

BOUNDEDNESS OF HIGHER ORDER COMMUTATORS OF FRACTIONAL VARIABLE ROUGH HARDY OPERATORS ON GRAND VARIABLE HERZ SPACES

BABAR SULTAN AND MEHVISH SULTAN*

Abstract. In this paper, we obtain the boundedness of higher order commutators of fractional variable rough Hardy operators on grand variable Herz spaces $\dot{K}_{q(\cdot)}^{\alpha(\cdot), u, \theta}$.

Mathematics subject classification (2020): 46E30, 47B38.

Keywords and phrases: Hardy operators, BMO spaces, commutators, Herz spaces, grand variable Herz spaces.

REFERENCES

- [1] A. ALMEIDA AND D. DRIHEM, *Maximal, potential and singular type operators on Herz spaces with variable exponents*, J. Math. Anal. and Appl., **394** (2) (2012), 781–795.
- [2] S. BASHIR, B. SULTAN, A. HUSSAIN, A. KHAN, T. ABDELJAWAD, *A note on the boundedness of Hardy operators in grand Herz spaces with variable exponent*, AIMS Math., **8** (9) (2023), 22178–22191.
- [3] D. CRUZ-URIBE AND A. FIORENZA, *Variable Lebesgue spaces, Foundations and Harmonic Analysis*, Appl. Numer. Harmon. Anal., Birkhäuser, Heidelberg, 2013.
- [4] D. CRUZ-URIBE et al., *The boundedness of classical operators on variable L^p spaces*, Acad. Sci. Fenn. Math., **31** (1) (2006), 239–264.
- [5] L. DIENING, P. HARJULEHTO, P. HÄSTÖ AND M. RUŽIČKA, *Lebesgue and Sobolev Spaces with Variable Exponents*, Lecture Notes in Mathematics., vol. 2017, Springer, Heidelberg (2011).
- [6] L. GRAFAKOS, X. LI AND D. YANG, *Bilinear operator on Herz-type Hardy spaces*, Trans. Amer. Math. Soc., **350** (3) (1998), 1249–1275.
- [7] C. S. HERZ, *Lipschitz spaces and Bernstein's theorem on absolutely convergent Fourier transforms*, J. Math. Mech., **18** (1968/69), 283–323.
- [8] A. HUSSAIN, G. GAO, *Multilinear singular integrals and commutators on Herz space with variable exponent*, ISRN Math. Anal., **2014** (2014), 1–10.
- [9] A. HUSSAIN, I. KHAN AND A. MOHAMED, *Variable Her-Morrey estimates for rough fractional Hausdorff operator*, J. Inequal. Appl., **33** (2024).
- [10] M. IZUKI, *Boundedness of commutators on Herz spaces with variable exponent*, Rend. Circ. Mat. Palermo., **59** (2020), 199–213.
- [11] M. IZUKI, *Boundedness of sublinear operators on Herz spaces with variable exponent and application to wavelet characterization*, Anal. Math., **36** (1) (2010), 33–50.
- [12] M. IZUKI, *Boundedness of vector-valued sublinear operators on Herz-Morrey spaces with variable exponents*, Math. Sci. J. **13** (10) (2009), 243–253.
- [13] V. KOKILASHVILI AND A. MESKHI, *Boundedness of operators of Harmonic Analysis in grand variable exponent Morrey spaces*, Mediterr. J. Math., **20** (71) (2023).
- [14] V. KOKILASHVILI AND A. MESKHI, *Maximal and Calderón-Zygmund operators in grand variable exponent Lebesgue spaces*, Georgian Math. J., **21** (4) (2014), 447–461.
- [15] V. KOKILASHVILI, A. MESKHI, H. RAFAIRO AND S. SAMKO, *Integral Operators in Non-Standard Function Spaces. Vol. 1: Variable Exponent Lebesgue and Amalgam Spaces*, Oper. Theory Adv. Appl., **248**, Birkhäuser/Springer, Cham, 2016.

- [16] V. KOKILASHVILI, A. MESKHI, H. RAFAIRO AND S. SAMKO, *Integral Operators in Non-Standard Function Spaces. Vol. 2: Variable Exponent Hölder, Morrey-Campanato and Grand Spaces*, Theory Adv. Appl., **249**, Birkhuser/Springer, Cham, 2016.
- [17] V. KOKILASHVILI AND S. SAMKO, *On Sobolev theorem for Riesz-type potentials in the Lebesgue spaces with variable exponent*, Z. Anal. Anwend., **22** (2003), 899–910.
- [18] O. KOVÁČIK AND J. RÁKOSNÍK, *On spaces $L^{p(x)}$ and $W^{k,p(x)}$* , Czechoslov. Math. J., **41** (4) (1991), 592–618.
- [19] A. KUFNER, L.-E. PERSSON AND N. SAMKO, *Weighted inequalities of Hardy type*, World Scientific Publishing, second ed., 2017.
- [20] M. LIU AND X. YAO, *Grand Weighted Variable Herz-Morrey Spaces Estimates for Higher Order Commutators of Fractional Integrals*, preprint, [doi:https://doi.org/10.21203/rs.3.rs-3034978/v1](https://doi.org/10.21203/rs.3.rs-3034978/v1).
- [21] V. MAZ'YA, *Sobolev spaces*, Springer Series in Soviet Mathematics, Springer-Verlag, Berlin (1985).
- [22] A. MESKHI, *Maximal functions, potentials and singular integrals in grand Morrey spaces*, Complex Var. Elliptic Equ., **56** (2011), 1003–1019.
- [23] H. NAFIS, H. RAFAIRO, AND M. ZAIGHUM, *A note on the boundedness of sublinear operators on grand variable Herz spaces*, J. Inequal. Appl., **2020** (1) (2020), 1–13.
- [24] H. NAFIS, H. RAFAIRO, AND M. A. ZAIGHUM, *Boundedness of the Marcinkiewicz integral on grand Herz spaces*, J. Math. Inequal., **15** (2) (2021), 739–753.
- [25] H. RAFAIRO, *A note on boundedness of operators in grand grand Morrey spaces*, in: Advances in harmonic analysis and operator theory, vol. **229** of Oper. Theory Adv. Appl., pp. 349–356, Birkhäuser/Springer Basel AG, Basel, 2013.
- [26] H. RAFAIRO, S. SAMKO AND S. UMARKHADZHIEV, *Grand Lebesgue sequence spaces*, Georgian Math. J., **25** (2) (2018), 291–302, [doi:10.1515/gmj-2018-0017](https://doi.org/10.1515/gmj-2018-0017).
- [27] S. SAMKO, *Variable exponent Herz spaces*, Mediterr. J. Math., **10** (4) (2013), 2007–2025.
- [28] Y. SAWANO, G. DI FAZIO, D. I. HAKIM, *Morrey Spaces Introduction and Applications to Integral Operators and PDE's*, vol. I, II, CRC Press, Taylor and Francis, 2020.
- [29] B. SULTAN, F. AZMI, M. SULTAN, T. MAHMOOD, N. MLAIKI, N. SOUAYAH, *Boundedness of fractional integrals on grand weighted Herz-Morrey spaces with variable exponent*, Fractal fract., **6** (11) (2022), 660, <https://doi.org/10.3390/fractalfract6110660>.
- [30] B. SULTAN, F. AZMI, M. SULTAN, M. MEHMOOD, N. MLAIKI, *Boundedness of Riesz potential operator on grand Herz-Morrey spaces*, Axioms., **11** (11) (2022), 583.
- [31] B. SULTAN AND M. SULTAN, *Boundedness of commutators of rough Hardy operators on grand variable Herz spaces*, Forum Math., **36** (3) (2024), 717–733.
- [32] B. SULTAN, M. SULTAN, *Boundedness of higher order commutators of Hardy operators on grand Herz-Morrey spaces*, Bull. Sci. Math., **190** (2024).
- [33] M. SULTAN, B. SULTAN, A. ALOQAILY, N. MLAIKI, *Boundedness of some operators on grand Herz spaces with variable exponent*, AIMS Math., **8** (6) (2023), 12964–12985, [doi:10.3934/math.2023653](https://doi.org/10.3934/math.2023653).
- [34] M. SULTAN, B. SULTAN AND A. HUSSAIN, *Grand Herz-Morrey spaces with variable exponent*, Math. Notes., **114** (5) (2023), 957–977.
- [35] B. SULTAN, M. SULTAN AND I. KHAN, *On Sobolev theorem for higher commutators of fractional integrals in grand variable Herz spaces*, Commun. Nonlinear Sci. Numer. Simul., **126** (2023), <https://doi.org/10.1016/j.cnsns.2023.107464>.
- [36] M. SULTAN, B. SULTAN, A. KHAN, T. ABDELJAWAD, *Boundedness of Marcinkiewicz integral operator of variable order in grand Herz-Morrey spaces*, AIMS Math., **8** (9) (2023), 22338–22353, [doi:10.3934/math.20231139](https://doi.org/10.3934/math.20231139).
- [37] B. SULTAN, M. SULTAN, M. MEHMOOD, F. AZMI, M. A. ALGHAFLI, N. MLAIK, *Boundedness of fractional integrals on grand weighted Herz spaces with variable exponent*, AIMS Math., **8** (1) (2023), 752–764, [doi:10.3934/math.2023036](https://doi.org/10.3934/math.2023036).
- [38] H. WANG, *Commutators of Marcinkiewicz integrals on Herz spaces with variable exponent*, Czech Math. J., **66** (2016), 251–269.
- [39] S. R. WANG AND J. S. XU, *Boundedness of vector-valued sublinear operators on weighted Herz-Morrey spaces with variable exponent*, Open Math., **19** (1) (2021), 412–426.
- [40] S. R. WANG AND J. S. XU, *Commutators of bilinear Hardy operators on weighted Herz-Morrey spaces with variable exponent*, Acta Math. Sin. (Chin. Ser.), **64** (1) (2021), 123–138.

- [41] J. L. WU, *Boundedness for fractional Hardy-type operator on Herz-Morrey spaces with variable exponent*, Bull. Korean Math. Soc., **51** (2014), 423–435.