Enhancement of the mass transport by numerical simulation in an electrochemical reactor with concentric cylindrical electrodes

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INTRODUCTION

The mass transport optimisation in electrochemical reactors for metal extraction is essential for developing an energy-efficient process and for obtaining pure and uniform deposits. Such as performances can be obtained for various electrode configurations under convective intensified mass transport conditions [1,2]. The concentric cylindrical electrodes reactor (CCER) with axial (ascending) electrolyte flow between the electrodes, provides a uniform distribution of current density that leads to a uniform deposition at the cathode even after a long electrodeposition time (e.g. hours).

The aim of the study is to evaluate the optimal combination of the operating parameters (geometrical, hydrodynamical and electrochemical) in order to assure a selective and uniform copper electrodeposition from leaching solutions resulted from the WEEE processing [3].

EXPERIMENTAL

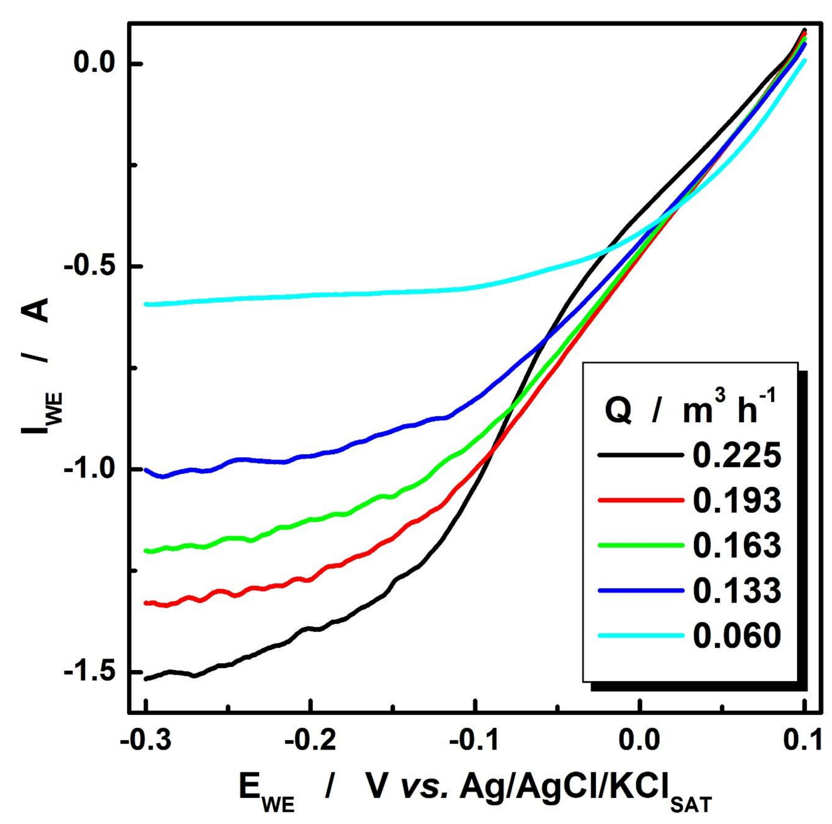
Hydrodynamic voltammetry

Cathode - working electrode (WE): Copper foil cylinder Φ = 0.045 m; H = 0.07 m
Anode - counter electrode (CE): Copper foil cylinder Φ = 0.035 m; H = 0.09 m
Reference electrode (Ref): Ag/AgCl/KCl_{SAT}
Electrolyte solution: H_2SO_4 [10^3 mol/m^3] + $CuSO_4$ [50; 100 and 150 mol/m^3]
Scan rate: 5mV/s

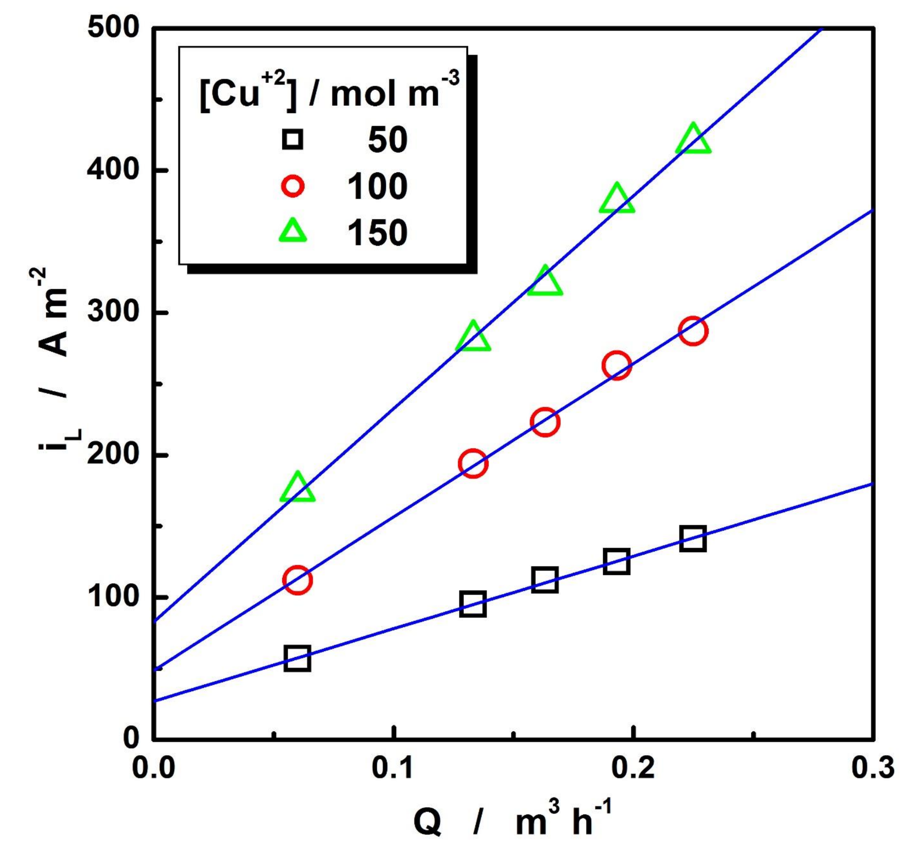
Numeric simulation

The numerical simulation have been performed in Ansys Fluent software. Additional to data indicated in figure captions, next parameters were used :
Copper diffusion coefficient: D_{Cu} = 8.1 E-10 m^2/s
Electrolyte kinematic viscosity: υ = 1.2 E-6 m^2/s

RESULTS AND DISCUSSION



Example of polarisation curves recorded for [Cu^{2+}] = 50 mol/m^3 at different Q values

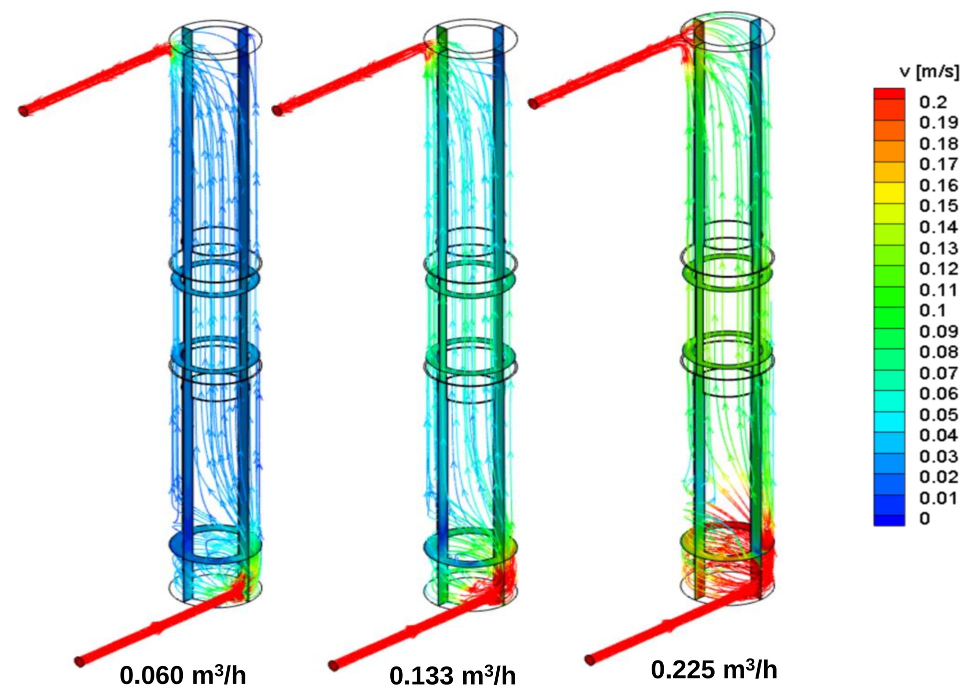


Linear correlations i_L = f(Q) for different [Cu^{2+}] values

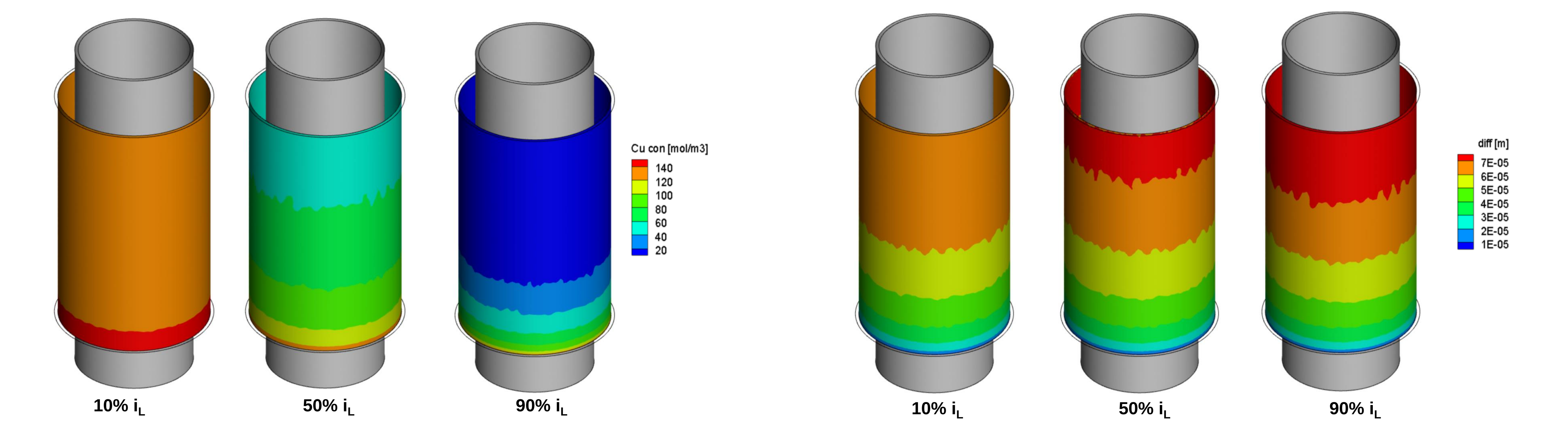
Evolution of the average global mass transport coefficient ($k_{m,a}$) for different Q values

Q (m^3/h)	$k_{m,a}$ (m/s)	SD
0.225	1.47 E-05	1.87 E-07
0.193	1.32 E-05	3.63 E-07
0.163	1.14 E-05	3.05 E-07
0.133	9.87 E-06	1.74 E-07
0.060	5.92 E-06	1.21 E-07

- **Excellent linear correlations between i_L and Q or [Cu^{2+}] were obtained in the studied domains**
- **Similar $k_{m,a}$ data (small SD values) were evaluated in all tested solutions**
- **The evaluated hydrodynamic parameters correspond to a laminar flow in the inter-electrode gap**



Velocity profile for different Q values



Profile of superficial copper concentration (left) and diffusion layer thickness (right) at different % from i_L corresponding to Q of 0.225 m^3 /h and inlet [Cu^{2+}] of 150 mol/m^3

CONCLUSIONS

➢**The hydrodynamic voltammetry measurements allows the evaluation of mass transport parameters required for the numerical simulations**

➢**Both experimental and simulation results emphasise a fully developed laminar flow within the inter-electrode gap of CCER**

➢**Both experimental and simulation recorded data, allow the optimal CCER design and optimal operational parameters for achieving the selective metal electro-extractions from solutions resulted from the WEEE recycling process**

References
1. F. C. Walsh, C. Ponce de Léon, Electrochimica Acta 280 (2018) 121-148.
2. K. Scott, Renewable and Sustainable Energy Review 81, Part 1 (2018) 1406-1426
3. S.-A. Dorneanu, A.-A. Avram, A.-H. Marincaș, N. Cotolan, T. Frențiu, P. Ilea, Studia UBB Chemia, LXIII, 4, (2018) 147-158

Acknowledgements.
This work was supported by a grant of the Romanian Ministry of Research and Innovation CCCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0652/84PCCDI ⁄2018, within PNCDI III.