Electromagnetic Processing From AC to DC Field and Multiphysics Modeling: A Way for Process Innovation

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Abstract

Examples of Electromagnetic processes are presented: (1) cold crucible, (2) electromagnetic pump, (3) DC electromagnetic brake. A combined approach by using multiphysics modeling with COMSOL software and experimental validation is used in order to give some guidelines for process improvement and integration at industrial scale. A time-dependent 2D or 3D multiphysics electromagnetic fluid mechanics coupled numerical model including an ALE deformed mesh technique was set up. New design of cold crucible with improved energetic efficiency was defined. MHD effects resulting from a strong coupling between fluid flow and electromagnetics is evaluated in a large annular linear pump for nuclear applications. The control of zinc coating thickness by DC magnetic field resulting from braking of a liquid driven by an upcoming strip was demonstrated.

Introduction :
Technology of Electromagnetic processing of Materials (EPM) is relatively well known and mature. This knowledge gives the possibility to improve such processes and to integrate them in specific application (aeronautics, automotive, nuclear sector, metallurgy...) at an industrial scale process. Thanks to a transverse and multiphysics approach which combined fluid dynamics, heat transfer, process metallurgy, solidification…, it is possible know to define new innovative processes with the integration of new design of electromagnetic system. An association of more complex EM configurations can be realized: combination of AC and DC field, or two AC field…

Future development of EPM technologies are in agreement with energy savings and CO2 reduction demand [2]. In metallurgy industry and siderurgy, the integration of EPM technologies is more basically associated with productivity improvement, maintenance reduction and also safety consideration [2]. EM processing can be classified by type of magnetic field involved: from AC to DC field [3]. The choice depends on the desired action on the electro-conductive materials. These processes are suitable for heating, melting, flow and shape control, solidification control (steering, pumping)…but for each application a specific configuration needs to be defined, selected and optimized.

Use of COMSOL Mutliphysics :
This paper gives some examples of EPM technologies applications for the development of new

industrial process and main challenge to succeed in order to be relevant: (i) cold crucible technology, (ii) electromagnetic pump, (ii) DC electromagnetic brake. A combined approach by using multi-physics modeling with COMSOL and experimental validation is used in order to give some guidelines for process improvement, or new electromagnetic design: feasibility and potentiality at industrial scale. A time-dependent 2D or 3D multiphysics electromagnetic /fluid mechanics coupled numerical model including an ALE deformed mesh technique is set up which allows the deformation of the free surface.

Results :

From this study, new design of cold crucible with improved energetic efficiency was defined [4,5] and seems very promising for investment casting application due to overheating potentiality of the melt induced by a better levitation (Figure1). MHD effects resulting from a strong coupling between fluid flow and electromagnetics is evaluated in a large annular linear pump for nuclear applications with high flow rate (up to 4 m3/s to ensure a sufficient heat transfer through the cooling secondary circuit of power plant [6]). Another electromagnetic phenomena presented in this paper is the control of zinc coating thickness (hot-dip coating on galvanizing lines) by DC magnetic field resulting from braking of a liquid driven by an upcoming strip (Figure 3, [8]).

Conclusions

This paper gives an overview of EPM from AC to DC field thanks to examples of potential industrial processes. It demonstrates also the necessity of EPM process improvement of common device in order to be more use in industrial scale. The better understandings of each configuration combined with a multiphysics modelling approach allows us to figure out more complex system and define design for specific industrial needs.

Reference

[1] E.Baake, B.Ubbenjans, (2012), Journal of Iron and Steel Research International, 19, p. 679-681.

[2] L.Levacher, I.Hita, C.Bethenod, S.Hartmann (2009), ECEEE 2009 summer study proceedings " Act! Innovate! Deliver! Reducing Energy Demand Sustainability.

[3] K. Spragg, A. Noeppel, J.C. Lacombe, M. Dumont, R. Ernst, K. Zaidat, Y. Delannoy, P. Petitpas, C. Garnier, J. Etay, C. Trassy and Y. Fautrelle (2008), 16th Int. Conference on Electricity Applications in a Modern World UIE2008, Krakow, 18-21 mai

[4] M.Dumont, R.Ernst, C. Garnier, P.Petitpas (2009), 6th Int. Conference on Electromagnetic Processing of Materials, Dresden(Germany), 19-23 october

[5] M.Dumont, R.Ernst, C.Garnier, H.Gathfan, P.Petitpas (2012), Journal of Iron and Steel Research Int.,19 p.669-672.

[6] S.Vitry, A. Morcillo, F. Rey, M. Dumont, J. Etay and Y. Fautrelle (2011), 8th PAMIR International Conference on Fundamental and Applied MHD (2011), Borgo (France) – September 5 – 9

[7] C. Roman, M. Dumont, S. Letout, C. Courtessole, S. Vitry, F. Rey, Y. Fautrelle, International Symposium on Heating by Electromagnetic Sources, HES 2013, Padova, Italy

[8] M. Dumont, R. Ernst, Y. Fautrelle, B. Grenier, J.J. Hardy, M. Anderhuber (2011), Compel,Vol.30, 5.

Figures used in the abstract

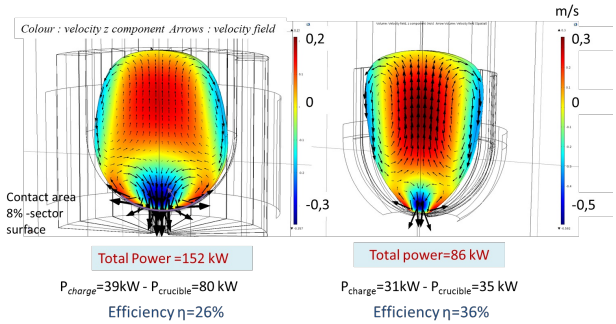

Figure 1

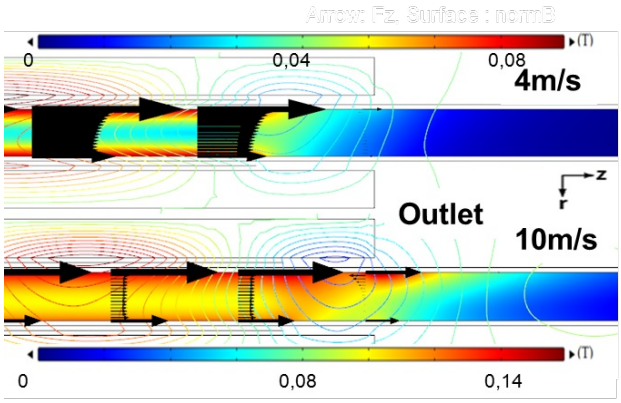

Figure 2: Distribution of the magnetic field as well as the axial electromagnetic force component in the channel for two mean velocities, U = 4 and 10 m.s-1 [7].

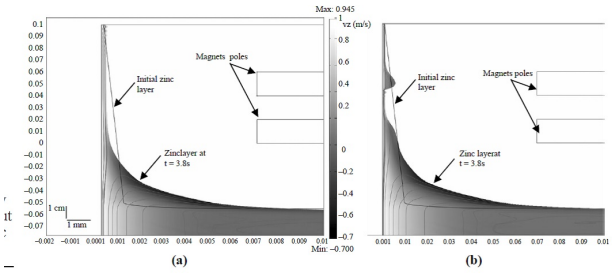

Figure 3: Free surface and velocity field (streamlines) without (a) and with (b) magnetic field at t=3.8s [8].