NON-DESTRUCTIVE TESTING OF BARELY VISIBLE IMPACT DAMAGES OF CFRP

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Carbon fiber reinforced polymers (CFRP) are increasingly applied in different industries. Structural and technological advantages provided by these materials determine their wide usage in newly designed aircrafts: Boeing 787 and Airbus 350XWB have about 50% wt. of composites in the structure. However composites have disadvantages: susceptibility to impact damaging due to viscoelastic deformation behavior. Thus impacts during aircraft operation lead to the formation of large amount of barely visible impact damages (BVID) which can grow over time producing cracked and delaminated defects. Any formed defects should be detected and repaired timely but the areas of CFRP skins are quite large demanding fast and productive non-destructive testing (NDT) to reduce maintenance time.

Traditional ultrasonic NDT method is applicable to testing of CFRP, but time consuming due to small scanning area. Due to non-contact and full-field application shearing speckle pattern interferometry (or shearography) is a robust NDT method which measures the strain of the testing object directly. Analysis of the strain fields and searching for non-homogeneities allow revealing damages and flaws in different structures. Finally shearography provide not only qualitative investigations (to identify and evaluate the defect) but also quantitative: measuring in-plane and out-of-plain strains with high accuracy.

The paper deals with application of newly designed shearography device and developed software for digital processing of the shearograms. Based on the previous studies the robust algorithm for digital processing of speckle images was established. It is based on the sin/cos filtering with iterative approach providing smooth high contrast phase map without any disturbances and loss of phase information. The software for image capturing and processing procedures was developed. The device utilizes 5 Mpx CCD image sensor and five step phase shifting technique using piezodriven mirror in order to retrieve relative phase change. The lasers used are four DPSS 50 mW modules.

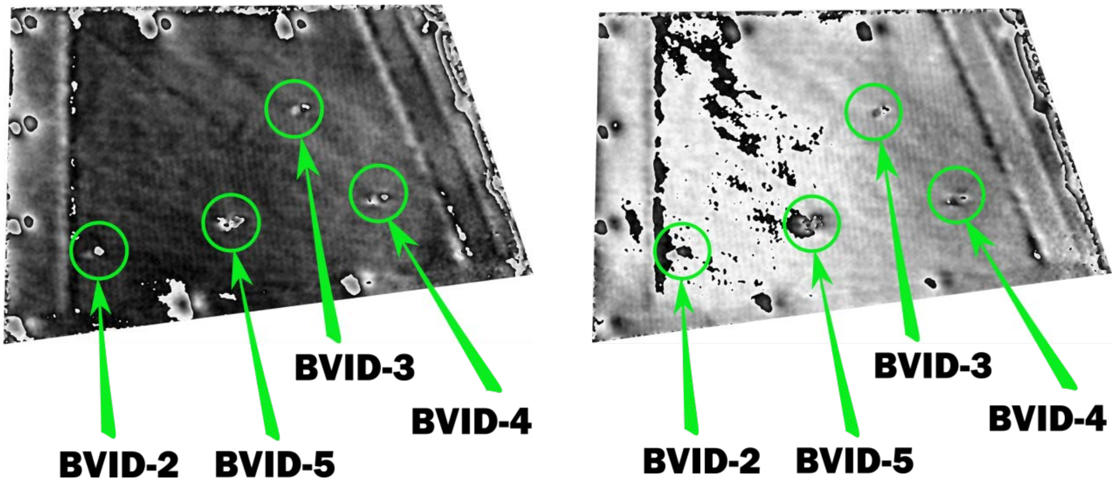
The objects were stressed using thermal method by means of cooling in a refrigerator or heating with IR device. In order to reveal barely visible impact damages the shearography was operated in the out-of-plane sensitivity mode: the object to be tested was illuminated and imaged normally to the surface. Thus the out-of-plane strains $\partial w/\partial x$ and $\partial w/\partial y$ depending on the shearing direction (x or y) were measured.

Table 1 - List of impact damages

Test number	Impact energy, J	Coordinates of impact	
		X, mm	Y, mm
BVID-1	1	132	62
BVID-2	2	65	202
BVID-3	3	251	74
BVID-4	4	321	153
BVID-5	5	187	177

Experimental testing was carried out on honeycomb panel (part of Sukhoi Superjet 100 rudder) with CFRP skins (lay-up of $[(0,45,-45)_2,0]$). The testing procedure consists in detection of BVIDs of honeycomb panel obtained using drop-weight technique according to the ASTM D7136 (Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event). There were 5 impacts with a step of

1 J (Table 1). After each impact procedure the NDT testing was performed: the proposed device was applied along with thermal loading to visualize the defects.



a) b)

Figure 1 - Phase map for the test BVID-5. Stressing method: a) cooling; b) IR heating

Figure 1 demonstrates the phase maps obtained after the last 5 Joule impact damaging of the honeycomb panel. Thus there are all 5 impact defects presented in the CFRP panel. Both types of stressing allow revealing the damages but cooling provides more stable results: the phase map is uniform with disturbances corresponding only to piezotransducers (bonded to the surface and utilized in another experiment) and barely visible impact damages.

After the extensive analysis of all results it was found that obtained shearograms easily revealed the BVIDs as non-uniformities in the strain fields except BVID-1 (the impact doesn't produce any significant damage). The honeycomb specimens show the regular texture associated to the honeycomb core while stacking of plies in the laminate is easily seen in the shape of straight lines coincidental to the direction of reinforcement. The results are analyzed and discussed in view of sensitivity of shearography to BVID and delamination.

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