Certification Techniques for the Deformation Compliance of Civil Aviation Passenger Seat

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Abstract. The deformation requirements for passenger seats of civil aviation are complicated. The author provides the experience of real civil aviation programs for seat deformations' certification, including the significance of seat deformations' airworthiness compliance, relevant regulations and tests and the measuring requirements for passenger seat deformations. FAR25 and CCAR25 both require that the passenger seats shall not yield to the extent they would impede rapid evacuation of the airplane occupants, but the relevant factors are not defined clearly. Seat deformations are the key factors that would impede occupants’ rapid evacuation. This article discussed the related requirement and the right way to measure and analyze seat deformations.

1. Introduction
Emergency Evacuation Demonstration Test is a vitally important test for civil transport aircraft, as a practicable way to show the compliance with FAR/CS/CCAR25.803. But the most easily neglected factor is the deformations of PASSENGER SEAT. According to AC25-17A[1], the passenger seats used in Emergency Evacuation Demo Test are assumed that they have no deformations. This strategy provides convenience for Emergency Evacuation Demo Test, but set a high requirement for seat deformations.

If we make a deep research into FAR/CS/CCAR25.561 and 562 regulations[2], it will be found that these two regulations both only required “the passenger seats shall not yield to the extend they would impede rapid evacuation of the airplane occupants”, but what deformations, which would impact occupations’ evacuation, are not defined clearly in regulations.

The truth is the requirements for passenger seat deformations are so highly hidden that it’s easy to overlook them before making preparations for Emergency Evacuation Demonstration Test.

Which deformations need concerning and where to collect these deformations, what kind of deformations are acceptable and what aisle width should be used in Emergency Evacuation Demonstration Test will be discussed in this article.

2. Tests Required by Regulation
According to TSO-C127b, a passenger seat has to pass Dynamic Test and Static Test[3]. FAR/CS/CCAR 25.561, 562 and 785 have the similar requirement. The difference is that TSO-C127b’s concerning is only the performance of seat itself, but FAR/CS/CCAR concern the interface strength between the seat and the track as well.

Dynamic Test includes 16g Dynamic test, 14g Dynamic test, Head-path test, Front-row HIC test and Row-to-row HIC test.
Passenger Seat is a TSO part. Its certification can be divided to TSO approval and Installation approval. To reduce cost, it’s suggested to combine these two certificate activities.

For 16g Dynamic test, the real aircraft seat track shall be used. Otherwise, a supplemental dynamic test or static test shall be carried out to prove the interface strength between seat and seat track is acceptable[4]. To carry out this supplemental test, the 6 loads (3 forces and 3 moments) shall be measured in 16 dynamic test using steel track (or other aircraft track). And then carry out the supplemental dynamic or static test with these loads.

For 14g Dynamic test, the unreal aircraft seat track (like steel track or other aircraft’s track) is acceptable. The 14g load can be decomposed to two component loads: one (component A) is along track and the other one (component B) is perpendicular to track. For component A, it must be smaller than 14g and then also smaller than 16g, which means 16g dynamic test can cover this situation. For component B, it’s a compressing force not drawing force, which means it will not destroy track since there’s structure beams under track.

Head-path test is used to collect the head-path data of passenger seat. This data will be used to analyze head hit area in row-to-row HIC test and front-row setback distance.

Front-row HIC test is usually avoided by using a big front-row setback distance, because bulkhead in aircraft is usually made by honeycomb sandwich panel and will cause HIC value exceed 1000.

Row-to-row HIC test needs to do two tests using min pitch and max pitch. If ATD head only has a glance on the seatback, an additional row-to-row HIC test using a 3 inches smaller pitch than max pitch shall be carried out.

Static test actually includes 5 tests using the loads in different directions: forward, rearward, upward, downward and sideward. The load factors for static tests shall take into account the aircraft Ground/Flight load envelope and the load factors required in FAR/CS/CCAR25.561, even though TSO/ETSO/CTSO-C127 only requires to comply with FAR/CS/CCAR25.561. It’s required to select the max load factor in each direction for static test.

In dynamic test, it’s usually use high-speed photography to measure the deformations. In static test, optical measurement or linear displacement measurement are commonly used.

### 3. Deformations That Needs Considering

FAR25.803[2] requires Emergency Evacuation Demonstration Test. But this regulation doesn’t define the aisle width for the test mentioned above. FAR25.815 defines a min aisle width of 15 inches for civil aircraft[2], although the actual aisle width used in aircraft operation is usually bigger than this requirement and an aisle width of 17 inches or more is common.

In Emergency Evacuation Demonstration Test, it’s not required to use the passenger seat with the deformations caused by dynamic/static tests. But passenger seat deformations have to be in an acceptable range to avoid impacting crew and passengers’ egress (required by FAR25.561(d) and 562(c)(8)[2]).

In principle, passenger seat deformations (forward, downward, upward, sideward and rearward) are measured in 16g dynamic test, 14g dynamic test, row-to-row HIC test and static test, and finally the max deformation in each direction is used as seat deformation.

The extreme sideward deformation usually appears in sideward loaded static test.

The extreme forward deformation usually appears in 16g dynamic test. In this test, a special tooling is used to simulate the aircraft floor with 10 degrees yaw, 10 degrees pitching and 10 degrees rolling. The real aircraft seat track is necessary for this test, otherwise the deformation couldn’t represent the real deformation in the aircraft, because in dynamic test the seat track also has deformations.

The extreme downward deformation usually appears in 14g dynamic test.

The extreme forward deformation of seatback usually appears in row-to-row HIC test. The head of the ATD would hit the seatback of the front-row seat and cause a big deformation of the seatback.

The extreme rearward deformation appears in rearward loaded static test. It has influence on the row-to-row distance after seats deform. But, according to experience, its influence is smaller than forward deformation of the rear row seat, since the rearward inertia factor (commonly less than 2.0g)
is usually much smaller than the forward one (commonly 9.0g). The forward deformation in static test usually is smaller than the one in 16g dynamic test. The max sideward deformation can be obtained in static sideward test. But in some less common cases, the 16g dynamic test also can cause the max sideward deformation.

When a passenger seat type is certificated for installation approval, not every test would be carried out, because many tests can be covered by the tests of TSO prototype seat. TSO prototype seat uses the critical configuration of the seat family. At the aspect of strength of seat, this idea is perfect. But it may not at the aspect of deformation of seat. Usually critical seat configuration generates critical deformations. If every aircraft type’s aisle width and seat pitch had to to keep the margin for the critical deformations of passenger seat, the economical efficiency would be affected negatively. According to engineering experience, it’s suggested to do 16g dynamic test and sideward loaded static test at least, because the forward deformation and the sideward deformation have a great influence on aisle width and passenger seat pitch which have further influence on aircraft economical efficiency and passenger experience.

4. Seat Deformation Requirements
AC25.562-1B defined passenger seat deformations’ acceptable range[5], as shown in Table 1:

| No. | Direction   | Source                        | Requirements                                                                 |
|-----|-------------|-------------------------------|-------------------------------------------------------------------------------|
| 1   | Forward     | AC25.562-1B. appendix 2.a     | a) Minimum clearance between two deformed seats is 6”. See Figure 1. The displacements on Armrest and Bottom Cushion both need concerning.  
    | Rearward    |                               | b) The deformation on seatbacks shall comply with the requirement in Figure 2. |
| 2   | Sideward    | AC25.562-1B. appendix 2.d.(1)  | The deformed seat should not encroach more than 1.5 inches (38 mm) into the required longitudinal aisle space at heights up to 25 inches (635 mm) above the floor. |
|     |             | AC25.562-1B. appendix 2.d.(2)  | The deformed seat should not encroach more than 2.0 inches (50 mm) into the longitudinal aisle space at heights 25 inches (635 mm) or more above the floor. |
| 3   | Downward    | AC25.562-1B. appendix 2.b     | There is no limit on downward permanent deformation, provided that the feet or legs of occupants will not be trapped by the deformation. |
| 4   | Rotation    | AC25.562-1B. appendix 2.c     | a) The seat bottom rotational permanent deformation must not result in an angle that exceeds 20 degrees pitch down or 35 degrees pitch up from the horizontal plane. This rotational deformation is measured between the fore and aft extremities of the seat pan at the centerline of each seat bottom. See Figure 3.  
    |             |                               | b) Rotation of the seat pan must not entrap the occupant. |
| No. | Direction       | Source                                           | Requirements                                                                 |
|-----|-----------------|--------------------------------------------------|------------------------------------------------------------------------------|
| 5   | Additional      | AC25.562-1B, appendix 2.e.(1)                    | Affect the operation of any emergency exit or encroach into an emergency exit opening for a distance from the exit not less than the width of the narrowest passenger seat installed in the airplane. |
|     | requirements    | AC25.562-1B, appendix 2.e.(2)                    | Encroach into any required passageway.                                       |
|     |                 | AC25.562-1B, appendix 2.e.(3)                    | Encroach more than 1.5 inches (38 mm) into any cross-aisle or flight attendant assist space. |

**Figure 1.** Minimum clearance

The deformation for seatback also needs concerning, as following:
C/B shall be not smaller than 50%

**Figure 2.** Deformation requirement for seatback

Pan pitch down: angle not to exceed 20°

**Figure 3.** Rotation requirements
5. Conclusion
This article summarized the deformation requirements for passenger seat in dynamic/static tests and are reference to Emergency Evacuation Demonstration Test, passenger seat upgrading and cabin retrofitting. In aircraft certification, a common mistake is carry out Emergency Evacuation Demonstration Test exactly using the aisle width in cabin LOPA (Layout of Passenger Accommodation). That would cause not enough space left for the deformations of passenger seat. It’s suggested to use an as narrow aisle width in this test as possible to make sure passenger seat upgrading (like promoting seat width) will have enough space. For making a narrow aisle, foam is commonly used to increase the whole width of passenger seats in Emergency Evacuation Demonstration Test. It should be attached to seats’ backrest and armrest to create the aisle width which the Emergency Evacuation Demonstration Test wants to certificate.

References
[1] AC25-17A Transport Airplane Cabin Interiors Crashworthiness handbook, 05/18/2009.
[2] 14 CFR Part 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES (FAR25). 11/18/2003.
[3] TSO-C127b Rotorcraft, Transport Airplane, And Small Airplane Seating Systems, 06/06/2014.
[4] SAE AS8049B Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft, 01/2005.
[5] AC25.562-1B Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes. 01/20/2006.