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Wheels Up Landing Certification By Analysis of Regional Jet Aircraft

Qi Li, Xiaodong Zhu, Guangrong Zhu, Yong Chen
COMAC (Commercial Aircraft Corporation of China)
Shanghai, China

Frank Abdi , Harsh Baid, Jerry Housner
AlphaSTAR Corporation, Long Beach, California 90804

ABSTRACT

In this paper a building block certification strategy is implemented for Regional Jet for Wheels-Up Landing drop test condition compliance with FAR/CCAR 25.994. Multi-scale progressive Failure Dynamic Analysis (MS-PFDA) is implemented on large scale structural models prepared to predict significant deformations, damage and fracture evolution subject to wheels up landing (WUL) scenario. MS-PFDA was validated for B737 drop test scenario with fuel, and luggage. A building block MS-PFDA simulation validation strategy compared FAA conducted B737 fuselage drop tests for the final shape change, acceleration of floor panel, and velocity versus time for two test conditions: a) With fuel tank deformation; and b) With luggage only deformation. Next ARJ21 fuselage and APU fuel lines including a global FEM of the aircraft and local FEM models of fuel line joints were simulated for wheels up landing on a paved runway to determine possibility of fuel leakage. A sink rate of 5ft/sec based on minimum FAA WUL requirement and 17 ft/sec based on FAA reference documents where FAA performed wheels up landing of a B720 at 17ft/sec was selected for the wheels up landing simulations. Simulation results at 5 ft/sec and six degree pitch angle concluded that: (1) The fairing stays intact; (2) Maximum plastic strain in the fuel line is below the failure strain limits and the fuel tank remains intact; (3) Flex Joints reaches axial, and rotation limits, without major deformation and load bearing capability of flex joints are based on Local Flex Joint FEA results; and (4) The work focused on passenger safety by meeting requirements for floor panel acceleration shock wave duration & distribution due to fuel line leakage. Designated Engineering Representatives (DER) verified no leakage based on local flex joint FE model, and CAAC accepted Type certification by analysis supported by Test.

Keywords: **1**) Aircraft certification, 3) CAAC **2**) fuel line safety, **3**) emergency wheels up landing, **4**) global detail FE model, **5**) Local fuel line Flex Joint detail model, advance composite structures, **6**) modeling validation, **7**) Certification by analysis supported by Test, **8**) Drop Test

INTRODUCTION

This effort focuses on passenger safety due to fuel line leakage and FAA rules and regulations in addressing FAR/CCAR 25.994 with application to ARJ 21 Regional Jet. A Guillotine test was conducted in 1967 on Boeing 727and continues to be utilized to address many recurring issues observed since then in various aircrafts. It is determined that FAA accepts either actual drop tests or accurate analysis (~ 30% of test) supported by test evidence. Under this effort a detail global full scale model of the ARJ21 aircraft fuselage structure including floor panels, windows, ribs, stiffeners, bulkhead, kill beam, connections, etc were developed. In addition a detail FE local fuel line flexible joint models were generated and verified with hand calculations for both 2D and 3D models.

The certification process includes: **1**) ***Model Verification*** – to meet FAR/CCAR 25.305, FAR/CCAR 25.307 and recent dynamic and filtering requirements using: (**a**) Analytically generated closed form solutions for flex joint; (**b**) Validated Global FE model against static and ground vibration test; **2**) ***Test Validation*** ground vibration test; and **3**)***FAA DER Review & Recommendation***: In performing the simulation, the FAA DER recommends that no fuel leakage at fuel line joints will occur even if their deflection and strength limits are exceeded provided the shroud does not fail. Failure of the shroud includes failure of the outer joint O-Rings which can occur if the O-Rings become deformed or lose their proper "squeeze" and seal. Moreover, the shroud "witness drains" must not be near any hot sources per FAA AC25.994-1.

Certification by Analysis was successfully achieved to meet FAR 25.994 under a controlled wheels-Up landing scenario. The requirements were met in scenarios where there is no evidence of fuel leakage eliminating the risk for fire during a compromised landing scenario. Further Recommendations by DER were followed by WUL team to establish confidence and to justify Certification by Analysis supported with test .

Further Recommendations:(a) More building block validation; (b) Further Prediction Validation and use published of FAA Boeing 737 drop test data and compare with the analysis; (c) Establish ARJ 21 sink speed calculation as to how the plane breaks (simulation determined maximum sink speed of 35 ft/sec); (d) Model Accreditation: Detail global FE model is accurate to be used for risk mitigation under various scenarios of emergency (such as water ditching, passenger safety evaluation).

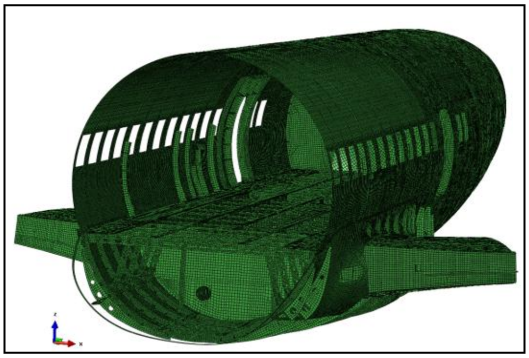
RESULTS

A finite element based detailed model of ARJ21-700 regional jet commercial aircraft was generated and analyzed to determine fuselage body/fuel line deformation and possible damage as a result of wheels-up landing scenario (**Figure 1**).

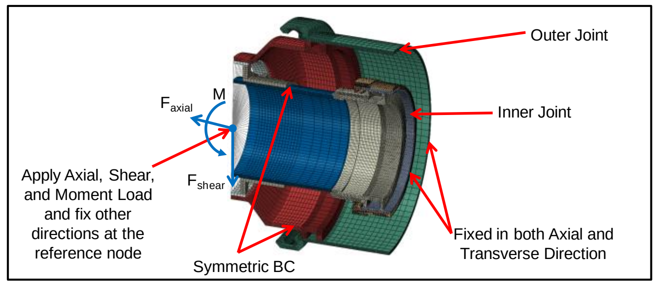
Local FE Flex joint Model: Under direction of WUL project lead, a detailed FE (Nonlinear) model of three different types of Flex Joint was analyzed to understand the failure process and to calculate the capabilities of all the flex joints under combined loading (axial, shear and moment). Apart from the FE model, analytical linear hand calculations were also carried out to calculate the axial, shear and moment capabilities of one of the flex joints. The stiffness of the flex joint was also established based on the FE analysis to be used in the global model.

Key Findings:

a) Global FE Model Analysis up to 150 ms shock wave duration can further damage floor panel, and fuel line.
b) Average fuel line vertical velocity is approaching zero indicates no need to investigate beyond 150 ms
c) Ground reaction force reached its maximum around 70 ms indicates simulation is carried out way beyond maximum damage occurrence
d) APU Fuel line reaches failure strain above FAA requirements
e) Flex Joints reaches axial, and rotation limits
f) DER recommendation verified no leak based on local flex joint FE model



a) Detailed FE Global model



b) Boundary conditions applied on Engine Line Flex Joint 3-D FE model for combined load condition.

Figure 1. A finite element based detailed model of ARJ21-700 regional jet commercial aircraft