Exploration of Aerial Torsional Work Using an Add-on Thrust Vectoring Device

Ricardo Rosales Martinez[1], Hannibal Paul[2], and Kazuhiro Shimonomura[1]

I. INTRODUCTION

Torsional tasks are of great interest, since they allow for applications such as the replacement of light bulbs [1] at different altitudes, loosening/fastening nuts [2], material drilling/sampling, and valve manipulation[3]. However, this types of interactions require special considerations in the field of aerial manipulation, since UAVs are limited in the magnitude and direction of the forces that can be generated. With the previous research [4] we showed the effectiveness of an add-on system for UAVs, allowing for planar translational motion. In this study we further expand this concept, by presenting two design configurations for a thrust vectoring device, which allows a UAV to perform torsional work.

II. ADD-ON THRUST VECTORING DEVICE

The add-on thrust vectoring device is composed of electric ducted fans (EDFs), where the thrust vector of each EDF is independently controlled by a servomotor. The moment used for the torsional task is generated by the thrust vectoring device, independent of the multirotor's propellers. The number and position of EDFs determines the torsional capabilities of the system, in this research we focused on the following; The **high torque configuration** shown in Fig. 1(a), uses three EDFs positioned at a separation of 120° from each other. The rotation axis of each EDF is parallel to z axis of the UAV. The decoupling of the torque generated by the EDFs and the propeller's thrust, allows the multirotor to land on a vertical valve through a passive landing mechanism. Once successfully landed, the system can disarm its propellers, and operate the valve through the add-on device. In the **dual torque configuration** shown in Fig. 1(b), two edfs are positioned at a separation of 180° from each other. In this case the rotation axis of the edfs is perpendicular to the z axis of the UAV. This configuration is capable of generating a torsional moment which can be rotated around the frame of the UAV. Additionally this enables the system to generate pushing forces at different orientations, without requiring to tilt the UAV.

III. EXPERIMENTAL RESULTS

The high torque configuration is able to generate a maximum moment of 10.78 $N \cdot m$ on the UAV's z axis. In this configuration the system is able land on an industrial valve and operate it from its shut state. During the valve operation the add-on device allows for continuous rotation as well as higher rotation rates, which can be controlled according to the requirements of the task and the characteristics of the valve. The dual torque configuration produces a maximum moment of 4.40 $N \cdot m$. However, this moment is not limited to act on the z axis, and can be rotated around the frame of the UAV. By reorienting this moment, the system can be used to operate valves at different orientations. Likewise, its thrust vector has a range of motion of 360° and has a maximum force of 17.50 N.

Fig. 1. Add-on thrust vectoring device configurations: (a) High torque configuration. (b) Dual torque configuration

IV. CONCLUSIONS

In this study, the design and development of an add-on thrust vectoring system for torsional tasks, which can be equipped on a commercial multirotor was described. The decoupling of the propellers' thrust and the torque generated by three EDFs in the proposed system, allowed the generation of torques of higher magnitude compared to the torque in the yaw axis of a conventional UAV. Moreover,the current thrust system is capable of directing these forces and moments independent of the orientation of the vehicle.

REFERENCES

[1] S. Shimahara, S. Leewiwatwong, R. Ladig, and K. Shimonomura, "Aerial torsional manipulation employing multi-rotor flying robot," in *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2016, pp. 1595–1600.

[2] A. Rastegarpanah, R. Ner, R. Stolkin, and N. Marturi, "Nut unfastening by robotic surface exploration," *Robotics*, vol. 10, no. 3, p. 107, 2021.

[3] M. Zhao, K. Nagato, K. Okada, M. Inaba, and M. Nakao, "Forceful valve manipulation with arbitrary direction by articulated aerial robot equipped with thrust vectoring apparatus," *IEEE Robotics and Automation Letters*, vol. 7, no. 2, pp. 4893–4900, 2022.

[4] R. Miyazaki, H. Paul, and K. Shimonomura, "Development of add-on planar translational driving system for aerial manipulation with multirotor platform," *Applied Sciences*, vol. 11, no. 4, 2021. [Online]. Available: https://www.mdpi.com/2076-3417/11/4/1462

*This work was not supported by any organization

[1]Department of Robotics, Graduate School of Science and Engineering, Ritsumeikan University, Japan gr0396fe@ed.ritsumei.ac.jp

[2]Research Organization of Science and Technology, Robotics Research Center, Ritsumeikan University, Japan