The Effect of Turbulence on RPC Incipience and Workload

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INTRODUCTION

Rotorcraft-Pilot couplings (RPCs) are defined as undesirable phenomena originating from an anomalous interaction between pilot and rotorcraft [1–3]. The term RPC includes any kind of unfavorable event related to involuntary unstable rotorcraft responses resulting from pilot control actions within the control loop, whether they are active or passive, oscillatory or non-oscillatory. The most common or well-known form of RPC is a Pilot-Induced Oscillation (PIO). The term PIO refers specifically to an oscillatory aircraft response, characterized by an 'active' pilot trying to control the vehicle within the control loop, which inadvertently excites potentially divergent vehicle oscillations.

This work aims to *enhance rotorcraft safety* by reducing the number of RPC events with the use of a real-time PIO detection system. This study focuses on the *effect of turbulence on RPC incipience and pilot workload*.

Previous work at the University of Liverpool focused on a means to identify/detect PIO events, after they had occurred. This led to the development of the Phase-Aggression Criterion (PAC) [4, 5]. The objective of the current research with the NITROS project consists in developing and evaluating a toolset able to *detect PIOs in (near) real-time* in modern rotorcraft, as well as *alleviating* the unwanted event if it occurs. The detection is "near real-time" because it lags real-time by the sampling period. The PAC has been used as a post-processing tool in previous works related to the interaction between pilot, rotorcraft and the environment [6]. For this reason the current research focuses on deepening aspects of rotorcraft safety, such as the *human-machine-environment interaction* and the relative consequences. Hence, this research sits well within the NITROS "key pillars" of flight safety [7,8], contemplating rotorcraft safety as a inter-dependent job between pilot, vechicle and environment.

For this study, a rotorcraft model based upon the Bo-105, which has a rate command (RC) response type, was used. An alert system has been designed to provide the pilot with visual cues to enable him/her to suppress a PIO either before or as it happens (i.e. a form of manual alleviation). Furthermore, the experimental conditions tested provide a comparative overview of different cases in which both system (pilot-rotorcraft) and environmental parameters were changed. Specifically, different values of swashplate actuator rate limiters were used, as well as different turbulence parameter settings.

The full paper will be potentially structured as follows. RT-PAC is briefly described, along with the associated PAC chart and PIO severity regions. The turbulence model [9] is shorty introduced, in order to highlight its main characteristics (its complete characterization is not part of this research). The experiment setup is outlined and the experimental results are provided, comparing the objective data output coming from the HeliFlight-R flight simulator and the pilot subjective opinions and ratings collected during the tests. The paper ends with a Section describing the author's suggestion on the future work for a potential journal paper submission.

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[1] NITROS: Network for Innovative Training on Rotorcraft Safety - https://www.nitros-ejd.org/fellowship-esr6/

REFERENCES

[1] Anon., "Aviation Safety and Pilot Control: Understanding and Preventing Unfavorable Pilot-Vehicle Interactions," Committee on the Effects of Aircraft-Pilot Coupling on Flight Safety Aeronautics and Space Engineering Board Commission on Engineering and Technical Systems National Research Council, Washington, D.C., 1997.

[2] D. T. McRuer, "Pilot-Induced Human Oscillations Behavior and Dynamic," NASA Contractor Report, 1995.

[3] M. D. Pavel *et al.*, "Adverse rotorcraft pilot couplings - Past, present and future challenges," *Prog. Aerosp. Sci.*, vol. 62, pp. 1–51, 2013.

[4] M. Jones and M. Jump, "New methods to subjectively and objectively evaluate adverse pilot couplings," *J. Am. Helicopter Soc.*, vol. 60, no. 1, p. 011003, 2015.

[5] M. Jones, "Prediction, Detection, and Observation of Rotorcraft Pilot Couplings," Univeristy of Liverpool, 2015.

[6] P. Lehmann, M. Jones, M. Höfinger, "Impact of Turbulence and Degraded Visual Environment on Pilot Workload," CEAS Aeronautical Journal, 2017.

[7] G. Quaranta et al., "NITROS: An Innovative Training Program to Enhance Rotorcraft Safety," Annual Forum Proceedings - AHS International 74th Annual Forum & Technology Display, Phoenix, Arizona, USA, May 14-17, 2018.

[8] G. Padfield, "Helicopter Flight Dynamics - The Theory and Application of Flying Qualities and Simulation Modelling," Blackwell, 2007.

[9] S. H. Huecas, M. White, G. Barakos, "A Turbulence Model for Flight Simulation and Handling Qualities Analysis based on a Synthetic Eddy Method," Vertical Flight Society's 76th Annual Forum & Technology Display, Virginia Beach, Virginia, USA, October 6-8, 2020, 2020.