MICRO AND NANO PARTICLES PRODUCED BY WATERJET ABRASION

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ABSTRACT
The debris produced by a waterjet machining equipment was observed and analyzed by optical microscopy, scanning electron microscopy, energy dispersive spectroscopy, backscattered electrons, and transmission electron microscopy. Micro and nano particles of different forms were found as result of the cutting process.

Keywords: nano particles, micro particles, waterjet machining

MICRO Y NANO PARTICULAS PRODUCIDAS POR LA ABRASION DE CORTE POR AGUA

RESUMEN
Los residuos producidos por un equipo de corte por agua fueron observados por microscopía óptica, microscopía electrónica de barrido, análisis dispersivo en energía, electrones retrodispersados y microscopía electrónica de transmisión. Se hallaron partículas nano y microscópicas de distintas formas como resultado del proceso de corte.

Palabras clave: nano-partículas, micro-partículas, maquinado por corte de agua.

INTRODUCTION

Aimed at the production of particles by non traditional methods for nuclear fuels, we have started experiences to obtain particles of uranium and molybdenum alloys (UMo). The previous attempts were based on the material fusion and the subsequent swift cooling in different atmospheres: electro erosion with an electric arc as heat source [1-3]; laser ablation using oxygen as propellent gas [4,5]; high power plasma with air as impelling gas [6] and arc furnace [7]. The waterjet machining (WJM) [8,9] presented in this work as a source of particles -also known as hydrodynamic machining- consists essentially of a small section high pressure water flux, as a cutting tool.

This process is limited to non metallic materials. However, if fine abrasive particles are injected into the water stream it can be used to cut harder materials. The cutting is produced by the abrasion of high energetic particles of water and abrasive impinging on a reduced sample area.

Table 1. Mass distribution by particles size

Sieve	interval (µm)	mass (g)
100	>150	143.1
120	125-150	123.9
140	106-125	61.8
200	75-106	54.8
270	53-75	46.1
325	44-53	15.2
-325	-44	73

Once the abrasion is finished, the removed materials as well as the abrasive powder are dragged to the debris reservoir. We observed the usually discarded material cut by WJM with rhodesite as abrasive powder and found that they consisted of a mix of micro and nanoscopic particles of different composition, either metallic or non metallic coming from the cut metal and from abrasive respectively.

MATERIALS AND METHODS

The particles were taken from the debris reservoir, after cutting different alloys in a MS 2500 WJM machine TRUMPF model. The water was used at 3200 bar pressure. A flux from 400 to 420 g/min of 100 µm rhodesite was mixed with the water in the nozzle by Bernoulli Effect. The collected material, rhodesite and pieces of alloy were grouped in batches, see Table 1. Then the external particles surface was observed by optical microscopy (OM) and scanning electron microscopy (SEM). In order to observe the particles interior they were embedded in acrylic and polished with different emery papers and examined by OM, SEM, backscattered electrons (BSE) and analyzed by energy dispersive spectroscopy (EDS). Fragments belonging to the smallest size particles group were observed by TEM in Philips EM300 equipment. TEM samples were prepared as follows: a Cu grid was covered with an amorphous carbon layer; the particles were introduced in an Ependorff recipient, mixed with ethanol and detached by sonication. A small drop of the mix containing the particles was laid on the carbon film.

On the other hand, we also examined the abrasive particles by SEM. Furthermore it was cut an AISI 304 stainless steel and observed its surface modifications by the WJM process of cutting.

RESULTS AND DISCUSSION

Fig. 1 shows a SEM micrograph of the abrasive particles. Form and surface could be clearly seen; the EDS analysis

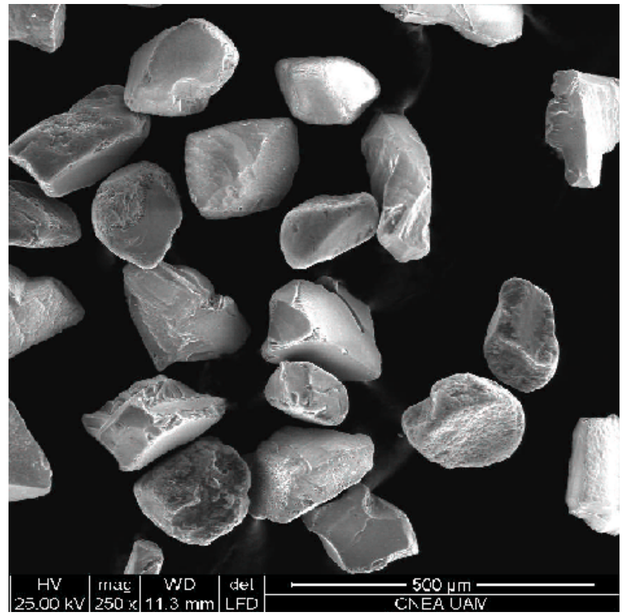

Fig. 1. Electron micrograph of rhodesite abrasive particles, obtained with secondary electrons and large field detector.

showed the rhodesite low atomic number elements like Si, Ca, Al and P. A view of the surface of a 304 stainless steel cut piece is shown in Fig. 2, there can be seen some pieces of abrasive adsorbed particles on the specimen surface shaped by abrasion. Fig. 3 shows the external view of the debris constituted by abrasive and metallic particles. It shows particles with smooth abrasive surfaces (A) and other metallic (M) as it was checked by EDS. The metallic ones have indented surfaces and are cracked by erosion, see Fig. 4. In Fig. 5, taken by BSE on a sample included in acrylic, can be seen metal particles of Ti and Fe, clearly differentiated from abrasive S, Ca, Al and P.

In TEM micrographs it can be seen the existence of nanoparticles whose size is in the range 25 to 200 nm. We measured the specimen mean temperature during the cut process and found an increase of 10 ºC.

The range of particle size is rather large. As a matter of fact, we found particles larger and smaller than the 100µm abrasive ones, Fig.1. We suppose, observing the cut piece surface, Fig. 2, that abrasive particles act as a usually cut tool does in a metallic specimen because the surface presents the similar indentation of metal shaving.

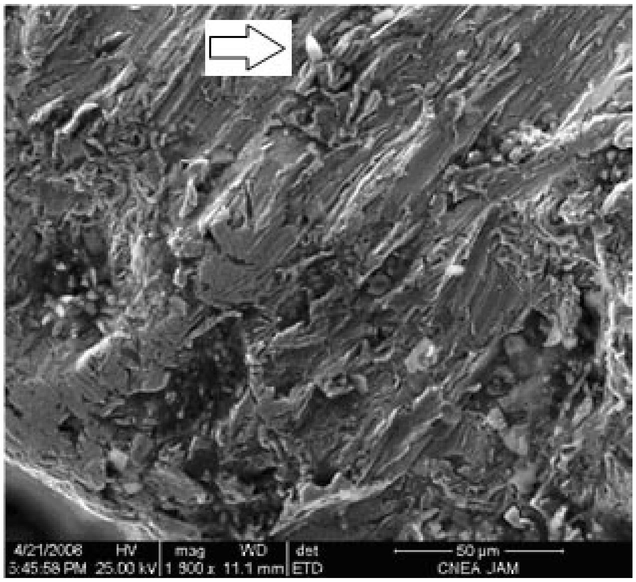

Fig. 2. Electron micrograph, of an AISI 304 stainless steel surface cut by WJM, arrow indicates abrasive particle. Using Everhart Thornly detector.

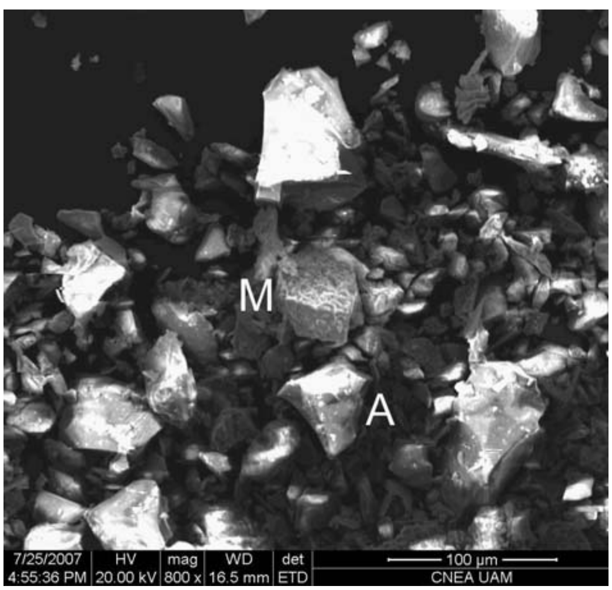

Fig. 3 Electron micrograph of abrasive (A) and metal (M) particles, obtained with Everhart Thornly detector.

We presume that the properties of the metallic particles are a consequence of the abrasive pieces, their kinetic energy and the work velocity, [10]. The increase in temperature might be a result of the intense abrasion that takes place during the cut process.

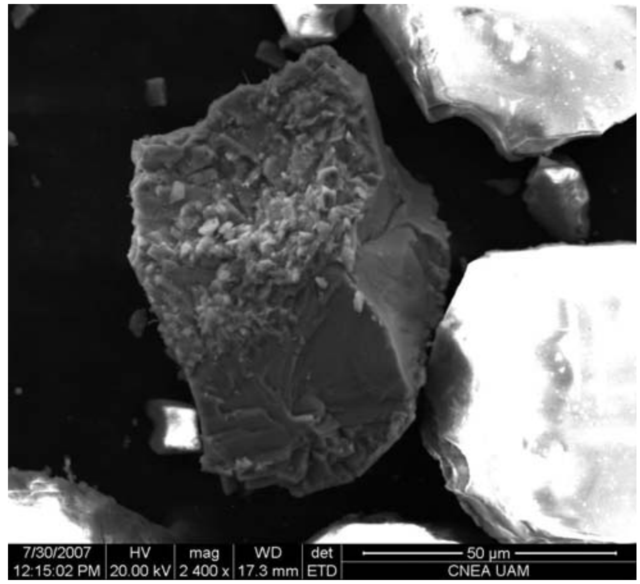

Fig. 4. Electron micrograph of metal particles obtained with Everhart Thornly detector.

In the case of an AISI 304 stainless steel cut by WJM, not published yet, we measured the residual stress which gave a value of -200 GPa, which could correspond to a heat process during the WJM.

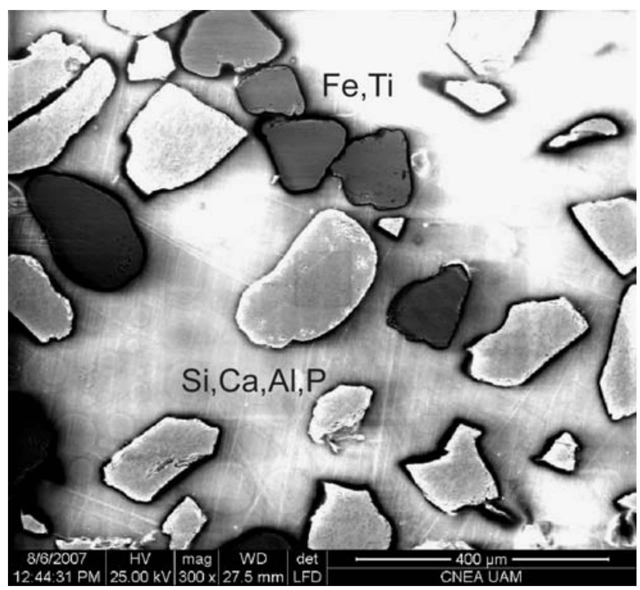

Fig. 5. BSE micrograph, showing abrasive (Si, Ca, Al and P) and metal (Fe, Ti) particles, light and dark respectively, obtained with large field detector.

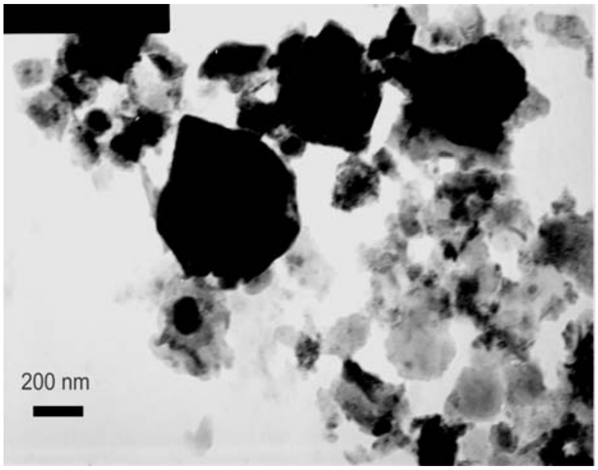

Fig. 6. TEM micrograph of nanoscopic particles.

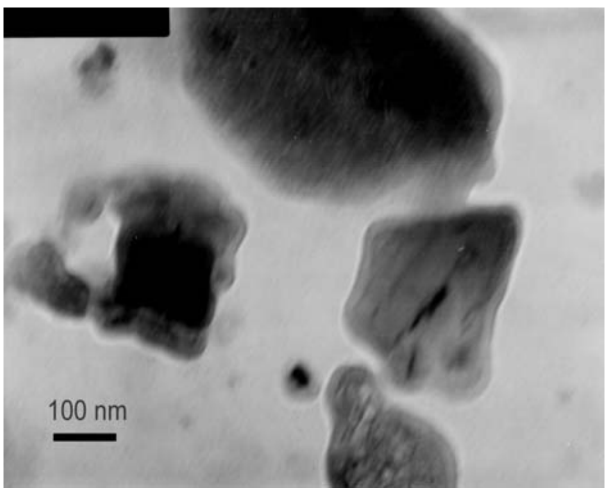

Fig. 7. TEM micrograph of isolated nanoscopic Particles.

CONCLUSIONS

With adequate cameras and methods to separate particles of interest from abrasive -if this were necessary- the WJM could be useful to obtain particles of different sizes coming from different materials when other methods fail, or if temperature effects have to be avoided. On the other hand, if some cut pieces were fused again, their surface should be cleaned of the abrasive particles adsorbed on them, because they will be impurities to the new alloy.

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