

## COUPLED HILFER AND HADAMARD FRACTIONAL DIFFERENTIAL SYSTEMS IN GENERALIZED BANACH SPACES

SAÏD ABBAS\*, MOUFFAK BENCHOHRA\*\* AND ADRIAN PETRUŞEL\*\*\*

\*Department of Electronics,  
Tahar Moulay University of Saïda, P.O. Box 138, EN-Nasr, 20000 Saïda, Algeria  
E-mail: said.abbas@univ-saida.dz, abbasmsaid@yahoo.fr

\*\*Laboratory of Mathematics, Djillali Liabes University of Sidi Bel-Abbès,  
P.O. Box 89, Sidi Bel-Abbès 22000, Algeria  
E-mail: benchohra@yahoo.com

\*\*\*Department of Mathematics, Babes-Bolyai University, 400084 Cluj-Napoca, Romania  
E-mail: petrusel@math.ubbcluj.ro

**Abstract.** This article deals with some existence and uniqueness of solutions for some coupled systems of Hilfer and Hilfer-Hadamard fractional differential equations. Some applications are made of generalizations of classical fixed point theorems on generalized Banach spaces.

**Key Words and Phrases:** Fractional differential equation, left-sided mixed Riemann-Liouville integral of fractional order, left-sided mixed Hadamard integral of fractional order, Hilfer fractional derivative, Hadamard fractional derivative, coupled system, generalized Banach space, fixed point.

**2020 Mathematics Subject Classification:** 26A33, 47H10, 54H25, 34A08.

### REFERENCES

- [1] S. Abbas, M. Benchohra, J.R. Graef, J. Henderson, *Implicit Fractional Differential and Integral Equations: Existence and Stability*, De Gruyter, Berlin, 2018.
- [2] S. Abbas, M. Benchohra, J.E. Lazreg, Y.Zhou, *A survey on Hadamard and Hilfer fractional differential equations: analysis and stability*, Chaos, Solitons & Fractals, **102**(2017), 47-71.
- [3] S. Abbas, M. Benchohra, G.M. N' Guérékata, *Topics in Fractional Differential Equations*, Springer, New York, 2012.
- [4] S. Abbas, M. Benchohra, G.M. N'Guérékata, *Advanced Fractional Differential and Integral Equations*, Nova Science Publishers, New York, 2015.
- [5] G. Allaire, S.M. Kaber, *Numerical Linear Algebra*, Texts in Applied Mathematics, Springer, New York, 2008.
- [6] M. Benchohra, J. Henderson, S.K. Ntouyas, A. Ouahab, *Existence results for functional differential equations of fractional order*, J. Math. Anal. Appl., **338**(2008), 1340-1350.
- [7] K.M. Furati, M.D. Kassim, *Non-existence of global solutions for a differential equation involving Hilfer fractional derivative*, Electron. J. Differential Equations, 2013, no. 235, 10 pp.
- [8] K. M. Furati, M.D. Kassim, N.E. Tatar, *Existence and uniqueness for a problem involving Hilfer fractional derivative*, Comput. Math. Appl., **64**(2012), 1616-1626.

- [9] J.R. Graef, J. Henderson, A. Ouahab, *Some Krasnosel'skii type random fixed point theorems*, J. Nonlinear Funct. Anal., **2017** (2017), 1-34, Article ID 46.
- [10] R. Hilfer, *Applications of Fractional Calculus in Physics*, World Scientific, Singapore, 2000.
- [11] R. Kamocki, C. Obczyński, *On fractional Cauchy-type problems containing Hilfer's derivative*, Electron. J. Qual. Theory Differ. Equ., 2016, no. 50, 1-12.
- [12] A.A. Kilbas, *Hadamard-type fractional calculus*, J. Korean Math. Soc., **38**(6)(2001), 1191-1204.
- [13] A.A. Kilbas, H.M. Srivastava, J.J. Trujillo, *Theory and Applications of Fractional Differential Equations*, Elsevier Science B.V., Amsterdam, 2006.
- [14] L. Liu, F. Guo, C. Wu, Y. Wu, *Existence theorems of global solutions for nonlinear Volterra type integral equations in Banach spaces*, J. Math. Anal. Appl., **309**(2005), 638-649.
- [15] H. Mönch, *Boundary value problems for nonlinear ordinary differential equations of second order in Banach spaces*, Nonlinear Anal., **4**(1980), 985-999.
- [16] D. O'Regan, R. Precup, *Theorems of Leray-Schauder Type and Applications*, Gordon and Breach, Amsterdam, 2001.
- [17] M.D. Qassim, K.M. Furati, N.E. Tatar, *On a differential equation involving Hilfer-Hadamard fractional derivative*, Abstr. Appl. Anal., vol. 2012, Article ID 391062, 17 pages, 2012.
- [18] M.D. Qassim, N.E. Tatar, *Well-posedness and stability for a differential problem with Hilfer-Hadamard fractional derivative*, Abstr. Appl. Anal., Volume 2013, Article ID 605029, 12 pages, 2013.
- [19] I.R. Petre, A. Petruşel, *Krasnoselskii's theorem in generalized Banach spaces and applications*, Electron. J. Qualitative Theory Differ. Equ., (2012), no. 85, 20 pp.
- [20] R. Precup, *Methods in Nonlinear Integral Equations*, Kluwer Academic Publishers, Dordrecht, 2002.
- [21] S.G. Samko, A.A. Kilbas, O.I. Marichev, *Fractional Integrals and Derivatives. Theory and Applications*, Gordon and Breach, Amsterdam, 1987, Engl. Trans. from the Russian.
- [22] M.L. Sinacer, J.J. Nieto, A. Ouahab, *Random fixed point theorems in generalized Banach spaces and applications*, Random Oper. Stoch. Equ., **24**(2016), 93-112.
- [23] V.E. Tarasov, *Fractional Dynamics: Application of Fractional Calculus to Dynamics of Particles, Fields and Media*, Springer, Heidelberg; Higher Education Press, Beijing, 2010.
- [24] Ž. Tomovski, R. Hilfer, H.M. Srivastava, *Fractional and operational calculus with generalized fractional derivative operators and Mittag-Leffler type functions*, Integral Transform. Spec. Funct., **21**(11)(2010), 797-814.
- [25] R.S. Varga, *Matrix Iterative Analysis*, Springer Series in Computational Mathematics, 27, Springer-Verlag, Berlin, 2000.
- [26] A. Viorel, *Contributions to the Study of Nonlinear Evolution Equations*, Ph.D. Thesis, Babes-Bolyai University Cluj-Napoca, Department of Mathematics, 2011.
- [27] J.-R. Wang, Y. Zhang, *Nonlocal initial value problems for differential equations with Hilfer fractional derivative*, Appl. Math. Comput., **266**(2015), 850-859.
- [28] Y. Zhou, J.-R. Wang, L. Zhang, *Basic Theory of Fractional Differential Equations*, World Scientific Publishing Co. Pte. Ltd., Hackensack, NJ, 2017.

*Received: November 4, 2020; Accepted: June 14, 2021.*