DESIGN AND CONTROL OF AN EXPERIMENTAL WIND TUNNEL SYSTEM

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Abstract

The main aim of this project is to develop, model, and control the appropriate characteristics of an experimental wind tunnel system inspired by traditional wind tunnels. A PID controller and a Lyapunov-based non-linear Robust controller designed with a novel approach are utilized for the control purpose. The prepared system can be readily implemented in a laboratory environment, allowing the relevant parameters to be monitored under various conditions. The system's physical design phase is focused on keeping costs low and making it simple to understand. The system's main goal is to induce a pressure change in the pipe, measure the output fan's speed, and verify that it reaches the reference value. The system's hardware, control software, and test results are all thoroughly detailed.

1. Introduction

A wind tunnel is a tunnel in which air is moved at a controlled pace to research, evaluate, and interpret the effect of gas on solid objects in a gas moving like air. It's utilized in a wind tunnel to evaluate the aerodynamic properties of real or scaled-down parts and vehicles under controlled conditions. The experimental wind tunnel system presented in this study is designed and constructed as a simple laboratory setup inspired by standard wind tunnels.

The goal of the control strategy is to deliver the fan speed at the pipe's end and to achieve the desired value by managing the air speed in the pipe. The PID controller and a non-linear Robust controller that we utilize are used to optimize system performance. The fans at the pipe's head create air pressure in the pipe, allowing the fan at the pipe's end to rotate. This poster describes an automatic non-linear system for controlling the airflow rate and pressure drop of a low speed wind tunnel.

2. System Design

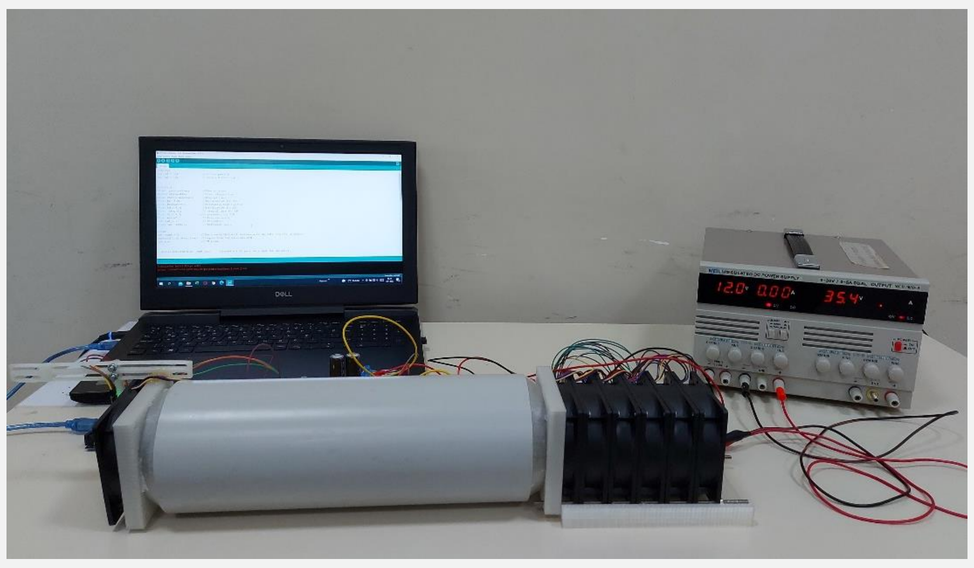

Figure 1. Wind Tunnel System

The experimental wind tunnel system was created by placing six cooling fans at the input of the system and one passive cooling fan at the output of the system. The system was put together by 3D - printed pieces drawn in SolidWorks.

Pipe Length	30 cm
Pipe Diameter	11 cm
DC Fans	12V
3D Printed Parts	3 pieces

Table 1. Hardware

The system's electronics include an infrared (IR) sensor that measures and detects infrared radiation in its environment, an Arduino, an open-source electronics platform based on easy-to-use hardware and software, and a motor driver that applies voltage to the system in the range of 0-255 in proportion to the PWM signals produced and sent by the Arduino.

3. Modeling

Modeling the system was our first attempt at using control methods. A fluid mechanism system can be used to model a wind tunnel. The Bernoulli equation is an approximation of pressure, velocity, and elevation in regions of constant, incompressible flow with negligible net frictional forces. Because our research is focused on air as a fluid, a generic equation is inappropriate. This is how the Bernoulli equation for compressible, steady-state ideal gas flow and its isotropic condition is written[1].

$$\left(\frac{k}{k-1}\right)\times\frac{P_1}{\gamma}+\frac{V_1^2}{2g}+z_1+H_p-H_L-H_M=\left(\frac{k}{k-1}\right)\times\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+z_2 \qquad (1)$$

4. Control

The speed of the output fan is controlled in this study using PID and a non-linear Robust controllers. The coefficients required for controller optimization have been obtained experimentally. The system has been given two different types of desired trajectories; a constant desired trajectory and a sinusoidal desired trajectory. The PID controller's structure is given as

$$u = K_p.e(t) + K_i.\int_0^t e(\tau).d\tau + K_d.\frac{de(t)}{dt} \qquad (2)$$

The designed nonlinear robust controller's structure is given as

$$u = \frac{1}{\hat{P}_2}\left[\dot{\omega}_d - \rho_{b_1} sgn(e) - k_1 e\right] + k_2\int_0^t e(\tau).d\tau \qquad (3)$$

where $e(t)$ denotes the error term defined as a difference between desired trajectory and the measured fan speed.

Control results for the mentioned control designs can be seen in Figure 2.

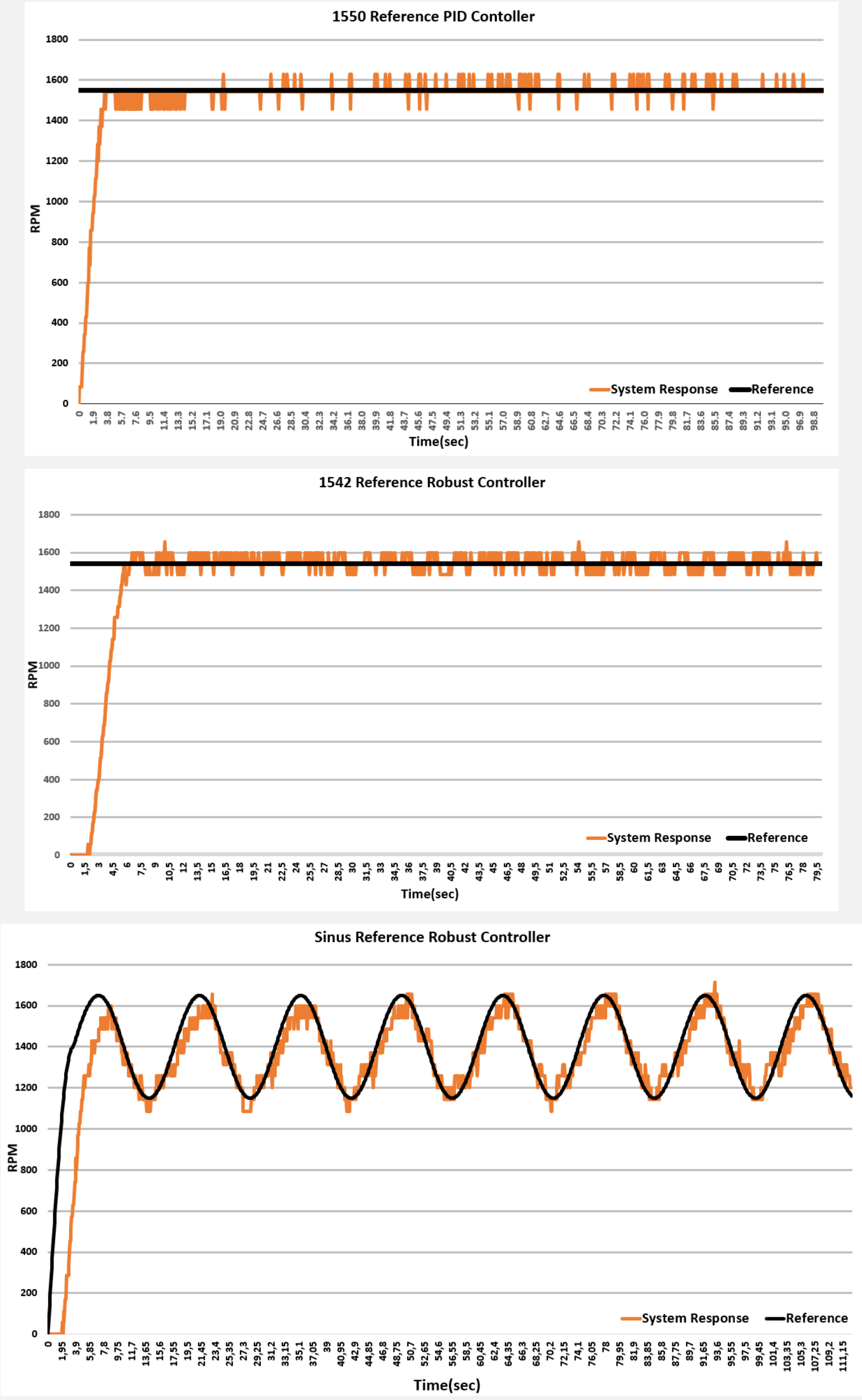

Figure 2. Control Results for PID and Non-linear Robust Controllers

5. Conclusions

The main objective of wind tunnels is to simulate various conditions in order to test scale models of aircraft and spacecraft. Before the control stage, we tried to create a model of the system using the Bernoulli Equation, but due to hardware problems, we could not get a reliable model. Because these techniques can be utilized without modeling the system, we used PID control and a non-linear Robust control algorithms to control the system. The response of the system was observed for various references and disturbances, and the results revealed that our experimental wind tunnel design performed as expected.

References

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[3] Bayrak A. Design of an experimental wind tunnel system for control applications Available from: DOI: 10.1177/0020720918800442,2018.

Department of Mechatronics Engineering Graduation Projects 2021-2022