

POSITIVE SOLUTIONS FOR A SYSTEM OF SINGULAR SECOND-ORDER INTEGRAL BOUNDARY VALUE PROBLEMS

JOHNNY HENDERSON* AND RODICA LUCA**

*Baylor University, Department of Mathematics
Waco, Texas, 76798-7328 USA
E-mail: Johnny_Henderson@baylor.edu

**Gh. Asachi Technical University, Department of Mathematics
Iași 700506, Romania
E-mail: rluca@math.tuiasi.ro

Abstract. We investigate the existence of positive solutions of a system of second-order nonlinear differential equations subject to integral boundary conditions, where the nonlinearities do not possess any sublinear or superlinear growth conditions and may be singular.

Key Words and Phrases: System of second-order differential equations, integral boundary conditions, positive solutions, singular functions, fixed point index.

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REFERENCES

- [1] B. Ahmad, A. Alsaedi, B.S. Alghamdi, *Analytic approximation of solutions of the forced Duffing equation with integral boundary conditions*, *Nonlinear Anal., Real World Appl.*, **9**(2008), 1727-1740.
- [2] F.M. Atici, G.Sh. Guseinov, *On Green's functions and positive solutions for boundary value problems on time scales*, *J. Comput. Appl. Math.*, **141**(2002), 75-99.
- [3] A. Boucherif, *Second-order boundary value problems with integral boundary conditions*, *Nonlinear Anal.*, **70**(2009), 364-371.
- [4] A. Boucherif, J. Henderson, *Positive solutions of second order boundary value problems with changing signs Caratheodory nonlinearities*, *Electron. J. Qual. Theory Differ. Equ.*, **7**(2006), 1-14.
- [5] N.P. Cac, A.M. Fink, J.A. Gatica, *Nonnegative solutions of quasilinear elliptic boundary value problems with nonnegative coefficients*, *J. Math. Anal. Appl.*, **206**(1997), 1-9.
- [6] J.R. Cannon, *The solution of the heat equation subject to the specification of energy*, *Quart. Appl. Math.*, **22**(1964), 155-160.
- [7] R. Yu. Chegis, *Numerical solution of the heat conduction problem with an integral condition*, *Litov. Mat. Sb.*, **24**(1984), 209-215.

- [8] Y. Cui, J. Sun, *On existence of positive solutions of coupled integral boundary value problems for a nonlinear singular superlinear differential system*, Electron. J. Qual. Theory Differ. Eq., **41**(2012), 1-13.
- [9] D.G. de Figueiredo, P.L. Lions, R.D. Nussbaum, *A priori estimates and existence of positive solutions of semilinear elliptic equations*, J. Math. Pures Appl., **61**(1982), 41-63.
- [10] C.S. Goodrich, *Nonlocal systems of BVPs with asymptotically superlinear boundary conditions*, Comment. Math. Univ. Carolin., **53**(2012), 79-97.
- [11] D. Guo, V. Lakshmikantham, *Nonlinear Problems in Abstract Cones*, Academic Press NY 1988.
- [12] D.J. Guo, V. Lakshmikantham, *Multiple solutions of two-point boundary value problems of ordinary differential equations in Banach spaces*, J. Math. Anal. Appl., **129**(1988), 211-222.
- [13] X. Hao, L. Liu, Y. Wu, *Positive solutions for second order differential systems with nonlocal conditions*, Fixed Point Theory, **13**(2012), 507-516.
- [14] J. Henderson, R. Luca, *Positive solutions for singular systems of multi-point boundary value problems*, Math. Methods Appl. Sci., **36**(2013), 814-828.
- [15] J. Henderson, R. Luca, *Positive solutions for systems of second-order integral boundary value problems*, Electron. J. Qual. Theory Differ. Eq., **70**(2013), 1-21.
- [16] J. Henderson, R. Luca, *Existence and multiplicity of positive solutions for a system of higher-order multi-point boundary value problems*, Adv. Dyn. Syst. Appl., **8**(2013), no. 2, 233-245.
- [17] J. Henderson, R. Luca, *Positive solutions for singular systems of higher-order multi-point boundary value problems*, Math. Model. Anal., **18**(2013), no. 3, 309-324.
- [18] J. Henderson, R. Luca, *Positive solutions for systems of multi-point nonlinear boundary value problems*, Comm. Appl. Nonlinear Anal., **21**(2014), no. 3, 1-12.
- [19] J. Henderson, R. Luca, *Existence of positive solutions for a system of nonlinear second-order integral boundary value problems*, Discrete Contin. Dyn. Syst., Suppl. 2015, Dyn. Sys. Differ. Equ. Appl., AIMS Proceedings, 596-604.
- [20] J. Henderson, R. Luca, *Boundary Value Problems for Systems of Differential, Difference and Fractional Equations. Positive Solutions*, Elsevier, Amsterdam, 2016.
- [21] G. Infante, F.M. Minhos, P. Pietramala, *Non-negative solutions of systems of ODEs with coupled boundary conditions*, Commun. Nonlinear Sci. Numer. Simul., **17**(2012), 4952-4960.
- [22] G. Infante, P. Pietramala, *Existence and multiplicity of non-negative solutions for systems of perturbed Hammerstein integral equations*, Nonlinear Anal., **71**(2009), 1301-1310.
- [23] N.I. Ionkin, *Solution of a boundary-value problem in heat conduction with a nonclassical boundary condition*, Differ. Eq., **13**(1977), 204-211.
- [24] T. Jankowski, *Positive solutions to second-order differential equations with dependence on the first-order derivative and nonlocal boundary conditions*, Boundary Value Probl., **8**(2013), 1-20.
- [25] M. Jia, P. Wang, *Multiple positive solutions for integro-differential equations with integral boundary conditions and sign changing nonlinearities*, Electron. J. Differ. Eq., **31**(2012), 1-13.
- [26] D.D. Joseph, E.M. Sparrow, *Nonlinear diffusion induced by nonlinear sources*, Quart. Appl. Math., **28**(1970), 327-342.
- [27] P. Kang, Z. Wei, *Three positive solutions of singular nonlocal boundary value problems for systems of nonlinear second-order ordinary differential equations*, Nonlinear Anal., **70**(2009), 444-451.
- [28] G.L. Karakostas, P.Ch. Tsamatos, *Multiple positive solutions of some Fredholm integral equations arisen from nonlocal boundary-value problems*, Electron. J. Differ. Eq., **30**(2002), 1-17.
- [29] H.B. Keller, D.S. Cohen, *Some positive problems suggested by nonlinear heat generation*, J. Math. Mech., **16**(1967), 1361-1376.
- [30] K.Q. Lan, *Positive solutions of systems of Hammerstein integral equations*, Commun. Appl. Anal., **15**(2011), 521-528.
- [31] B. Liu, L. Liu, Y. Wu, *Positive solutions for singular systems of three-point boundary value problems*, Comput. Math. Appl., **53**(2007), 1429-1438.
- [32] R. Luca, A. Tudorache, *Existence of positive solutions to a system of higher-order semipositone integral boundary value problems*, Comm. Appl. Anal., **19**(2015), 589-604.
- [33] R. Ma, Y. An, *Global structure of positive solutions for nonlocal boundary value problems involving integral conditions*, Nonlinear Anal., **71**(2009), 4364-4376.

- [34] R. Ma, B. Thompson, *Positive solutions for nonlinear m -point eigenvalue problems*, J. Math. Anal. Appl., **297**(2004), 24-37.
- [35] A.A. Samarskii, *Some problems of the theory of differential equations*, Differ. Urav., **16**(1980), 1925-1935.
- [36] W. Song, W. Gao, *Positive solutions for a second-order system with integral boundary conditions*, Electron. J. Differ. Eq., **13**(2011), 1-9.
- [37] H. Su, Z. Wei, X. Zhang, J. Liu, *Positive solutions of n -order and m -order multi-point singular boundary value system*, Appl. Math. Comput., **188**(2007), 1234-1243.
- [38] J.R.L. Webb, G. Infante, *Positive solutions of nonlocal boundary value problems involving integral conditions*, Nonlinear Differ. Eq. Appl., **15**(2008), 45-67.
- [39] Z. Yang, *Positive solutions to a system of second-order nonlocal boundary value problems*, Nonlinear Anal., **62**(2005), 1251-1265.
- [40] Z. Yang, *Positive solutions of a second-order integral boundary value problem*, J. Math. Anal. Appl., **321**(2006), 751-765.
- [41] Z. Yang, D. O'Regan, *Positive solvability of systems of nonlinear Hammerstein integral equations*, J. Math. Anal. Appl., **311**(2005), 600-614.
- [42] Z. Yang, Z. Zhang, *Positive solutions for a system of nonlinear singular Hammerstein integral equations via nonnegative matrices and applications*, Positivity, **16**(2012), 783-800.

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