Derivation of conservative load spectrum for fatigue proof test of UAV structure

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Abstract:

Widely use of unmanned vehicles makes important the problem of possible safety infringement caused by failures of the UAV systems. As in case of all aviation - one of the most important problems is strength and fatigue safety of the aircraft structure. Therefore structure of heavier UAV classes should be investigated for proving their resistance to operational loads. **The aim of this paper is to present the method of load spectrum (LS) elaboration based on the data written in an UAV-autopilot logs, which can be used in fatigue proof tests. Such a LS should be more conservative then the LS observed during flying session (i.e. has to produce higher fatigue effect).** In this paper the attention is focused on photogrammetry mission of PW-ZOOM. It is the UAV constructed in Warsaw University of Technology on the needs of Polish-Norwegian grant 197810 (acronym MONICA). The PW-ZOOM was used in 3 Antarctic expeditions (2014, 2015 & 2016) flying the total distance of 3641km and spending in the air 35.6 hours over King George Island (KGI). In addition to several thousands of aerial photos, which were used for orthophotomaps creation - also a collection of autopilot logs has been accumulated. For the analysis presented in this paper were chosen 23 autopilot logs from photogrammetry flights performed during mentioned expeditions.

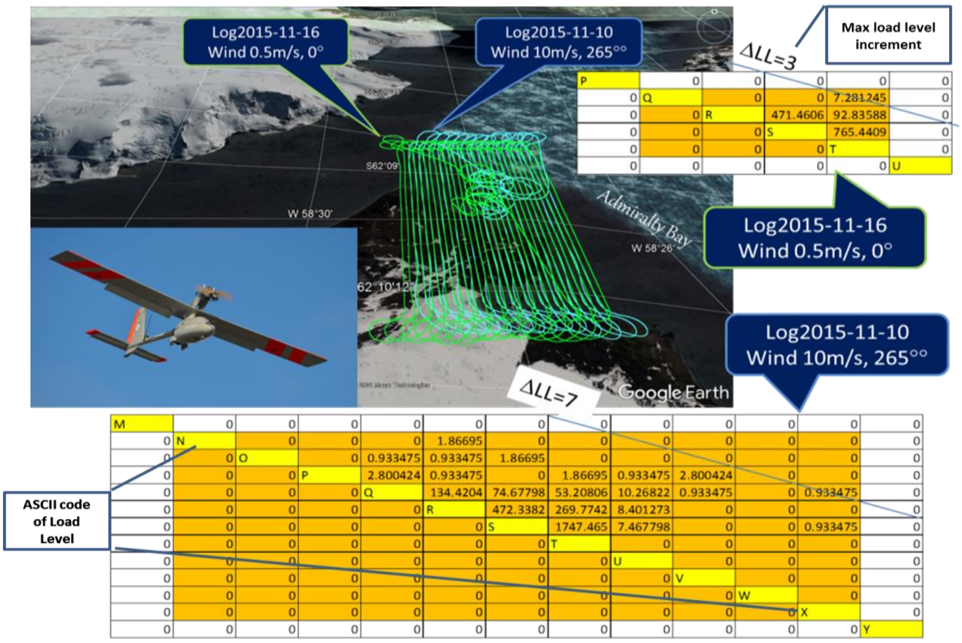

Fig. 1 The PW-ZOOM and examples of load spectra of two flights over the same turn-points in different weather condition (Note: only envelopes of Full Cycle Arrays active zones are shown here)

Basing on acceleration signal written in those logs, the load spectrum was derived for each flight and was written in the form of 32x32 Full-Cycle Array (FCA1), containing in the cell indexed as *i,j* the number of load oscillations between *i* and *j* load levels (LL*)* - related to flight duration (Fig.1). Later several statistical analysis of the cells having the same indexes *i,j* were performed within the set of 23 FCA1s. Especially there was derived an aggregated LS (representing actual load spectrum for all 23 flights), as well as the LS envelope (i.e. the array containing maxima appearing in the set of cells with the same indexes *i,j*). Method of conservative LS developing consists in adding to the actual load spectrum a special, additional FCA1 array. In order to obtain this array, at first was created the array representing differences between LS envelope and the array containing mean values plus standard deviations for all sets of 23 cells having the same indexes *i,j*. Then there was applied a special dispersion algorithm for moving a part of each cell value to adjacent cells representing higher load increments ΔLL. A new LS obtained in such manner contains more load cycles located in the cells representing higher load increments, while the total number of load cycles is only slightly higher than in the actual load spectrum. This results in a lower value of estimated fatigue life and gives the safety margin when operational period for the UAV structure is evaluated. Such safety margin is necessary especially due to noise of acceleration signal, which influences qualification of observed value to proper LL. The effect of described above procedure is presented in form of incremental load spectra (Fig. 2a). Number of % concerns different variants of dispersion algorithm regarding its effectiveness.

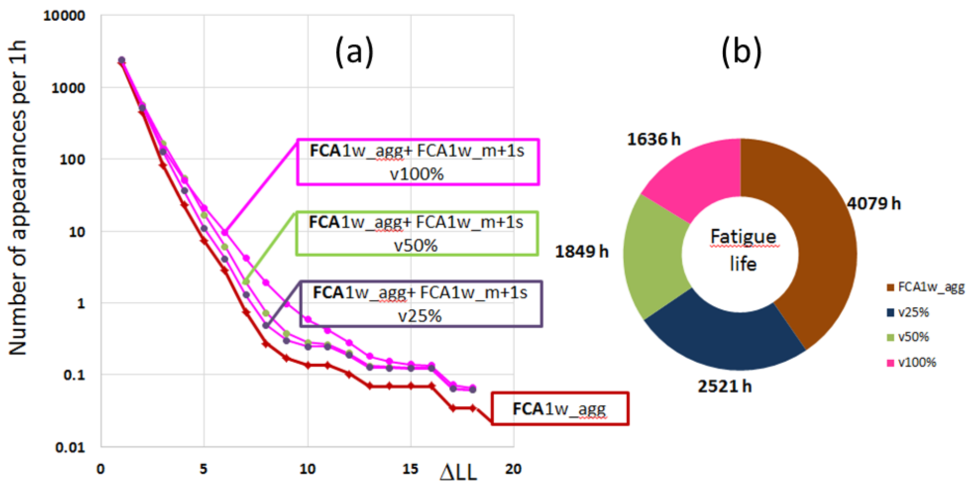

Fig. 2 Comparison of incremental load spectra for the actual LS (i.e.: FCA1w_agg) and for three variants of dispersion algorithm

In order to evaluate how conservative is the LS obtained in the way described above – the fatigue life was calculated. It was assumed that critical element of UAV structure is an aluminum joiner for connecting wings with the fuselage. Taking into account fatigue properties of aluminum alloy, and basing on Palmgren-Miner hypothesis, a fatigue life was calculated for each LS. The results of calculation are shown in graphic and numerical form in Fig.2b.

Conclusion: Depending on the variant of dispersion algorithm, evaluated value of fatigue life drops down from 1.6 up to 2.5 times in comparison with result for the actual LS. Those outcome shows that presented here method allows obtaining conservative LS suitable for fatigue proof test, which gives a greater safety margin in determining the service life of UAV structure. More details one can find in full version of presentation.