**Electrochemical dissolution behavior of WC-Co in different electrolytes during micro wire-electrochemical machining**

Abhijeet Sethi1, Biswesh Ranjan Acharya2, Partha Saha3*\**

*1,2,3 Department of Mechanical Engineering, Indian Institute of Technology Kharagpur, West Bengal - 721302, India*

*\*Corresponding author: psaha@mech.iitkgp.ernet.in*

**Highlights**

* Micro tool fabrication by micro wire-electro chemical machining process
* Study of electrochemical dissolution behavior of WC-Co in aqueous electrolytes
* Potentiodynamic polarization analysis through linear sweep voltammetry

**1. Introduction**

Micro tools, due to their versatility in creating profiles like micro holes, micro channels, micro gears, micro nozzles, micro grooves etc., have become the cornerstone of the micromachining industry [1]. The high hardness and the superior properties like high toughness and high rigidity of tungsten carbide cobalt alloy (WC-Co) have established it as an ideal material to be used as micro tools [2]. Electrochemical machining (ECM) easily dissolves hard metals with advantages like negligible tool wear, no machining force, no thermally induced stress, excellent surface quality and low roughness [1]. One of the most important factors in any electrochemical process is the selection of suitable electrolyte for successive electrochemical dissolution of work material. Therefore, attempts have been made in this study to investigate the performance of different electrolytes to find out their suitability in successive anodic dissolution of WC-Co using a cylindrical WC-Co rod of 510 µm initial diameter for fabricating micro tools, which are required for subsequent micro machining operations.

**2. Methods**

The electrolytes under this investigation were alkaline aqueous potassium hydroxide (KOH), neutral aqueous potassium nitrate (KNO3) and acidic aqueous perchloric acid (HClO4). To study the electrochemical dissolution behaviour of WC-Co in the above electrolytes, experiments were conducted by two processes: one is micro wire-electrochemical machining (WECM) and the other one is linear sweep voltammetry (LSV). The experiments in case of micro WECM process were conducted at three levels of a parameter keeping other parameters constant. Among the input parameters only electrolyte concentration and applied voltage were varied, one at a time. The electrolyte concentrations taken into consideration were 0.05 M, 0.15 M and 0.25 M and applied voltage 5 V, 10 V and 15 V for low, mid and high level respectively. The product oriented analysis like material removal rate (MRR) and average surface roughness (Ra) of the machined surface obtained through micro-WECM process were carried out. Furthermore, the electro chemical behaviour of WC-Co in three different electrolytes has been analysed by obtaining polarization curves from linear sweep voltammetry (LSV) where the voltage is varied from -1 V to 1 V at a rate of 0.05 V/s.

**3. Results and discussion**

As WC-Co is metal matrix composite of a hard phase (WC) enclosed in a binder phase (Co) its electrochemical dissolution needs to be homogenous for greater dissolution efficiency [3]. During the micro tool fabrication process through micro WECM, large amount of sludge is generated on the WC-Co alloy surface whose energy dispersive spectroscopy (EDS) study reveals the presence of tungsten, cobalt and oxygen. From figure 1 it can be found that the MRR in the alkaline electrolyte KOH is very poor, a higher MRR is obtained in case of neutral solution of KNO3 at all levels, however, the MRR in case of HClO4 is even higher in comparison to KNO3. Figure 2 shows the comparison of average surface roughness of the machined surface. In case of neutral KNO3 electrolyte the Ra values are found to be 0.469 µm,0.358 µm and 0.383 µm at low, mid and high level of parameters, respectively, which are lower in comparison to alkali and acidic electrolytes. The potentiodynamic polarisation curves (figure 3) obtained from linear sweep voltammetry show passivation in case of KOH electrolyte and the current density is very low in comparison to neutral and acidic electrolytes. In case of both KNO3 and HClO4, WC-Co alloy shows active dissolution and maximum current density is obtained in case of HClO4, which confirms the higher MRR obtained in case of micro wire-ECM.

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| **Figure 1.** Relationship between material removal rate (MRR) and the level of process parameters for KOH, KNO3 and HClO4 electrolyte | **Figure 2.** Relationship between material removal rate (MRR) and the level of process parameters for KOH, KNO3 and HClO4 electrolyte | **Figure 3.** Linear sweep voltammetry (LSV) for WC-Co alloy in different electrolytes |

**4. Conclusions**

The acidic electrolyte HClO4 produces a higher MRR in comparison to both alkali KOH and neutral KNO3 electrolytes at all levels of parameters. However, neutral electrolyte KNO3 shows homogeneous dissolution of both WC and Co as the average surface roughness (Ra) values are found to be 0.469 µm, 0.358 µm and 0.383 µm at low, mid and high level of parameters, respectively, which are lower in comparison to alkali and acidic electrolytes. The potentiodynamic polarisation curves obtained from linear sweep voltammetry show better current density as evident for HClO4 in comparison to KOH and KNO3, which confirms the higher MRR obtained in micro WECM.

**References**

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