Development of Control Strategies for Vertical Mobility of Adaptive Telescopic High-altitude Aerostats

Cezary Graczykowski*, Lech Knap†, Jan Holnicki-Szulc* and Zbigniew Wołejsza*

* Institute of Fundamental Technological Research
Polish Academy of Sciences
Pawińskiego 5B, 02-106 Warsaw, Poland
e-mail: cezary.graczykowski@ippt.pan.pl, web page: http://www.ippt.pan.pl

† Warsaw University of Technology
Faculty of Automotive and Construction Machinery Engineering
Narbutta 84, 02-524 Warsaw, Poland
Email: Lech.Knap@pw.edu.pl, web page: http://www.simr.pw.edu.pl

ABSTRACT

In this article we propose a new concept of adaptive telescopic high-altitude aerostat designed in a modular form which allows for sequential changes of volume during the flight. The proposed telescopic aerostat can be easily enlarged or contracted due to application of multi-segmented construction, controllable segments' couplings and proper adjustment of internal pressure by the use of the additional gas tank, the controlling valve and the compressor [1]. Conducted changes of aerostat volume allow to precisely establish the value of required lift force and to obtain desired path of ascending and descending [2].

The paper briefly presents some ideas of possible technical solutions for modular construction and controllable inter-segment couplings using smart materials actuators. Then, the mathematical model of the aerostat vertical motion is derived and the control problems related to optimization of aerostat trajectory are formulated using previous research works [3, 4]. The main emphasis is put on elaboration of the vertical motion control strategies aimed at: i) reaching the subsequent predefined altitudes in the shortest period of time, ii) reaching the subsequent altitudes with the smallest cost of control (defined by total work done by compressor), iii) following the assumed vertical path with the smallest total discrepancy and minimal cost of applied control.

The conducted numerical analyses prove that vertical mobility of the proposed adaptive telescopic aerostats can be adjusted to various operational conditions. It is possible achieve desired altitudes very fast, operate in very slow low-energetic manner and precisely track the desired vertical paths. It can be concluded that adaptive telescopic aerostats offer exceptional vertical mobility and thus they seem to be promising solution in many practical applications in the coming years.

REFERENCES

[1] J. Holnicki-Szulc, R. Faraj, P. Pawłowski, Z. Wołejsza, K. Kaźmierczak and K. Hinc, "Deployable structure of stratospheric airship and method of volume change of deployable structure of stratospheric airship" (in Polish), Polish Patent Pending No. 419786, (2016).

[2] L. Knap, C. Graczykowski, J. Holnicki-Szulc, Z. Wołejsza, "Vertical mobility of the adaptive telescopic stratospheric HAPS aerostats", Chinese Journal of Aeronautics, submitted, (2019).

[3] Y.J. Zhao, J. Mueller and W. Garrard, "Benefits of trajectory optimization in airship flights", AIAA paper No. **2004-6527**, (2004).

[4] L. Sun and Z. Zheng, "Nonlinear adaptive trajectory tracking control for a stratospheric airship with parametric uncertainty", *Nonlinear Dynamics*, Vol. **82**, pp. 1-12, (2015).