TOOL DEVELOPMENT FOR AIRCRAFT LOADS POST-PROCESSING

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Abstract

This paper presents the methods and tools developed for visualization and selection of critical aircraft loads. Since the aircraft structure is designed to endure those critical loads, it is important to understand and select load cases. In order to develop an understanding of those loads; a tool, L-VIS – Loads Visualization Program, is developed for detailed post-processing activities for loads analysis.

1 Introduction

Aircraft structures are designed as lightweight structures while considering external air loads that act on the aircraft during its operational limits. These external forces are;

- Aerodynamic Forces
- Inertial Forces
- Propulsive Forces
- Reaction Forces from Ground
- Cabin Pressure Forces, etc.

Loads analyses involve the evaluation of those forces for flight conditions of the aircraft defined in its flight envelope. As a result, an aircraft has many different combinations consisting of different parameters such as,

- Airspeed
- Mass State
- Altitudes
- Configurations (Flaps, Brakes, External Stores, etc.)
- Thrust Levels
- Maneuver, Gust, Landing Conditions

Those conditions are defined by project requirements and certification regulations. The number of combinations, which is the number of load cases, exceeds hundreds of thousands. However, the number of critical load cases to be used in structural analyses must be a reasonable number in an order of tens or hundreds. The evaluation of those critical cases requires database handling and an understanding of aircraft loads.

Therefore, a capable load visualization tool named L-VIS, Load Visualization Program was developed. Tool can plot loads envelopes, select critical cases in margins, separate and show different maneuver types on the envelopes. Also application of reserve factor contours is implemented.

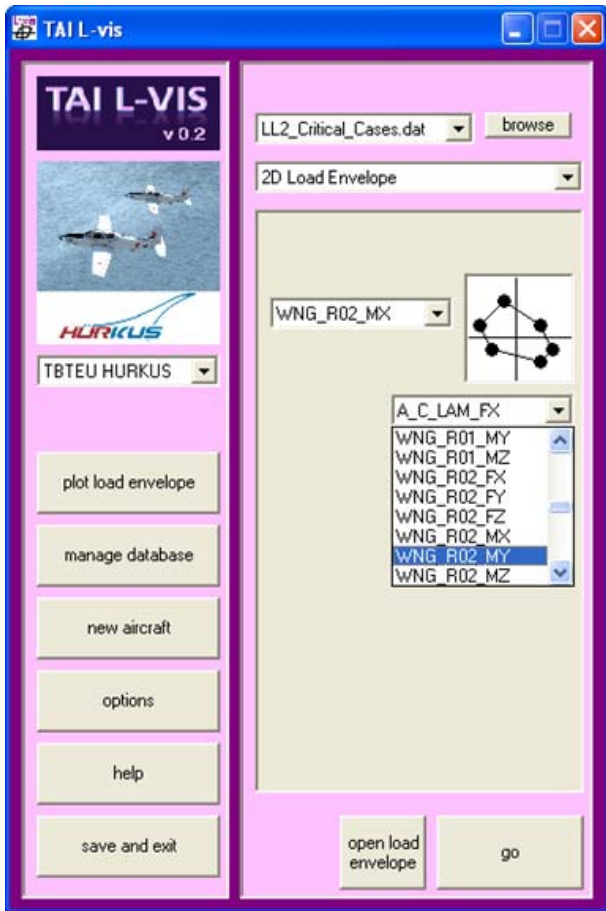L-VIS is an in-house developed tool with graphical user interface for ease of use (Fig. 1).

Fig. 1. L-VIS Graphical Interface

Fig. 2. A typical 1-D Loads Envelope Generated by L-VIS

2 Aircraft Loads and Flight Parameters Envelopes

In order to visualize the aircraft loads and evaluate the critical load cases, load envelopes are used. These load envelopes are classified as 1-D and 2-D envelopes.

2.1 1-D Load Envelopes

The 1-D loads envelopes shows the distribution of forces and moments along a component, such as wing, fuselage or tail. An example to a 1-D load envelope generated by L-VIS can be seen in Fig. 2. Those load envelopes are used for monitoring and selection of critical load cases [1], [2].
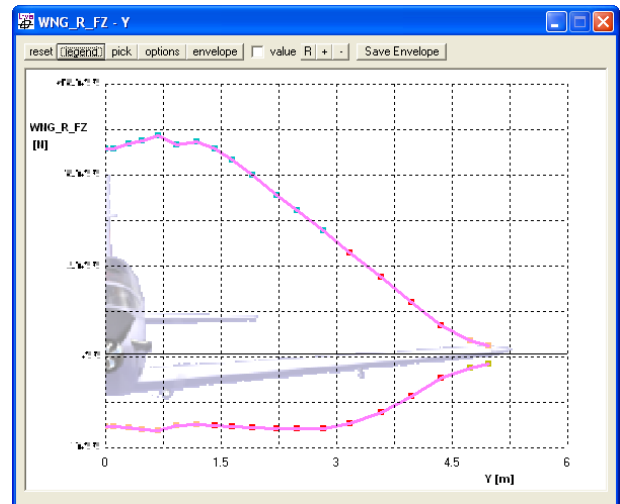
2.2 2-D Load Envelopes

Instead of plotting a loads parameter along the aircraft component, 2-D loads envelopes plots two loads parameters at a given monitor station on the aircraft. A typical 2-D loads envelope can be seen in Fig. 3.
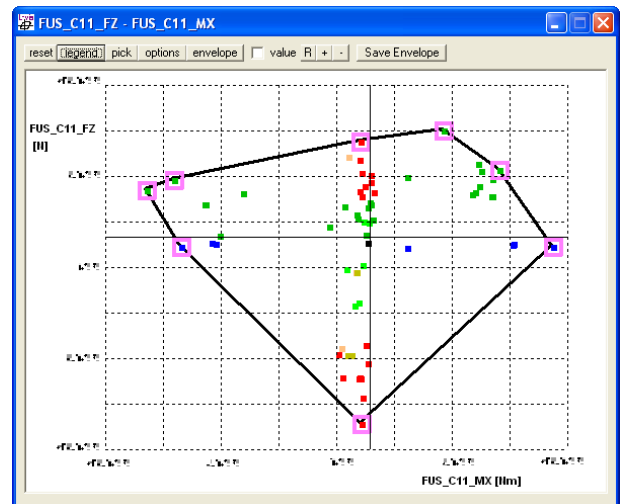

Fig. 3. A Typical 2-D Loads Envelope Generated by L-VIS

Each point in the envelope represents a load case. The 2-D loads envelopes also help engineers to monitor the loads and decide the critical cases. [3]. L-VIS can work with unlimited number of interactive load envelope windows. Those windows work synchronously with to illustrate the selected load cases in different load envelopes. Working with multiple

load envelopes with real time updating gives better understanding of loads at different sections and components (Fig. 4).
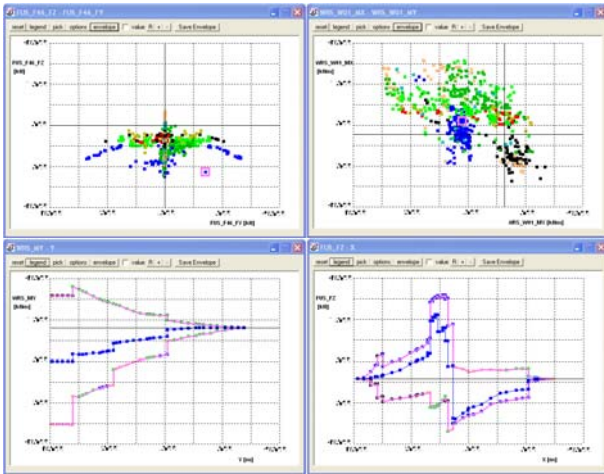

Fig. 4. Selected Load Case Highlighted in Multiple Loads Envelopes

2.3 Flight Parameter Envelopes

Not only the load parameters such as forces and moments, but also the flight parameters can be plotted in 2-D envelopes. These envelopes are called flight parameter envelopes. Those envelopes are used to monitor the critical loads for setting the maneuver limits. This approach helps to alleviate the maneuver loads by providing data for flight control system (FCS) design [4], [5]. L-VIS includes the corresponding flight parameters of load cases in its database and it plots the flight parameter envelopes at different monitor stations, similar to 2-D envelopes. Flight parameters include angle of attack, angular rates and accelerations, load factors, altitude, airspeed, mass state data of load cases are also included in L-VIS database. As an example flight parameter plot; altitude – velocity plot generated by L-VIS is shown in Fig. 5.
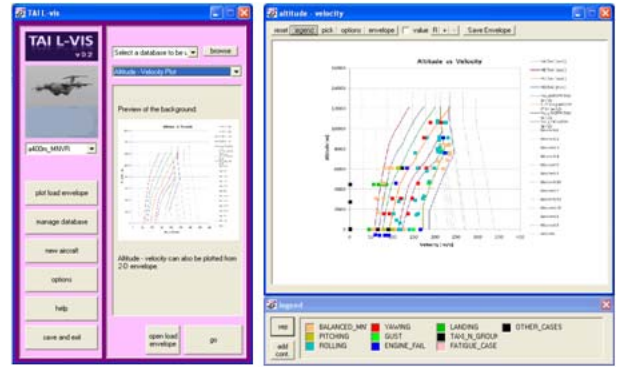

Fig. 5. Altitude - Velocity Plot with L-VIS

3 Flight and Ground Conditions

In is important to understand which flight and ground conditions are critical for which part of the aircraft [1], [6]. Therefore the flight and ground conditions are plotted in load envelopes with different colors to differentiate and understand the effects of different conditions on aircraft loads. (Fig. 6)
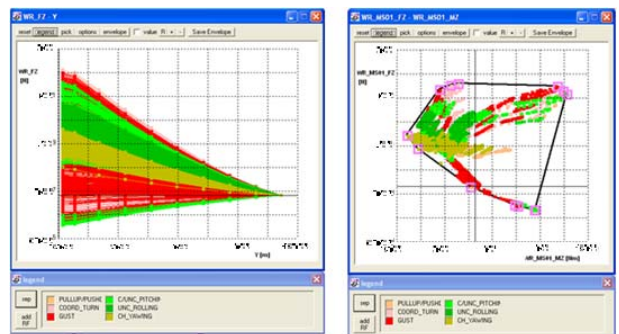

Fig. 6. Load Cases Sorted by Maneuvers on Load Envelopes

Moreover, the classification of load cases is not possible by not only their flight and ground condition, but also by their mass states, altitudes, airspeeds, etc. to further understand the effects of those combinations on aircraft loads. Thus, in L-VIS, every detail of the load cases are loaded in envelopes and can easily be accessed for a point of interest. Example details for a load case can be seen in Fig. 7.
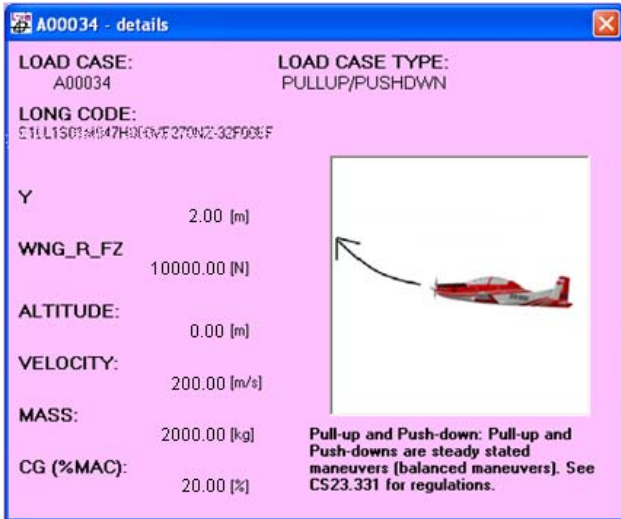
Fig. 7. Load Case Detail Window

4 Dynamic Cases

For large aircraft, gust and landing conditions are required to be analyzed with dynamic analyses according to certification requirements [7], [8]. Mentioned analyses are generally performed by finite element analysis (FEA) software such as NASTRAN. The results are formatted output files with time domain solutions.

To include the dynamic gust and landing conditions in overall design cycle, load cases are generated from those dynamic analyses. The generation of load cases from the dynamic analysis results is performed by considering each incremental time step of each condition as separate load case, which amounts a large number of cases. L-VIS makes it possible to post-process the results of those dynamic analyses to visualize the generated dynamic load cases and select the critical dynamic load cases (Fig 8).
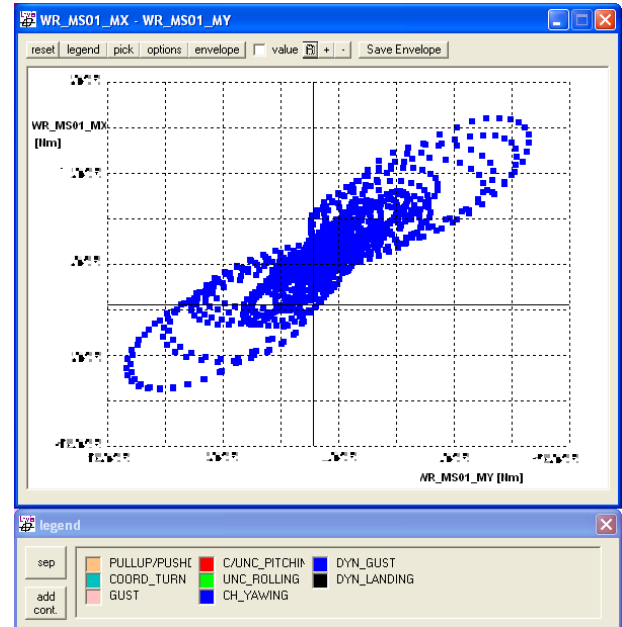

Fig. 8. Load Cases from Dynamic Gust Analysis

5 Critical Load Case Selection

As stated in above chapters, the total number of load cases to be submitted to structural analysis must be reduced from hundreds of thousands to a reasonable number. Those load cases are critical load cases which determine the sizing criteria for aircraft structures. L-VIS enables the automatic load case selection from both 1-D and 2-D envelopes. It does not only select the load cases from the boundaries of the envelope, but also the cases can be selected from a specified percent of margin from the envelope (Fig. 9).
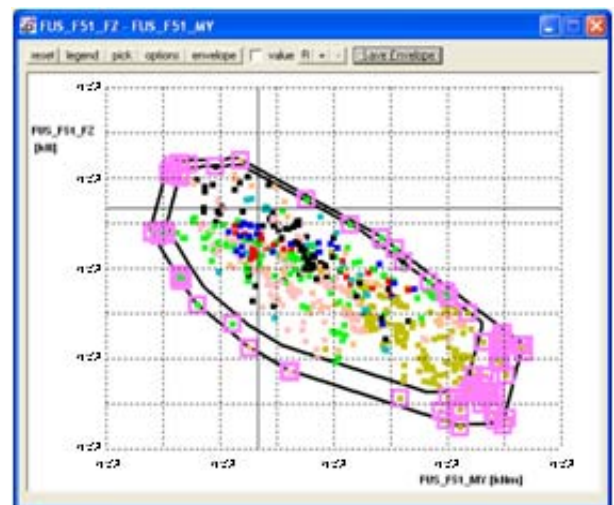

Fig. 9. Critical Load Case Selection within a Margin

6 Application of Reserve Factor Contour

The reliability of critical load case selection criteria is critical to take all possible loads into account. A unique capability of L-VIS is using the results of structural analyses to apply reserve factor (RF) contours on load envelopes. (Fig. 10)

After the selected load cases are submitted to structural analysis and the reserve factors at different locations are evaluated, those RF values are supplied to L-VIS to apply RF contour on the envelopes. The most critical load cases can be expected to be the cases with lowest reserve factor. This feature provides valuable information for studies of load selection criteria.
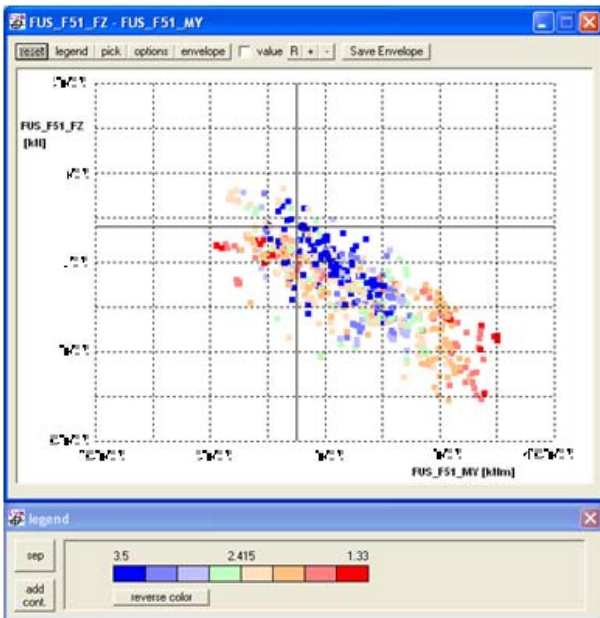

Fig. 10. Reserve Factor Contour on Load Envelope

7 Additional Post-Processing Features of L-VIS

In addition to previous studies, L-VIS can visualize more than one envelope in same plot. Therefore it becomes possible to compare the load envelopes from either different load loops, or different locations, or different databases. (Fig. 11)

Also, L-VIS generates clearly formatted database and envelope files in ASCII format. This enables to use the data from L-VIS with other software for visualization or analysis.
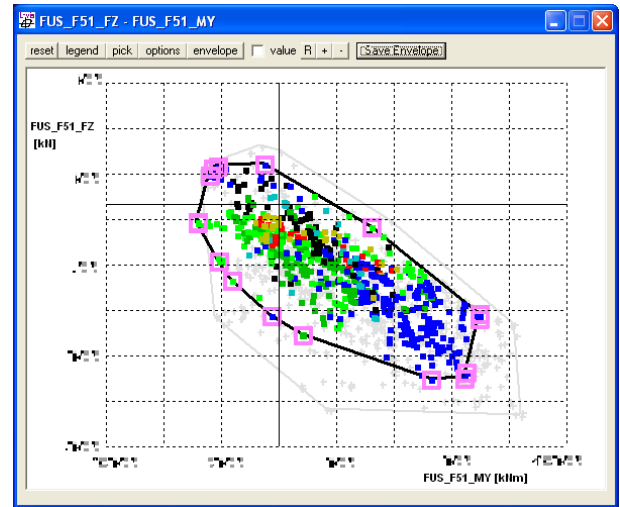

Fig. 11. Comparison of Two Load Envelopes

8 Future Work

As the updating, maintenance and debugging of L-VIS are still ongoing; changes and updates shall be done upon user feedback and request. L-VIS was designed to deal with hundreds of thousands number of load cases, as a result, as the number of load cases increases, the performance decreases. Hence some performance optimization will be performed.

As the next step of this activity, by the support of this tool, it is planned to obtain the relation between the margin of safety of each section and the flight parameters for the typical freight/passenger/training A/Cs. Based on this outcome, the simplest way of airframe optimization can be obtained without performing the sectional analysis for each load conditions. A few flight parameters could be sufficient for the optimum airframe sizing. .In addition to optimization scope; it could also be possible to determine the inspection areas in the case of any load exceedances during the flight easily.

9 Conclusion

Since its development, L-VIS has been used in various projects in Turkish Aerospace Industry, Inc. L-VIS made the results of load analyses accessible and enabled monitoring the aircraft loads with detail by all related engineers. L-VIS

provides up to date loads information with all load case details.

With L-VIS, the selection of critical load cases became more controllable, accurate and faster. The advanced features, such as reserve factor contouring, helped the engineers make sure that the load selection criteria are reasonable. Also other features such as envelope comparison helped engineers to comment on the changes in aircraft loads.

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