

SHAVO control of a morphing wing

P. Beneš^a, Z. Šika^a, M. Hromčík^b, F. Svoboda^b, A. Balon^a

^a Faculty of Mechanical Engineering, CTU in Prague, Technická 4,160 00 Praha 6, Czech Republic

^b Faculty of Electrical Engineering, CTU in Prague, Technická 2,166 27 Praha 6, Czech Republic

Conventional wings are usually designed for a single typical flight condition, or for a balanced combination of multiple flight conditions. Therefore, they cannot be fully optimal for a wide range of flight modes simultaneously. Continuously variable profile geometries promise significantly increased efficiency, minimized drag, and low noise levels compared to wings with conventional flaps with necessary constructional gaps. The use of smart materials eliminates the large and heavy traditional actuators. The associated reduction in weight and air resistance also means significant fuel savings and therefore cost savings. Moreover, the usage of smart materials reduces energy conversions and related losses (classical servomechanisms with electrical to mechanical or hydraulic forces). Reducing the number of individual parts also provides better system reliability.

The morphing wing technology appears as feasible and very promising way for near future air transportation and wind power generation systems. The airfoil fabricated from smart materials and equipped with a vast number of integrated actuators and sensors can be used for active damping, increased resistance to flutter, higher lift-to-drag ratio of air vehicles or better efficiency of wind power generators in various operational regimes. Finding the right control concept is key to achieve the desired features. The SHAVO control approach combines advantages of the feedforward command shaping and the feedback control. The command shaping part based on the model of the system is capable to quickly and efficiently eliminate residual vibration while the feedback part ensures the stability and robustness to unmodeled disturbances and deviations. The structure of SHAVO control is in Fig. 1.

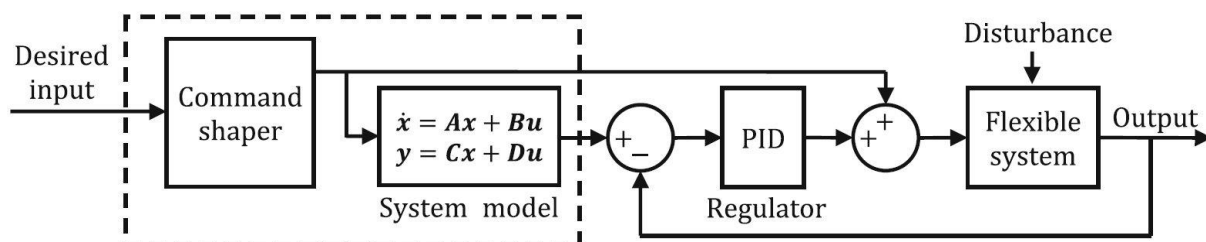


Fig. 1. Structure of SHAVO control, [1]

The system model is used not only to design the shaper itself, but also to predict the behaviour of the controlled system. The feedback part then compensates only differences between the expected and the actual state.

Command shaper used in the SHAVO structure is based on an optimized control curve that is converted into the form of a dynamic shaper with re-entry property [2]. Unlike traditional approaches to command/shaping control the length of the shaper is not determined by the system natural frequency and thus can be set arbitrarily (with respect to limits of the actuator).

The simulation model is based on state space representation of the wing dynamics [3]. We considered small displacements and linear elastic material, thus the Hooks law is valid. Some of the first simulation results are in Fig. 2. The desired input was a step signal. The model error has been introduced in the form of 10% change of mass. The external disturbance was represented by randomly added noise. The performance of SHAVO control was compared to command shaping without feedback.

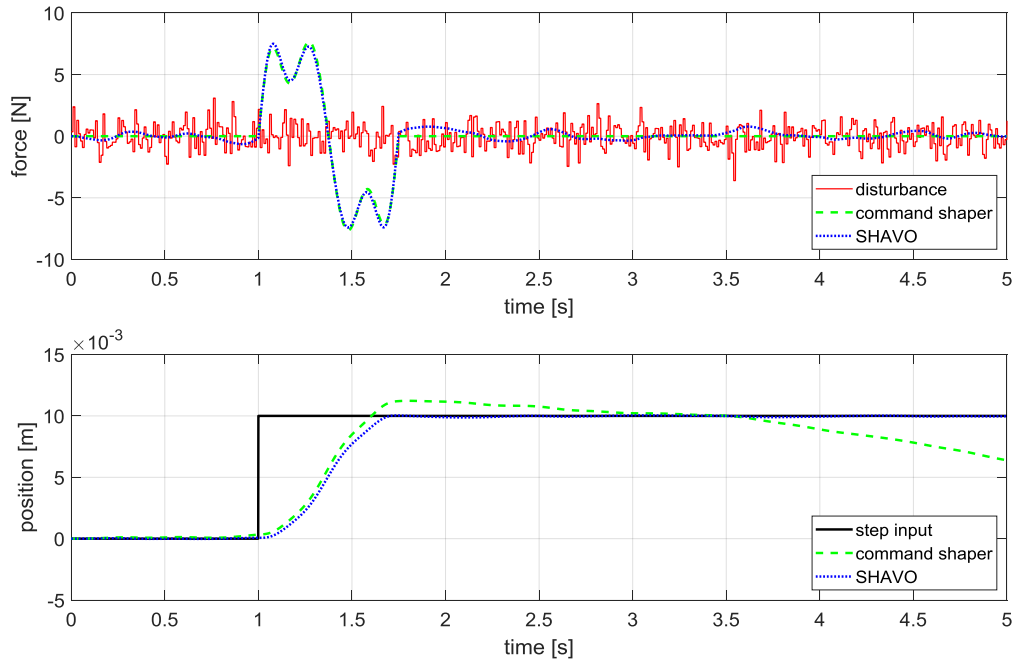


Fig. 2. Simulations: model error and external disturbance

Simulation experiments proved that SHAVO approach is capable to deal with both model error and unpredicted external disturbance. Actuator requirements remain practically the same as in the case of the pure command shaper. The next step will be the application to the smooth morphing trailing edge demonstrator [4].

Acknowledgements

The work has been supported by the Czech Science Foundation project GA19-16772S - Aerodynamic bodies with actively controlled morphing.

References

- [1] Beneš, P., Valášek, M., Šika, Z., SHAVO control: the combination of the adjusted command shaping and feedback control for vibration suppression, *Acta Mechanica* 230 (5) (2019) 1891-1905.
- [2] Beneš, P., Valášek, M., Optimized re-entry input shapers, *Journal of Theoretical and Applied Mechanics* 54 (2) (2016) 353-368.
- [3] Svoboda, F., Hromčík, M., Finite element method based modeling of a flexible wing structure, *Proceedings of the 21st International Conference on Process Control*, 2017, pp. 222–227.
- [4] Svoboda, F., Hromčík, M., Construction of the smooth morphing trailing edge demonstrator, *Proceedings of the 22nd International Conference on Process Control*, Piscataway, 2019, pp. 136-139.