

INEQUALITY CHAINS FOR WILKER, HUYGENS AND LAZAREVIĆ TYPE INEQUALITIES

CHAO-PING CHEN AND JÓZSEF SÁNDOR

Abstract. We offer various refinements of inequalities related to the Wilker, Huygens, or Lazarević type inequalities for trigonometric and hyperbolic functions.

Mathematics subject classification (2010): 26D05, 26D07.

Keywords and phrases: Inequalities, trigonometric functions, hyperbolic functions.

REFERENCES

- [1] G. D. ANDERSON, S.-L. QIU, M. K. VAMANAMURTHY AND M. VUORINEN, *Generalized elliptic integral and modular equations*, Pacific J. Math. **192** (2000), 1–37.
- [2] G. D. ANDERSON, M. K. VAMANAMURTHY AND M. VUORINEN, *Conformal Invariants, Inequalities, and Quasiconformal Maps*, New York, 1997.
- [3] G. D. ANDERSON, M. K. VAMANAMURTHY AND M. VUORINEN, *Monotonicity of Some Functions in Calculus*, available online at <http://www.math.auckland.ac.nz/Research/Reports/Series/538.pdf>.
- [4] A. BARICZ AND J. SÁNDOR, *Extensions of generalized Wilker inequality to Bessel functions*, J. Math. Inequal. **2** (2008), 397–406.
- [5] C.-P. CHEN, *Sharp Wilker- and Huygens-type inequalities for inverse trigonometric and inverse hyperbolic functions*, Integral Transforms Spec. Funct. **23** (2012), 865–873.
- [6] C.-P. CHEN, *Wilker and Huygens type inequalities for the Lemniscate functions*, J. Math. Inequal. **6** (2012), 673–684.
- [7] C.-P. CHEN, *Wilker and Huygens type inequalities for the Lemniscate functions, II*, Math. Inequal. Appl. **16** (2013), 577–586.
- [8] C.-P. CHEN AND W.-S. CHEUNG, *Wilker- and Huygens-type inequalities and solution to Oppenheim's problem*, Integral Transforms Spec. Funct. **23** (2012), 325–336.
- [9] C.-P. CHEN AND W.-S. CHEUNG, *Sharpness of Wilker and Huygens type inequalities*, J. Ineq. Appl. **2012**, 2012: 72, available online at <http://www.journalofinequalitiesandapplications.com/content/2012/1/72>.
- [10] B.-N. GUO, B.-M. QIAO, F. QI AND W. LI, *On new proofs of Wilker inequalities involving trigonometric functions*, Math. Inequal. Appl. **6** (2003), 19–22.
- [11] C. HUYGENS, *Oeuvres Complètes 1888–1940*, Société Hollondaise des Science, Haga.
- [12] I. LAZAREVIĆ, *Neke nejednakosti sa hiperbolickim funkcijama*, Univerzitet u Beogradu. Publikacije Elektrotehničkog Fakulteta. Serija Matematika i Fizika, **170** 1966, 41–48.
- [13] D. S. MITRINOVİĆ, *Analytic Inequalities*, Springer-Verlag, Berlin, 1970.
- [14] C. MORTICI, *The natural approach of Wilker-Cusa-Huygens inequalities*, Math. Inequal. Appl. **14** (2011), 535–541.
- [15] E. NEUMAN, *One- and two-sided inequalities for Jacobian elliptic functions and related results*, Integral Transforms Spec. Funct. **21** (2010), 399–407.
- [16] E. NEUMAN, *On Wilker and Huygens type inequalities*, Math. Inequal. Appl. **15** (2012), 271–279.
- [17] E. NEUMAN AND J. SÁNDOR, *On some inequalities involving trigonometric and hyperbolic functions with emphasis on the Cusa-Huygens, Wilker, and Huygens inequalities*, Math. Inequal. Appl. **13** (2010), 715–723.

- [18] I. PINELIS, *L'Hospital rules of monotonicity and Wilker-Anglesio inequality*, Amer. Math. Monthly, **111** (2004), 905–909.
- [19] S. PONNUSAMY AND M. VUORINEN, *Asymptotic expansions and inequalities for hypergeometric functions*, Mathematika **44** (1997), 278–301.
- [20] J. SÁNDOR AND M. BENCZE, *On Huygens' trigonometric inequality*, RGMIA Res. Rep. Collection **8** (2005), no. 3, Article 14.
- [21] J. S. SUMNER, A. A. JAGERS, M. VOWE AND J. ANGLESIO, *Inequalities involving trigonometric functions*, Amer. Math. Monthly **98** (1991), 264–267.
- [22] J. B. WILKER, *Problem E 3306*, Amer. Math. Monthly **96** (1989), 55.
- [23] S.-H. WU, *On extension and refinement of Wilker's inequality*, Rocky Mountain J. Math. **39** (2009), 683–687.
- [24] S.-H. WU AND A. BARICZ, *Generalizations of Mitrinović, Adamović and Lazarević's inequalities and their applications*, Publ. Math. Debrecen **75** (2009), 447–458.
- [25] S.-H. WU AND L. DEBNATH, *Wilker-type inequalities for hyperbolic functions*, Appl. Math. Lett. **25** (2012), 837–842.
- [26] S.-H. WU AND H. M. SRIVASTAVA, *A weighted and exponential generalization of Wilker's inequality and its applications*, Integral Transforms and Spec. Funct. **18** (2007), 529–535.
- [27] S.-H. WU AND H. M. SRIVASTAVA, *A further refinement of Wilker's inequality*, Integral Transforms and Spec. Funct. **19** (2008), 757–765.
- [28] L. ZHANG AND L. ZHU, *A new elementary proof of Wilker's inequalities*, Math. Inequal. Appl. **11** (2008), 149–151.
- [29] L. ZHU, *A new simple proof of Wilker's inequality*, Math. Inequal. Appl. **8** (2005), 749–750.
- [30] L. ZHU, *On Wilker-type inequalities*, Math. Inequal. Appl. **10** (2007), 727–731.
- [31] L. ZHU, *Some new inequalities of the Huygens type*, Comput. Math. Appl. **58** (2009), 1180–1182.
- [32] L. ZHU, *Some new Wilker-type inequalities for circular and hyperbolic functions*, Abstr. Appl. Anal. 2009, Article ID 485842.
- [33] L. ZHU, *A source of inequalities for circular functions*, Comput. Math. Appl. **58** (2009), 1998–2004.
- [34] L. ZHU, *Inequalities for Hyperbolic functions and their Applications*, J. Ineq. Appl. Vol. (2010), Article ID 130821.