intensity and the filter manufacturing cycle, which is a disadvantage.

An analysis of the applied methods of manufacturing metal filters shows that obtaining channels with a stable geometry in processing depth, accurate positioning and a high-quality surface layer is more effective when processing thin-walled materials. Consequently, the transition to multilayer structures allows us to solve most of the problems of a technological nature - optimization of hole stitching methods, production of channels of the required shape and flow trajectory of the filtered medium, exclusion of deburring operations, stabilization of the thickness of the filter layers.

The technology of manufacturing a multilayer filter

Multilayer filter designs have significant advantages over solid products, namely:

- the total depth of the processed holes is reduced, which expands the technological capabilities of beam and combined processing methods, in particular, it allows to intensify the process while increasing the accuracy and quality of the surface layer;
- reducing the thickness of each layer changes the conditions for the mass removal of material from the recesses, especially when stitching holes of small cross–section, creates conditions for leveling the profile according to the depth of the holes, and for filters - the ability to increase the density of channel placement and the filtering ability of the product;
- with beam processing methods, it is possible to eliminate the problems of the occurrence of molten metal particles (burr) on the surface of the parts by choosing the optimal layer thickness.

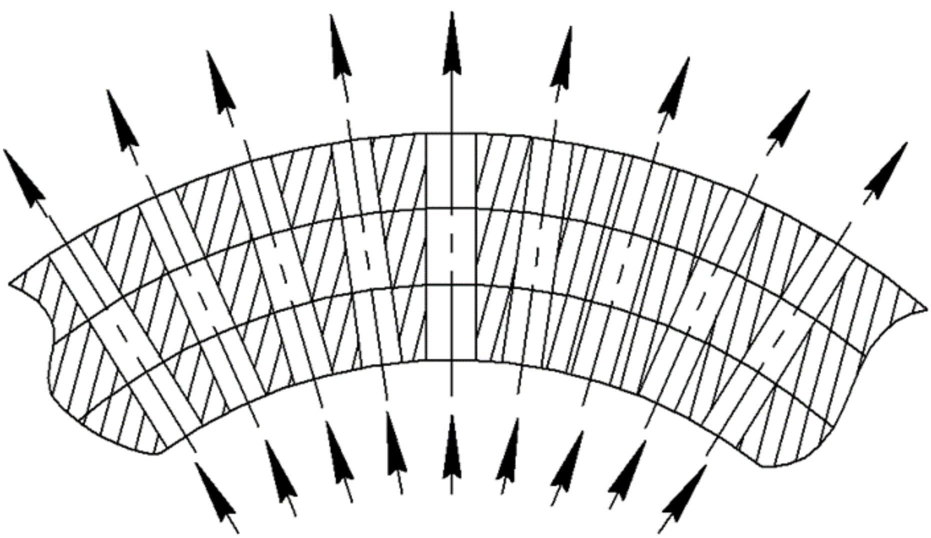


Fig. 4. Diagram of the radial flow of the filtered medium

Figure 4 shows the scheme of radial flow of the working medium used in most filters through circular channels without shifts of the axis of the flowing jet at the interface of layers (the product is multilayer). When using a multi-layer filter design, in which the thickness of the layers ensures the preservation of the geometry and operating conditions of the filters (rigidity, lack of fluid flow between the layers) during operation, it is possible to effectively apply high-performance beam processing methods and avoid the appearance of deburring.

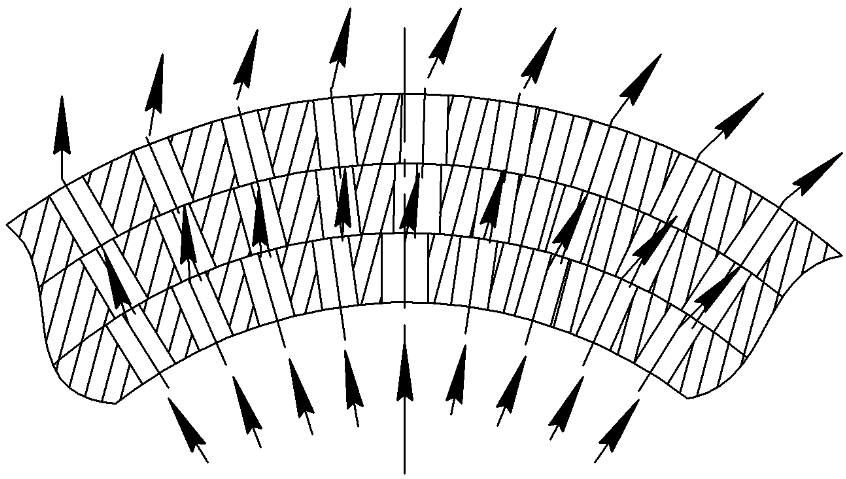


Fig. 5. Flow diagram of the filtered medium through channels with axis shift at the boundaries of layers

The flow diagram of the filtered medium presented in Fig. 5 through the channels of a multilayer filter with a shift of axes at the boundaries of the layers clearly shows the possibility of changing the radial direction of the flow of the cleaned liquid to a curved (tangential, spiral, helical, etc.) with an adjustable angle of attack of the jet, which provides a shock-free flow output, eliminating pressure losses due to rotation and shock expansion of the jet, which reduces the consumption indicators of the product

The developed technology for manufacturing a multilayer filter element is as follows: through holes are made in a metal strip with a thickness of 0.15 mm to 0.4 mm using beam or combined processing methods. In this case, the position of the axes of all holes is uniformly shifted in the intended direction of subsequent winding by the amount of elongation of each subsequent layer of the strip. This value is determined due to the circumference of each subsequent layer and the increasing diameter of the filter during the winding process. Then the strip is wound onto the housing with the application of a tension force in the direction of winding until the axes of the base holes coincide and each layer is fixed with screws in the base holes made in the extreme rows of each layer. After the layers are fixed by soldering at the ends, the screws from the base holes are removed and the filter is removed from the housing [9].

In addition, a number of advantages from the use of multilayer metal filters in heat engines in comparison with other products have been identified:

1. Stability of operation in conditions of prolonged vibrations.
2. A high level of resistance to low-frequency and high-frequency vibrations, providing normalized fatigue strength of products.
3. The absence of deburring operations in the area of piercing holes using high-performance beam processing methods, which reduces the overall complexity of manufacturing filters.
4. Intensification of consumable characteristics of products by increasing the accuracy and stability of channel sizes along the length of the holes, which allows to increase the density of channel placement

It should be noted that multilayer structures require the inclusion of a filter assembly operation from a sheet in the manufacturing process, where it is necessary to use a removable or permanent frame to give the object the desired geometric shape. This leads to an increase in the complexity of manufacturing multilayer filters, which, however, is insignificant compared to the advantages obtained when processing thin layers of the workpiece.

Summary

For engines of a new generation of aviation and rocket and space technology, it is important to create effective high-performance filters that ensure the required level of cleanliness of working fluid, which in turn is a determining factor in assessing the reliability of the product. The results of the work indicate that the transition to multilayer filter designs allows us to solve most of the problematic issues that limit the improvement of products. In particular, the use of multilayer metal filters can effectively increase the consumption characteristics of products, reduce the size and weight of products, eliminate the appearance of deburring and eliminate the time-consuming operation to remove it.

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