

NEW REVERSE HÖLDER-TYPE INEQUALITIES AND APPLICATIONS

JORGE A. PAZ MOYADO, YAMILÉT QUINTANA,
JOSÉ M. RODRIGUEZ AND JOSÉ M. SIGARRETA*

Abstract. In this paper, we establish several Hölder-type inequalities using Jensen-type and Young-type inequalities as key tools. Particularly noteworthy is a reverse Hölder inequality with the Specht's ratio. Furthermore, we obtain a reverse Young-type inequality and we apply these results to the fractional context, both globally and locally.

Mathematics subject classification (2020): 26A33, 26A51, 26D15.

Keywords and phrases: Hölder inequality, Hölder-type inequalities, Riemann-Liouville integral operators, conformable fractional integral operators.

REFERENCES

- [1] T. ABDELJAWAD, *On conformable fractional calculus*, J. Comput. Appl. Math. **279** (2015) 57–66, <https://doi.org/10.1016/j.cam.2014.10.016>.
- [2] R. ABREU-BLAYA, A. FLEITAS, J. E. NÁPOLES VALDÉS, R. REYES, J. M. RODRÍGUEZ, J. M. SIGARRETA, *On the conformable fractional logistic models*, Math. Methods Appl. Sci. **43:7** (2020) 4156–4167.
- [3] J. M. ALDAZ, *A stability version of Hölder's inequality*, J. Math. Anal. Appl. **343** (2008) 842–852.
- [4] J. M. ALDAZ, *Comparison of differences between arithmetic and geometric means*, Tamkang J. Math. **42** (2011) 445–451.
- [5] J. M. ALDAZ, *Strengthened Cauchy-Schwarz and Hölder Inequalities*, J. Ineq. Pure Appl. Math. **10:4** (2009) 116.
- [6] P. BOSCH, H. J. CARMENATE, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Generalized inequalities involving fractional operators of the Riemann-Liouville type*, AIMS Math. **7:1** (2022) 1470–1485, <https://doi.org/10.3934/math.2022087>.
- [7] P. BOSCH, J. F. GÓMEZ-AGUILAR, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Analysis of dengue fever outbreak by generalized fractional derivative*, Fractals **28:8** (2020) Art. 2040038.
- [8] P. BOSCH, E. D. MOLINA, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Generalized inequalities involving Inequalities on the Generalized ABC Index*, Mathematics **9:10** (2021) 1151.
- [9] P. BOSCH, Y. QUINTANA, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Jensen-type inequalities for m -convex functions*, Open Math. **20** (2022) 11–13, <https://doi.org/10.1515/math-2022-0061>.
- [10] P. BOSCH, A. PORTILLA, J. M. RODRÍGUEZ, J. M. SIGARRETA, *On a generalization of the Opial inequality*, submitted.
- [11] P. BOSCH, J. M. RODRÍGUEZ, J. M. SIGARRETA, *On new Milne-type inequalities and applications*, J. Inequal. Appl. **2023** (2023) 3, <https://doi.org/10.1186/s13660-022-02910-0>.
- [12] P. BOSCH, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Oscillation results for a nonlinear fractional differential equation*, AIMS Math. **8** (5) (2023) 12486–12505.
- [13] M. P. CRUZ, R. ABREU BLAYA, P. BOSCH, J. M. RODRÍGUEZ, J. M. SIGARRETA, *On Ostrowski type inequalities for generalized integral operators*, J. Math. **2022** (2022) Article ID 2247246, <https://doi.org/10.1155/2022/2247246>.
- [14] D. CRUZ-URIBE, A. FIORENZE, C. J. NEUGEBAUER, *The maximal operator on variable L^p spaces*, Ann. Acad. Sci. Fenn. Math. **28** (2003) 223–238.

- [15] Z. CVETKOVSKI, *Inequalities: Theorems, Techniques and Selected Problems*, Springer-Verlag, Berlin, 2012.
- [16] Z. DAHMANI, *On Minkowski and Hermite-Hadamard integral inequalities via fractional integral*, Ann. Funct. Anal. **1** (2010) 51–8.
- [17] L. DIENING, *Riesz Potential and Sobolev Embeddings of generalized Lebesgue and Sobolev Spaces $L^{p(\cdot)}$ and $W^{k,p(\cdot)}$* , Math. Nachr. **263:1** (2004) 31–43.
- [18] L. DIENING, M. RUŽIČKA, *Calderón-Zygmund operators on generalized Lebesgue spaces $L^{p(\cdot)}$ and problems related to fluid dynamics*, J. Reine Ang. Math. **563** (2003) 197–220.
- [19] S. S. DRAGOMIR, C. J. GOH, *A counterpart of Hölder's inequality*, Mitt. Math. Ges. Hamburg **16** (1997) 99–106.
- [20] X. FAN, D. ZHAO, *On the spaces $L^{p(x)}(\Omega)$ and $W^{m,p(x)}(\Omega)$* , J. Math. Anal. Appl. **263** (2001) 424–446.
- [21] A. FLEITAS, J. F. GÓMEZ-AGUILAR, J. E. NÁPOLES VALDÉS, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Analysis of the local Drude model involving the generalized fractional derivative*, Optik **193** (2019) 163008.
- [22] A. FLEITAS, J. E. NÁPOLES VALDÉS, J. M. RODRÍGUEZ, J. M. SIGARRETA, *Note on the generalized conformable derivative*, Rev. Uni. Mat. Argen. **62:2** (2021) 443–457.
- [23] X. GAO, M. GAO, X. SHANG, *A refinement of Hölder's inequality and applications*, JIPAM. J. Inequal. Pure Appl. Math. **8:2** (2007) Article 44, 9 pp.
- [24] R. GORENFLO, F. MAINARDI, *Fractals and Fractional Calculus in Continuum Mechanics*, 1st ed., Vienna, Springer, 1997.
- [25] J. HAN, P. OTHMAN MOHAMMED, H. ZENG, *Generalized fractional integral inequalities of Hermite-Hadamard-type for a convex function*, Open Math. **18** (2020) 794–806.
- [26] G. H. HARDY, J. E. LITTLEWOOD, G. PÓLYA, *Inequalities*, Cambridge University Press, Cambridge, 1934.
- [27] P. HARJULEHTO, P. HÄSTÖ, *A capacity approach to Poincaré inequalities and Sobolev imbedding in variable exponent Sobolev spaces*, Rev. Mat. Complut. **17:1** (2004) 129–146.
- [28] F. JARAD, E. UGURLU, T. ABDELJAWAD, D. BALEANU, *On a new class of fractional operators*, Adv. Differ. Equ. **2017** (2017) 247, <https://doi.org/10.1186/s13662-017-1306-z>.
- [29] J. L. W. V. JENSEN, *Sur les fonctions convexes et les inégalités entre les valeurs moyennes*, Acta Math. **30:1** (1906) 175–193.
- [30] U. N. KATUGAMPOLA, *A new fractional derivative with classical properties*, arXiv:1410.6535.
- [31] R. KHALIL, M. AL HORANI, A. YOUSEF, M. SABABHEH, *A new definition of fractional derivative*, J. Comput. Appl. Math. **264** (2014) 65–70.
- [32] P. KÓRUS, J. E. NÁPOLES VALDÉS, *q -Hermite-Hadamard inequalities for functions with convex or h -convex q -derivative*, Math. Ineq. Appl. **25** (2) (2022) 601–610.
- [33] P. KÓRUS, J. E. NÁPOLES VALDÉS, J. M. RODRÍGUEZ, J. M. SIGARRETA ALMIRA, *Petrović-type inequality via fractional calculus*, submitted.
- [34] D. S. MITRINoviĆ, *Analytic Inequalities*, Springer-Verlag, Berlin, 1970.
- [35] D. S. MITRINoviĆ, J. E. PEĆARIĆ, A. M. FINK, *Classical and New Inequalities in Analysis*, Kluwer Academic, 1993.
- [36] S. MUBEEN, S. HABIB, M. N. NAEEM, *The Minkowski inequality involving generalized k -fractional conformable integral*, J. Inequal. Appl. **2019** (2019) 81.
- [37] K. S. NISAR, F. QI, G. RAHMAN, S. MUBEEN, M. ARSHAD, *Some inequalities involving the extended gamma function and the Kummer confluent hypergeometric K -function*, J. Inequal. Appl. **2018** (2018) 135.
- [38] J. PEĆARIĆ, V. ŠIMIĆ, *A note on the Hölder inequality*, JIPAM. J. Inequal. Pure Appl. Math. **7:5** (2006), Article 176, 3 pp.
- [39] G. RAHMAN, T. ABDELJAWAD, F. JARAD, A. KHAN, K. SOOPPY NISAR, *Certain inequalities via generalized proportional Hadamard fractional integral operators*, Adv. Difference Eq. **2019** (2019) 454.
- [40] G. RAHMAN, K. SOOPPY NISAR, B. GHANBARI, T. ABDELJAWAD, *On generalized fractional integral inequalities for the monotone weighted Chebyshev functionals*, Adv. Difference Eq. **2020** (2020) 368.

- [41] S. RASHID, M. ASLAM NOOR, K. INAYAT NOOR, Y.-M. CHU, *Ostrowski type inequalities in the sense of generalized K -fractional integral operator for exponentially convex functions*, AIMS Math. **5**:3, 2629–2645.
- [42] Y. SAWANO, H. WADADE, *On the Gagliardo-Nirenberg type inequality in the critical Sobolev-Orrey space*, J. Fourier Anal. Appl. **19** (2013) 20–47.
- [43] E. SET, M. TOMAR, M. Z. SARIKAYA, *On generalized Grüss type inequalities for k -fractional integrals*, Appl. Math. Comput. **269** (2015) 29–34.
- [44] W. SPECHT, *Zur Theorie der elementaren Mittel*, Math. Z. **74** (1960) 91–98.
- [45] M. TOMINAGA, *Specht's ratio in the Young inequality*, Sci. Math. Japan **55** (2002) 583–588.