EXPERIMENTAL METHOD FOR REDUCING OXIDE LAYER DEPOSITION ON ELECTRICAL DISCHARGE MACHINING EQUIPMENT

Catalin-Stefan Negrea [1,2], Silviu Ionut Gheorghe[1], Mihai Tutoveanu [1,2], Dorin Angelescu [1], Mircea Gabriel Burtoiu [2,3]
[1]National Institute of Research and Development of Mechatronics and Measurement Technique, Bucharest, Romania
[2]University POLITEHNICA of Bucharest, Industrial and Robotic Engineering, Department of Strength of Materials, 313 Splaiul Independenței, 060042, Bucharest, Romania
[3]YOKOGAWA B.V. The Netherlands, Bucharest, Romania Branch
Emails: catalin.negrea95@gmail.com , dorinnirod@yahoo.com

Abstract - The aim of this paper is to present the working principle of an experimental device aimed at reducing the maintenance interventions and cleaning consumables usage for electric discharge machining systems particularly concerning wire electric discharge machines. The device is expected to reduce maintenance interventions, dielectric filtering medium consumption and part cleaning work and consumables while also offering small improvements to the machining process itself.
The paper will detail the working principle and functional elements of the device as well as the benefits that are to be expected from its usage.

Keywords: DMLS, EDM, 3D metal, Wire EDM, Electroplating.

1. EDM Technology

Electrical discharge machining (EDM) is a machining method seen as a cheaper alternative for working hard metals or those that pose difficulties with traditional machining techniques.

EDM usually requires the use of electrically conductive materials and allows for the machining of complex contours or cavities with high precision without the need of any heat treatments to the work-piece and without affecting those that have already been applied to it.

This method allows for the machining of all types of electrically conductive metal alloys like nickel, chrome, titanium, Inconel, etc.

EDM is considered to be a non-conventional machining method having similarities with other machining methods such as water jet cutting and laser cutting as opposed to traditional milling methods.[1]

Figure 1: Electrical discharge machining on a metallic part

EDM can be described in a simplified manner as the repeated creation of an electric arc between an electrode and the work piece in a controlled environment with monitored conductivity.

The electric arc is repeatedly created and destroyed bombarding the workpiece resulting in the formation of small craters with sizes depending on the machining approach ranging in size from nanometres to a tenth of a millimetre in diameter under roughing conditions. The craters form both on the workpiece as well as the electrode itself leading to wear over time.

To avoid the negative effects of electrode wear on the machining process there are a few constructive methods that can be employed: Wire EDM machines use a continually running wire with a constant diameter to combat wear presenting a new area for each discharge, Sinker EDM machines employ the use of multiple electrodes designed for each of the stages of the machining cycle. These electrodes are often quite complex in geometry and used for machining negative shapes in workpieces. [2]

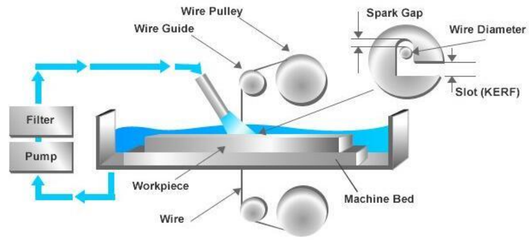

Figure 2: Wire EDM working principle

Electrode wear depends on the technological parameters used for the machining method with slower, more precise machining and smaller spark gaps proving to be the most problematic. This problem requires the use of wear mitigating solutions.

Some particularly interesting solutions for graphite electrode wear is the use of a digital generator programmed to reverse the polarity immediately after the spark in an attempt to redeposit the removed particles back onto the electrode itself.

The distance between the electrode and the workpiece is referred to as the spark gap and the machining parameters are adjusted so that it is constant throughout the machining process to ensure correct removal of material. The spark gap is affected by the dielectric liquid used during machining as well as all the removed material from the cutting area. The cut material from the erosion process can produce unwanted arcing and reduce the cut precision so various flushing methods are used to clear it from the area. The release of electrically conductive material into the dielectric fluid also raises its electric conductivity so special filtering stations are employed alongside sensors to filter contaminants and maintain a stable level of electrical conductivity in the dielectric fluid.[3]

2. Wire EDM – Areas of Improvement

Wire electrical discharge machining uses a thin metal wire usually made from brass but sometimes alloyed with other metal to make it more flexible to cut plates sometimes as thick as 300mm. Wire EDM is usually CNC controlled allowing for the precise following of contours sometimes allowing for even angled cuts. This allows the machines to machine very complex shapes in very tough metals.

During the wire EDM machining process the excess burnt metal from the machining site needs to be flushed away from the part to ensure proper spark gap formation and avoid unwanted arcs. For this reason wire EDM machines use powerful flushing nozzles alongside the wire itself in an effort to move as much material as possible from the area and the general consensus is that the stronger the flow the better performance one can get as long as the wire itself doesn't vibrate.[4]

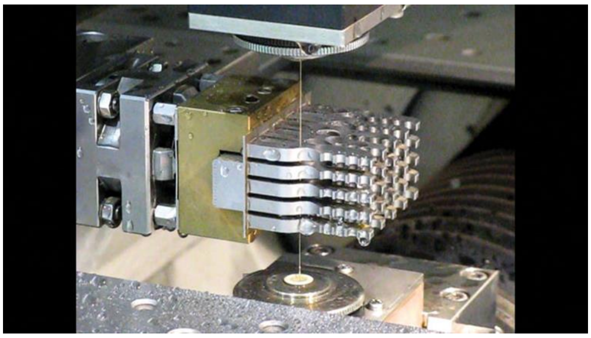

Figure 3: Wire electrical discharge machining

The excess material expunged from the machining site is formed mostly of heavily oxidised powder from the wire itself but mostly from the machined part. This powder is carried by the dielectric fluid and has a tendency to stick to most surfaces it touches potentially causing problems with time. The first affected surface is that of the part itself with areas closer to the cutting side and the second is the working table of the machine itself showing sometimes considerable build up. This paper shows a method to reduce the oxide build-up helping in reducing the frequency of maintenance breaks and slightly increasing the machining speed of the equipment.[5]

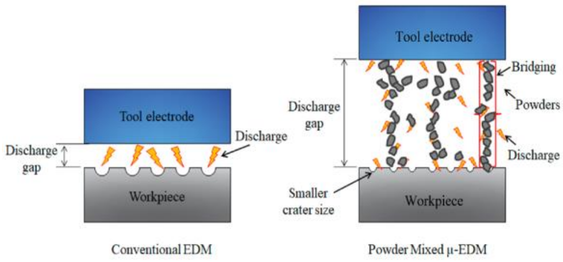

Figure 4: Metal oxide powder influence

Oxide deposits need to be periodically scrubbed from the machine itself to ensure a flat working area for parts to be mounted to precisely with ease as well as avoiding damaging the surfaces themselves. As for the parts being machined it is also very important for the oxide layers to be removed to avoid further corrosion. Wire EDM is usually done in multiple passes each removing less and less material from the part. For each pass there is oxide residue that tends to stick back onto the part which will need to be removed in the next pass. In the improving machining speed aspect of the technology the expected gains are negligible for all but the second pass which is usually reserved for removing thick deposits created by the roughing process where large quantities of material are pumped by the flushing nozzles. [6]

Fig. 5. Heavy oxide deposits on part and machine after the process

3. Proposed Device

The proposed device is made of firstly from an adjustable power source capable of electrically charging the workpiece and table of the machine with a similar charge to that of the material removed from the machining process as such creating an electromagnetically repelling force and drastically reducing the rate at which oxide layers build up on the machine and part itself and as such reducing the need to scrub the equipment as often and reducing the cleaning agent quantities required to scrub the parts of oxides after the process.

The power source is connected directly to the machining table and does not require any contact with the workpiece itself. In order not to interfere with the originally electronic parts we preferred an analogue power source galvanically disconnected from the 220Vac power supply as presented in Figure 6.

The main transformer (TR1) is transforming the 220Vac into a 5,8 Vac – 6,2 Vac secondary voltage. The source itself being similar to a power repeater of the secondary voltage having the possibility to adjust the final voltage to 5.2 Volts dc (using VR01). The force module is a composed transistor (Q2 and Q3) and he power ballast represented by Q4 (2N3055).

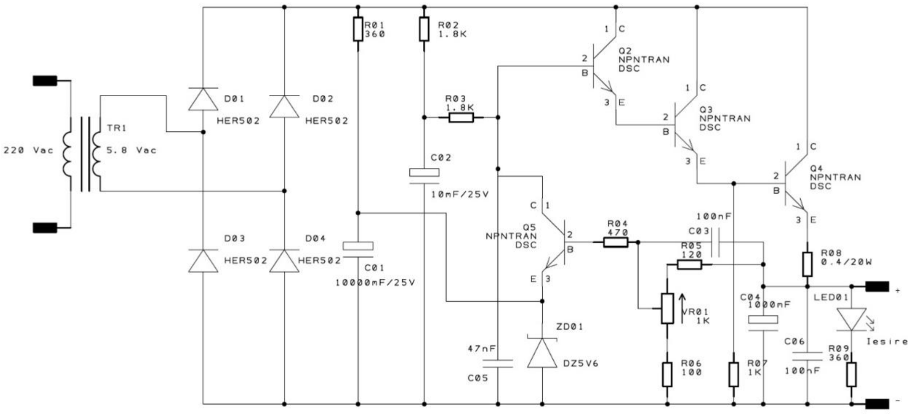

Fig. 6. Electrical diagram with the controllable DC power source

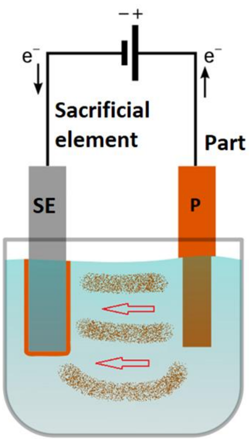

Figure 7: Flow of oxide particles from the part to the sacrificial element

In that configuration the source output can provide 5.2V at a 2.5 A current. In our case the 1 A should be good enough, but if for any reason it is necessary to have a bigger output current it's sufficient to mount 1, 2 or 3 ballast transistors in parallel with Q4 (R08 included). With 2 x 2N3055 the resulting output would be 5A, with 3 x 2N3055 it would be a 7.5A output, etc. (in that case please be assured the main transformer (TR1) can provide the needed current). Q5 and DZ01 is the feedback reaction in order to stabilize the output tension.

The power source is connected with the + electrode directly to the machining table and does not require any contact with the workpiece itself.[7]

The second element is meant to protect the nonconductive areas of the machine by attracting the charged oxide particles floating in the dielectric fluid. This is done through a process similar to electroplating by charging a sacrificial metallic part with a high surface area to attract and encourage the deposition of oxides on it. This sacrificial part must be completely isolated from any conductive areas in the machining tank and connected to the controllable power source to be able to accumulate the powder deposits from the dielectric fluid. A very important added benefit to this device is that since a lot of the material is caught by the sacrificial element it does not need to be filtered and neutralised down the line reducing maintenance costs in filters and ion resin consumables.

Operational tests have been done on the Electric discharge machines part of the CERMISO centre for rapid prototyping and unconventional machining techniques on a U6 Heat electric discharge machine produced by Makino. The U6 Heat electric discharge machine is used as a post-processing machine mainly for metal parts created through metal additive machining in the DMLS laboratory.

4. Conclusions

To sum up the proposed device helps by electromagnetically displacing powder oxide removed from the workpiece during wire electric discharge machining supporting the flushing process. By charging the workpiece the device creates an electromagnetic field around it and the connected machining table reducing the oxide deposit speed helping reduce the surface cleaning amount required after the machining process is done.

Additionally, the device allows for the connection of a sacrificial piece of metal that will act as a “magnet” towards the oxide powder present in the dielectric fluid attracting large quantities and electroplating it onto itself. This allows for a more efficient filtering of the dielectric fluid and easier control over its electrical conductivity reducing consumables used as filtering mediums.

Finally, a small but still present gains is a small increase in machining speed as a result of the better flushing process.

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