App. IV

BIRD IMPACT CAPACITY OF CIVIL AIRCRAFT

INTRODUCTION

Although the birds created by God are much weaker than those manufactured by man, the created birds are nevertheless, at least from a statistical point of view, a much greater hazard to the man made birds, than the man made birds are for their feathered counter-parts. The reason is that the birds in which the ornitologists are interested, even more than Chinese, are found in such great quantities. Therefore the aircraft, being outnumbered, has only a fair change to operate safely, if it is sufficiently bird resistant, or if it can effectively avoid bird encounters.

In the next few minutes we will review the present state of the art in the bird versus aircraft controversy.

THREE APPROACHES

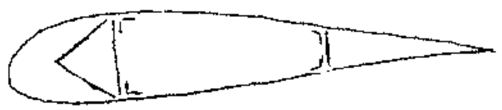
In principle there are three ways to approach the bird problem; to avoid strikes, to protect the aircraft, and thirdly, to increase the inhearent ability of the aircraft to counteract bird strikes. All three methods have their merits and will be reviewed briefly.

To avoid bird strikes by operational measures seems to be a more suitable approach for military, than for civil operations. Generally airlines are not inclined to postpone or cancel their flights in case of a high bird intensity.

On the other hand, the only way to deal with large birds is to avoid them, because it is impracticle to build aircraft that can with-stand strikes with the largest birds.

As far as protection is concerned, in the past a lot of work has been done in developing suitable means of protection, like steel cables in front of cockpit windows, guards in front of engines, and special protective devices for front spars of tail surfaces.

This approach has the disadvantage of adding construction weight to the aircraft. Quite often it means also a drag increase. Furthermore one has to be careful that the guard or reinforcement is really an improvement. A stiff structure in front of the forward spar for instance, precludes the bird from entering the structure, but on the other hand results in considerably higher impact forces because of the much shorter deceleration distance. These higher impact forces generate excessive bending moments at the root of the tail surfaces which, quite easily, can be catastrophic. A much more effective protection in this case is a stainless steel plate in front of the spar. This plate can absorb a great amount of energy without introducing excessive bending moments.



The disadvantage of guards in front of engines is that they can quite easily generate new problems, like ice accumulation, or getting covered entirely with small birds, which otherwise could be quite easily absorbed by the engine.

Guards in front of the windshield are not very effective and are a real nuisance for the pilots.

The only way in which protection is used in practice now, is that the aircraft is designed in such a way that the weaker parts are protected by the stronger ones that are already there.

This brings us to the third and most important aspect of bird protection; the inhaerent capability of the aircraft to survive strikes. Concentrating first on the larger civil transport category aircraft, one can distinguish three major week spots; the windshields, the engines, and the tail surfaces.

WINDSHIELDS

Since 1952 there is already a requirement in the airworthiness regulations, which prescribes that the windshield shall have sufficient strength to withstand, without penetration, the impact of a 4 lbs bird, when the velocity of the airplane relative to the bird is equal to the design cruising speed.

This requirement remained essentially the same untill now, but it became more difficult to fulfil, as the speed of the aircraft increased and the windshields became larger. There are already some aircraft types, like the Trident and the Lear Jet, that do have speed restrictions at lower altitudes due to this requirement. For other aircraft one can say that in general they just fulfil the requirement, without ample margins.

There are various reasons why these windows are pretty hard to improve further. Thicker window panes become very heavy, difficult to manufacture, and are very expensive. Another reason is that the obtical qualities deteriorate with increasing thickness. So even for the largest aircraft that are in operation now, the windshield is vulnerable for impacts with birds of more than 4 lbs.

There is one relieving factor, namely that at lower altitude usually the speed of the aircraft is also considerably lower than the design cruising speed. At these lower speeds a much heavier bird can be withstood without catastrophic failure. For instance, if an aircraft windshield is designed for a 4 lbs bird at 400 m.p.h., an 8 lbs bird can be withstood at 300 m.p.h. and a 16 lbs bird at 250 m.p.h., without catastrophic failure. This characteristic, in combination with an effective bird warning system for larger birds, can be the basis for a workable solution for the larger bird problem.

ENGINES

As far as I know piston engines where not seriously effected by bird strikes. Turbine engines on the other hand appeared to be very vulnerable. At least one fatal accident was caused by bird ingestion and there are several narrow escapes. Besides the financial consequences of bird ingestions are quite impressive.

Fortunately the newer generation of turbine engines has been improved considerably in this respect. They now can meet the following specifications :

- for each 50 sq. inches of engine intake a 1 ½ ounce bird (starling) must be ingested, with a maximum of 16
- for each 150 sq. inches of engine intake a 1 ½ lbs bird (gulls, pigeons, ducks) must be ingested, with a maximum of 10
- for each 2000 sq. inches of intake a 4 lbs bird must be ingested (geese, buzzards, large gulls and ducks).

This means that a DC-8 engine with a diameter of 1.3 m must be able to ingest at the same time 16 starlings, 10 pigeons and one goose.

Tests to substantiate this ability are quite impressive. The engine sucks in the whole amount of birds but usually cannot digest it immediately. This causes engine stall. Due to this stall the birds come out again and are sucked in for the second time and are then quite easily processed. At the rear end of the engine great flame's appear., but within one to three seconds everything is normal again.

Compared with the first generation of turbines one of the main improvements is that the distance between the static vanes in the inlet and the first rotor wheel has been increased. This means that damage to the static vanes cannot lead easily to damage of the rotor. The newest engine designs have no static vanes at all. This appeared to be favourable both for the noise characteristics and the bird eating capabilities of the engine.

TAIL SURFACES

Finally the tail surfaces have to be discussed. Comparing wing, fuselage and tail, the tail is the weakest part for bird strikes. The wing and fuselage usually are so strong, at least for the larger aircraft we are discussing now, that for these parts birds are only a nuisance and not a real hazard. Although the tail surfaces are weaker, they nevertheless can withstand remarkable high impact loads before they callapse.

After the Viscount accident in 1962 which was caused by a collision of a whistling swan against the stabilizer, a quite extensive program has been initiated in the U.S.A. to investigate the bird resistance of existing stabilizers. At a somewhat later date the same kind of tests has been carried out in the U.K.

The results of these tests were quite encouraging, especially for the tail surfaces of the larger jet aircraft. Birds of approximately 10 lbs, with a forward speed of 300 m.p.h. severely damaged the structure, but it remained intact and it was still capable to withstand the normal flight loads.

From the analysis of the test results it was learned that the amount of damage is proportional to the mass of the bird times the speed to the power 2.7

$$m.V^{2.7}$$

The validity of this law is not general and depends on the type of structure, relative to the size of the bird. As long as the distance between the spar caps is sufficient for the bird to pass thorugh, this law is reasonably valid. In cases where the bird is too large to pass through, the influence of the mass is greater than suggested by this law.

The consequences of this law can be illustrated with the following example. A structure that can withstand a 2 lbs bird at 400 m.p.h., can survive a 4.5 lbs bird at 300 m.p.h. and a 14 lbs bird at 200 m.p.h., assuming that even for a 14 lbs bird this law is still valid, which is however doubtful as mentioned before.

Anyhow, this example illustrates quite conclusively the influence of speed reduction on the bird strike capability of the structure; the same tendency that was found already for the windshields.

Since 1967 there is a British requirement saying that the whole structure must be capable to withstand safely the impact with a 4 lbs bird at all speeds up to the design cruising speed at 8000 ft. In the U.S.A. there is a proposal for a new requirement asking for an 8 lbs bird on the tail only,up to the design cruising speed at sea level. Interested persons and organisations are invited to comment on this proposed 8 lbs requirement. In the R.L.D. comments the question was raised whether 8 lbs was the right figure. Analysis from available bird strike data revealed the following picture.

Weight of the bird	1	2	3	4	5	6	7	8	9	10	11	12
Strike frequency	127	40	3	16	1	1	1	6	7	8	0	2

There is quite some guesswork invalved in such an analysis, but we got the impression that between 4 and 8 lbs there are hardly any birds . They are at least not encountered very frequently by aircraft,if these statistics are correct. Our proposal was either to stick to the 4 lbs value, which is widely accepted now or to go a step further and to ask for 12 lbs. I am very anxious to get your views on this during the discussions.

SMALLER AIRCRAFT

Up to now we focussed our attention on the larger transport category aircraft. For the light airplane category, that are aircraft with a maximum take-off weight of at most 12500 lbs, the situation is quite different.

There are now well over hundred thousand aircraft in this category and this number is growing rapidly. Besides that, there is a tendency to design these aircraft for higher speeds. Another important trend is that recently quite a number of new designs appeared in this category that are as large as possible, which means that their maximum take-off weight is just 12500 lbs. These aircraft are used as feeder liners, as so called third level aircraft,and for taxi operations.

They carry between 10 and 20 passagers. The point is that the requirements for small aircraft are less stringent than those for transport aircraft, which means that as long as the maximum weight is less than 12500 lbs. these aircraft are relatively easy to design and to build. So what is happening now is that aircraft, which size-wise and operation wise are essentially transport aircraft, are build according to requirements intented for pleasure aircraft.

Up to now the category of small aircraft did not suffer too much from bird strikes. One can expect however that in the future this problem will become more serious. The first reason is that the average flying speed increases. The second reason is that these aircraft are used more intensively.

The airworthiness regulations will be adopted to the changing situation, but this is a very slow process. Since 1967 in the U.K. there is a requirement for this category of aircraft asking for a 2 lbs bird capability of the windshield at approach and climb speed. There are no requirements for the airframe. In the U.S. there are no bird strike requirements at all for this category, but one is reviewing there the whole light aircraft code, which may result in bird strike requirements for the larger small aircraft.

An operational approach to the bird strike problem for these smaller aircraft is very difficult as these aircraft operate mainly from small airfields. It is not practicle to remove the birds from these small airports. Another problem is that these aircraft quite often cruise at low altitudes.

It is not yet entirely clear at this moment how serious the bird hazard is for this category of aircraft and how much the situation probably may deteriorate in the near future. You may have better information on this than I have. If so, I should be very happy to get it. Just like for the transport aircraft the most practicle solution will be to increase the bird impact capacity of the aircraft in order to be safe for the smaller birds. For the larger birds a bird warning system has to be developed to make it possible to avoid effectively collisions with these large birds.

CONCLUSIONS

From the foregoing the following conclusions can be drawn.

1e Due to the great amount of high speed low altitude flying the bird strike hazard is more serious for military operations than for civil operations.

2e On the average the bird impact capacity of civil aircraft is increasing.

3e Birds less than 4 lbs can be dangerous for smaller aircraft, but are only a nuisance for transport category aircraft.

4e Birds of more than 4 lbs are dangerous for all type of aircraft, especially if encountered at high speeds.