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## Particle hydrodynamics of the electrical discharge machining process. Part 1: Physical considerations and wire EDM process improvement

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### Abstract

During these last years, the evolution of the machining speed of the EDM processes has become a key challenge for this technology. The recent progress made on the spark generators leads to a higher production speed in all processes such wire EDM, die-sinking, drilling, milling, etc. Nevertheless, if the electrical process is developing fast, many limiting factors still remain under investigations. In this context, our group started 7 years ago a research program to increase the understanding of the EDM particle hydrodynamics. We describe in this paper some results obtained and discuss the physical aspects related to the evacuation of the machining debris.

During the EDM process, if the cleaning of the dielectric is not effective and some debris remain in the gap, the electrical resistance is locally reduced and the spark occurs at the same place. The process cannot go farther. In this situation, i.e. when the spark frequency and power are high enough, the machining speed is governed mainly by hydrodynamics. In this paper we will present efficient strategies to clean the gap in the wire EDM (part 1) and die sinking processes (part 2).

For the wire EDM process (part 1), we have designed and analysed dielectric injection nozzles with the aim of improving the cleaning processes in the gap. Three main tools have been used to achieve this goal. The first is a fluid flow simulation model using CFD solvers. Then, the results have been validated using experimental techniques at full scale on EDM machines. Finally, a test rig has been developed and experimental analyses have been done.

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### 1. Introduction

In the EDM process (Fig. 1), the plasma generated during the heating phase leads to the presence of liquid material and gas. When the plasma disappears, a pressure wave is generated that move the melted material in the dielectric. Solid particles are formed (Fig. 2). A crater is formed; this is the machining action (Fig. 3). The particles remain in the dielectric closed to the crater (Fig. 4). These have a spherical shape and move in the liquid. The density of these is higher than the liquid,

then the trajectories of the debris are not directly which of the fluid particles. They need to be observed or calculated, according to the laws of the motion of a high density solid in a fluid flow. The forces are the hydrodynamic force, the hydrostatic force (Archimedes' force) and the mass forces (gravity and acceleration).

The EDM process needs some impurities in the dielectric liquid. If these are not present sparks cannot be generated. At the other hands, if the impurities are in big quantities and located at the same place, the spark will be produced always at the same place. This is due to the fact the particles decrease the resistance of the dielectric.



Fig. 1: Wire EDM production of a complex part.

The spark will not move and will try to remove material always at the same place. The machining process will not work properly. The objective of the project is to understand what is a good cleaning of the gap and how to obtain it.

## 2. Project approach

The project is based on three approaches. Machining tests were performed at the beginning and all along the project. Also, technicians having a great experience regarding the EDM process have followed the project and commented the analyses. Machining tests are very helpful to confirm the conclusions but don't give the possibility to understand the process and the fluid flow behaviour in the nozzle and in the part. For this reason, we built a test rig with an instrumented nozzle. Finally, we decided to develop CFD models and benefit from high performance simulation technics. This last approach, after a validation phase, gave us the possibility to visualize the flow inside the part and the nozzle in a very efficient way. The flows obtained with several prototypes of nozzle have been described and their cleaning performances have been evaluated.

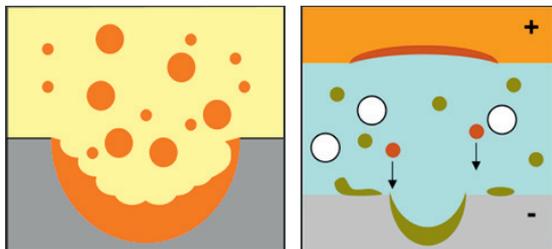


Fig. 2: Particle generation process.

## 3. Theoretical design and machining tests

The great experience of the industrial partner of the project is the starting point. It appears immediately the flexibility of the nozzles designed is generally important. Some specific designs can be implemented to obtain high particle cleaning efficiencies, but these give limiting application flexibility.

$$\frac{c^2}{2} + \frac{p}{\rho} + g dz = 0 \quad (1)$$

$$c = \sqrt{\frac{2}{\rho}(p_0 - p)} \quad (2)$$

The research group first designed nozzles based on a theoretical approach. This approach was to ensure the static pressure at the nozzle outlet is equal to the pressure existing in the dielectric tank closed to this point. In this nozzle, the upstream pressure energy is completely transformed in kinetic energy at the outlet. In this case the nozzle is called "adapted". The speed of the jet at the outlet is the maximal reachable. This can be called a "dynamic pressure nozzle". The law governing the transformation of the energy is given by equations 1 and 2, and represented in figure 5. This is a simple law based on Bernoulli equation. This approach is really known by hydrodynamic engineers and the work appears to be easy.

In practice, machining tests and the technician experience show this is difficult to work with such nozzles. The results we got confirm that. When the part to be machined is not there, the jet is straight and everything seems to work fine. A strong jet is present. However, when we are in machining conditions, the jet is modified by the presence of the part, and the flow cannot be considered ending in a infinite space. The expected result is not reached.

The cleaning effect is not bad, but the jet speed is high and the wire vibrates. The flow generates instabilities at the slot entrance that propagate in the gap. Practically, it was difficult to work with such dynamic



Fig. 3: View of a crater produced at the surface by the spark. Melted material can be seen [2].

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