Stampless fabrication of sheet bars using disposable templates

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Abstract. The article is devoted to the new method of small-scale fabrication of sheet bars. The procedure is performed by using disposable overlay templates, or those associated with a sheet, which parameters are obtained directly from the drawing. The proposed method used as a substitution of die cutting enables to intensify the preparatory technological process, which is particularly effective when launching the market-oriented items into production. It significantly increases the competitiveness of mechanical engineering and creates the conditions for technical support of present-day flexible production systems.

1. Introduction

The cost of a cutting die is economically justified if the production program assumes the fabrication of tens or hundreds of thousands of identical thin sheet bars. The modern flexible production systems require a limited number of bars, and their fabrication carried out by using cutting dies is sometimes unprofitable, taking much time for manufacture and finalization. The available technological methods of fabricating small lots of sheet bars are quite labor-intensive and applicable only for manufacturing products with simple contours and limited sheet thickness (primarily, from 0.1 to 1.0 mm).

To separate the sheets of less than 1.0 mm in thickness, the new method of shape creation has been devised which involves the use of disposable templates with contours of various complexity. To implement this method, it was necessary to work out the scientific principles and technical means of their application by the control of local processing, based on unilateral (or bilateral) disposable dielectric and metal templates, regulating the parameters of primary and ancillary electric fields. As a result, new templates have been designed, including those having conductive layers connected to voltage source [1-3]. By this method it is possible to obtain the bars of required accuracy during separation of sheet materials having constant (variable) thickness, or various workability of their segments. Such products include the components obtained from sheets (rather than by stamping) of various thickness, and also the parts made from sheets having areas of various workability (e.g. by soldering or welding of homogeneous or heterogeneous materials). An acute need for such components is caused by the present-day development of flexible production systems, especially, small enterprises manufacturing diversified products.

2. Technological schemes of material separation using the disposable templates

Figure 1 shows the initial state of the system, preceding the material separation, with a unilateral (Figure 1a) or bilateral (Figure 1b) location of templates, one of which is a dielectric one.

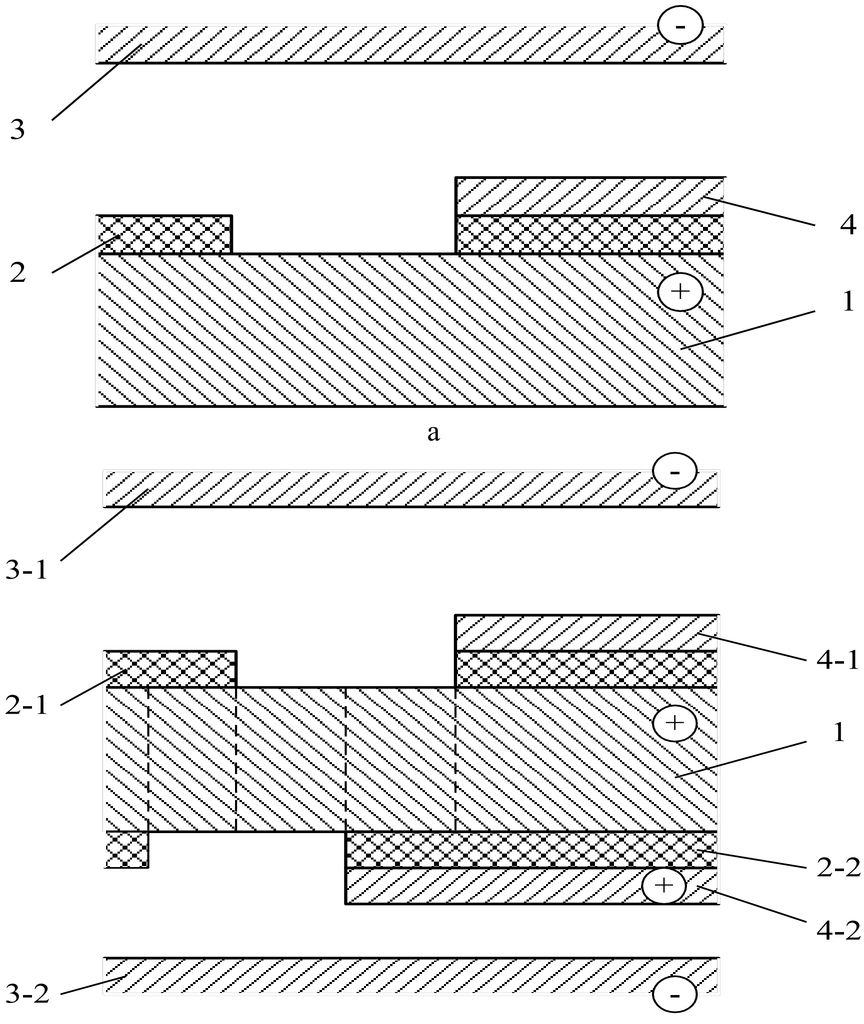

Figure 1. A scheme of material separation using the disposable templates:
a – unilateral processing; *b* – bilateral processing; 1 – a bar; 2 – a dielectric template; 3 – an EDM cathode; 4 – a metal template.

The bilateral location of templates (2-1; 2-2 and 4-1; 4-2) makes it possible to double the thickness of a sheet, available for separation, increasing it to 1.0…1.2 mm. This requires the use of two EDM cathodes (3-1 and 3-2). The displacement of templates, as shown in Figure 1b, enables matching of the skewed slots, formed on both sides of a sheet bar, and helps to control the position of the separation plane by energizing the metal templates (4, as shown in Figure 1a and 4-1; 4-2, as shown in Figure 1b). This provides the possibility of obtaining skewed side walls and openings with a curvilinear axis, passing through the bar and having one-way outlet openings

3. Technological modes

Table 1 presents various technological modes for fabricating sheet metal bars, using disposable dielectric templates, shown in Figure 1.

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Table 1.Technological modes.

Length of the contour to be cut, mm	Thickness of the dielectric template, mm	Initial inter-electrode gap, mm	Electrode voltage, V	Speed of electrolyte pumping, m/s	Note
up to 20	up to 0.2	0.15...0.2 (h_2=0, h_3=0)	8...10	1...3	Unilateral processing
	0.2...0.4	0.15...0.3 (h_2=0, h_3=0)	8...10 10...12	1...3 2...4	Bilateral processing
	0.4...1.0	0.5...0.6	10...12	2...4	
20-50	up to 0.2	0.2...0.25 (h_2=0, h_3=0)	10...12	2...3	Unilateral processing
	0.2...0.4	0.2...0.3 (h_2=0, h_3=0)	10...12	2...3	Bilateral processing
	0.4...1.0	0.5...0.7	12...15	2...4	
over 50	up to 0.2	0.25...0.3 (h_2=0, h_3=0)	10...12	2...3	Unilateral processing
	0.2...0.4	0.25...0.3 (h_2=0, h_3=0)	12...15	22...4	Bilateral processing
	0.4...1.0	0.7...0.8	12...15	3...4	

If the anode process requires the separation of sheets having constituent segments of various workability, it is necessary to set the technological modes, providing equal time of anode dissolution for all constituent materials. It is most feasible in cases whenever the sufficiently precise data related to electrochemical equivalents of alloys are known, and the initial constancy of inter-electrode clearance value is available. In these cases, it is possible to accelerate or retard the process of local anode dissolution depending on specified parameters for constituent fragments of bars, as well as to obtain the high-precision bars composed of heterogeneous materials.

The detailed recommendations on the selection of parameters for various technological modes are presented in [4, 5].

The results of the estimated technological modes help to design the procedure for the technological process, which includes:

- selection of the medium suitable for anode dissolution of all the constituent materials of the bar;
- setting of the medium pumping speed;
- calculation of the medium pressure at the inlet of the inter-electrode gap;
- electrode voltage selection for types of materials subjected to processing, in consideration of the properties of all bar segments;
- selection of the value of voltage loss from manuals;
- selection of the electrochemical equivalent ;
- calculation of voltage at bar segments;
- creation of the technological scheme of processing performed by still electrodes (i.e., unilateral and bilateral types of processing), selection of the template pattern, its type of manufacture, position and connection to power supply.

4. The area of the surveyed method application in fabricating sheet bars

Table 2 presents the results of feasibility study obtained from implementation of the surveyed method for manufacturing the batches of bars (up to 100 items) from metal sheets (up to 1 mm in thickness).

Table 2. Technical and economic parameters of electrochemical template-based sheet separation [4].

Designation	Original sheet		Production time, min	Tolerance, mm	Roughness of the cut, R_a, μm	Edge finishing
	Material	Thickness, mm				
Screen filters with openings, 0.02×0.02 mm	Heat-and rust-resistant steel	0.08	1...2	0.02	0.32	Not required
Slats	Brass	0.15	1 ... 2	0.02	0,63	Not required
Stator plates	Transformer steel	0.35	2 ... 3	0.03 ... 0.04	0.63 ... 1.25	The smoothing of the rounding radius of the exit edge
Edge strips	Constructional steel	0.5	4 ... 5	0.05 ... 0.1	0.63	Not required
Inserts (bilateral processing using the dielectric and metal templates)	Alloy steel	0.85	6 ... 7	0.7... 0.8 (0.02...0.04 (after calibration)	0.63	Calibration of openings (up to the 5th degree of precision)

In recent years, the extensive study dealing with electrochemical and combined separation of sheet metal materials has been conducted in Russia. The scientific works touch upon processing of bars with variable thickness. The new methods and devices (mainly developed by Voronezh scientific school) (patents [1-3]) provide the basis for advancement in research and solution of problems related to effective separation of metal materials with the most common sheet thickness (up to 1.0…1.2 mm) in small-scale bar fabrication. Patent 2257981 [1] solves the task by means of the proposed new method of electrochemical sheet bar processing using the dielectric templates. In this procedure, the processing is performed in flowing electrolyte using the tools, connected to the source of DC power supply, with a bar acting as an anode. The novelty of the method consists in the following. In the first part of the procedure, one of the EDM electrodes is connected to the negative pole of power supply, and the electrochemical processing is implemented through the stencil located on the bar (namely, at the EDM electrode side), up to a depth of 0.75…0.8 of the bar thickness. Further, at the second stage, the electrochemical processing is performed with disconnecting of the first EDM electrode and connecting of the second one, until obtaining the separating cavity of the size equal to the sheet thickness.

To conduct the electrochemical processing, the stencils are installed coaxially relative to the position of the cavity being processed. The template being used in processing by the first EDM electrode has the operating contour resembling that of the bar. In turn, the second stencil has the operating contour copying that of the cavity, and corresponding to the pattern, specified by the drawing. In this case, the thickness of the first template is half that of the second one.

The separation scheme is presented in Figure 2. Prior to processing, conductive sheet bar 1 (as shown in Figure 2), having thickness t, is supplied with the dielectric template (thickness – t_{T1}, contour size – H_{T1}), and stencil 3 (thickness – t_{T2}, contour size – H_{T2}), equal to preset width of the separation cavity. Thickness t_{T1} of the first template is half the corresponding thickness t_{T2} of the second stencil. EDM electrodes 4 and 5 are located at a distance of S_0 from the bar. This is the initial position for the bar, the templates and the EDM electrodes.

Figure 2 b represents the position and the dimensions of the cavity after completing the first stage of processing. At the end of the first processing stage, the cavity depth of bar 1, processed with electrode 4, equals (0.75…0.8) h. The size of the cavity contour is H_{T2}, due to broadening ΔH.

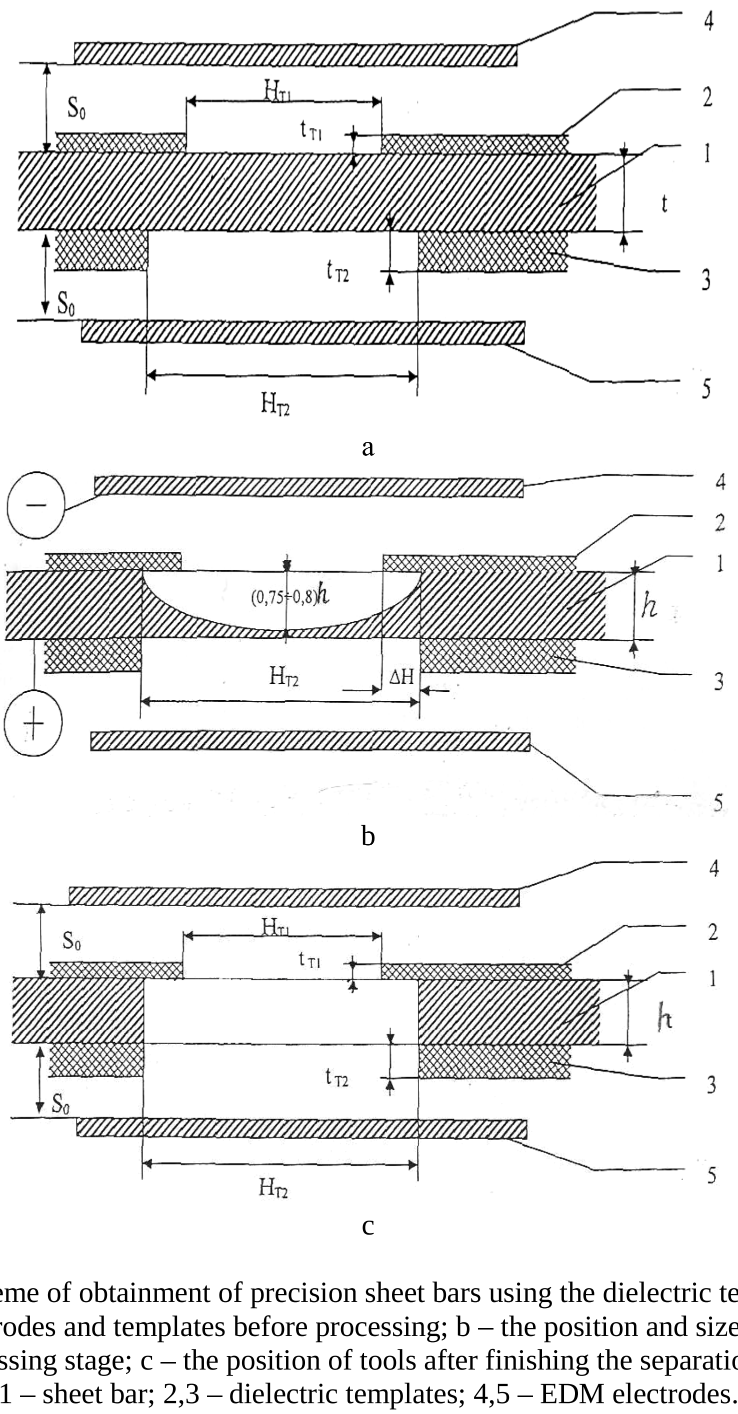

Figure 2. A scheme of obtainment of precision sheet bars using the dielectric templates: a – the adjustment of electrodes and templates before processing; b – the position and size of the cavity at the end of the 1st processing stage; c – the position of tools after finishing the separation zone processing. 1 – sheet bar; 2,3 – dielectric templates; 4,5 – EDM electrodes.

Figure 2 demonstrates the completion of the second stage of processing, performed by connecting EDM electrode 5 to the negative pole of power supply, provided that EDM electrode 4 is disconnected. In view of the small thickness of the cavity part, unprocessed after the first stage of piercing, and the doubled thickness of the second stencil, as compared with the first one, the size of the opening contour (as viewed from the side of template 3) is identical to size H_{T2} of the opening, predefined by the drawing, as well as to the size of the processed fragment (as viewed from the side of template 2).

The time of the first (τ_1) and the second (τ_2) processing stages is calculated according to the following formula:

$$\tau_1 = \frac{\left(\left[(0.75 \div 0.8)h + S_0\right]^2 - S_0^2\right)\gamma}{2\alpha\eta\chi(U - \Delta U)},$$

$$\tau_2 = \frac{\left[(0.2h + S_0)^2 - S_0^2\right]\gamma}{2\ \alpha\ \alpha\ \eta - \chi\Delta(U)},$$

where h – bar thickness; S_0 – initial gap between the processed bar surface and the EDM electrode; α – electrochemical equivalent of the material to be processed; η – current output; χ – electrolyte conductivity; γ – bar material density; U – electrode voltage; ΔU – voltage loss.

According to patent 2275279 [3], the goal of the invention is to obtain the vertical or special cutting profile, which increases the accuracy of sheet material separation by local template-based anode dissolution. To achieve this goal, the amount of electricity, applied to the metal template for creating the vertical cutting profile, is determined by the following dependence:

$$Q = \gamma h L \Delta H / 2\alpha,$$

where Q – the amount of electricity; h – the thickness of the bar; L – the length of the bar contour; ΔH – inverse broadening.

The proposed method is implemented according to the scheme, presented in Figure 3. To obtain a precision part with the desired inclination of the side wall (e.g. vertical or curvilinear), dielectric template 2 is placed on metal sheet material 3.

On the side of the backward shift of the material, it is covered with metal template 6, for example, the titanium one, passivated against anode dissolution.

The edge of the separation area shifts relative to dielectric template 2 by the value, equal to inverse broadening of the cutting profile.

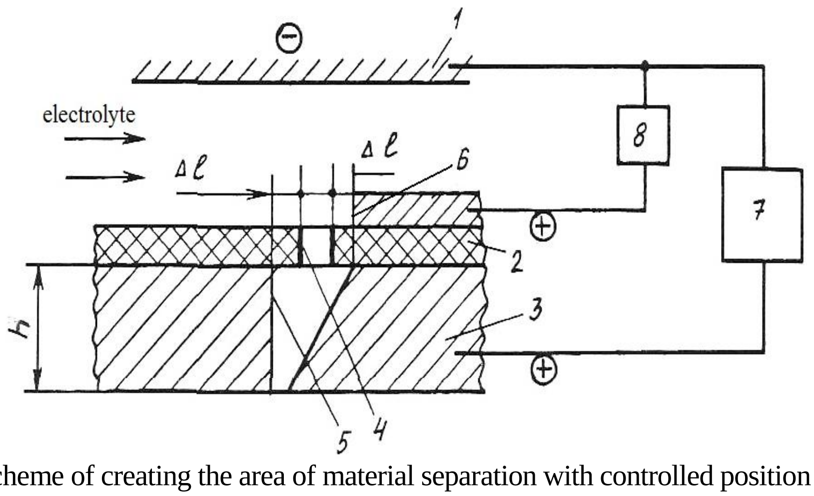

Figure 3. A scheme of creating the area of material separation with controlled position of the lateral surface/1 – EDM cathode, 2 – dielectric template; 3 – processed bar. 4 – slot in the dielectric template, 5 – part to be cut out; 6 – slot in the metal template, 7 – the first power supply, 8 – the second power supply; *h* – specified bar thickness; *l* – size of the part to be cut out.

Material 3 and EDM cathode 1 are connected to the first power supply 7. Metal template 6 and EDM cathode 1 are connected to the second power supply 8. The electrolyte is conducted along the template (as marked with arrows in figure 3), by applying constant voltage 7 and the variable voltage, produced by the power supply.

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5. Conclusion

The analysis, taking into account table 3, shows that the method of the electrochemical phototemplate-based separation, used in fabrication of a batch of sheet bars (20…100 items) has clear advantages with regards to per-unit costs. Besides, the process of sheet bar fabrication can take several hours for manufacturing products of every size, which is unattainable for any other method of small-scale fabrication of sheet bars.

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