REVIEW OF THE NONCONVENTIONAL MANUFACTURING WORK PREPARATION FOR WIRE EDM MACHINING

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ABSTRACT: : With the improvement of the technological processing system, improvement massively directed towards increasing their amount of removed material, the distance between the productivity of EDM processing and the productivity of other conventional processes is constantly decreasing. This has led to an improvement in the technological relationship of EDM processing compared to other processing processes. This paper presents the process of preparing manufacturing work for wire EDM machines used to produce extrusion dyes based on digital engineering data. The final part of the paper argues that EDM is the technological process of dimensional processing that will require the development of many areas of human existence, through the possibilities of this technology to solve major material problems.
KEYWORDS: electrical discharge machining, nonconventional technologies, wire EDM, aerospace industry, quality

1. 1. INTRODUCTION TO NONCONVENTIONAL TECHNOLOGIES

At present, electrical discharge machining (EDM) is the nonconventional dimensional machining process that has "already left the scope of the nonconventional" being a common processing process, unanimously accepted and with particularly wide industrial applications [1].

There are already specific areas of application for this process, where "the use of other dimensional processing processes is no longer necessary, EDM alone being able to complete all the requirements for processing, from roughing to finishing or superfinishing [2].

Dimensional processing by EDM is the process of processing methods with concentrated energies in which the removal of surplus material on the surface of the object to be processed is based on complex, discontinuous and localized erosive effects of impulse discharges repeatedly primed between the object of processing and an object of transfer (electrode - tool), in the conditions of observing some physical conditions regarding the existence of discharges, locating their effects as well as ensuring the continuity of the erosive process [3].

The placement of this process in the technological hierarchy of dimensional processing processes is determined on the one hand by the relatively low technological characteristics and on the other hand by the possibilities of very easy generation of surfaces of high complexities with very good execution accuracies and relative independence, technological characteristics of the mechanical properties of the object to be processed [4].

These technological features place EDM dimensional machining to areas where cutting machining restrictions are overcome, or are close to them or when machining has low economic efficiency (high hardness of the object to be processed, impossibility or difficulty of surface generation, rigidity low of one of the elements of the technological system).

2. GENERAL CONSIDERATIONS

The criteria underlying the classification of variants of the EDM processing process are imposed on the one hand by the priming mode, duration and shape of the impulse discharges and on the other hand by the shape of the electrode - tool used for processing [5].

Looking at the prism of the way of priming the electric discharges, the processing process by EDM is classified in:

- EDM processing with primed discharges by penetrating a dielectric medium;
- EDM processing with pulsed primes by breaking electrical micro-contacts (EDM with contact breaking).

From the point of view of the electrode shape - EDM tool with impulses primed by piercing the erosive gap is qualified in:

- EDM with solid electrode (EDM with copying the shape of the electrode);
- EDM with filiform wire.

From the point of view of the duration of EDM current pulses with pulses primed by piercing the erosive interstice can be:

- Spark discharge processing;
- Processing with non-stationary electric arc discharges.

3. PRESENTATION OF THE EDM FIELD

The scientific and industrial development of the dimensional processing process by EDM has gone through important moments, determined on the one hand by the increasing deepening of the scientific field, and on the other hand by the improvement of the developments of some industrial branches, such as power electronics, technology, automation of processing processes, design and construction of machine tools, etc. [6,7].

The 1950s marked the world premiere of EDM processing technology systems. In 1954, the first EDM processing machines produced by prestigious European companies - AGIE, CHRMILLES, SPARCWTRON, were presented at the exhibition of machine tools in Milan.

The processing technology system is the meeting of all the elements that contribute to the processing and the interactions between them [8,9].

The structure of the systems is adapted to the particularities of each process. There are variants of processing within a processing method, respecting the basic principles, but there are also many main and constructive differences [10,11].

These few guidelines on technological processing systems are also found in nonconventional processing systems [12,13].

On the other hand, technological processing systems using nonconventional technologies have a much different structure from the structure of conventional technological systems, which is determined by the specifics of processing principles [14,15].

On the other hand, large differences in structure are also identified between the technological systems specific to each nonconventional processing process, but there are major differences even between the structures of technological systems adapted to the application variants of different processes [16].

3.1 Presentation of the processing with wire electrode

When processing by EDM with a wire electrode, part of the semi-finished material is transformed into EDM products, and another part remains in the form of solid waste. The amount of material removed from the part, which must be taken into account when calculating the processing productivity, is represented by that part of the part material which is transformed into EDM products.

The EDM processing technology with wire electrode is relatively complex and for this reason it is necessary to comply with specific conditions, the most important of which are the following:

Material properties: this process processes electrically conductive materials such as steels, cast irons, non-ferrous materials, having a good tightening ability when the part is installed on the table of machines, respectively a good chemical behavior under the action of dielectric liquid.

Parts geometry: EDM machining with wire electrode allows the realization of a diverse range of objects to be processed, having a geometry and configuration difficult or impossible to achieve by other processes: deep holes, narrow slits, complicated paths and many bends, high adjustments precision, practiced in hard and extra hard materials.

Protection zone: represents the minimum distance between two paths of its wire electrode measured on the blank which ensures a dimensional accuracy and shape acceptable to the machined part, especially the punches.

Installation conditions of the semi-finished product: in general, technological machines for EDM processing with a wire electrode provide a cutting area determined by the maximum dimensions of the workable part and a working area determined by the maximum dimensions of the semi-finished product that can be installed on car table.

Edge radii and cutting width: the radius of the edges is determined by the diameter of its wire electrode which, although it has small values, cannot be neglected.

Surface quality: the surface of a part cut by EDM with a wire electrode must be clean and without visible signs of processing.

The cutting speed depends on: the material and condition of the surface of the object to be processed, the height of the object to be processed, the capacity of the pulse generator, the diameter of the transfer object, the working current. The electric is primed successively and is located selectively in different areas of its working gap, producing the removal of particles from the object to be processed, respectively the wear of its wire electrode.

The dimensional, shape and reciprocal position accuracy that can be obtained from the application of a conventional machining process is influenced by a number of factors such as: geometric accuracy of machine tools, rigidity of the elastic technological

system consisting of the machine tool - clamping device - tool - part, tool wear, thermal deformations of the tool and machine tools, parameters of the cutting regime.

4. CASE STUDY

In this paper, it is presents the design and production process of extruding paints of manufacturing companies in the aerospace industry.

Most of the structural parts of the aircraft, but not only, are made of aluminum alloys such as the 7000 and 2000 series.

Airspace engineers design some of the characteristics of the components that will be produced by the extrusion process.

The extrusion tools used for this process required special materials, and the exact manufacturing process resulted from a complex set of parameters required for the design requirements. Extrusion molds are generally produced by the EDM process.

After a brief review of the literature was presented, a study was conducted on the process of preparation of production work for wire EDM processing used for the production of extruded paints based on digital engineering data.

Engineering digital data contains geometric product properties and process properties. We call this process common because all the geometric product features and process features designed are transferred directly to the EDM system, eliminating the conventional preparation method for manufacturing work, such as production drawing preparation, where there is manual input of product features from 2D to EDM programming.

The amount of these manual activities can affect the quality of the product.

This process approach is increasingly used in industries to produce a high quality product in a very short period of time in response to customer needs.

By removing some process steps from the production preparation process and transferring product requirements directly to the EDM machine, the new method provides shorter lead time and reduces the risk of missing some product requirements.

The process of preparation of manufacturing work, which is usually applied in manufacturing companies, has the same basic principles.

Data on all designs received from the customer are converted into documents, methods, tools, media used during the production inspection process. In this case study, a similar process is presented, but with an optimized approach to the work preparation process (Figure 1) [17].

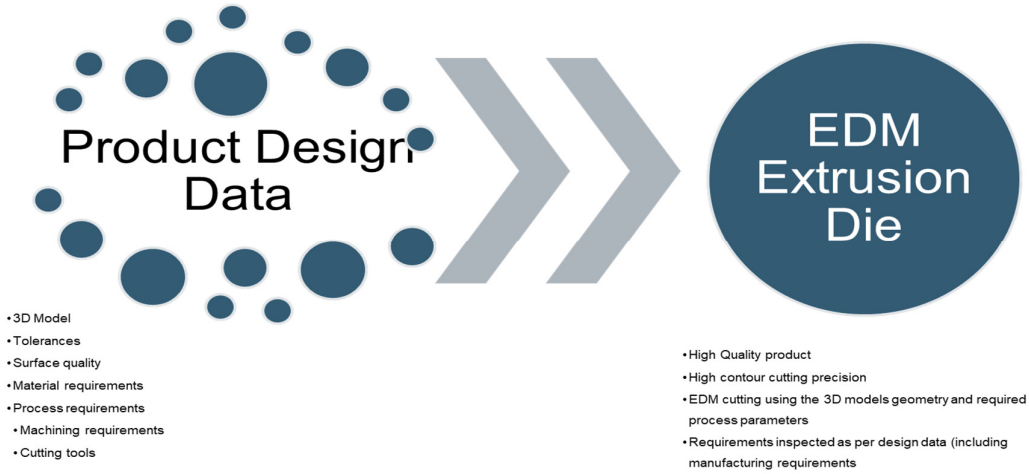

Figure 1. Manufacturing Work Preparation process overview [17]

Also the product and process features are those that are transferred directly to the manufactured products and at the same time used for product validation.

The work preparation process must follow the basic steps required in a manufacturing process, part of the feasibility study process, product reviews and organizational capabilities and capabilities, and must follow the requirements of the required processes by examining the commercial aspects. As part of a special work in product engineering required for the use of CAD / CAM tools capable of transmitting requirements from project data obtained as an input process through production process preparation, product processing and validation of product requirements.

The manufacturing media manufacturing process integrates product and process requirements, production and design rules, and manufacturing engineering knowledge to ensure optimal results for the equipment and at the same time for inspection equipment.

The aerospace industry needs to include extrusion die design activities, extrusion processes, and space design features in addition to extruded product division requirements.

Aerospace design companies design these specifications to limit and control the production company in various parameters of the manufacturing process. The work preparation process, which includes all these different materials, requires an integrated requirements management system, it is becoming very important. The mold design company designs and integrates all requirements with 3D models using CAD software (computer aided design). The 3D product model is a virtual product company produced by CAD Software. In other words, a 3D product model is the best mathematical estimate of product features. All of this data used in the CAM software allows production engineers to determine a processing strategy. CAM software integrates the CAD 3D model and uses the virtual body nominally for all product features. The CAM software transfers the CM strategy to the NC program, which controls the EDM machine to cut the size of the die shape.

As a result the product is inspected by optical machines that measure the cut counter using the reference representation of the 3D model. Notable aspects of this process are the parameters of the virtual body conversion between different CAD / CAM software. Almost all software vendors use the import and export of geometry through neutral formats such as State File (Product Model Data Exchange Standard - ISO 10303) and IGES (Graphics Exchange Preliminary Specification).

Combined with all the steps to work through a unique reference 3D model, make this process more controlled and easier to manage.

The aluminum extrusion process required that the aluminum material be heated to 400ºC before the material passed through the dye. In addition to the operating temperature, there are other process requirements, which lead to the use of steel materials for hot work equipment to die.

Fanuk Robocot 1.IE, Charmills 240 SLP and Charmills 440 CCS died on an EDM CNC machine.

For this study, we consider the Fanuk RoboCot 1.IE, which has a cutting accuracy of 2 microns with a workspace of KS = 600 mm, I = 400 mm and Z = 310 mm.

For material H13, cutting parameters are used, for rough cutting of 0.2-0.3 mm / min and for finishing of 7-8 mm / min. These machines are able to use an NC program that produces CAM software called RoboCom Cami Programming.

As mentioned earlier, CAM software provides all the design features for the definition of cutting techniques without manual input in the work preparation process.

Using CNC postprocessors, the CAM software automatically cuts to the NC code (numerical control code) using a software algorithm without manual input in disguise and transfers the design features to the EDM machine in a very short time without manual input.

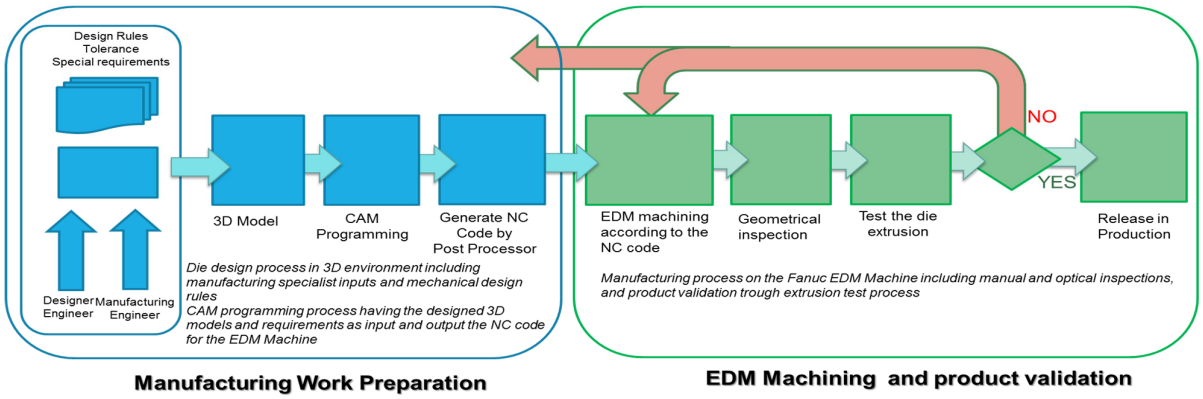

Figure 2. The aluminum extrusion die design and manufacturing process overview [17]

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After EDM treatment, the matrices are cured at 103^{0}C, and atmospheric nitrogen is cured, followed by 2° stress relievers at 570°C - 600°C. These preparation methods harden the die to 48-56 HRC.

The obtained product, extrusion die, is hardened to 48-50 HRC, measured using an optical inspection equipment, microwave vertex machine.

This inspection tool uses the same input, a 3D model to define the NC code.

This method ensures accurate inspection, eliminates potential errors caused by manual measurement

methods and manual definition of nominal values of properties.

The final product, in the extruding die, aerospace industry, inspected with the same optical equipment using the 3D model of the final product, the dimensional product quality results, are confirmed by the extruded aluminum profile. The same 3D models were used to design the die.

As shown in Figure 2, an integrated system between work preparation process and production allows the organization to improve any step of the process in a very short time and by controlling all parameters. [17]

5. CONCLUSIONS

The problems that arise in the case of machining with wire electrode are even simpler than in the case of volumetric processing. This can be stated because the recommendations made by the companies producing such machines are, for example in the case of the electrode, an anime, namely a wire with diameters between 0.1 and 0.3 m, made of copper, rarely brass or tungsten is recommended.

In all cases, the processing technology is designed according to the methodology provided in the machine brochures, and which are based on their own software. At the beginning of the industrial application of EDM processing, the process presented a multitude of advantages, advantages that determined its continuous development, but certain limitations led to its "technological isolation".

The main limitation of the process refers to the low processing productivity, which led to the impossibility of comparing it with most conventional processing processes.

With the improvement of the technological processing system, improvement directed massively towards increasing the amount of material removed, the distance between the productivity of EDM processing and the productivity of other conventional processes is constantly decreasing.

This has led to an improvement in the technological relationship of EDM processing compared to other processing processes.

Another relationship that has been strongly emphasized is the one determined by the processing precision, which places the dimensional machining process by EDM among the processes applicable to finishing and over finishing processing. This technological feature is very well achieved by EDM processing, both in terms of surface quality resulting from processing and in terms of all parameters of dimensional accuracy, shape and position.

Correlating these qualities with the ease with which all precision requirements are met by EDM shows that EDM processing is a favorable process. Under these conditions, the integration of EDM processing into technological lines or flexible manufacturing systems has become a reality.

However, this has led to the development of new concepts of implementation, where the ability to automatically adapt to certain tasks in a process of change is no longer necessary but also conditional.

Obviously, this adaptation presupposes the existence of the process computer, all the more necessary for EDM processing as this process excels through the random values, within wide limits, of the adjustment parameters.

These realities have already led to the improvement of the adaptive self-controls of the technological systems of EDM processing, favoring the wide use of systems capable of almost completely eliminating the intervention of the operator, even if the operations required to be performed are extremely diverse, technological design, manufacturing preparation design to interphase and final control operations.

In this direction, a priority for the evolution of EDM processing, the development trend already started refers to the accumulation of all their improvement and improvements that will be brought to the very varied fields of human knowledge that contribute to processing.

In detail, it can be admitted that the development of EDM processing will be determined by the evolution of computer control systems, the improvement to which power and control electronics can be applied, the design and manufacture of new materials with superior thermal and physical properties, from which to make electrodes - tool capable of improving the processing accuracy, the application of new automatic advance systems through which the commands can be transmitted in real time improved and to ensure superior stability of the system, the refinements that will be brings mechanical blocks or dielectric liquids and their recirculation systems.

The technological possibilities, the flexibility, the adaptability of the process are qualities that make this dimensional processing process a very high degree of capitalization attached to it.

A new way for design engineers to work by collecting data on engineering results and inspection results and integrating them into design data is the nonconventional preparation for production work.

This integrated system allows the manufacturing company to handle design data in a short period of time and ensure high quality products.

EDM machine manufacturers support this new method of work by integrating the capabilities of their digital data import tools (NC codes).

This paper depicts the existing methodology of work as an integrated system between job preparation and manufacturing activities and inspection work in aeronautical manufacturing companies.

At the same time, this paper creates an opportunity for future research into this approach to other obsolete technologies.

EDM is the technological process of dimensional processing that will require the development of many areas of human existence, through its possibilities to solve major material problems.

It will be the one that will determine the development of their micro-processing and those in the nanotechnology field, but at the same time it will be the engine that will lead to the development of macro technologies.

EDM will be the process around which many other processing methods and processes will be oriented and subordinated.

6. REFERENCES

1. Czelusniak, T., Higa, C.F., Torres, R.D. et al. Materials used for sinking EDM electrodes: a review. *J Braz. Soc. Mech. Sci. Eng*. 41, 14 (2019).
2. Patel,J.D., Maniya, K.D. A Review on: Wire cut electrical discharge machining process for metal matrix composite, *Procedia Manufacturing,* Vol.20, 2018, pp 253-258, (2018).
3. Dwaipayan D., Nandi, T. Bandyopadhyay, A. Analysis of machining parameters for wire cut electrical discharge machining of pure titanium using response surface methodology, *Materials Today: Proceedings*, Vol. 5, Issue 2, Part 1, pp. 5374-5383, (2018).
4. Kumar, D., Singh, N.K. & Bajpai, V. Recent trends, opportunities and other aspects of micro-EDM for advanced manufacturing: a comprehensive review. *J Braz. Soc. Mech. Sci. Eng*. 42, 222 (2020).
5. Gotoh H., Tani T., Mohri N. EDM of insulating ceramics by electrical conductive surface layer control. *Procedia CIRP*, (2016).
6. Algodi S.J., Murray J.W., Fay M.W., Clare A.T., Brown P.D. Electrical discharge coating of nanostructured TiC-Fe cermets on 304 stainless steel. *Surf Coat Technol* 307:639–649, (2016).
7. Raju L., Hiremath S.S. A state-of-the-art review on micro electro-discharge machining. *Procedia Technol* 25:1281–1288, (2016).
8. Chiou A.H., Tsao C.C., Hsu C.Y. A study of the machining characteristics of micro EDM milling and its improvement by electrode coating. *Int J Adv Manuf Technol* 78:1857–1864, (2015).
9. Luis C.J., Puertas I., Villa G. Material removal rate and electrode wear study on the EDM of silicon carbide. *J Mater Process Technol* 164–165:889–896, (2005).
10. Katiyar J.K., Sharma A.K., Pandey B. Synthesis of iron-copper alloy using electrical discharge machining. *Mater Manuf Process,* (2018).
11. Ho K.H., Newman S.T. State of the art electrical discharge machining (EDM). *Int J Mach Tools Manuf* 43:1287–1300, (2003).
12. Kumar P., Singh P.K., Kumar D., Prakash V., Hussain M., Das A.K. A novel application of micro-EDM process for the generation of nickel nanoparticles with different shapes. *Mater Manuf Process*. https://doi.org/10.1080/10426914.2016.1244832, (2017).
13. Mohd Abbas N., Solomon D.G., Fuad Bahari M. A review on current research trends in electrical discharge machining (EDM). *Int J Mach Tools Manuf* 47:1214–1228, (2007).
14. Peng Z., Wang Z., Dong Y., Chen H. Development of a reversible machining method for fabrication of microstructures by using micro-EDM. *J Mater Process Technol* 210:129–136, (2010).
15. Mastud S.A., Kothari N.S., Singh R.K., Joshi S.S. Modeling debris motion in vibration assisted reverse micro electrical discharge machining process (R-MEDM). *J Mircoelectromech Syst* 24:661–677, (2015).
16. Ghiculescu D., Marinescu N., Ghiculescu D., Nanu S Aspects of finite element analysis of microdrilling by ultrasonically aided EDM and related knowledge management. *Appl Mech Mater* 371:215–219, (2013).
17. Pop, G.I., Țîțu, A.M., Cupșan, V.C. Nonconventional manufacturing work preparation for wire edm machining, *Nonconventional Technologies Review*, Romania, June, pp. 41-46, (2019).