2021 DSTA dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Fractional Order Controllers for Twin Rotor Aerodynamical System,

MAGDALENA SANGEORZAN[1], EVA-H. DULF[2*]

1. Technical University of Cluj-Napoca
2. Technical University of Cluj-Napoca [0000-0002-6540-6525]

* Presenting Author

Abstract: The twin-rotor aerodynamical system (TRAS) is a highly nonlinear system with a cross-coupling effect. Although several controllers are published in the literature, all solutions are with great complexity. The novelty of this work consists in the design of fractional order controllers using two innovative methods. Two controllers are designed for adjusting the rotational speed of the azimuth motor, respectively two controllers for the rotational speed of the pitch motor. The two sets of controllers are implemented and tested on the physical TRAS equipment in the laboratory, yielding results comparable with any complex solution already acknowledged.

Keywords: fractional-order controller; frequency design method; optimum magnitude

1. Introduction

Fractional order controllers ($PI^{\lambda}D^{\mu}$) are a generalization of the classical PID controllers with integral and derivative parts replaced by a fractional integral of order λ and a fractional order derivative of order μ. Fractional order controllers perform better for nonlinear systems or for systems with variables that change over time. The fractional order controller uses more degrees of freedom compared to the conventional PID controller and has better robustness and fault rejection properties.

2. Results and Discussion

Two Rotor Aero-dynamical System (TRAS) is an equipment created by INTECO [1]. It is a multi-variable system with two inputs and four outputs. The inputs of the system are the voltages applied on the two DC-motors, while the outputs are the rotational speed of the rotors and the position. The transfer matrix (1) represents the linearized TRAS model identified between the rotational speed of the main, pitch and tail, azimuth motor and the input voltage signals applied on these DC-motors.

$$\begin{pmatrix}\omega_h\\ \omega_v\end{pmatrix} = \begin{pmatrix}\frac{8393}{0.22s+1} & \frac{-28.66}{0.17s+1}\\ \frac{-39.33}{0.75s+1} & \frac{5965}{0.83s+1}\end{pmatrix} \quad (1)$$

The TRAS being a cross-coupled system, decoupling technique is used to control the individual outputs. For the decopuled model, fractional order controllers are designed, based on two generalizations of Kessler's optimum magnitude method [2, 3]. The form of the used fractional order controller is:

$$H_R = K_P + \frac{K_I}{s^{\alpha}} \quad (2)$$

Given the advantages of the IMC scheme as well as FOPID controllers and taking into account the inevitable presence of delays in a real-life control system, a control scheme is used as in [4], which combines both fractional order controllers and the IMC scheme for phase delay systems. As design performances, the crossover frequency ω_{gc} and the phase margin γ_k of the closed loop system are imposed. The final form of the resulted controllers are presented in equation (3).

$$Q_{fb} = \frac{1}{K\zeta s^n + KT_1 s^{\beta-1}}(\psi + \frac{1}{s} + Ts^{\alpha-1} + \psi s^{\alpha}) \quad (3)$$

In this way the final control structure is a cascade between a fractional filter and a fractional PID controller. For the implemntation of both type of fractional order controllers, the NRTF approximation approach is used, having the advantage of low order [5]. The results are presented in Table 1.

Table 1. Comparison between the two types of designed fractional order controllers

The controller	Steady state error ε_{ssp} [rad]	Overshoot σ [%]	Settling time t_s [s]	Control effort [V]
Azimuth controller with [3]: $H_{R\_11} = 0.008 + \frac{-1.083 * 10^{-5}}{s^{-0.0454}}$	ε_{ssp} =0.0044	σ =0	$t_s = 0.95$	$c_{max} = 2.387$ c_{min}=0.00353
Azimuth controller with [4]: $Q_{fb\_11} = \frac{1}{8390 * 0.0774 * s^{0.111}}(0.232 + \frac{1}{s} + 0.00263s)$	$\varepsilon_{ssp} = 0$	$\sigma = 8.8$	$t_s = 0.2$	$c_{max} = 0.0616$ c_{min}=0.00358
Pitch controller with [3]: $H_{R\_22} = 0.042 + \frac{-3.546 * 10^{-4}}{s^{-0.0121}}$	ε_{ssp} =0.0012	σ =0	t_s =0.00935	$c_{max} = 1.247$ c_{min}=0.00501
Pitch controller with [4]: $Q_{fb\_22} = \frac{1}{5930 * 0.0975 * s^{0.0111}}(0.837 + \frac{1}{s} + 0.0099s)$	ε_{ssp} =0	$\sigma = 4$	t_s =0.262	$c_{max} = 0.5146$ c_{min}=0.005055

3. Conclusion

Fractional order controllers designed by innovative methods are suitable even for cross-coupled nonlinear MIMO systems, because the system becomes much more robust, the performance of the transient mode is realistic. The experimental results proves that these controllers are comparable with complex elements like

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