Fatigue Life Prediction of CFRP Laminate under Quasi-Random Loading

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Introduction

It is well known that the possibility of control the physical and mechanical characteristics of layered composites, including their fatigue resistance characteristics, is of paramount significance. However, reliable prediction methods for evaluating these characteristics are absent up to now, which is a serious obstacle to the implementation of layered composites in the manufacture of structural elements, in particular, in the manufacture of various elements of aircraft composite structures.
A distinct problem is the lack of reliable calculation methods for fatigue life prediction of layered composites under complex fatigue loading spectra simulating a realistic flight loading of structural members of present-day aircraft. This type of programmed loading is represented, for example, by the well-known standardized quasi-random "TWIST" (Transport WIng Standard Test) program [1], which imitates the flight loading of the transport aircraft wing.
The results of fatigue test of CFRP T300/5208 $[45/0/-45/90]_{2s}$ specimens with open holes under uniaxial loading of quasi-random "TWIST" program with different levels of truncation of large and small loads are presented in [2] and are considered in this paper. The results of fatigue life predictions of the specimens under consideration performed by the author of the paper [2] using the Palmgren-Miner rule are also given there. The results of the predictions are compared with the experimental data. It was noted in [2] that the fatigue life predictions made using the Palmgren-Miner rule showed an unacceptable accuracy of the results.
In order to increase the accuracy of such predictions, two new prediction methods formed by using two different non-liner fatigue damage accumulation models are proposed. Results of fatigue life predictions for considered specimens with use of new methods are presented.

Results of Fatigue Tests

Frequency of occurrence of flight types and load cycles within each flight of "TWIST" program are given in Table 1.

Table 1. Frequency of occurrence of flight types and load cycles within each flight of "TWIST" program

Flight Type	Frequency in One Block of 4000 Flts	Frequency of Occurrence of Flight Cycles at the Ten Load Levels									
		I 1.60[a]	II 1.50	III 1.30	IV 1.15	V 0.995	VI 0.84	VII 0.685	VIII 0.53	IX 0.375	X 0.222
A	1	1	1	1	4	8	18	64	112	391	900
B	1		1	1	2	5	11	39	76	366	899
C	3			1	1	2	7	22	61	277	879
D	9				1	1	2	14	44	208	680
E	24					1	1	6	24	165	603
F	60						1	3	19	115	512
G	181							1	7	70	412
H	420								1	16	233
I	1090									1	69
J	2211										25
Total number of load cycles per block		0	0	5	18	52	152	800	4170	34800	358665
Total number of load cycles per block		0	0	5	23	75	227	1037	5197	39997	398662

[a] Ratio of alternating load to the flight mean load.

The average values of fatigue lives ($N_{test\ median}$) obtained in fatigue test of considered specimens by using baseline spectrum "TWIST" and truncated spectra are given in Table 2 [2].
Flight mean gross-section stress $\sigma_m = -111$ MPa for baseline spectrum and truncated spectra.

Table 2. Results of the spectrum loading fatigue tests using baseline and truncated spectra

Spectrum Truncations	$N_{test\ median}$, flights
None (baseline spectrum)	88655
Load level # X omitted	75955
Load levels # X-IX omitted	106555
Load levels # VII-X omitted	111555
Load levels # I-II omitted	189962
Load levels # I-IV; X omitted	759374

Fatigue Life Prediction Methods
For the purpose of the fatigue life prediction of the considered specimens the fatigue life prediction method #1 was used [2]. As a model of the damage accumulation for this method the well-known Palmgren-Miner rule was applied.
A new fatigue life prediction method #2 was used too. As a model of the damage accumulation for this method the Owen and Howe model was applied.
A new fatigue life prediction method #3 was used too. As a model of the damage accumulation for this method the special fatigue damage accumulation model was applied.
Fig. 1 shows a comparison of the obtained values of fatigue lives predictions and experimental data.

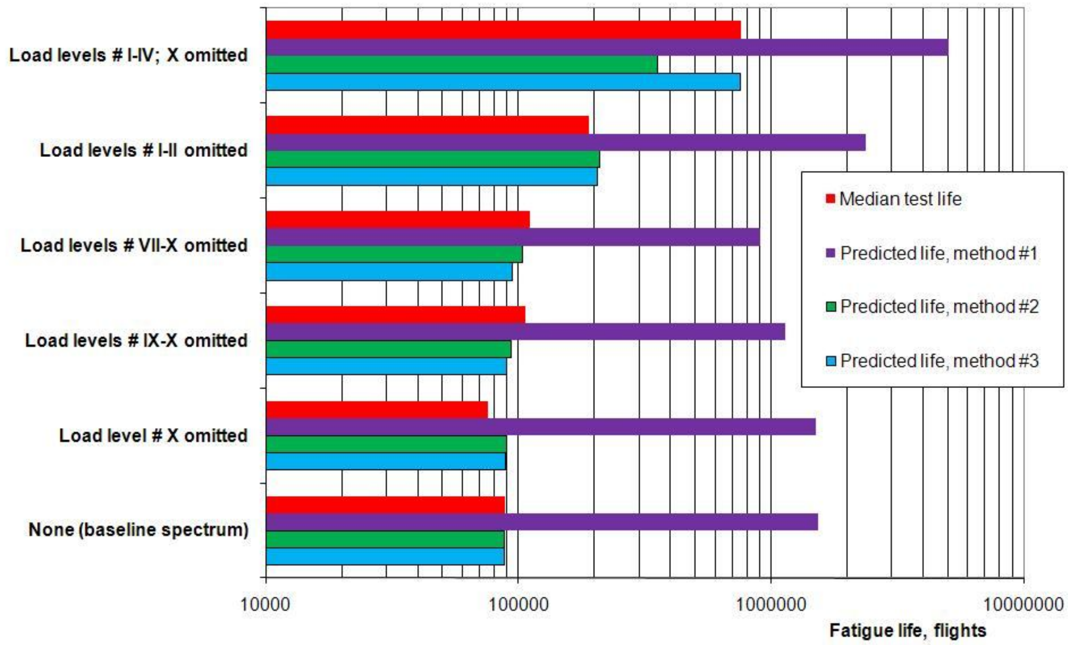

Figure 1. A comparison of the obtained values of fatigue lives predictions and experimental data

Keywords: fatigue life predictions, CFRP laminate,sSpecimens with open holes,quasi-random loading

References

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