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Effect of fatigue loading on impact damage and buckling/post-buckling behaviors of stiffened composite panels under axial compression

Yu Feng[a*], Yuting He[a], Haoyu Zhang[a], Xiangfei Tan[a], Tao An[a], Jie Zheng[b]

[a] Aeronautics and Astronautics Engineering College, Air Force Engineering University, Xi′an,710038, China

[b] The First Aircraft Institute, Aviation Industry Corporation, Xi′an,710089, China

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ABSTRACT

Effect of fatigue loading on impact damage and buckling/post-buckling behaviors of stiffened composite panels under axial compression were studied in this paper. Barely visible impact damage (BVID) was introduced to stiffened composite panels. Damage areas and crater depths data were analyzed and their distributions were determined, whose upper limits were also calculated under different reliability. Then fatigue experiments were conducted on impact specimens. Damage areas, damage site shapes and crater depths were measured at every certain fatigue cycles. Compression after impact (CAI) as well as compression after impact and fatigue (CAIF) were also studied, with a comparison of virgin specimens. The results exhibited impact damage and the following fatigue loading had no obvious influence on the bucking load and buckling modes. Additionally, failure modes of all types of specimens were similar, which included debonding and fracture of stiffeners together with splitting and cracking of skin bays. However, the average failure load of impact specimens decreased 9.9% compared to that of virgin specimens. Fatigue loading would lead a further decrease about 6.1% in failure load compared to impact specimens, although the impact damage had no obvious changes during and after fatigue loading.

1 Introduction

Composite materials, especially carbon fiber reinforced polymer, are widely used in aeronautic industry because they show higher strength/weight, stiffness/weight ratios, and good corrosion/fatigue resistance, which can lead the aircraft lighter and better performances[1-4]. Thus composite materials become more and more popular and tend to be an excellent replacement for traditional metallic materials[5,6]. Particularly, composite structures, composite stiffened panels, are widely applied in many parts of both civil and military airplane, such as fuselages, vertical/horizontal tails, wings and so on, because this type of composite structure not only has the advantages of composite materials but also shows the outstanding properties of thin-walled structure[1,7]. During the service life axial compression is one of the most common load cases for the stiffened composite panels of airplane. It is well known that under compression this type of structure can bear more loads instead of collapse when the buckling occurs in panels or stiffeners, which is called post-buckling carrying ability[8]. For example, the failure load or ultimate collapse load of some stiffened composite panels were 4 times larger than the buckling load or even more[9]. So buckling and post-buckling performances are interesting for many researchers and the issues have been studied by many researchers[10-14] and some famous project such as COCOMAT (Improved Material Exploitation at Safe Design of Composite Airframe Structures by Accurate Simulation of Collapse)[15] and POSICOSS (Improved Post-buckling Simulation for Design of Fiber Composite stiffened Fuselage Structures)[16]. Mo[17] studied the buckling load and failure load of stiffened curve composite panels with hat stringers under axial compression. Several influence factors, such as skin thickness, panel radius and distance between two adjacent stringers were investigated. Riccio [18] proposed a novel numerical methodology to study the compressive performances of stiffened composite panel with pre-debonding. The novel methodology was implemented in finite element platform and verified by the test of single stiffener composite panels. Excellent agreement with experimental data was obtained using the proposed methodology. Raimondo[19] studied the inter-laminar and intra-laminar damage of stiffened composite panels numerically. A model considering both inter-laminar and intra-laminar damage was built, which could overcome mesh and time step sensitivity problems. The model could predict the experiment data more accurate than the model only considering