Acoustic Analysis and Optimization of Embedded Exhaust-Washed Structures

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As aerospace technology continues to advance across the globe, demand is ever increasing for future capabilities of aircraft. These requests call for improvements in extended flight intervals, rapid attack and defense mechanisms, reusable launch system techniques, and improved configurations for low observability. In each of these cases, the critical sections more susceptible to failure, such as aircraft skin, embedded engine exhaust systems, etc., on aircraft structures may endure extreme environments characterized by elevated temperatures, intense acoustic effects, as well as additional structural loads introduced by high speed and prolonged flight. Although many of these disciplines have been considered in the past, most works focus only on part of the combined loading situation that these new extreme conditions pose. In addition, many times specific loading conditions, such as the ones created from vibro-acoustics, are neglected because of their relatively small size compared to other structural or thermal loads. This approach is insufficient for the effective design of complex aerospace structures, such as internal ducted exhaust systems and sensitive airframe designs, because the true structural response is a combined loading affect that requires attention from all disciplines. The high cycle acoustic loads resulting from the vibro-acoustics can significantly decrease the fatigue life of aircraft components when added to primary structural or thermal loading environments. Thus, a multidisciplinary computational analysis and simulation for aerospace structures should be considered in future aircraft designs.

This research investigates the acoustic excitations generated from the acoustic pressure produced by structurally integrated embedded engines. The goal of this work is to study the effects of the aircraft components involving the interactions between fluid and structural coupled systems, and to optimize these structures in order to decrease the internal acoustic signature. By optimizing these integrated aircraft components, the pressure magnitude of the frequency response functions and acoustic intensity can be reduced, therefore prolonging the fatigue life of the aircraft structure. This paper highlights an optimization technique that is utilized to reduce the acoustic related stress of a simplified engine exhaust-washed structure.

Previous investigations have allowed a comprehensive study of the current representation of the ducted exhaust system model. In this work, the structural-fluid coupling effects of the system had a significant effect on the mode shapes of the model, requiring future models to include the fluid domain in the analysis. Preliminary optimization results show that the structural thickness can be altered in order to reduce the maximum acoustic pressure observed within the system. Gradient based methods, such as SQP, as well as an adaptive/hybrid optimization search algorithm were utilized to optimize the structure in order to reduce the acoustic pressure and mass of the system. With the dynamic frequency dependent loads and stresses that are seen in this problem, a new optimization formulation was implemented utilizing a critical point constraints technique in which areas prone to experience larger stresses are monitored.

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