Mechanical action on edges of plastic parts using electrohydraulic effect

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Abstract. The paper reviews the methods of cleaning plastic parts from flash. The principle of plant operation to obtain L. A. Yutkin electro-hydraulic effect is considered. The design of a pilot plant, as well as replaceable devices used to remove the flash from the edges of plastic parts is presented. The results of experimental studies of the electro-hydraulic effect for deflashing are presented.

Keywords: edges of plastic parts, electro-hydraulic effect, cleaning device, spark discharge, work hardening

1. Introduction
Edge cleaning of plastic parts from flash is time-consuming and low mechanized operation. Flash often has to be removed from surfaces of complex configuration, which sharply limits the possibility of cleaning process automation. Currently, the methods of plastic parts cleaning being discussed below are widespread.

Tumble finishing is a process which is simple. The processed parts are in a rotating drum, flash is removed due to interaction of parts with each other and with drum walls [1], [2]. Disadvantages of tumble finishing are process duration, often tumble finishing allows parts pre-cleaning only (some parts are not processed by tumble finishing at all). Parts with the flash remained after tumble finishing subject to final treating. Tumble finishing sheen damages on the surface of parts, which is not always acceptable.

Using abrasive disks, and scrapers flash is removed by rotating abrasive disks or translation movement of scrapers. Surface of a simple configuration can be cleaned this way.

In dies flash is cut off by moving the punch. For each type of parts a particular die is required, the shape of the surface to be cleaned should be simple. The surface after removing flash often has chips [3], [4].

Manual deflashing with files, knives is the method of proper cleaning, but it is characterized by low productivity.

Ultrasound is used to clean the edges of plastic parts from flash. The parts are in the liquid exposed to sound and are subjected to cavitation. The disadvantage of this method is that simultaneous cavitation and flash destroy the body of the part [5], [6], [7].

Thus, currently used methods of cleaning plastic parts from flash have significant disadvantages that do not allow fast and efficient cleaning of a surface, both of simple and complex configurations. So, methods of abrasive disk cleaning and in dies that make it possible to automate the process are not applicable for products of complex shape, as well as for cleaning edges. The
method of manual deflashing, which gives high-quality cleaning, has low productivity. Simple and easily automated process of tumble finishing does not give a complete removal of the flesh and can be applied not for all types of parts.

To increase productivity in cleaning plastic parts a method is required which:

- provides fast and high-quality cleaning of complex surfaces,
- does not require complex adjustment in processing parts of different configurations,
- allows the process of automated cleaning.

All these requirements are met by the technological process of cleaning, developed on the basis of the electro-hydraulic effect, discovered in 1950 by L. A. Yutkin. The effect is a powerful water hammer with a local pressure above one hundred thousand atmospheres, which occurs when a spark discharge of high voltage passes through the water gap [8], [9].

2. Equipment for the implementation of the electrohydraulic effect
The electro-hydraulic effect unit consists of two circuits (Figure 1).

1. Charger.
2. Discharger.

![Diagram of a lab-scale plant](image)

**Figure 1.** Diagram of a lab-scale plant (C1=C2=C3=C4=0.001 µf)

The charging circuit is a high-voltage transformer with a rectifier. The discharge circuit consists of a capacitor forming a gap and a working gap submerged in a liquid.

The circuit works as follows. The transformer converts the mains voltage into high voltage (several tens of kilovolts). After the voltage on the capacitor C reaches the limit to which the forming gap (FG) is adjusted, the WG breakdown occurs and the pulse voltage is applied to the working gap (WG), creating a breakdown in the liquid in which the WG is located. In this case there is a hydraulic shock, producing work. The cycle is repeated again with the frequency determined by the power of the transformer, on which the capacitor charging speed depends.

In the working gap, the water acts as a conductor before breakdown and provides equal potential on the right side of the circuit (beyond the FG). At the time of the breakdown of the forming gap, the liquid ions do not have time to move from the electrode to the electrode, and the liquid instantly becomes a dielectric. In this case, from one electrode of the working gap (WG) to another one (located in the liquid), a streamer of a certain polarity grows. All the energy stored in the circuit is collected at the working gap.

Then there is an expansion of the spark channel and the formation of the cavity, which is accompanied by the main shock. After the discharge termination, the cavity closing takes place, and the closing speed reaches the speed of sound. The cavity closing is accompanied by a cavitation shock. The value of the resulting pressure is directly proportional to the power and inversely proportional to the pulse duration. Instantaneous pulse power can reach 100,000 kW and much greater values.
An advantage of the circuit is in its simplicity and reliability. A disadvantage is the low efficiency (20%), since capacitors charge by a pulsating current and voltage.

As a source of high voltage, a device for testing the insulation of high-voltage cable lines AKI-50 was used in the work.

A rectifier (Figure 2) is assembled on a half-wave circuit with the six silicon pillars D 1008, which was installed instead of the removed rectifier tube.

![Rectifier circuit](image)

**Figure 2.** Rectifier circuit

High-voltage ceramic capacitors TGC-1 A were used for voltage grading. The capacity is 0.001 µF, the voltage is 21 kV. The capacitor bank is also assembled on TGC-1A capacitors. The design allows one to change the capacity from 0.001 µF to 0.004 µF through 0.001 µF.

The casing of the unit (Figure 3) is welded from an angle iron and lined with steel shielding sheets. Device AKI-50 with the following characteristics is bolted to the casing:

- mains voltage is 127 (220) V;
- power consumption is up to 0.5 kVA;
- rectified voltage is 50 kV;
- rectified current is 3 mA.

![Unit design](image)

**Figure 3.** Unit design

A capacitor bank is assembled on the top shelf made of composite epoxy material, and a rectifier is on the bottom shelf. In the upper right part a forming gap is installed (Figure 4). A removable bath is installed on the top of the casing (Figure 3) with two transparent walls. Inside the bath replaceable devices for experiments can be installed.
Figure 4. Forming gap

The experiments were conducted in distilled water (in distilled water, the electrohydraulic effect is observed at lower voltages than in tap water). During the experiments, various versions of the shock wave impact on the flash were tested.

Parts (up to six pieces) were placed on the grid between the positive and negative electrodes. Discharges were made directly to the parts under cleaning (Figure 5).

Figure 5. Experiment implementation diagram

The diagram of the discharge circuit is shown in Figure 6.

Figure 6. Discharge circuit diagram

The device (Figure 7) consists of a plastic cup (a), the bottom of which is a spherical negative electrode. The electrode is covered by a grid of polyethylene (b). The grid is necessary for the
protection of edges from the burns, as the position of parts in-process is constantly changing, and, as a consequence, working gap value and the current magnitude flowing through the parts edges vary. The grid provides a minimum guaranteed working gap, in which there are no edge burns. The glass with the stand (c) is fixed inside the bath (Figure 3).

![Figure 7. Design of the unit](image1)

Two positive electrodes are installed on the cover of the bath (Figure 8). The electrode is the wire PVL-2, fixed in the plexiglass cylinder with a screw in the holder. The design allows one to move the electrodes in the vertical direction up to 40 mm. The cover with electrodes is fixed with two pins.

![Figure 8. Bath cover](image2)

Processing was conducted under the modes:
- working gap of 18 mm;
- forming gap of 13 mm;
- voltage of 38 kV;
- current of 1.5 mA;
- capacity of 0.004 µF.
3. Experimental results
On processing, the thick flash is completely removed from the edges within 1-2 minutes. At the edges of parts small flashed areas of a few micrometers are left. Removal of these areas was made within one minute in addition, and, the speed of cleaning in comparison with removal of thick flash sharply decreased.

No burns were observed on the processed parts.
Summary:
During processing, there is an intense destruction of flash, while the part remains undamaged.

The disadvantage of this processing procedure is that after 3 minutes of processing on the edges of some parts there are small areas of very thin plastic film, the speed of their deflashing decreases as the processing time increases. The thick flash is less firmly attached to the edges and is a monolithic structure. The segment of flash punched in one place carries neighboring sections, sometimes of considerable size. This phenomenon is not observed in case of the flash film. A small section of plastic removes at the point where the discharge enters the metal.

Therefore, to remove a thin film of flash it is necessary for the discharges to pass across the surface being cleaned. Here, each of a large number of discharges pulls out a small section of plastic film, while 3-10 discharges per a part are enough to remove a thick flash.

A sharp drop in the cleaning speed after two minutes of processing is obvious, when the thick flash has already been removed. This is due to the fact that the probability of discharge hitting the small remaining uncleaned areas (and, consequently, their cleaning) decreases with increasing the time of processing.

The disadvantage of this cleaning procedure can be eliminated by increasing the discharge frequency. (In the experiment, the discharge frequency was 15-20 Hz due to the low efficiency of the installation, equal to about 20%). It is possible to increase the discharge frequency by using a more complex multielectrode resonance circuit [10], which allows one to obtain a frequency of 50-300 Hz and above at high efficiency (95-98%).

For each type of parts a processing mode must be selected, and the adjustment for processing other types of parts will be in changing the working gap of capacity and voltage (for example, for the part 6.624.002 maximum capacity \( C=0.004 \) µF).

In experiments 2 and 3, separate actions on thick and thin flash were conducted. The cleaning device consists of a base (Figure 9), on which a negative electrode is fixed in the form of a plate, an electrode holder with a positive electrode, which is simultaneously a reflecting shield, a clamping device, that allows fixing the part between the positive and negative electrodes and a wire with a lug.

Figure 9. Cleaning device
The positive electrode is installed at a distance \( l = 1.6 \) mm from the part edge (Figure 10). The distance between the negative electrode and the edge \( \Delta = 1.8 \) mm. Processing mode: voltage of 28 kV, a capacity of 0.002 \( \mu \)F; forming gap of 12.5 mm.

![Electrode installation diagram](image)

**Figure 10.** Electrode installation diagram

In a series of ten parts for complete removal of thick flash from the edge surface and from the holes, it was spent from 3 to 5 seconds per a part, \( I_{\text{mn}} = 1.0 \) mA; \( t_{\text{max}} = 5 \) seconds; \( C = 0.002 \) \( \mu \)F; \( U = 28 \) kV; \( \Delta = 1.8 \) mm; \( l = 1.6 \) mm; forming gap of 12 mm (**Table 1**).

On some parts small areas with thin film of flash were observed, thick flash was removed completely.

At a capacity of \( C = 0.001 \) \( \mu \)F the cleaning is slower. Capacity \( C = 0.002 \) \( \mu \)F is the limit for parts. For example, with the capacity of 0.004 \( \mu \)F cleaning is accelerated, but after a few shocks, the part tip removes.

In the experiment 2 final edge cleaning from flash segments remaining after the experiment 1. The discharge was fed to each edge separately. In contrast to experiment 1, the distance between the positive electrode and the edge \( l = 3.5 \) mm and the distance between the edge and the negative electrode \( \Delta = 6.5 \) mm were increased (Figure 10).

Processing was performed by micro-discharges of high frequency (up to 50 Hz). \( I_{\text{mn}} = 1.7 \) mA; \( t_{\text{max}} = 20 \) sec; \( C = 0.002 \) \( \mu \)F; \( U = 26 \) kV; \( \Delta = 6.5 \) mm; \( l = 3.5 \) mm; forming gap of 11 mm (**Table 2**). As a result, a complete film deflashing on the edge of the part is performed for 10 – 20 seconds at an average current of 1.7 mA.

**Table 1.** The results of experiment 1

| Part number | \( t \) (sec) | \( I \) (mA) |
|-------------|---------------|-------------|
| 1           | 4.5           | 0.8         |
| 2           | 4.0           | 1.0         |
| 3           | 5.0           | 0.9         |
| 4           | 4.5           | 0.9         |
| 5           | 5.0           | 1.1         |
| 6           | 3.5           | 1.1         |
| 7           | 3.0           | 1.2         |
| 8           | 4.0           | 1.1         |
| 9           | 4.0           | 1.05        |
| Part number | $t$ (sec) | $I$ (mA) |
|------------|-----------|----------|
| 1          | 15        | 1.5      |
| 2          | 20        | 2.0      |
| 3          | 20        | 2.0      |
| 4          | 10        | 1.4      |
| 5          | 10        | 1.4      |
| 6          | 10        | 1.5      |
| 7          | 10        | 1.7      |
| 8          | 15        | 1.8      |
| 9          | 20        | 2.5      |
| 10         | 10        | 2.2      |

**Table 2. The results of experiment 2**

4. Conclusion

According to the conducted experiments, electrohydraulic pulses of a certain force intensively destroy the flash without any damage to a part.

The transition from processing one part to another is in changing the processing modes and position of the electrodes.

In conducting research on the action of the shock wave on the flash, optimal processing modes for removing the flash both from edges and the body of various parts will be determined, and this will enable to create very efficient machines for deflashing and thereby significantly increase productivity in cleaning operations.
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