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Topology Optimization Design of Transmission Structure in Flapping-Wing Micro Aerial Vehicle via 3D Printing

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Abstract : Flapping-wing micro aerial vehicle (FMAV) is a new type of aircraft by mimicking the flying behavior to that of small birds or insects. Comparing to the traditional fixed wing or rotor-type aircraft, FMAV only needs to control the motion of flapping wings, by changing the size and direction of lift to control the flight attitude. Therefore, its transmission system should be designed very compact. Lightweight design can effectively extend its endurance time, while engineering experience alone is difficult to simultaneously meet the requirements of FMAV for structural strength and quality. Current researches still lack the guidance of considering nonlinear factors of 3D printing material when carrying out topology optimization, especially for the tiny FMAV transmission system. The coupling of non-linear material properties and non-linear contact behaviors of FMAV transmission system is a great challenge to the reliability of the topology optimization result. In this paper, topology optimization design based on FEA solver package Altair Optistruct for the transmission system of FMAV manufactured by 3D Printing was carried out. Firstly, the isotropic constitutive behavior of the Ultraviolet (UV) Cureable Resin used to fabricate the structure of FMAV was evaluated and confirmed through tensile test. Secondly, a numerical computation model describing the mechanical behavior of FMAV transmission structure was established and verified by experiments. Then topology optimization modeling method considering non-linear factors were presented, and optimization results were verified by dynamic simulation and experiments. Finally, detail discussions of different load status and constraints were carried out to explore the leading factors affecting the optimization results. The contributions drawn from this article helpful for guiding the lightweight design of FMAV are summarizing as follow; first, a dynamic simulation modeling method used to obtain the load status is presented. Second, verification method of optimized results considering non-linear factors is introduced. Third, based on or can achieve a better weight reduction effect and improve the computational efficiency rather than taking multi-states into account. Fourth, basing on makes for improving the ability to resist bending deformation. Fifth, constraint of displacement helps to improve the structural stiffness of optimized result. Results and engineering guidance in this paper may shed lights on the structural optimization and light-weight design for future advanced FMAV.

Keywords : flapping-wing micro aerial vehicle, 3d printing, topology optimization, finite element analysis, experiment
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