NONCONVENTIONAL MANUFACTURING WORK PREPARATION FOR WIRE EDM MACHINING

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ABSTRACT: This paper present the manufacturing work preparation process for wired EDM machining used to produce an extrusion die based on the digital engineering data. This digital data contain product and process characteristic. We call this process as nonconventional because all geometrical and process characteristics, as designed are directly transferred to the EDM passing the conventional manufacturing work preparation process as, manufacturing drawing preparation, EDM program preparation using the manufacturing drawings, which can affect the quality of converted information.
This process approach becomes more and more used in manufacturing because the customer wants a high-quality product in a short time. By eliminate some process steps, from the manufacturing preparation process, and transfer product requirement direct to the EDM machine assure a shorter lead-time and reduce additional risks in manufacturing.
KEYWORDS: Manufacturing Work Preparation, EDM Machining, Digital Data, Short Lead Time, High quality.

1. INTRODUCTION

Wire Electrical Discharge Machining (WEDM) is a specialized heat treatment process capable of precision machining with complex shapes and variable hardness with sharp edges that are very difficult to process through main flow processing processes.

WEDM has evolved into an easy way to make tools and surface finishes. Molybdenum wire used in limited applications requires very high tensile strength to ensure a reasonable load capacity for a small diameter wire.

The effect of process parameters on accuracy, volumetric removal rate (VMRR) and surface roughness should be studied experimentally in wire EDM.

The process depends on different parameters, and it is challenging to analyse the efficiency of all process parameters. Thus, different techniques are used to analyse the parameters for better use of the process.

WEDM has an important unconventional machining process that is used to produce complicated shapes with high accuracy and good surface roughness. Many researchers develop a different model and optimize the process taking into account a large number of process parameters and response characteristics.

WEDM has become an essential nonconventional machining process widely used in the following areas: aerospace engineering, tool manufacturing, molds, metallurgy, and automotive industry because WEDM offers an efficient solution for machining hard materials with complex shapes. However, the selection of the cutting parameters to obtain a better efficiency or precision of the cut in the EDM is not yet completely solved.

WEDM is a thermoelectric process in which the material is eroded by a series of sparks between the workpiece and the wire electrode.

During the process, the wire carries part of the electrical load, and the workpiece is transported to the other side of the load. As the wire gets closer to this part, attracting electrical charges creates a microscopic particle of material, spark, smelting, and vaporization.

The spark also eliminates a small wire. Thus, once the wire has passed through a part, the machine discards the used wire and automatically advances the new wire, a thin copper, brass or tungsten wire electrode with a diameter of 0.05 to 0.30 mm.

The different process parameters, such as wire material, pulse on time, pulse off duration, wire diameter, peak current and wire tension, wire feeding speed,

Servomotor voltage and dielectric fluid, as well as significant influence on performance ratio measurements, surface roughness, wire wear rate, kerf width, and size differences (Figure 1). [1]

2. LITERATURE REVIEW

Over the last ten years, research and development of alternative machining methods have included conventional and nonconventional machining technologies involving milling configurations using both solid and indexable tools, abrasive techniques such as cup grinding, pencil grinding or polishing of the electrolytic point and, more recently, WEDM, alone or in combination [2-5].

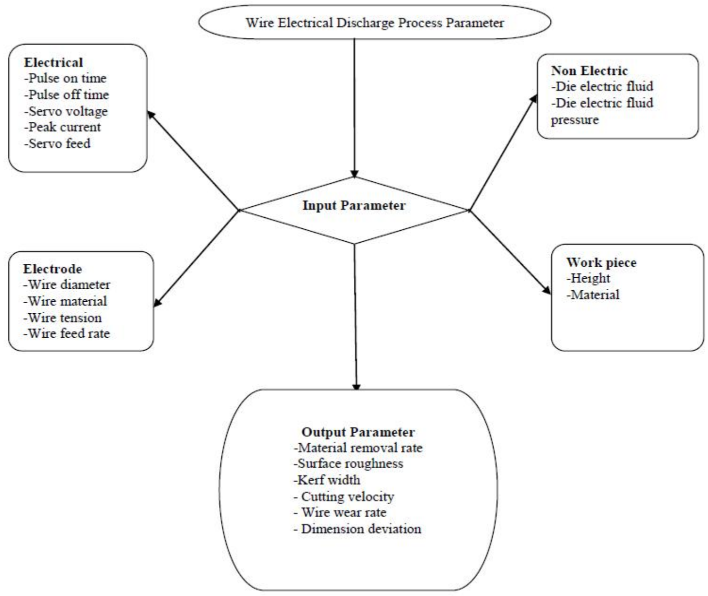

Figure 1. WEDM process and respond parameter [1]

Kannachai Kanlayasiri and Prajak Jattakul [6] examined an optimal cutting condition in terms of dimensional accuracy and surface roughness for the finishing cut of K460 tool steel from wire EDMed.

Cutting variables studied are including the cutting speed, peak current and offset distance.

The Box-Behnken design use as an experimental strategy and optimization of the multiple responses on dimensional accuracy and surface roughness was performed using the desirability function.

The results showed that the peak is current and offset distance have a significant effect on the sample size, whereas the peak current alone affects the surface roughness.

Farnaz Nourbakhsh [7] examined the influence of zinc coated brass wire on the performance of WEDM compared to high-speed brass and studied the effect of seven process parameters, including pulse duration, reference voltage the servomotor, the pulse current and the wire voltage on the process parameters performance (such as cutting speed, wire rupture, and surface integrity).

An experimental Taguchi L18 project (DOE) was applied. All the experiments were done with Charmilles WEDM. It has also been found that peak current and pulse width have a significant effect on cutting speed and surface roughness.

Analysis of variance (ANOVA) also indicated that tension, injection pressure, wire feed rate, and wire tension did not have a significant effect on cutting speed. Scanning Electron Microscopic (SEM) examination of the machined surfaces was performed to understand the effect of different wires on the characteristics of the work material.

Compared to high-speed brass, the zinc brass wire gives a higher cutting speed and a surface finish. Resistance to high strength brass wire under harsh conditions, high pulse width and reduced time between two pulses are far more than coated zinc wire.

Pragya Shandilya [8] discussed the optimization of process parameters when processing SiCp / 6061 Al metal matrix composite by WEDM using response surface methodology. Four input process parameters for WEDM (namely servo voltage, pulse-on time, pulse-off time and wire feed rate, Pulse Time, Pulse Time, and Wire Feed Rate were chosen as variables to study the performance of the process in terms of cutting width (kerf).

An analysis of variance ANOVA was performed to study the effect of process parameters on process performance.

The results of ANOVA show that the wire voltage and wire feed rate are fundamental parameters and that the and pulse-off time is less important.

Pulse-on time has an insignificant effect on kerf. Besides, mathematical models for the response parameters have been developed.

The surface properties of the surface were examined using a scanning electron microscope (SEM).

Ravindranadh [9] has made an experimental study on wire-cut electric discharge machining of hot-pressed boron carbide.

The effects of machining parameters, such as pulse on time, peak current, flushing pressure and spark voltage on material removal rate and surface roughness of the material, have been evaluated.

3. CASE STUDY

In this paper, it is presented the extrusion die design and manufacturing process in manufacturing organization in the aerospace industry.

The most of the structural parts of aircraft made out of aluminum alloys, like series, 7000 and 2000, but not only.

Aerospace design engineers are designing some of the components features to be manufactured by the extrusion process.

The extrusion tools used for this process required special materials, the precise manufacturing process coming from a complex set of parameters required by the design requirements. The extrusion dies are, in general, manufactured by EDM process.

After the short literature review presented, a study about the manufacturing work preparation process for wired EDM machining used to produce an extrusion die based on the digital engineering data is carried.

Engineering digital data contain geometrical product characteristics and process characteristics. This process we are calling nonconventional one, because that all product geometrical and process characteristics, as designed, are directly transferred to the EDM system, excluding the conventional manufacturing work preparation process as, manufacturing drawing preparation, where EDM programming has a manual input of product characteristic from 2D drawings.

The amount of these manual activities can affect product quality. This process approach becomes more and more used in manufacturing industries, as a response to the customer needs, high-quality product in a short time.

By eliminating some process steps, from the manufacturing preparation process, and transfer product requirement direct to the EDM machine, a new approach assures a shorter lead-time and reduce the risk of miss some product requirements.

1.1 The work preparation process in manufacturing organizations.

The manufacturing work preparation process applied, in general, in manufacturing organization are having the same basic principle.

All design data received from the customer are converted into manufacturing documents, methods, tools, media, which are used during manufacturing an inspection process.

In this case study (Figure 2), is presented a similar process, but with the optimized work preparation process approach.

Also, are highlighted the product, and process characteristics direct transferred to the manufactured product, and at the same time, these are used to validate the product.

Figure 2. Manufacturing Work Preparation process overview

The work preparation process has to follow the necessary main steps of any manufacturing process, part of the feasibility assessment process, a review of the product and process requirements by checking the organization capabilities and capacity and of course the commercial aspects. The preparation of manufacturing process, as part of the manufacturing engineering specials job, required to use CAD/CAM tools capable of transferring requirements from design data received as process input into the manufacturing media, required in product machining and product requirements validation.
In Figure 3, the manufacturing media preparation process highlights the product and process requirements, manufacturing and design rules and manufacturing engineering knowledge are integrated in order to provide the best output for the machining equipment and in the same time for the inspection equipment.
In the aerospace industry, the extrusion dies design activities, in addition to the extrusion process and the extruded product section requirements, aerospace design specification need to be incorporated. The aerospace design organizations, design these specifications having the scope to limit and control the manufacturing organization in varying the manufacturing process parameters.
The work preparation process, having all these different inputs, require an integrated system for requirements management, become very important.

The die design organization, using CAD software (Computer Aided Design), design and integrate all requirements into a 3D model. The 3D model of a product represents the virtual body of the product generated by CAD software. In other words, the 3D model of a product is the best mathematical approximation of product features. All these data e used in CAM software, allows manufacturing engineers to define the machining strategy. The CAM software integrate the CAD 3D model and use the virtual body as nominal for all product features. The CAM software transfer the CAM strategy into the NC program, which is controlling the EDM machine to cut the die shape.
The product resulted is inspected by the optical machines, which measure the cut counter using as reference the 3D model view.
Significant aspects of this process are the conversion parameters of the virtual body between different CAD/ CAM software. Almost all software manufacturer is using to import, and export geometries trough neutral formats as STEP files (Standard for the Exchange of Product Model Data - ISO 10303) and IGES (Initial Graphics Exchange Specification).
Having all the work preparation steps linked through the unique reference, 3D model, make this process more controlled and easy to manage.

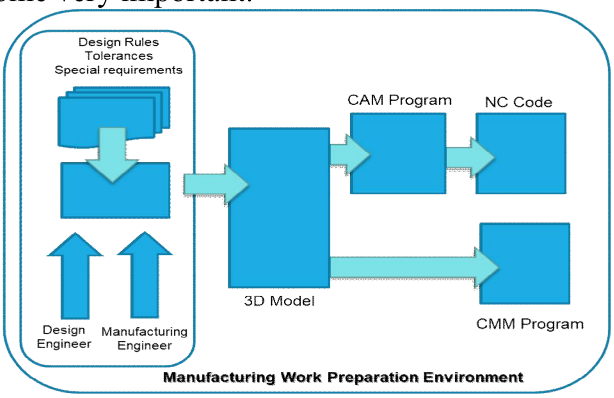

Figure 3. Manufacturing work preparation

1.2 The extrusion die EDM machining process

The aluminium extrusion process required that the aluminium material is warmed up to 400^{O}C before right before the material flows through die. In addition to the working temperature, are also other process requirements, which conduct to use the hot work tool steels materials for dies. The aerospace organization where this study was carried out, are using the H13 (according to ASTM standardization), chromium hot work tool steels which have the following characteristics [10]:

- Good resistance to abrasion at both low and high temperatures;
- High level of toughness and ductility;
- Uniform and high level of machinability and polishability;
- Good high-temperature strength and resistance to thermal fatigue;
- Excellent through-hardening properties;
- Very limited distortion during hardening.

Chemical and mechanical properties of H13 material are listed in table 1 [10].

Table 1. ASTM A681 H13 Chemical and mechanical properties

Material Acc. ASTM A681 H13	Chemical Composition													
	C		Mn		P	S	Si		Cr		V		Mo	
	Min	Max	Min	Max			Min	Max	Min	Max	Min	Max	Min	Max
	0.32	0.45	0.2	0.6	0.03	0.03	0.8	1.25	4.75	5.5	0.8	1.2	1.1	1.75

Material Acc. ASTM A681 H13	Mechanical Properties	
	Tensile strength (at 20°C/68°F, varies with heat treatment)	1200 – 1590 Mpa
	Modulus of elasticity (@20°C/68°F)	215 Gpa
	Poisson's ratio	0.27-0.30

The dies are machined on EDM CNC machine as like Fanuc Robocut 1.iE (Fig.4), Charmilles 240SLP and Charmilles 440 CCS.

For this study, we are considering the Fanuc Robocut 1.iE, which have a cutting precision of 2 microns, with a working zone of X=600mm, Y=400mm, and Z=310mm.

For H13 material, the cutting parameters used are, Rough cutting 0.2-0.3 mm/min and for finishing 7-8 mm/min.

Figure 4. Fanuc Robocut 1.iE [11]

These machines are capable of using the NC program generated by the CAM software called ROBOCUT CAMi programming.

As mentioned before, the CAM software, in the work preparation process, is making available all design features to define the cutting strategy, without manual input.

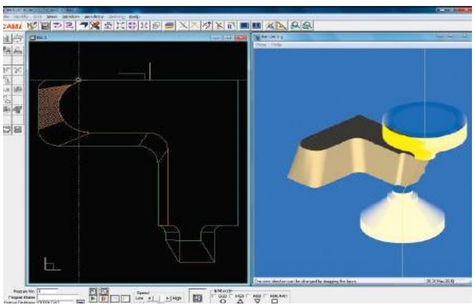

Figure 5. ROBOCUT CAMi programming [10]

As shown in Figure 3, the CAM software, using CNC machine postprocessor, covert the cutting strategy in NC code (numerical control code) automatically, using software algorithm, without manual inputs, assuring that the design features characteristics are transferred to EDM machine without manual input in very short time.

After EDM machining, the dies are hardening to 1030°C, and azoth atmospheric, followed by 2-3 stress relieving at 570°C - 600°C.

These preparation processes result in a die hardens at 48-56 HRC.

The resulted product, extrusion die, hardened to 48-50 HRC, is measured using an optical inspection tool, MicroVu Vertex machine (figure 6).

This inspection tool is using the same input, the 3D model used for defining the NC code.

This method assures proper inspection, eliminating potential errors, generated by manual measurements method and by manual definition of nominal values of characteristics.

Figure 6. Optical Measurement machine [12]

The final product, extrusion die, in the aerospace industry is validated by the dimensional a quality results of the product, aluminium extruded profile, inspected by the same optical equipment, using the 3D models of the final product.

The same 3D models used to design the die.

As shown in figure 7, the integrated system between the work preparation process and manufacturing allow the organization to improve any of the process steps, in a very short time and having under control all parameters.

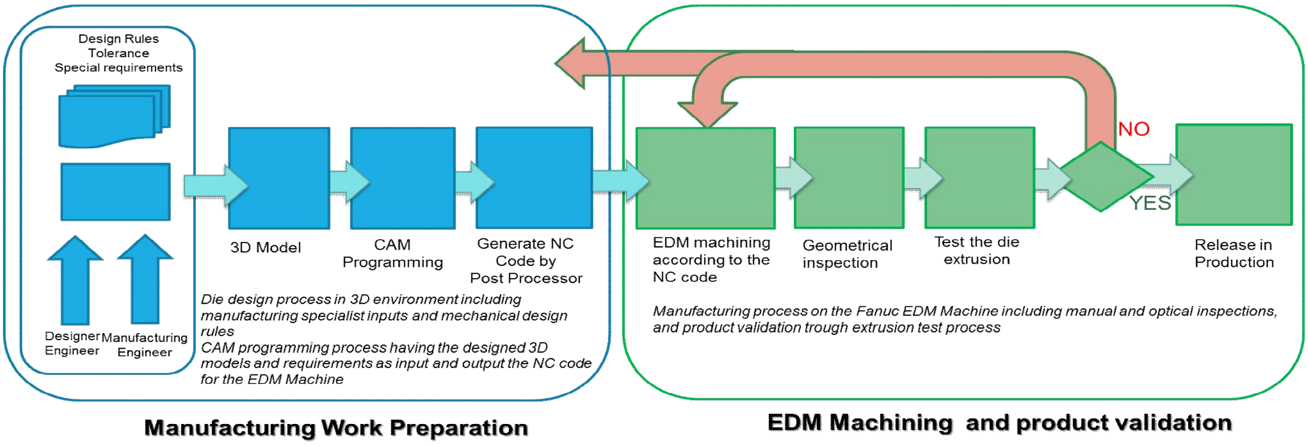

Figure 7. The aluminium extrusion die design and manufacturing process overview

4. CONCLUSIONS

Nonconventional manufacturing work preparation is a new way of working for design engineers by collection the manufacturing engineer's inputs and inspection results and integrate into design data.

This integrated system, allow manufacturing organization to manage design data in a short time and assure high-quality products.

The EDM machine manufactures, are supporting this new way of working by integrating into their equipment's capability to import digital data (NC Code).

This paper illustrates an existing working method, as an integrated system between work preparation activities and manufacturing and inspection operations, in an aerospace manufacturing organization. In the same time, this paper creates a possibility for future research for this approach on other nonconventional technologies.

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