



HYDRODYNAMICS OF THE ELECTRICAL DISCHARGE MACHINING PROCESS (EDM)

Patrick Haas, Prof. HES

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L'avenir est à créer

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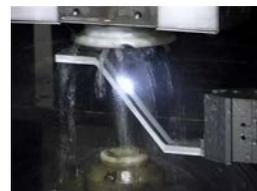
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THE ELECTRICAL DISCHARGE MACHINING PROCESS (EDM)

« Use of electrical discharges to remove material »

The processes available today are the following :

- EDM die-sinking (ex. credit card injection moulds)
- Wire-EDM (ex. extrusion moulds)
- EDM hole drilling (ex. engine injectors diam. < 0.100 mm)
- EDM milling (ex. complex parts, small, hard material).
New method developed by Agie Charmiles with hepia
(Prof. J. Richard)



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HISTORY

- 1770 Priesley (GB): Study of the effects on material of electrical discharges
- 1943 Work from the Lazarenko (2 persons from Russia)



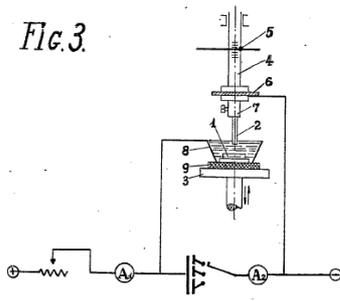
Work on the efficiency of an engine electrical contact breaker. Impact on the contacts.

- 1955 1st Charmilles Technologies (EMO show)



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Fig.3



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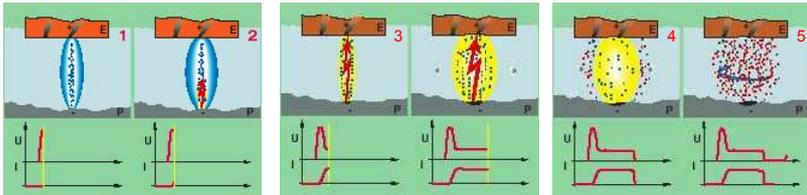
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THE EDM PROCESS

1. Application of a potential between the electrode and the material
2. A ionized channel is created
3. A plasma is formed. The spark generator decrease the potential to stabilize the current.
4. After a imposed time, the current is stopped. A plasma implosion is created (low pressure in the plasma zone)
5. Some material are removed.

- Temperature : 5000 – 8000 °C
- Pressure : 1 to 2 bars (?)
- Energy density : $10^{11} - 10^{14} \text{ W/m}^2$
- Temperature gradient : 10^8 °C/m



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THE EDM PROCESS : EFFECTS OF THE PROCESS ON THE MATERIAL (1)

- A pressure is generated by the plasma
- The plasma contains ions and electrons
- Craters are created on the cathode and the anode
- The pressure of the plasma is applied on the liquefied material surface

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THE EDM PROCESS : EFFECTS OF THE PROCESS ON THE MATERIAL (2)

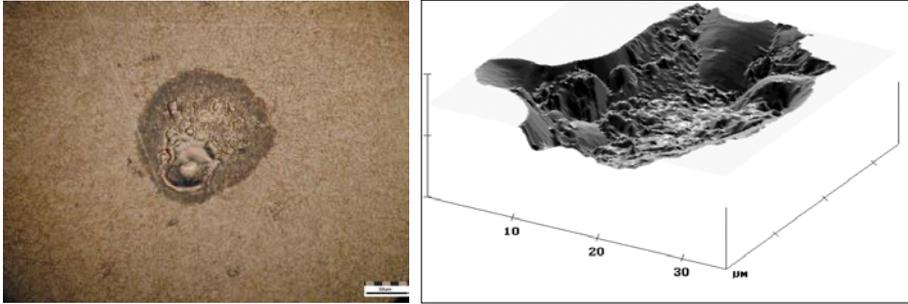
- When the plasma disappears, the pressure reduces suddenly
- The material starts to evaporate!
- Ejection of material particles in the dielectric (liquid) and solidification.
- One part of the particles solidifies in the crater
- The others are ejected in the gap

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THE EDM PROCESS



Views of craters

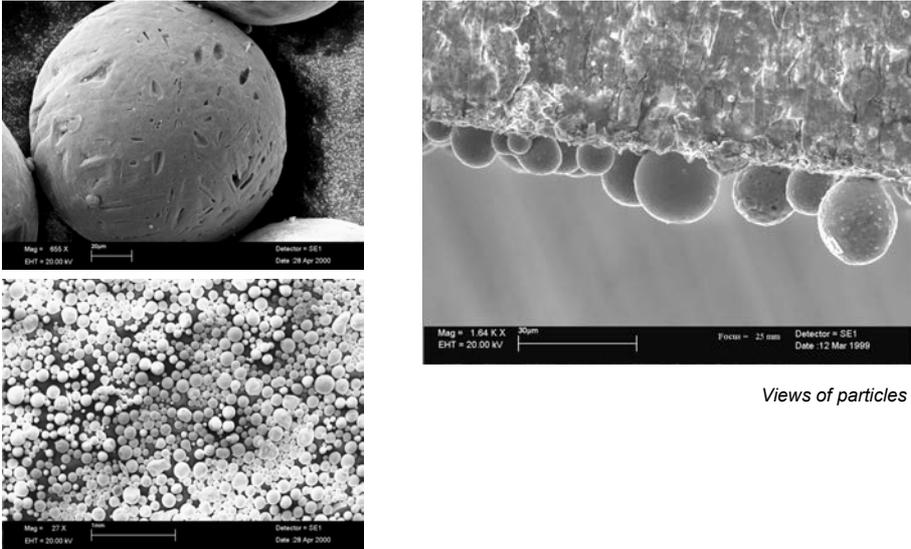
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THE EDM PROCESS



Views of particles

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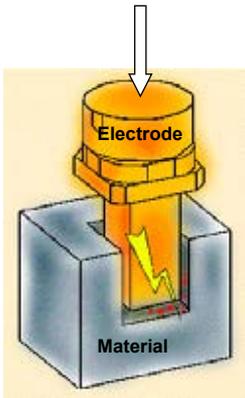
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PROCESS APPLICATIONS : DIE-SINKING

The electrode is pushed in the material or moved laterally



Electrode

Material

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Mobile phone moulds

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Detailed description: This slide illustrates the die-sinking process. It features a diagram on the left showing a yellow cylindrical electrode being pushed into a blue material block, with a yellow lightning bolt indicating electrical discharge. To the right is a photograph of several complex, multi-part metal moulds for mobile phones. The slide includes logos for 'hepia' and 'Hes-SO // Genève' at the top, and a URL 'http://www.cmefe.ch' at the bottom left.

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PROCESS APPLICATIONS : DIE-SINKING

The electrode can be very big !



Sport equipment moulds

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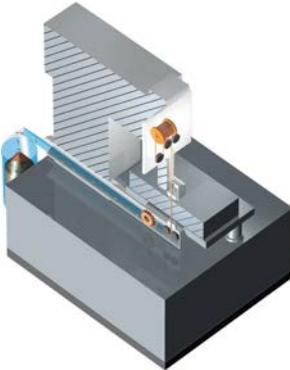
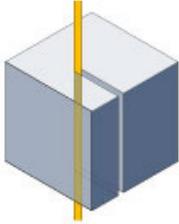
Detailed description: This slide shows a large-scale application of die-sinking. On the left, a large, copper-colored metal electrode is being used to sink a deep, curved cavity into a metal block. On the right is a photograph of a white, high-tech sport equipment mould, likely for a ski boot. The slide includes logos for 'hepia' and 'Hes-SO // Genève' at the top, and a URL 'http://www.cmefe.ch' at the bottom left.

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**PROCESS APPLICATIONS :
WIRE EDM**

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- The electrode is a wire moved to cut the marterial as a « butter knife »
- The wire is unrolled during the process



A wire in action

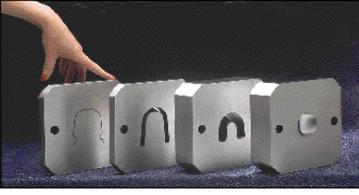
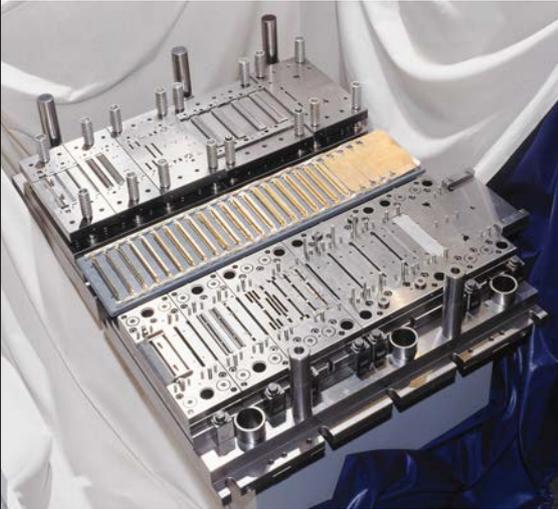
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**PROCESS APPLICATIONS :
WIRE EDM**

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Complex moulds for plastic injection

Extrusion moulds

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HYDRODYNAMICS OF THE EDM PROCESS

- During the EDM process, the spark starts at the location where the dielectric resistance is the smallest
- The EDM process can be used for production only if the next spark moves to the smallest gap location
- There is a necessity to find a way to **regenerate the dielectric** and to **clean the gap**. Although, the spark stays all the time at the same location and the process can not work.

→ The production speed is governed by **hydrodynamics**

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THE WIRE EDM SCENARIO

- A dielectric injection is applied continuously by 1 or 2 nozzles
- We can improve the production by working on the **nozzle design**
- The design methods are theoretical, experimental and CFD

The diagram illustrates the wire EDM process. A central yellow wire is shown moving downwards, indicated by a downward arrow labeled 'Wire in movement (mechanical tension and electrical potential)'. The wire is positioned between two blue nozzles: an 'Upper nozzle' at the top and a 'Lower nozzle' at the bottom. Two light blue arrows labeled 'Dielectric injection' point downwards from the upper nozzle and upwards from the lower nozzle, creating a dielectric fluid layer around the wire. This fluid layer is labeled 'Dielectric' and contains small black dots representing eroded material. The workpiece, labeled 'Material', is shown as a grey block on the right side of the wire.

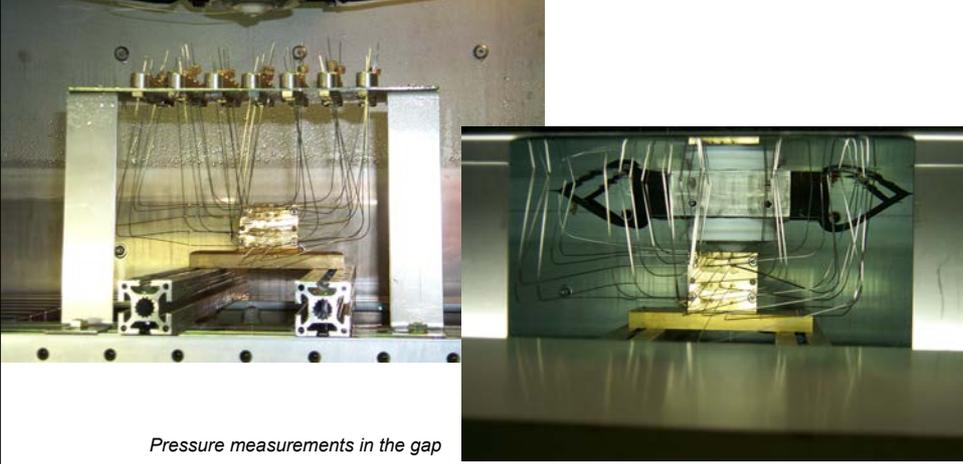
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THE DESIGN OF WIRE EDM NOZZLE

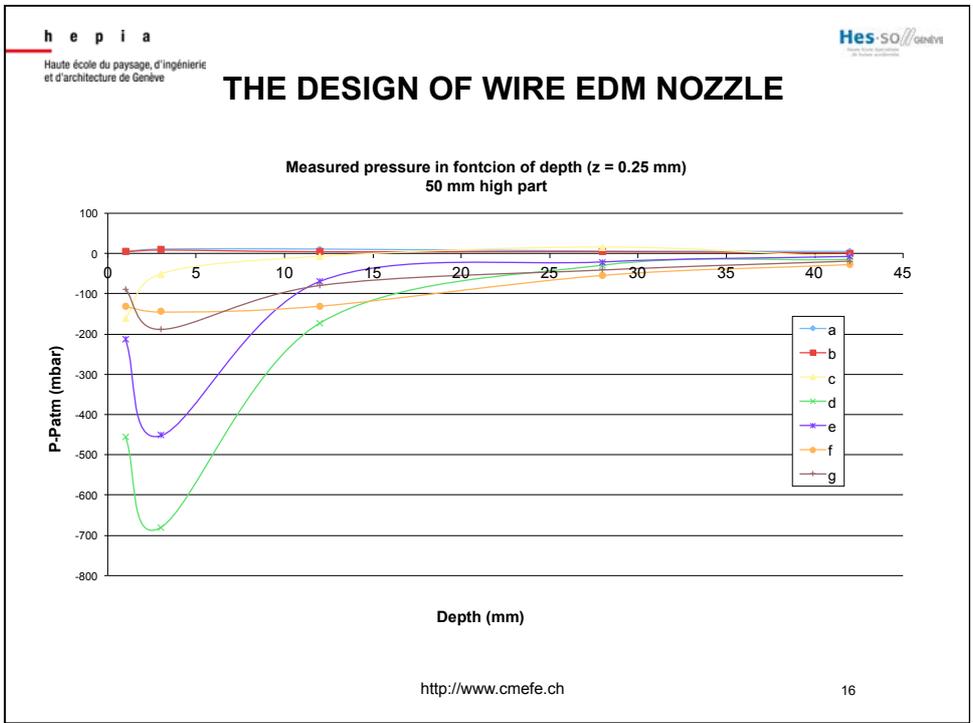
1) Experimental investigations



Pressure measurements in the gap

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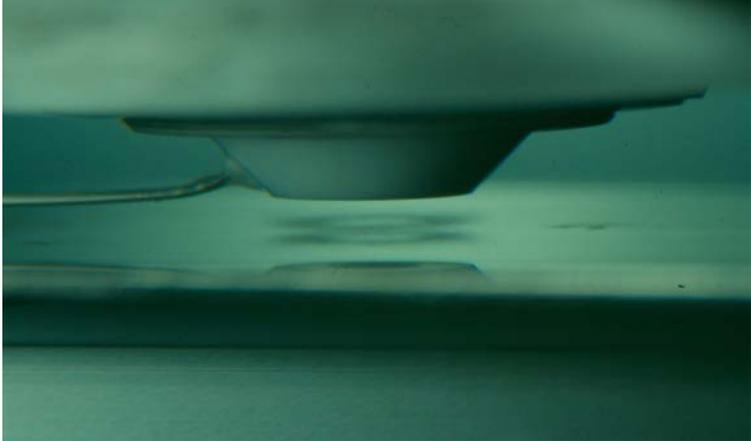
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THE DESIGN OF WIRE EDM NOZZLE



Annular vortices are generated

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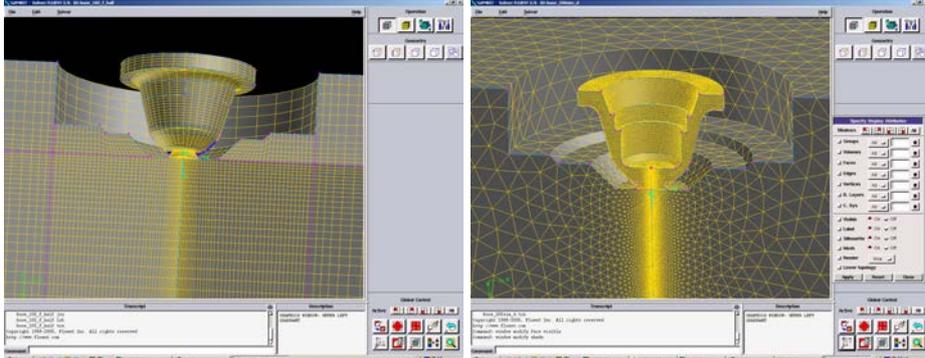
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THE DESIGN OF WIRE EDM NOZZLE

2) CFD investigations and design (Fluent)



Map mesh (hexahedra)

Tgrid patch conform mesh (tetrahedra)

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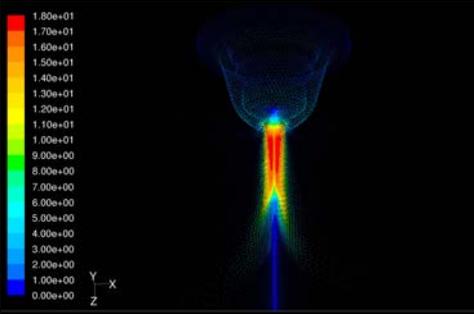
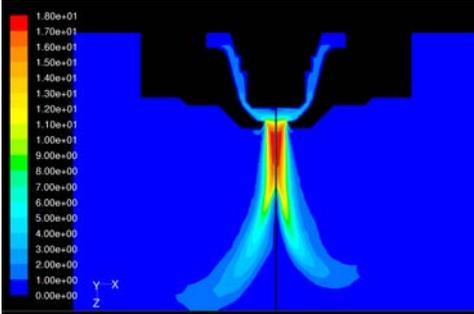
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THE WIRE EDM SCENARIO

- Free jet in the dielectric (without part)

Velocity Vectors Colored By Velocity Magnitude (m/s) Jun 08, 2005
FLUENT 6.2 (3d, segregated, sstkw)

Contours of Velocity Magnitude (m/s) Jun 07, 2005
FLUENT 6.2 (3d, segregated, sstkw)

Jet speed in m/s

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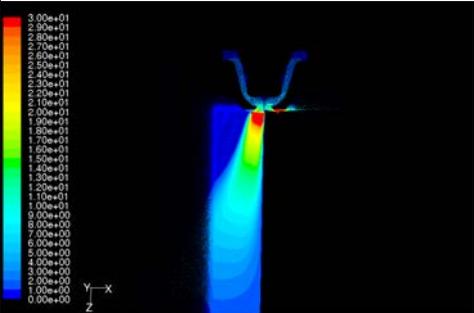
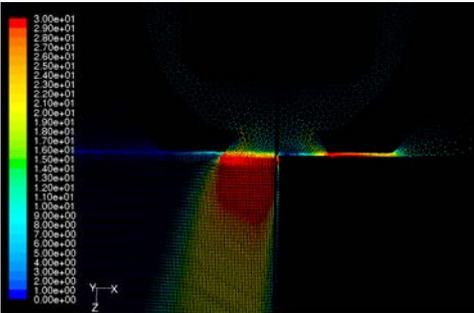
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THE WIRE EDM SCENARIO

- Jet during production (with part)

Velocity Vectors Colored By Velocity Magnitude (m/s) Jul 14, 2005
FLUENT 6.2 (3d, segregated, sstkw)

Velocity Vectors Colored By Velocity Magnitude (m/s) Jul 14, 2005
FLUENT 6.2 (3d, segregated, sstkw)

Jet speed in m/s

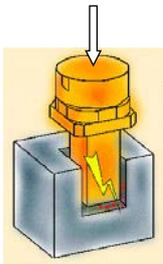
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THE DIE SINKING SCENARIO



The production scenario is :

1. Spark cycles are generated for a while
2. The spark generator detect the presence of particles (analysis of the current and potential curves) and control the CNC
3. When the quantity of particles is too high, the cleaning process starts : « the electrode is moved up and down to generate a flow through the lateral gap and in the cavity »

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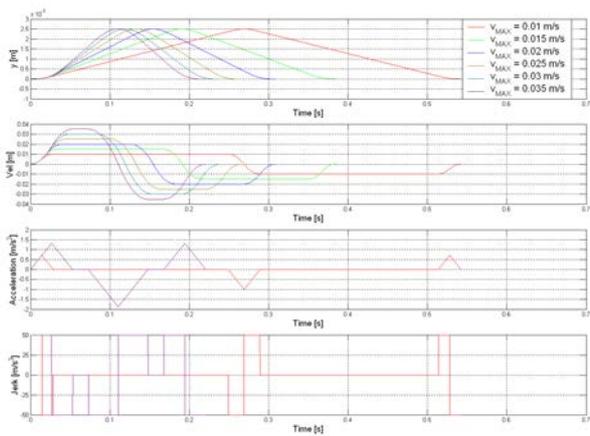
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THE DIE SINKING SCENARIO

The challenge : « What is the most efficient movement ? »

- Amplitude ?
- Speed ?
- Sequence of small and big jumps ?



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THE DIE SINKING SCENARIO

1) Experimental investigations



- On the EDM machine : scale 1:1
- On a test rig : scale 20:1 in similitude

20:1 scale test rig

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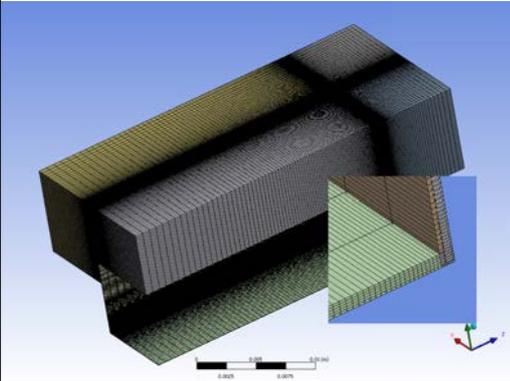
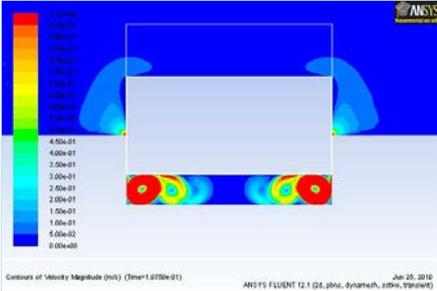
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THE DIE SINKING SCENARIO

2) CFD investigations (Fluent)

- Transient model
- 2D and 3D studies
- RANS k-w turbulence model

Contours of Velocity Magnitude (m/s) (Time=1.8750e-01)

ANSYS FLUENT 12.1 (64-bit, dynamic, 32Nv, 32nmbr)

Jan 25, 2018

Some CFD models

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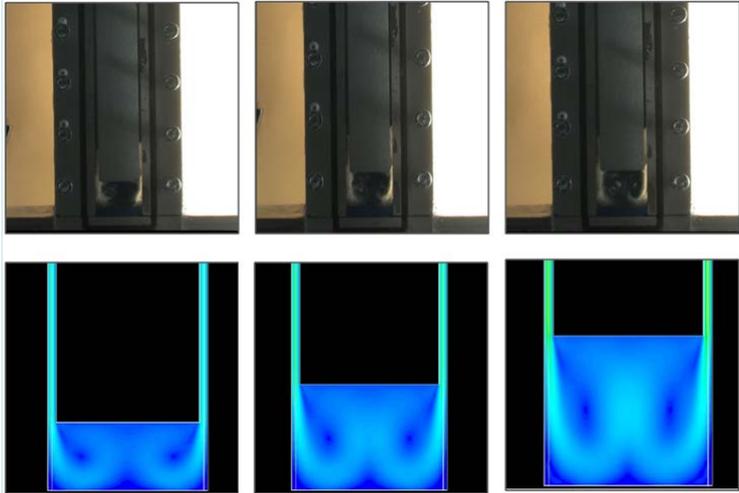
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THE DIE SINKING FLOW ANALYSIS

1. At the beginning of the movement, two symmetrical vortices are generated



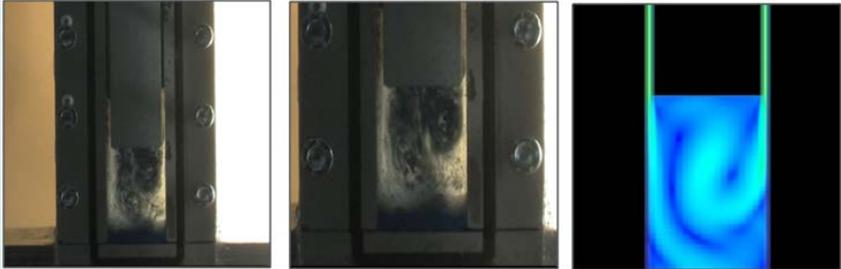
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THE DIE SINKING FLOW ANALYSIS

2. The electrode going up, the aspect ratio of the two vortices increases



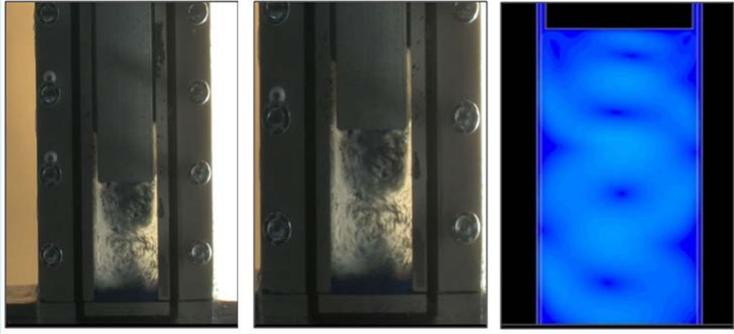
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THE DIE SINKING FLOW ANALYSIS

3. The vortices break into several ones aligned vertically (more stable configuration). The solid particles are mixed.



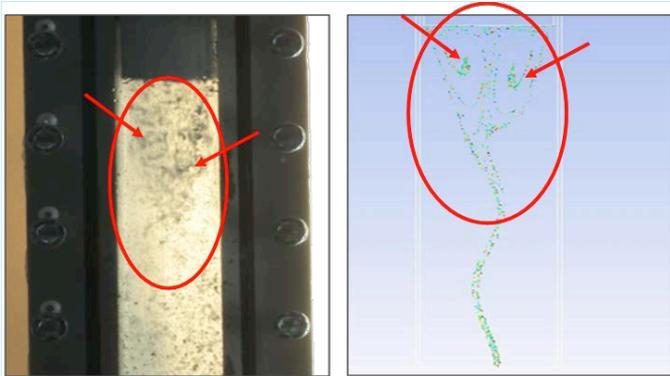
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THE DIE SINKING FLOW ANALYSIS

4. When the electrode is near 5 to 10 times the width of the cavity, the intensities of the vortices decrease and the particles start to fall. It is not interesting to go higher with the electrode.



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THE DIE SINKING FLOW ANALYSIS

5. When the electrode goes down, some particles stay under the horizontal part, the others are ejected through the vertical gap.

Sequences 1 & 2

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THE DIE SINKING FLOW ANALYSIS

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Thanks, questions ?

Patrick Haas, Prof. HES

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Groupe de compétences en mécanique des fluides
et procédés énergétiques

