

JET ENGINE CERTIFICATION STANDARDS

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Abstract

The ability of modern jet engines to ingest birds and continue to operate is largely misunderstood or not contemplated at all in the aviation industry. Currently there is not one jet engine operating in the world that is certified to ingest one large bird (goose, swan, stork, pelican, vulture, etc) and continue to operate. Ingestion of smaller birds is on a sliding scale of small proportion. The effort to harmonize bird ingestion rules between the FAA and JAA has failed. Controversy erupted in recent certification meetings regarding the database being used to certify engines. Additionally, should only rotating engine parts meet certain standards, or all engine parts exposed to impact meet standards? None of the work done by or papers presented to IBSC regarding bird ingestion are used in developing certification standards. Flightcrew members do not know, nor are they required to know, how fragile their engines are. Airport bird control personnel cannot appreciate the importance of their work unless they understand the small number of birds the engines can ingest and continue to operate. The industry needs education on the importance of strike avoidance due to the thin safety margin provided by engine ingestion standards.

Key Words: Engineering: Aircraft system-engines; Engineering: Certification standards; Hazard Management: Bird control team; Hazard Management: Training.

Introduction

Following the introduction of jet aircraft engines after World War II to the industry's civil fleet, both industry and government noted that jet engines were subject to damage and destruction by the ingestion of foreign objects, including birds, termed foreign object damage (FOD). The U.S. Federal Aviation Agency (FAA), under FAR Part 33, has instituted and amended design and construction standards for turbine aircraft engines for the ingestion of FOD. Recent attempts have been made to harmonize these FAA rules with the design and construction standards of the Joint Aviation Authority (JAA). Thus far the rule for FOD, including bird ingestion, has not been harmonized.

Current design standards

Currently turbine engine design and construction standards for foreign object ingestion, including birds, centers on the following requirements:

(A) all engines:

- in no case can the engine catch fire
- in no case can the engine burst (release fragments through the engine case)
- in no case can the engine generate design loads greater than its ultimate design load
- and, in no case can the engine lose the ability to be shut down.

Additionally, the engine must meet certain standards depending on the size of the bird (bird weight) ingested. These bird sizes are divided into 3 categories:

- 3 ounce size (.085 kg)
- 1.5 pound size (.675 kg)
- 4 pound size (1.8 kg)

The standards require a certain number of each sized bird be ingested with the following result after ingestion:

(B) 3 ounce size:

- comply with (A) above
- not more than a 25% loss in power or thrust
- not fail within 5 minutes of ingestion

(C) 1.5 pound size:

- comply with (A) above
- not more than 25% loss in power or thrust
- not fail within 5 minutes of ingestion

(D) 4 pound size:

- comply with (A) above

The number of birds required to be ingested varies with the size (weight) of the birds and the size of the engine inlet. For ease of illustration this paper will address two common sizes of modern aircraft engine: the 60 inch engine and the 100 inch engine. Aircraft in the civil fleet commonly powered by these engines include:

60" engine – B737-300/400/500/700/800;

100" engine – A-330; (B-767, B-747, DC-10 powered by 94" engine)

For the 60" engine, number of birds required to be ingested, by bird size category:

- 3 ounce birds – limited by rule to 16, ingested in rapid order to simulate a flock encounter
- 1.5 pound bird – limited by rule to 8, ingested in rapid order to simulate a flock encounter
- 4 pound bird – one

For the 100" engine, same number of birds ingested as the 60" engine.

The certification standard formula for computing the number of birds ingested varies with the size of the engine inlet and size of the bird, i.e., for 3 oz. birds the formula allows for as many as 56 birds ingested, but the certification standard limits the number to 16 (see FAR 33.77 for explanation of the formula).

Adequacy of standard

Bird size (weight)

The three bird sizes mentioned above try to replicate nature or demonstrate the types of birds a turbine engine may encounter. A 3 ounce bird may be a European Starling or Common Grackle. Starlings are troublesome birds from a collision viewpoint as they tend to flock in large numbers and have a dense body mass. The 1.5 pound bird could be described as a Barred Owl or Red-shouldered Hawk. Both of these animals are solitary and do not flock. The 4 pound bird could describe a Great Black-backed Gull or Snowy Owl. Black-backed gulls flock only in small groups and Snowy Owls are solitary animals.

Missing birds

The bird most often struck by aircraft is a gull of some species. Common species of gull range from 2-3 pounds. Gulls flock in large numbers. The second type of bird most often encountered by aircraft is waterfowl. A

common size for ducks is the same 2-3 pound range. Ducks, especially during migration, flock in large numbers. Neither of these types of birds is considered in the standard.

Heavy Bird

The ingestion standard stops at the 4 pound bird and no bird larger than 4 pounds needs to be demonstrated during engine certification. This leaves out a huge population of large, flocking birds. Geese, swans, pelicans, storks are all flocking birds of large size, large flocks and large populations. The resident Canada goose population in the United States has quadrupled since 1987. The size of the Canada goose varies by species, but generally is considered from 8 pounds on the small end to 15 pounds for the Giant race. In Europe and Africa storks routinely migrate in huge numbers. These animals can weigh as much as 30 pounds. Swans are likewise large flocking birds.

Ingestion numbers

The number of birds an engine must demonstrate it can ingest and comply with the standard is set by the standard at a maximum of 16 for small birds and 8 for mid-size birds, for either the 60" or 100" engine size. Anecdotal information from some significant strikes indicate that an MD-80 at Dallas encountered a large flock of starlings and left 430 dead birds on the runway. An Alaska MD-80 at Portland encountered a similar large flock of starlings and left over 200 dead birds on the runway. At Cincinnati a Delta B-757 had a similar encounter and left over 400 dead birds on the runway. At Daytona Beach a USAir B-737 encountered an unknown species of gull and left over 200 dead birds on the runway. In all of the above incidents all the aircraft had damage to both engines. In two of the incidents an engine failed. In his paper on "Three Dimensional Flock Structure" Budgey describes his predictive model for multiple ingestions and the effect of certain flock sizes on the 100" engine. The 95th percentile multiple ingestion, number of birds ingested, for the flocks modeled were:

Canada goose – 3

Mixed gulls – 4

Starlings – 9.

Growth of wildlife populations

There is no formula in the certification standard to consider an increasing incidence of birdstrikes as aviation continues to expand and wildlife populations explode. In their paper "Birdstrike Statistics as a Design Tool", Martindale and Reed argue that their Monte-Carlo technique indicates that as heavy bird (8 pounds or more) populations increase, the engine failure rate caused by these heavy birds will increase. According to their model the engine failure rate increases, but not at a pro-rata increase with the wildlife population, rather at a lesser rate.

Discussion

It would appear that design standards should be reflective of the type and size of birds actually encountered rather than a theoretical size. While the small bird size (3 oz.) seems to reflect the real threat of starlings, the 1.5 pound size ignores the two species of most struck birds: gulls and ducks. And the heavy bird has no category at all.

The number of birds ingested in each event likewise seems suitable with the small bird, but Budgey's initial work and anecdotal evidence indicates that the mid and large (4 pound) bird is not reflective of modern threat. While the number of birds an engine must demonstrate it can ingest can be argued, the unarguable fact is that wildlife populations are expanding dramatically and conflicting with aviation. There is no means whereby the current certification standards reflect the increasing threat of these increasing populations. The percentage of twin jets in the civil fleet continues to grow at a dramatic rate: in 1998 over 70% of air carrier's fleets were twin jet and by 2008 twin jets will comprise over 90% of carrier fleets. Fewer power plants available on aircraft clearly indicate that the turbine engines in operation must be able to handle the actual threats they will encounter.

Conclusion

- More work needs to be done with modern science such as Budgey's model to clearly identify the threat and the number of birds ingested in a multiple event
- There is no standard for ingestion of even one heavy bird, despite their abundance
- The mid-size bird category is using a size of bird which is not routinely encountered and ignoring data indicating the most struck birds
- Some effort must be made to reflect growing worldwide bird populations

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