ROBUST INTEGRAL OF SIGN OF ERROR BASED ATTITUDE CONTROL OF 2-DOF TWIN ROTOR SYSTEM

FARHAN AHMED QURESHI
REG # 51178

BAHRIA UNIVERSITY ISLAMABAD
KARACHI CAMPUS

AUTHOR'S DECLARATION

I, **Farhan Ahmed Qureshi** hereby state that my MS thesis titled **"Robust Integral of Sign of Error based Attitude Control of 2-DOF Twin Rotor System"** is my own work and has not been submitted previously by me for taking any degree from **Bahria University Karachi Campus** or anywhere else in the country/world.

At any time if my statement is found to be incorrect even after my graduation, the University has the right to withdraw/cancel my MS degree.

Name of Scholar: **Farhan Ahmed Qureshi**

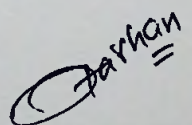
Date: 15-07-20

Plagiarism Undertaking

I, solemnly declare that research work presented in the thesis titled **" Robust Integral of Sign of Error based Attitude Control of 2-DOF Twin Rotor System"** is solely my research work with no significant contribution from any other person. Small contribution / help wherever taken has been duly acknowledged and that complete thesis has been written by me.

I understand the zero tolerance policy of the HEC and Bahria University towards plagiarism. Therefore I as an Author of the above titled thesis declare that no portion of my thesis has been plagiarized and any material used as reference is properly referred / cited.

I undertake that if I am found guilty of any formal plagiarism in the above titled thesis even after award of MS degree, the university reserves the right to withdraw / revoke my MS degree and that HEC and the University has the right to publish my name on the HEC / University website on which names of scholars are placed who submitted plagiarized thesis.

Scholar / Author's Signature: 

Name of Scholar: **Farhan Ahmed Qureshi**

ACKNOWLEDGMENT

I am thankful to the Creator of whole mankind The Allah Almighty to have guided me all through this research at each step and for every new thought which You setup in my intellect to improve it. Undoubtedly I might have done nothing without Your priceless help and guidance.

I would like to express my profound and earnest appreciation to my research supervisor, Engr. Muhammad Yasir Amir Khan, Senior Assistant Professor, Department of Electrical Engineering, Bahria University Karachi Campus, for giving me the opportunity to do research and providing his invaluable guidance throughout this research. It is not an overstatement that without his support this research would not be possible.

I would not forget to offer my sincere appreciation to my co supervisor Dr. Farah Haroon, Associate Professor at Institute of Industrial Electronics Engineering (IIEE). Her vision, sincerity and inspiration have profoundly motivated me. She has taught me the methodology to carry out and to present the research as clearly as possible. It was a great honor for me to work and study under her guidance.

I owe my special thanks of gratitude to my control teacher Prof.Dr. Vali Uddin Abbas, currently Vice Chancellor of Sir Syed University Karachi, for providing such a decent support and guidance, inspite of the fact that he had busy schedule managing the corporate affairs. It is pertinent to mention that he is the one who taught us how to flourish in the field of control engineering which leads to such a quality research.

I would also like extend my warm thanks to Mr. Adnan Sharif, my class fellow for his

tremendous support and cooperation. I appreciate his patience and guidance throughout the whole thesis.

Finally, I would like to specific my appreciation to all the people who have rendered profitable help to my research and study.

ABSTRACT

Attitude stabilization of 2-DOF Twin Rotor System (TRS) is always a challenging problem from the control point of view due to nonlinearity and instability in the open-loop and high cross-coupling effects. This paper proposes a controller to stabilize the pitch and yaw angles of 2-DOF TRS using Robust Integral of Sign of Error (RISE) based control. The proposed controller guarantees asymptotic tracking with bounded disturbances. It can also compensate various parametric uncertainties and modeling errors. Where cross coupling is considered as disturbance to each other. The stability of the proposed controller is shown by using lyapunov based analysis. In order to prove the effectiveness of proposed controller, Sliding Mode Controller (SMC) is taken as bench mark. MATLAB simulation results of both the controllers are compared critically. These simulation results are then validated by implementing RISE on TRS hardware.

keywords: Twin Rotor system (TRS), Robust Integral of Sign of Error (RISE), , 2-DOF, SMC, Lyapunov

Table of Contents

Chapter	Title	Page
	Acknowledgment	vi
	Abstract	viii
	Table of Contents	ix
	List of Tables	xi
	List of Figures	xii
1	Introduction	1
	1.1 Overview	3
	1.2 Statement of the Problem	4
	1.3 Objectives and Scope	4
	1.4 Motivation	4
	1.5 Assumptions and Limitations	5
	1.6 Methodology	5
	1.7 Thesis Outline	6
2	Literature Review	7
	2.1 Control of Twin Rotor System	7
	2.2 RISE based Control	8
	2.3 Summary	9
3	Mathematical Modeling of 2-DOF Twin Rotor System	11
	3.1 Forces on Pitch Axis	11
	3.1.1 Torque due to Pitch Rotor	12
	3.1.2 Torque due to Yaw Rotor	12
	3.1.3 Disturbances on Pitch Axis	13
	3.2 Torque on Yaw Axis	16
	3.2.1 Torque of Pitch Rotor affecting Yaw Axis	16
	3.2.2 Torque due to Yaw Rotor	17
	3.2.3 Disturbance on Yaw Axis	17
	3.2.4 Parametric Values of TRS	20
	3.3 Summary	20
4	Linear Controller Implementation on TRS	21
	4.1 State Equations of TRS	21
	4.2 Linearization of TRS	22
	4.3 Controller Implementation	25
	4.3.1 PID Controller	25
	4.3.2 State Feedback Controller	26
	4.3.3 LQR Controller	27
	4.4 Summary	29
5	RISE Feedback Control Development	30
	5.1 Control Law for RISE	30
	5.2 Prerequisite of RISE Control Implementation	31
	5.2.1 Bounded Disturbance on Pitch Axis	31
	5.2.2 Bounded Disturbance on Yaw Axis	33

5.3 RISE Feedback Control Design 35
5.4 Stability Analysis 37
5.5 Summary 42

6 Simulation and Experimental Results 43

6.1 Simulation Results 43
6.2 Hardware Results 52

7 Conclusion and Future Work 59

7.1 Conclusion 59
7.2 FutureWork 60

Appendix A: Laws of Physics in Ch-3 67