MULTIDIMENSIONAL LOADS CRITERIA FOR ACTIVE LOAD ALLEVIATION CONTROL DESIGN

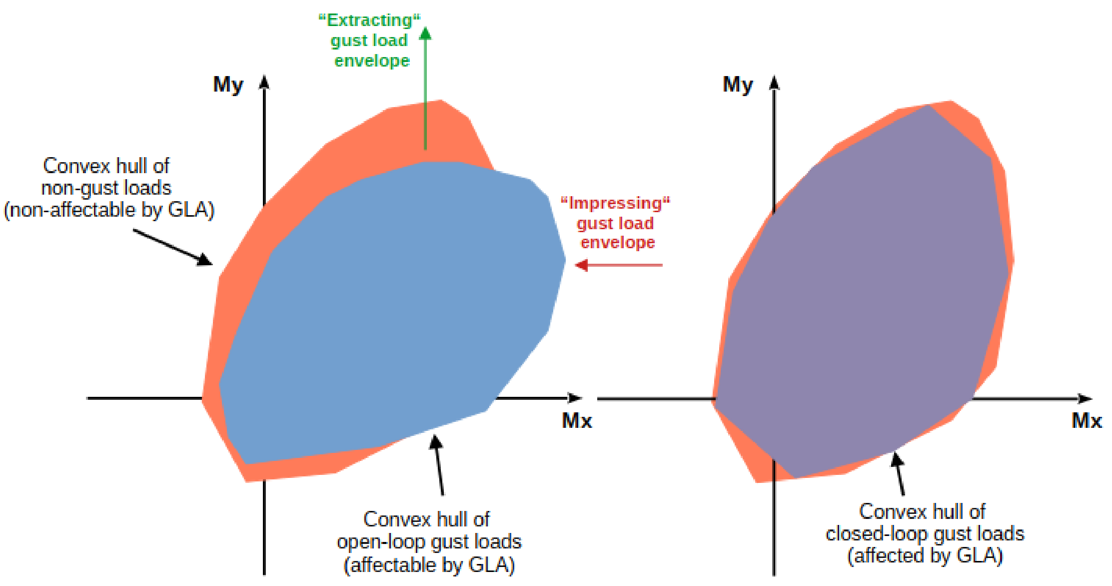
Christian Wallace*, Nicolas Fezans, Vega Handojo

**DLR (German Aerospace Center)*
Lilienthalplatz 7, 38108 Braunschweig,
Germany

ABSTRACT

The certification process for a new aircraft type requires the consideration of different load cases (manoeuvre cases, gust cases etc.) to determine critical structural loads. The airframe must be proven to withstand these loads, meaning that the structural loads associated with the evaluation of the load cases have a significant influence on the design of the primary structure. A successful reduction of critical loads leads to potential weight savings, which would be in line with the common objective of significantly reducing the emissions of modern transport aircraft.

Active control technologies are providing the opportunity to alleviate structural loads, to resize the aircraft primary structure and to save weight. The success of a structural optimisation in terms of effective mass reduction depends on affecting cut loads in several load dimensions simultaneously. The simultaneous analysis of different cut loads (e.g. bending and torsion) is thereby necessary, precise and thus already used regularly. Load alleviation control functions are often tuned with criteria considering combinations of load stations and directions, however considering each of them individually. The use of multidimensional load envelopes as part of the control design criteria is not common and this paper will present a new approach allowing the high-level specification of multidimensional load envelope targets as one of several control design criteria.



The consideration of multidimensional structural loads and the inclusion of multiple load cases go along with a complex load structure, leading to a superposition of several convex hulls ("load potatoes") at each structural point. Depending on the individual control task, some of these convex hulls can be affected, and some of these convex hulls cannot be affected. The presented approach is not restricted to the design of gust load alleviation controllers. As schematically represented in the figure above, a typical target in the case of gust load alleviation control design would be to reduce the multidimensional gust load envelopes to the union of the load envelopes from other load types (e.g. manoeuvre loads, landing loads, etc.). By optimising the GLA control function, this means, figuratively speaking, that the convex hull of gust loads should be "impressed" (noticeably) in some areas, while it can be "extracted" (slightly) in other areas.

The approach presented in this paper builds on prior work [5,6] and extend it to consider multidimensional loads. In order to exploit the fully available alleviation potential, novel optimisation criteria are presented. These criteria are based on the use of discrete gust impulse filters [5], but applied to artificial and linear-superposed performance channels of the plant (aeroservoelastic aircraft) as part of a robust and iterative controller optimisation [6]. At each design iteration, based on the current load envelope either new load outputs are added to the design model or their weights are adjusted to progressively steer the design to the target multidimensional load envelope. By doing so, in addition to the discrete, time-dependent and load case-individual affection of one-dimensional load criteria as presented in [6], the novel approach automatically defines and adjusts loads criteria based on any direction in the multidimensional load space as required in the course of the automatic tuning process. The application of these new criteria enables to "tailor" the resulting actively controlled gust load set to a reasonable level. It is shown that the optimisation algorithm deforms the convex hull of (formerly open-loop) gust loads properly.

Whilst the control design method is applicable to all forms of load alleviation controllers, it is illustrated with an application to the design of a lidar-based gust load alleviation controller for a long-range aircraft configuration. The lidar-based GLA controller structure is comparable to those presented in [1,3,4] and the automated design process is an extension of the one presented in [5,6]. On this application, the capacity of the design process to effectively deform the convex hull of gust loads according to the high-level multidimensional load envelope specifications provided by the control designer, is demonstrated. For this reason, the performance of the control architecture is finally evaluated in a hybrid and multi-rate simulation environment [2]. Beyond the controller and the aircraft model, the environment comprises i.a. a lidar sensor model and non-linear actuator models.

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