REQUIREMENTS AND SOLUTIONS FOR A DEVICE FOR WIRE ELECTRICAL DISCHARGE MACHINING

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ABSTRACT: Rectilinear kerfs in workpieces made of hard electroconductive materials can be made by wire erosion electrical discharge machining. However, since machine tools intended for such machining are rarer and more expensive, the problem of using devices for wire electrical discharge machining, but adaptable to ram electrical discharge machines, has been formulated. The identification of the functional requirements for such a device in accordance with the principles of axiomatic design led to the defining of a device solution flexible enough to be able to be adapted to different machining conditions. In the constructive solution of the device were incorporated subsystems for pulling and guiding the wire electrode, for changing the angular position of the wire electrode in the machining. The realization and preliminary experimentation of the device led to the formulation of some suggestions for improving the constructive solution of the device.
KEYWORDS: wire electrical discharge machining, functional requirements, device, ram electrical discharge machine, device components.

1. INTRODUCTION

Electrical discharge machining (EDM) is part of the wider group of unconventional machining processes. It is based on the removal of material from the workpiece as a result of electric discharges developed between the active surface of the tool electrode and the workpiece surface to be machined, in the presence of a dielectric fluid that contributes to the removal of metallic particles detached from the materials of the two electrodes. These electrodes are usually included in a pulse electrical circuit of constant polarity. The extension in recent decades of the electrical discharge machining is based on its possibilities to be used even in the case of workpieces made of hard electroconductive materials. Another important advantage of EDM processing derives from its ability to facilitate the realization of surfaces of complex shapes by using numerically controlled relative displacements of the two electrodes [1-6].

A main classification of the machining processes by EDM takes into account the machining on ram electrical discharge machines and the machining with wire tool electrode, respectively. In principle, wire electrical discharge machining (EDM) uses a wire electrode in progress from one spool and winding on another spool (fig. 1), thus being possible to avoid the influence exerted by the wire tool electrode wear on the machining accuracy. The connection to a source of electric pulses with constant polarity of the wire tool electrode and the workpiece and the realization of numerically controlled movements by the two electrodes leads to the detachment of simpler or more complicated profiles from workpiece usually in the form of a plate. Wire electrode electrical discharge equipment is equipped with numerical control subsystems, which significantly increases their purchase prices. Under such conditions, the use of WEDM devices adaptable to ram EDM machines has been investigated. Of course, the characteristics of the use of such devices are lower than those of specialized WEDM equipment, but in industrial practice there may be situations when it is efficient to use WEDM devices adaptable to ram EDM machines. Machine tools of the latter category can be found relatively often in medium-sized enterprises, as there are small enterprises that have such machines.

It was normal for some researchers to focus their attention on the design, manufacture and use of WEDM devices adaptable to ram EDM machines. Thus, a few decades ago, such a device was made and experimented at the Polytechnic University of Bucharest [2].

Another device was designed and used in the laboratory of nonconventional technologies at the

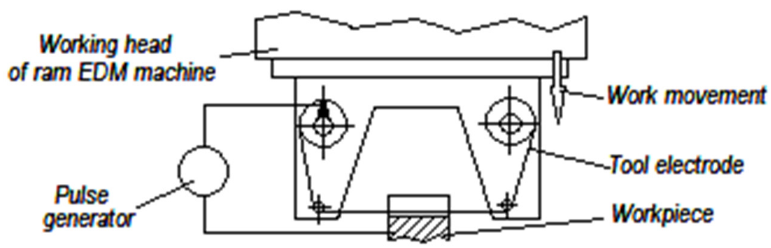

Figure 1. Schematic representation of the device for wire electrical discharge machining using a wire tool electrode adaptable to a ram electrical discharge machine

"Gheorghe Asachi" Technical University of Iasi [7, 8]. The constructive solution was the object of a patent application whose first author was T. Udrea [7].

Note that the two devices mentioned above provided conditions only for the processing of perforated rectilinear slots, they being used on ram EDM machines that did not have numerical control subsystems.

In the last decade, a more extensive research on the possibilities of making an EDM device on a ram EDM machine equipped with a numerical control subsystem was undertaken at the Technical University "Gheorghe Asachi" in Iaşi [9-11].

In a Chinese patent from 2015, a solution of device for machining by EDM with wire electrode was proposed [12]. The patent authors considered that an increase of the machining efficiency is possible by performing wire movements in opposite directions. A procedure of WEDM of the gear teeth was proposed in a technical solution patented in the Republic of Moldova [12].

The objective pursued by the research whose results are mentioned in the present paper was to identify a solution of WEDM device adaptable on a ram EDM machine with wider possibilities of positioning of the wire electrode in the working area.

2. PREMISES AND REQUIREMENTS FOR THE USE OF WEDM DEVICES ADAPTABLE ON RAM EDM MACHINES

Essentially, a device for wire EDM machining adaptable to a ram EDM machine should include a copper wire running from one spool and winding on another spool.

The wire electrode must be guided so that it has a rectilinear shape in the machining area. All components of the device must be placed on a plate that will be attached to the working head of the ram EDM machine. This working head will perform the movement necessary to generate a kerf in the workpiece, by gradually penetrating the wire tool electrode into the workpiece material.

Examining in more detail the process of electrical discharge machining with wire tool electrode likely to develop in the case of the device concerned and especially the possibilities of conducting an experimental research in this regard, we will find that certain groups of factors may influence the process results. These groups of factors could be the following (fig. 2):

1. Dimensional and operating characteristics of the ram electrical discharge machine;
2. Electrical parameters of the machining process (the shape of electrical pulses, but also their other characteristics, such as the average values of the intensity and voltage of the electric current, the amplitude and frequency of the voltage and current pulses, the filling factor, etc.):
3. The travel linear speed of the wire movement in the working gap specific to the EDM with wire tool electrode;
4. The tensile force in the wire electrode;
5. Way to guide the wire tool electrode in the working gap;
6. The nature, properties and mode of circulation of the working fluid in the working gap;
7. The nature of the material from which the wire electrode is made, some physical-mechanical and chemical properties of the wire material, the diameter of the wire tool electrode;
8. Nature of the material, some physical and chemical properties of the workpiece material.

On the other hand, there are a number of functional requirements that the constructive solution selected for the device in question must adequately meet.

Using some principles from axiomatic design [13], we can consider that the so-called first order functional (*FRs*) requirements could be the following:

*FR*1: ensure that there is a wire electrode on one spool and that it can be wound on another spool;

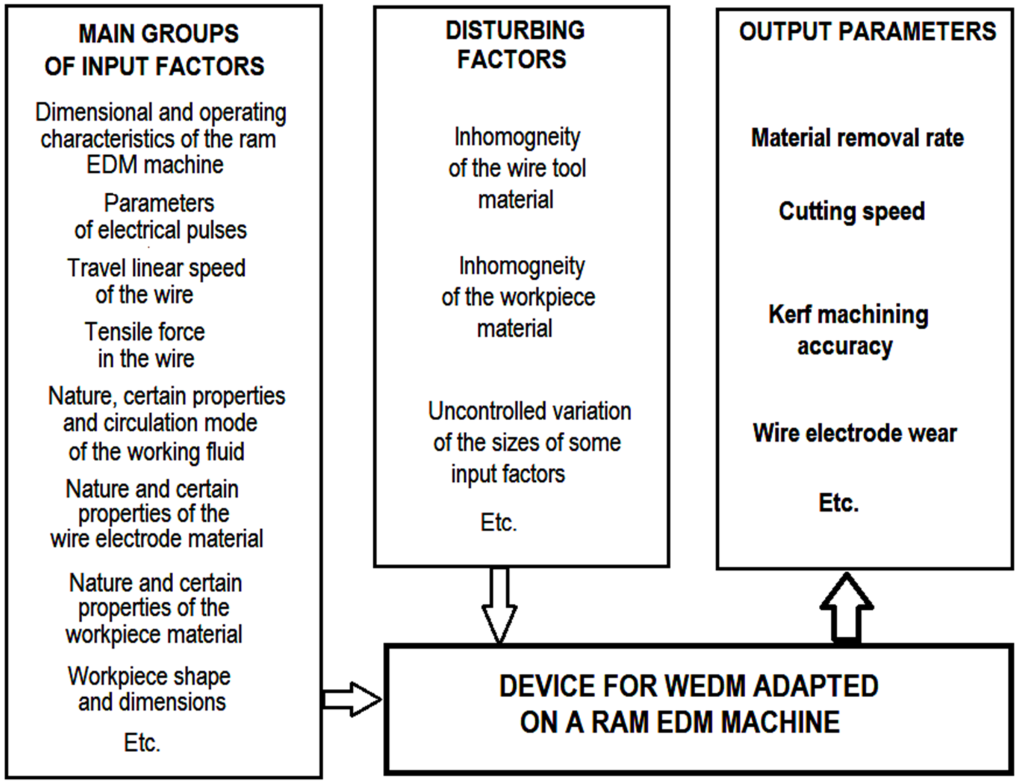

Figure 2. The result of applying a systemic analysis in the case of the device for wire electrical discharge machining adaptable on a ram electrical discharge machine

*FR*2: ensure the angular positioning of the wire in the machining area;
*FR*3: ensure the free rotation of the spool on which the wire is unwound;
*FR*4: ensure a certain value of the tensile force in the wire electrode;
*FR*5: ensure the guide of the filiform electrode at the level of the working gap;
*FR*6; provide possibilities for processing rectilinear kerfs in plate type workpieces of different widths;
*FR*7: provide possibilities for making kerfs in inclined positions in relation to the direction of movement of the working head of the machine tool;
*FR*8: ensure the connection of the wire electrode in the pulse generator circuit specific to the development of an EDM process;
*FR*9: ensure that the spools for unwinding and winding the wire and other subassemblies of the device, respectively, are placed on a component of the device;
*FR*10: ensure that the device is placed on the working head of the ram EDM machine;
*FR*11: as far as possible, provide possibilities for making kerfs in the workpieces along contours made up of straight segments and possibly segments from other categories of curves.

Appropriate solutions will have to be identified to meet each of the above-mentioned functional requirements, as it may be necessary to formulate additional functional requirements and identify new answers to these new functional requirements during the design of the device.

Note that according to the principles of using axiomatic design, there are also a number of so-called *constraints*, such as setting the overall dimensions of the device so that it can be placed on a particular ram electrical discharge machine, the one according to which the mass of the device cannot exceed a certain value, etc.

3. SOLUTION FOR WEDM DEVICE ADAPTABLE ON RAM EDM MACHINE

A device solution capable of largely fulfilling the functional requirements formulated for the WEDM device adaptable on a ram EDM machine is the one shown in figure 3. It was considered that the wire unfolds from one spool and gradually accumulates on the second spool.

The rotational drive of the spool takes place using a direct current electric motor including a reducer attached to the electric motor. This solution provides simpler conditions for changing the rotation speed of the spool on which the wire is wound by changing the supply voltage of the electric motor. The two spools are placed on a tubular part, with square section, by means of shafts supported in bearings.

The tubular part can be arranged in an inclined position at a certain angle with in relation to the

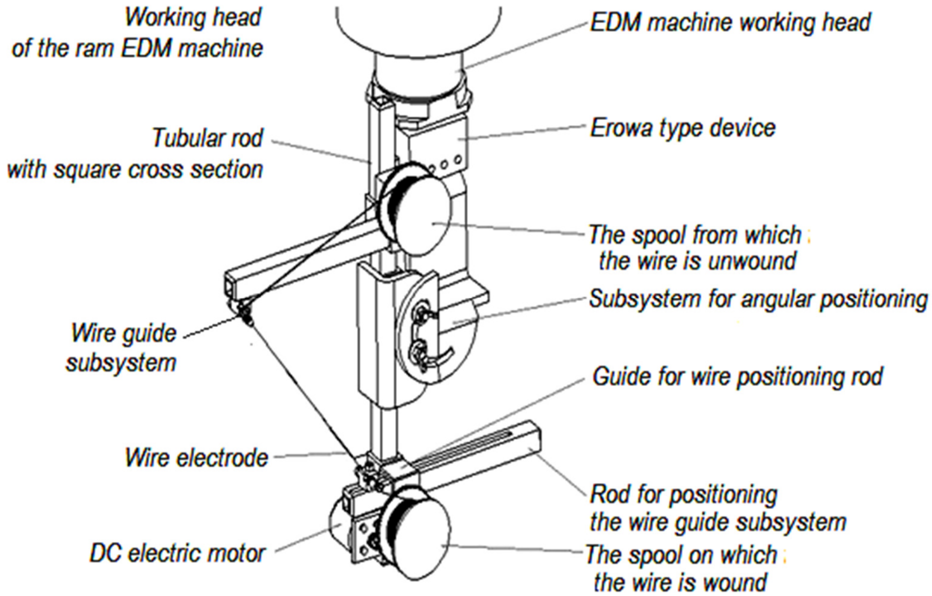

Figure 3. Variant identified for the WEDM device adaptable on ram EDM machine

horizontal plane, being used for this purpose an adequate subsystem.

A tilt of the wire tool electrode position in the machining area is also possible by the proper positioning of the support rods of the wire guide subsystems. For example, the rod can be moved linearly and immobilized in the required position inside a guide with a square section. A similar solution was adopted to support the second wire guide subsystem in the processing area. Since it was intended to use the device on a ram EDM machine, it was necessary to consider how to fix the tool electrodes on such a machine, which is not provided with a flat front surface encountered in many EDM machine frames. It has been preferred, in this respect, to use the facilities offered by the Erowa type device, this device being attached to the working head of the ram electrical discharge machine.

The need to ensure that the WEDM device has a total mass as low as possible led to the analysis of the possibilities of using parts made of plastic. It is topical to manufacture plastic parts using 3D printing processes. A variant of the device in which some of the components were made of plastics by 3D printing can be seen in figure 4.

A proper situation of use of the WEDM device, with the revelation of its possibilities of adaptation to the requirements of a certain machining process, is the one presented in figure 5. It can be seen in this case the need to achieve a kerf in a component located in a cavity of the workpiece. It can be seen in this case a movement of the two rods for supporting the wire guide subsystems along the rod on which the wire spools are placed.

Arranging the wire tool electrode in the desired angular position was possible using an adequate subsystem.

The analysis of the WEDM device solution led to the appearance of suggestions for the improvement of its various components. In this sense, ways to improve the conditions for ensuring extended use of the device

Figure 4. Made version of the device for WEDM

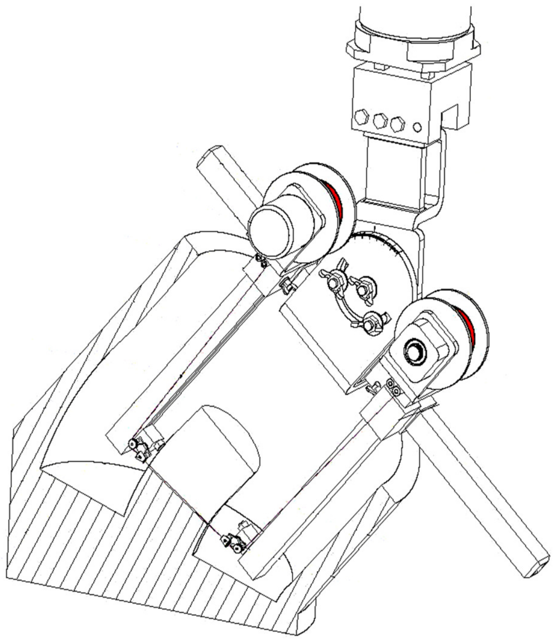

Figure 5. Using the device for machining a kerf whose bottom is inclined in relation to the direction of working movement

and for connecting the wire tool electrode in the pulse generator circuit were considered.

4. CONCLUSIONS

Electrical discharge machining has experienced a real expansion in recent decades, due to its ability to perform machining in workpieces made of electroconductive materials with high hardness, as well as to facilitate the obtaining of surfaces with complicated shapes. In many companies that manufacture mechanical equipment there are ram electrical discharge machines. On the other hand, the use of specialized wire electrical discharge machines is not always convenient, due to the high purchase prices of such machining equipment. Under such conditions, the problem of designing and developing devices for wire electrical discharge machining, but adaptable to the ram electrical discharge machines was formulated. A certain previous experience and the consultation of the specialized technical literature allowed the identification of possible solutions for the pursued devices. The use of principles from axiomatic design has led to the formulation of functional requirements that enlarge the possibilities of using the device. The restriction of ensuring a low mass of the device determined the consideration of the manufacturing of some of its plastic components by 3D printing processes. In the future, it is intended to extend the testing of the device on a ram electrical discharge machine and to take actions to optimize the constructive solution previously developed.

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