Study Of Composite Impact Dent Visual Detectability And Damage Relaxation Phenomena

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The studies focused on visual detectability of surface damage in aircraft composite skins were performed. The goal was to understand how inspection conditions affect the detectability during standard field control procedures in order to establish reasonable barely visible impact damage (BVID) threshold in the frameworks of Irkut MC-21 aircraft certification. The probability of surface damage detection as a function of damage size was evaluated in relation to qualification of experts, paint color, viewing distance and surface contamination. The experiments with 80 dents were carried out; the empirical detectability data was analyzed by methods of mathematical statistics. Using non-parametric tests the statistical significance of mentioned in-service factors was estimated. The bootstrap method was applied to make empirical data more representative. The statistical analysis of obtained experimental data provided possibility to determine which in-service factors are most significant for composite dents visual detectability in relation to local operating conditions.
The expert's qualification didn't have considerable effect on probability of surface dents detection leads to the conclusion that field experience and skills in inspection of metal structures does not guarantee 100% detection of external damage in composite elements. Thus the clear guidelines and training courses should be the important part of composite aircraft damage tolerance certification.
In Table 1 the BVID values determined according to the statistical definition, that "95% of the inspectors should find more than 90% of defects with BVID size or larger" are presented.

Table 1 The BVID size summary

Surface condition	Color	Viewing distance	BVID
Clean	Gray and Red	0.7 m	0.30 mm
		5 m	1.02 mm
	Blue	0.7 m	0.24 mm
		5 m	0.41 mm
Contaminated	Gray and Red	0.7 m	0.91 mm
		5 m	1.71 mm
	Blue	0.7 m	0.59 mm
		5 m	0.88 mm

It was determined that the probability of detection strongly depends on specimen painting color and that composite impact dents are more visible on dark surface providing that the surface is clean. The contamination is extremely significant and has a very complicated effect on detectability: in most cases it masks the dents but in some cases it can highlight them. In terms of statistics this phenomena results in high scatter of empirical data. So it can be recommended for airlines operating composite fleet to paint it dark and keep critical zones of structure clean for visual control.

In the frameworks of composite aircraft damage tolerance considerations it should be taken into account that the search for non-obvious damage in real operating conditions usually takes place not just after the impact event, but at the moment of planned visual inspection. Due to the specific features of aircraft maintenance programs the time between those two events may appear to be considerable. During that time the depth of the dent in composite structure subjected to operational and environmental factors can decrease (relax). To characterize the relaxation behavior of surface dents the experimental study based on the original methodology was performed. The phenomena of relaxation was studied on conventional carbon fiber reinforced panels under normal conditions as well as under elevated temperature dry (ETD) and elevated temperature wet (ETW) environments. The thickness-related difference in relaxation behavior was evaluated, the empirical law of relaxation in time was determined. It was demonstrated that among all the factors potentially reducing the dent depth in composite structure, the critical case is the combination of moisture and elevated temperature which can lead to 2-3 times dent depth reduction, (retaining the size of the internal delamination), during a relatively short period of time,

Fig. 1. In accordance with the developed algorithm of BVID threshold establishment, the BVID value in this case should be also increased by a factor of $K=2..3$.

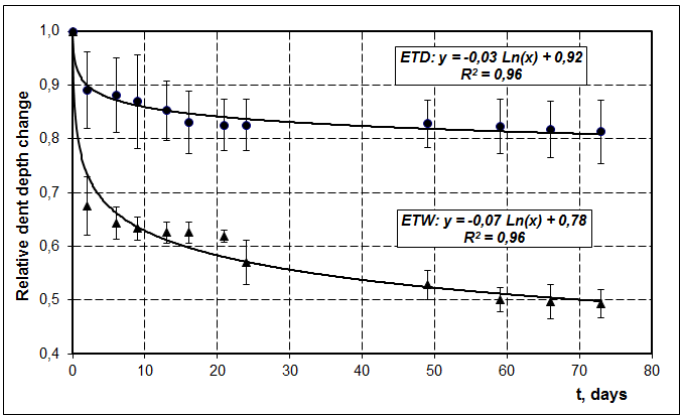

Figure 1. Relaxation under elevated temperature dry (ETD) and elevated temperature wet (ETW) conditions with error bars

The completed research program allowed not only to qualitatively characterize the BVID-affecting factors and dent relaxation behavior, but also to determine the quantitative relationships validated by experiments and continuous long-term observations. The effects of operational conditions and design features were evaluated, the critical cases were determined, the limits of relaxation levels were estimated and correlation dependence between dents of different size relaxing under identical conditions was established.

The obtained results were shown to be consistent with the conclusions of other authors in the applicable range of values and recommended for the Irkut MC-21 aircraft damage tolerance certification.

Keywords:barely visible impact damage, visual inspection, statistical analysis, dent depth, relaxation, temperature, humidity