

REVIEW OF WIRE ELECTRICAL DISCHARGE MACHINING OF THE ALUMINUM EXTRUSION DIE

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ABSTRACT: One of the most studied nonconventional technologies is the Electrical Discharge Machining. There is a lot of research in this area, due to the fact that the use of electric erosion machines is constantly increasing. This scientific work is a review of unconventional erosion processing processes. The importance of EDM processing of aluminum in the aerospace industry was emphasized, starting from the way of its preparation by extrusion with the help of molds. In the last part of the paper are presented the own views on the analyzed topic.

KEY WORDS: nonconventional technology, Electrical discharge machining, extrusion, aluminum, die

1. INTRODUCTION

The limitations of the cutting processes have led to the emergence and development of nonconventional technologies [1], [2]. These limitations involve: the surfaces to be processed with complex configurations; the processing of parts made of metals and alloys with special properties (very high resistance to breakage, high refractory, high resistance to corrosion and cavitation, high fragility, etc.); obtaining a very high dimensional accuracy and a very good quality of the processed surfaces and making micro-dimensional bores; achieving increased productivity under the conditions of significant conventional fuel savings, raw materials and energy resources [3], [4].

In the case of nonconventional technologies, the removal of the added processing is done in the form of microparticles as a result of the interaction between the part - semi-manufactured and an erosive agent.

The classification of the erosion processing is done according to several criteria, aspect presented in figure 1 [5], [6], [7].

2. MODERN APPROACHES OF THE ALUMINUM PROCESSING. EXTRUSION

EDM processing is one of the most widely used nonconventional processes of materials in which electrical discharges are used to process electrically conductive parts, regardless of their hardness [8]. Electric discharge generates high thermal energy which eliminates erosion material [9].

EDM is a polyvalent process for the machining of the complex shapes, and has an advantage in the molds manufacture, car, aerospace and surgical components from materials difficult to process by conventional methods.

There are various investigations of this EDM process using different materials, such as titanium alloys, alloy steels and metallic matrix composites [10], [11], [12], [13]. However, there are not too many researches in this context on aluminum alloy. For example, Selvakumar et al [14] investigated the WEDM processing of aluminum alloy 5083 using the experimental design method Taguchi. Although their study presented some information on several input and output parameters, it does not provide any information on the basic mechanisms. Dave et al. [15] also used the Taguchi methodology to study the micro-holes generated on the aluminum alloy 1100 using micro-electro-discharge processing.

Aluminum alloys are known as materials that are easy processed traditionally, due to their high thermal conductivity and low hardness [16], [17].

For example, Pramanik and co-workers studied in their work [17] electrically discharged machining (EDM) on 6061 aluminum alloy in the aspect of kerf / slit, width, surface finish and wear of electrode wire for different pulse on time and wire tension. The authors performed eight experiments on a wire EDM machine, varying the pulse in time and the voltage of the wire.

The results showed that the rate of removal of the material increases with the increase of the pulse over

time, although the tension of the wire does not affect the rate of removal of the material.

The authors also tracked the effect of the pulse over time on the cutting speed.

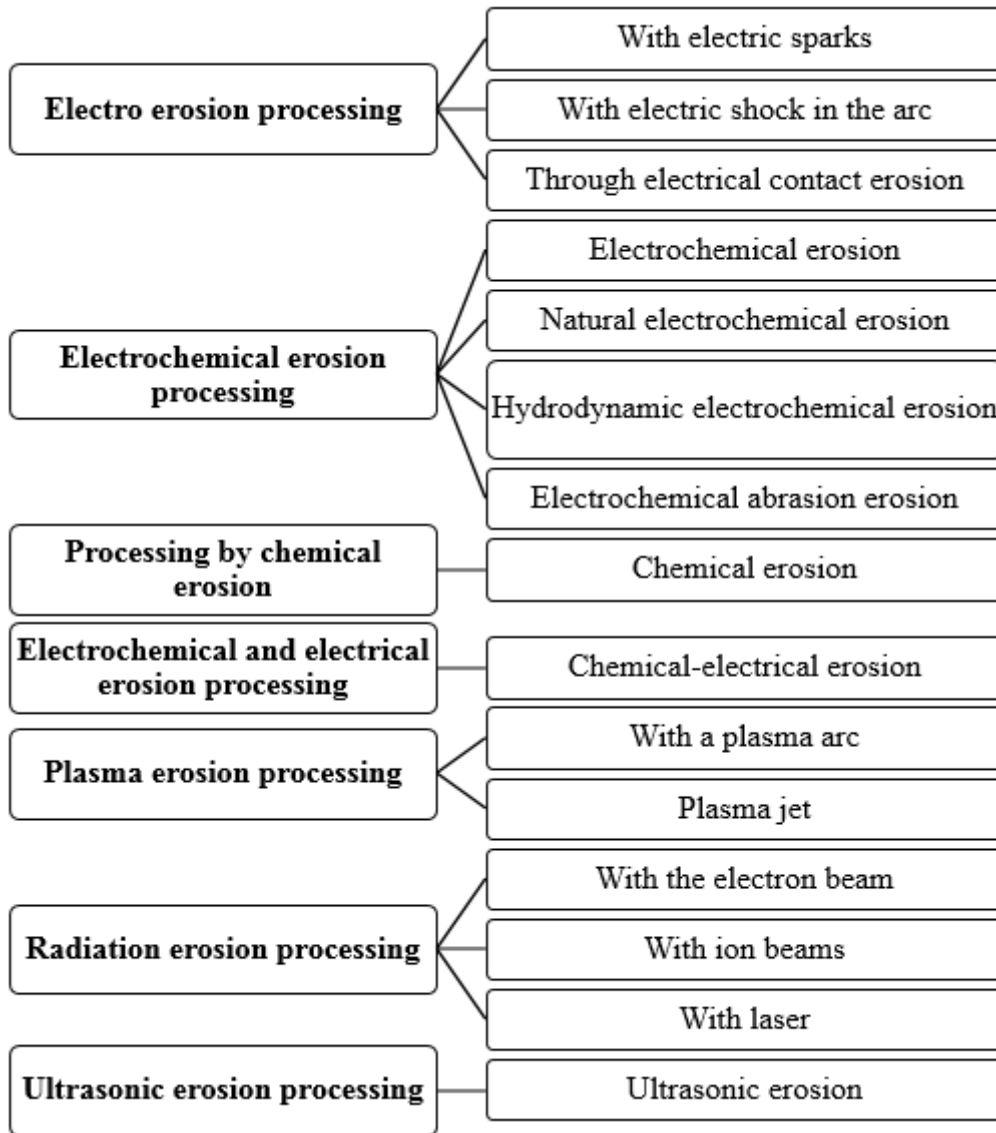
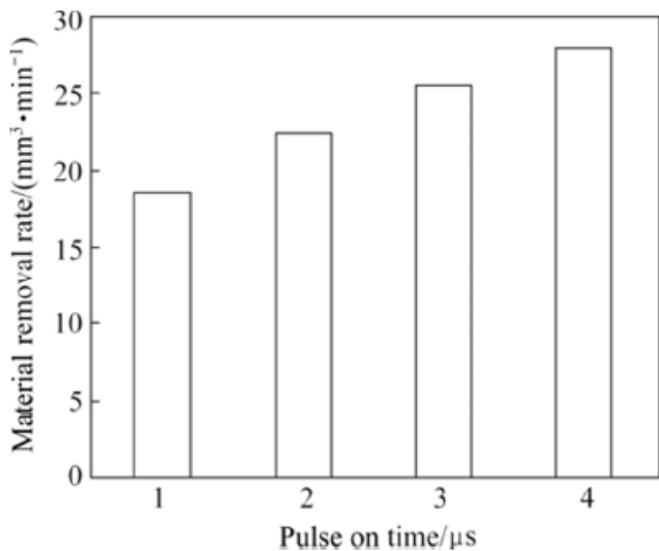


Figure 1. Classification of erosion process

Figure 2 shows how the cutting speed increases with the increase of the pulse on time - which controls the generation of heat and the formation of the spark.

Figure 2. Effect of pulse on time on cutting speed at wire tension of 17.64 N [17]



Also, increasing the pulse on time also increases heat production, which improves the elimination of the material and extends the heat more time, which helps in the efficient removal of the material. Thus, the longer pulse on time increases the material removal rate. The increase of the removal speed of the material is linear proportional to the increase of the pulse on time.

Also, the authors observed that the higher voltage of the wire facilitates the process of constant processing, resulting in a low wear of wire electrodes and a better finish of the surface. The surface roughness does not show significant changes in the pulse variation on time, and the processed surfaces have a similar appearance in all processing conditions. Figure 3 shows a tendency of the surface roughness to decrease with the increase of the wire tension,

although the variation of the corresponding surface roughness is not significant. It seems that higher tension reduces the flexibility of the wire that generates the smoother surface.

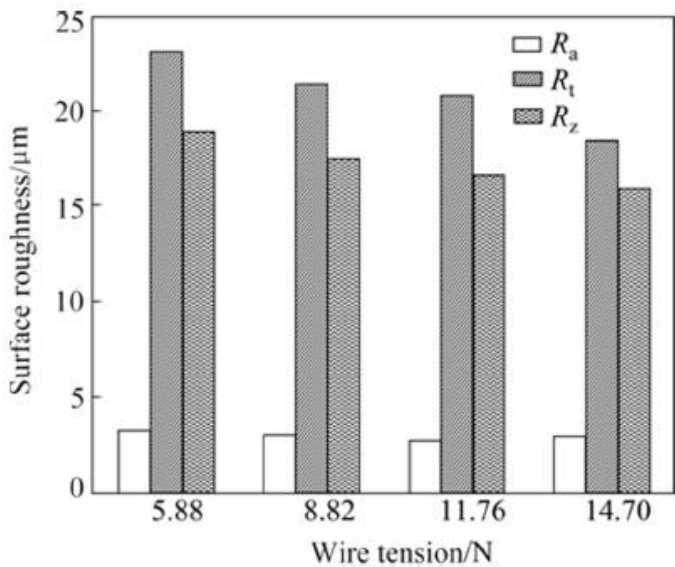


Figure 3. Effect of wire tension on surface roughness parameters (pulse on time 4 μs) [17]

The processed surface contains solidified molten material, splash of materials and blisters. Increasing the pulse on time increases the wear of the wire electrode due to the increase of heat input. Wire electrode wear generates a tapered slot that has a greater kerf width at the top than at the bottom (Figure 4). Therefore, higher electrode wear introduces greater conicity.

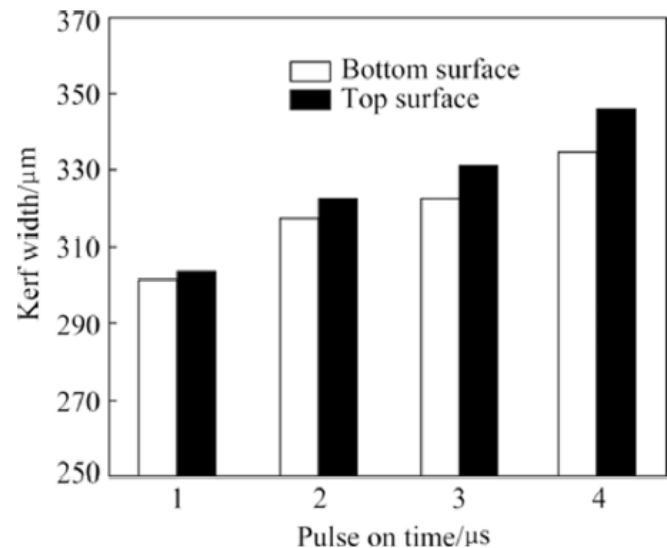


Figure 4. Effect of pulse on time on kerf width (wire tension 17.64 N) [17]

Another aspect pursued in this research was also the wire diameter of the electrode which is reduced after EDM processing of the aluminum alloy 6061. The effect of the pulse on time on the diameter of the wire after EDM processing is shown in Figure 5. From this it is shown that the diameter of the wire decreases

with increasing momentum. The decrease of the diameter of the wire is not significant when the impulse in time is very short, but the diameter decreases significantly with the small increase of the pulse over time. The decrease in the diameter of the wire continues at a slower speed, with the further increase of the pulse over time. The greater the pulse on time is, the greater the heat input and the longer the heat utilization are. Thus, the larger pulse on time introduces more wear to the wire.

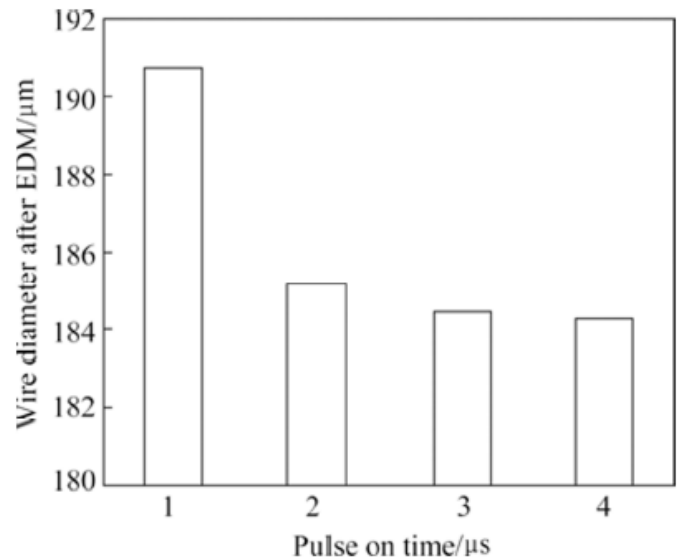


Figure 5. Effect of pulse on time on wire diameter (wire tension 17.64 N) [17]

However, if the complex aluminum form is to be realized, then EDM may be the best option in terms of time and cost.

This research is a continuation of the study conducted by [18] on nonconventional manufacturing work preparation for wire EDM machining.

Aluminum, which today occupies a market share of over 1.5 million tons with applicability in the field of construction and aerospace components. Extruded products include practically all families of alloys, and vary in dimensions, sections and structures for aircraft [19].

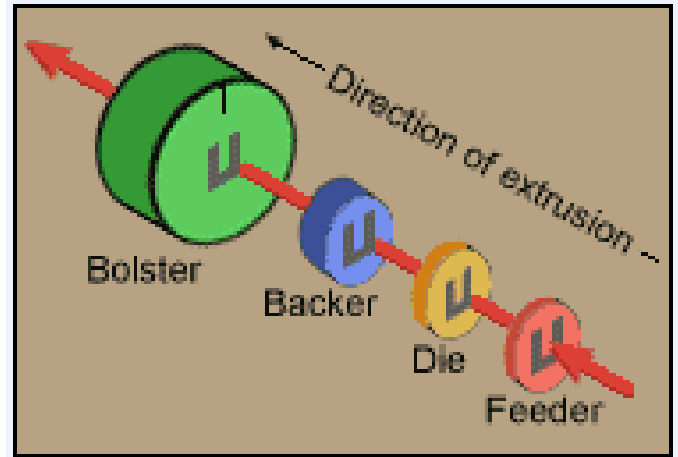
The 6063-aluminum alloy was used for extruded products for the first time in 1944. Since it was a low-solute aluminum-magnesium-silicon alloy, it can be heat treated, it can be extruded at high speeds, but age-harden to obtain adequate strength. In addition, the alloy can be easily anodized and colored, and the corrosion resistance has been superior to the alloy 6061. The market requirements for extruded construction products and transport products are satisfied by a variety of alloys and processing methods. Alloy 6463, with low iron content, is suitable for applications where a light, anodized finish is required. Use even less solute alloy and even

higher productivity 6060 if 6063-T5 alloy strength is not required. Extrusions can be extinguished by air, fog, sprays, permanent wave or extinguishing tank, depending on the geometry and final destinations of the product may be quenched by air, mist, sprays, standing wave, or quench tank, depending upon the geometry and final product needs. Low copper alloys in Class 7xxx are also commonly extinguished for press for a variety of applications, from bridge decks to car bumpers.³⁰ These alloys include 7005, 7003 and 7108 commonly press quenched. for a variety of applications ranging from bridge decks to automotive bumpers. [20] These alloys include 7005, 7003, and 7108).

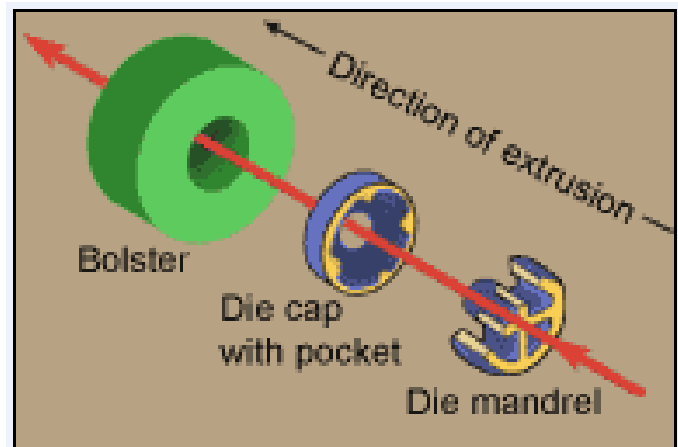
The aluminum extrusion process is a metal forming process in which a specific section is produced in length by forcing the aluminum under pressure through one or more holes. The molds are designed according to the profiles required by the customers. Such profiles consist of various forms of cross-section; solid, hollow or combined and made by molds designed. The mold shapes are made according to the profile shapes. There are solid molds, empty molds and semi-empty molds. The typical mold includes the mold holder enclosed in the ring, bolt and sub-weapon. Ten are mounted in a tool holder. Mold design involves two critical parts; the characteristics of the mold and its parameters. The mold design can be created from scratch or adapted to meet the new mold requirement. The process of extruding aluminum is the process of forcing it to flow through a molded opening in a mold. The extruded material appears as an elongated piece with the same profile as the opening of the mold [21]. The process involves several significant components, such as: pressing machine, mold, wedge, oven, stretching equipment, cutting machine, etc. In addition, the methods of producing the final profile are also important. They influence the quality, efficiency and productivity, especially the information on the manufacture of the mold, which refers to the use of such a mold on the shop floor. For the most part, they result from the experience of the operators.

The solid die is used to produce the solid profile. Not too complicated in terms of design and operations, while hollow or semi-hollow die or semi-hollow die is complicated enough to produce hollow aluminum profiles. The solid profile is used in order to obtain a strong and solid weight and the increased surfaces that benefit from a good conductivity of the electric current flow. On the other hand, the hollow profile is used for light weight, large size and sometimes for home decoration. A press machine should produce a smooth and good quality profile with maximum

production efficiency. Figure 6 shows the components of the aluminum mold. The solid die is shown in Figure 6a. There are four components: feeder, die, backer and bolster. The hollow die is shown in Figure 6b. These are composed of mandrel, die cap and bolster i.e. It can be seen that the two types of molds are based on geometric shapes and can be defined by characteristics [22].



a) Solid Die



b) Hollow Die

Figure 6. Aluminum Die Components [22]

Aceste matrițe de extrudare în industria aerospațială sunt fabricate cu ajutorul technology of wire-cut EDM. Aspecte privind această nouă tehnologie sunt prezentate în continuare.

3. THE TECHNOLOGY OF WIRE-CUT EDM

The evolutions of the manufacturing industry today are characterized by the fact that the machines are integrated with a certain level of "intelligence" that allows them to independently control their tasks and communicate with their environment.

These intelligent machines are equipped with a multitude of sensors capable of ensuring the quality of the parts manufactured by taking corrective measures such as self-optimizing process parameters.

They will also monitor their own condition and detect real or future needs, regarding the maintenance or replacement of consumables, performing the self-diagnosis and self-configuring according to the processing tasks.

In a production environment of multiple connected intelligent machines and connected processing tasks, the machines could select the most appropriate tasks in terms of the desired quality and quantity, taking into account their actual capacity.

EDM machines, especially wired EDM machines are already highly computerized, as well as equipped with many sensors, capable of monitoring different parameters of the physical process. These machines are also extremely sensitive to changes in the parameters due to the wear of the machine parts, or to the life or consumption components.

Generally used EDM machine models differ from one company to another. Numerical Computer Control (CNC) - EDM Machine is used in many industries due to the fact that instrument switching issues can be reduced, but other industries still prefer to use the manual machine.

In the last years, the requirements regarding EDM wire-cut have increased significantly, according to the requirements regarding the high precision processing of industrial products and at the same time the high labor cost. Therefore, ROBOCUT - wire-cut EDM is one of the new advanced cutting technologies developed, which performs various efficient functions and is also a management tool for production (Figure 7). One of the latest cutting technologies is “High precision cutting for thick work-pieces”, developed for resin molding die cutting.

Figure 7. FANUC ROBOCUT α -CiA series [23]

Continuous development of new technologies is required to meet market demands. These include [24]:

- Improved performance and functions - useful for practical cutting and various efficient functions: high precision cutting for thick work-pieces; automatic wire feeding function at the wire break point in taper cutting; rotary table ROBOCUT CCR;
- Improvement of the rate of operation by a management tool for productions and quality data;
- Automation by robot.

In EDM wire-cutting, wire feed is required before cutting or restarting. The two-wire feed system using FANUC digital servo motors can perform the automatic wire feed (Figure 8).

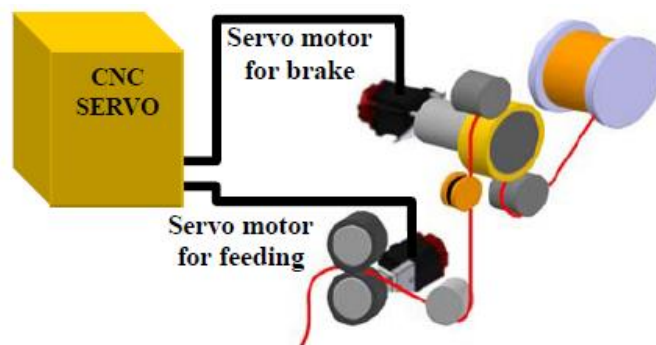


Figure 8. Twin servo wire feeding system [24]

There are two possibilities to thread the wire when the wire is breaking and the cutting restart is necessary. The first one assumes to move back to the start point to thread the wire and the second one assumes to thread the wire at the wire break point. In order to reduce recovery time, automatic wire feeding at the wire break point is more efficient than doing at the start point. In case of the automatic wire feeding at the wire break point, the straightness of the wire itself is very important.

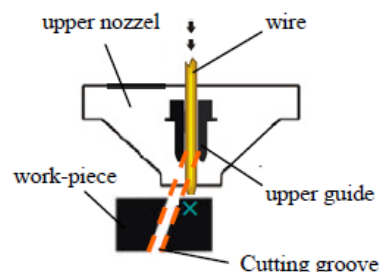


Figure 9. Conventional automatic wire feeding [24]

So far, many technologies have been developed in this regard.

However, if the workpiece has relief angles such as press dies (Figure 9), while the machine tries to attach the wire to its breaking point, the wire reaches the

surface of the workpiece and the wire cannot be fed. For this reason, if the thread breaks during a tapered cut, it must be moved back to the starting point to thread the thread, and not to the break point of the thread as it would be conventional.

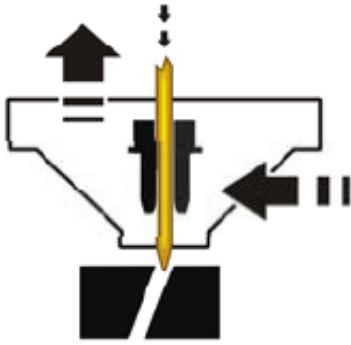


Figure 10. Automatic wire feeding in taper cutting [24]

In figure 10 it is presented the automatic wire feeding function at the wire break point in taper cutting.

4. CONCLUSIONS

The technical information projected in the production is converted using systems and engineering applications in the aerospace industry, especially in the process of making the extrusion dies of aluminum semi-manufactures. These blanks are used to make structural components from aircraft whose final surfaces coincide with those of the blank, i.e. there is no longer a mechanical process to remove an addition resulting from the extrusion process.

Given the industrial evolution and the fact that the machines are intended to integrate a certain level of "intelligence" that allows them to independently control their tasks and to communicate with their environment, it is necessary to develop a process of transfer of technical data. The role of this transfer is to be used for analyzing the non-conformities of the parts, given that the geometric model of the final product is used as a virtual geometric reference for the design of the mold, a reference that later through the engineering systems and applications minimize the risk of geometry alteration. parts.

The precision of the mold processing is critical because the extruded surfaces are the ones that remain only to be painted on the final piece, which is why the processing by wire erosion is used.

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