STATIC BLADES UNDER LOAD FOREIGN OBJECTS DAMAGES TESTING PROGRAM

Ingénieur de l'Armement Jean-Pierre DEVAUX
Head of TURBOENGINES TEST SECTION
DGA/CEPr SACLAY
FRANCE

ABSTRACT

To analyse the gun and projectiles main influences on Foreign Object Damages tests done on High ByPass Ratio engines French certification authorities have asked CEPr to find a test mounting able to support the study. CEPr has chosen to simulate the projectile impact on a static blade placed in similar mechanical conditions as those encountered on engines.

As the main study has been delayed due to surprising first results, other studies were proposed and performed with this special mounting : in particular CEPr was interested in using it for propeller composite blade development. The mounting has helped CEPr to prepare TRANSALL FOD qualification tests.

Today, the initial study is still on work, but the research is mainly aimed to the definition of a realistic «false bird».

INTRODUCTION

In the foreign object damages field, French certification authorities and CEPr main concern has always been the tests representativity. In fact it is essential to be sure that the tests being done are conform to the regulations and that they effectively cover almost all dangerous bird strike cases encountered by the engine.

Five years ago, the problem of the bird type was raised without any technical arguments to help CEPr to make a decision [1]. In parallel, certification authorities wanted to know the effects of gun acceleration and bird conserving on the final result as they suspected that those parameters might have some influence on it.

Therefore, CEPr has launched a research program in collaboration with STPA (Service Technique des Programmes Aéronautiques) to try to answer partly or completely to those questions.

CEPr knowledges are mainly based on our HBPR engine testing experience : we have tried to take this experience in account in order to be able to do comparative analysis between the test mounting we were preparing and the real bird strikes encountered by all kind of engines.

STATIC BLADES UNDER LOAD MOUNTING

The chosen mounting principle is based on the bird impact velocity triangle analysis (figure 1) : a bird sent against a rotating fan blade at a given velocity will have a relative velocity in the blade reference system which can be easily calculated if you know the fan rotational speed and the blade impact radius.

The chosen mounting principle consists in doing the bird shot in the blade reference system (figure 2) : the projectile velocity is then the relative one in the further galilean reference. Blade pitch angle and projectile velocity impact angle on the fan front are kept similar to the real ones.

Then the main problem to solve was the mechanical behaviour simulation. The fan rotation main effect is the centrifugal force acting on the blade which induces a metal centrifugal stiffness : to simulate it we have put the aimed blades under controlled loads. Only three blades are used in order to ensure a compromise between a good test representativity on the second blade and a low test cost.

Another problem was the dynamical behaviour, and mainly the embedding effects related for example to the shroud or the blade tip: CEPr has put a flexible movement clearance at the tip of the blade to avoid strong embedding effects.

The blade support built by CEPr is shown figure 3. Figure 4 give a detailled scheme of the chosen solution.

GUN PARAMET

After a
to study the gun
aims were reach
during the first t
ments research

As a r
with the aimed r
at take-off cond

This r
knocked : the m
axis and the rel
as shown in fig

No re
modelization w
main research

1 - a

2 - a

In pa

With
check if the re
by analysing t

- gu

- gu

- gu

This
in terms of bl

PROJECTILE

Incl
campaign do
birds :

- se

GUN PARAMETERS STUDY

After a blade support reception campaign, the first campaign main aims were to study the gun parameters effects on the final deformation set : none of the previous aims were reached at the end of the campaign, due to simulation problems encountered during the first tests. Then the campaign has been transformed in shooting adjustments research (figure 5).

As a matter of fact, the first shots adjustment conditions were in accordance with the aimed relative velocity corresponding to normal HBPR bird strike on blade tip at take-off conditions : the deformation set obtained was too large.

This result was related to a too severe bird impact as only one blade was knocked : the main explanation was to be found in the angle between the projectile main axis and the relative velocity (no angle in the static simulation contrary to the real case as shown in figures 1 and 2).

No real solution has been found during the campaign and in fact a change of modelization was necessary to bring the simulated results near again. Therefore two main research axis are presently studied :

1 - an impacting angle increase to improve the bird repartition on several blades,

2 - a bird velocity decrease to minimize the permanent deformation set.

In parallel, we have to find a coherent rotational speed.

With this new adjustment parameters, a second campaign will start soon to check if the results are more sensible. If they indeed are, we will continue the program by analysing the influence at the same initial velocity of :

- gun diameter,

- gun length,

- gun air quality.

This last campaign will give us very interesting results on the test repeatability in terms of blades permanent deformation set.

PROJECTILE STUDY

Included in the initial study aims, the projectile study was part of the first campaign done to analyse the gun parameters. We have sent three types of medium birds :

- sea gull (5 shots)

- chicken (10 shots)

- homogeneous synthetic bird (called «false bird» : 5 shots)

We have found that considering the mean permanent deformation set obtained, the sea gull was the less severe bird, followed by the chicken. The homogeneous «false bird» was really the most severe projectile, probably because it was the most homogeneous one.

If the differences between the real birds and the false one were significant, the differences between chickens and gulls are too small to conclude definitely. The trend observed is confirmed by the rotating tests : however, the chickens are freshly killed in contrary to the gulls which are delivered each two or three months from south of France and therefore must be freezed an defreezed before shooting, which might change their global behaviour.

Results obtained were considered as very encouraging and during the third campaign, we will try to characterize the defreezing influence on real birds and the gun acceleration effects on the three bird types.

Finally, the poor results obtained with our homogeneous «false bird» have convinced CEPr that an effort has to be made in this direction in order to define a cheap standard projectile, which will resist to acceleration effects inside the gun and will not be degraded by defreezing operations : CEPr tries to develop an axisymetrical «false bird» composed of three density types respectively replacing feather, meat and bones in respect with their repartition in a real bird.

PROPELLER BLADE QUALIFICATION

As the previous test campaign was a failure and considering that we had no experience on propeller foreign object damages testing, we have tried to see if the static blade under load mounting could be use for preliminary testing: CEPr need was mainly the definition of the stone projectile.

Extension to bird strike tests were done to compare the results obtained with rotating tests ones : they fit good and were also comparable to the manufacturers observations made on real impacts in its overhaul workshop.

CEPr has tried to explain the differences between the good results encountered with propeller blade and the bad ones obtained during HBPR blades testing. Two kinds of explanation are put forward to understand the encountered differences :

- only one blade is knocked in real propeller FOD tests. Therefore the argumentation put forward to explain the HBPR simulation failure is no more true for propeller blades : whatever the angle of the bird will be, the blade (rotating or static) divides it into two parts only.

- axial loads are also less important for propeller mounting,

- centrifugal effects on the impacting bird can be neglected when considering a propeller strike : it is no more possible when studying an HBPR strike.

As explained in [2], the results were so satisfactory that this method is today put forward to qualify propeller blades and also propfan [3].

CONCLUSIONS

CEPr has developed a special mounting to study the gun geometry and projectile type influences on the final results of FOD testing : the results observed on HBPR engines blades were not satisfactory and indicate that the chosen mounting, although sophisticated, is inadequate to characterize the blade behaviour during a bird strike. The results transposition is also a real problem which is not simple to solve, as both the projectile behaviour and the blade response are not the same.

At the opposite, the mounting was proved to be very useful for propeller qualification and CEPr thinks that a complete propfan qualification process should include such tests.

Finally CEPr has tried to define the «false bird» main characteristics : the definition of such a projectile, the qualification to each kind of bird strike tests and the agreement from civil aviation authorities is a difficult and very long process we have just begun. Next shooting campaign on static blades will include a first approach of a two density «false bird».

Bibliography

[1] BIRD STRIKE TESTS METHODS IMPROVEMENTS
JP DEVAUX WP32 BSCE 19

[2] PROPELLER FOREIGN OBJECT DAMAGES TESTING
JP DEVAUX WP** BSCE 20

[3] PROPFAN BIRD STRIKE TESTING
JP DEVAUX WP** BSCE 20

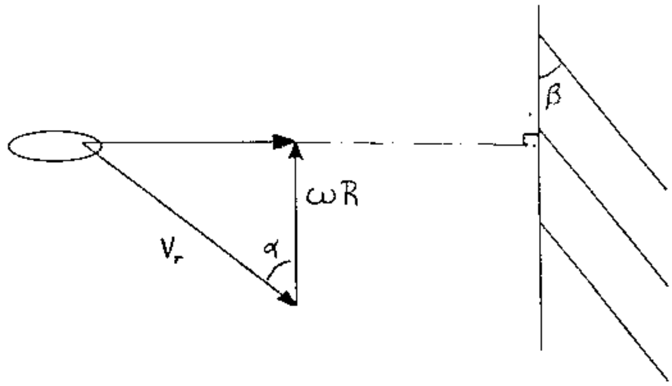

Figure 1 : REAL BIRD IMPACT VELOCITY TRIANGLE

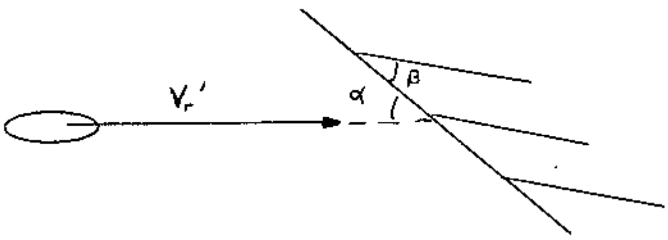

Figure 2 : SIMULATED BIRD IMPACT VELOCITY TRIANGLE

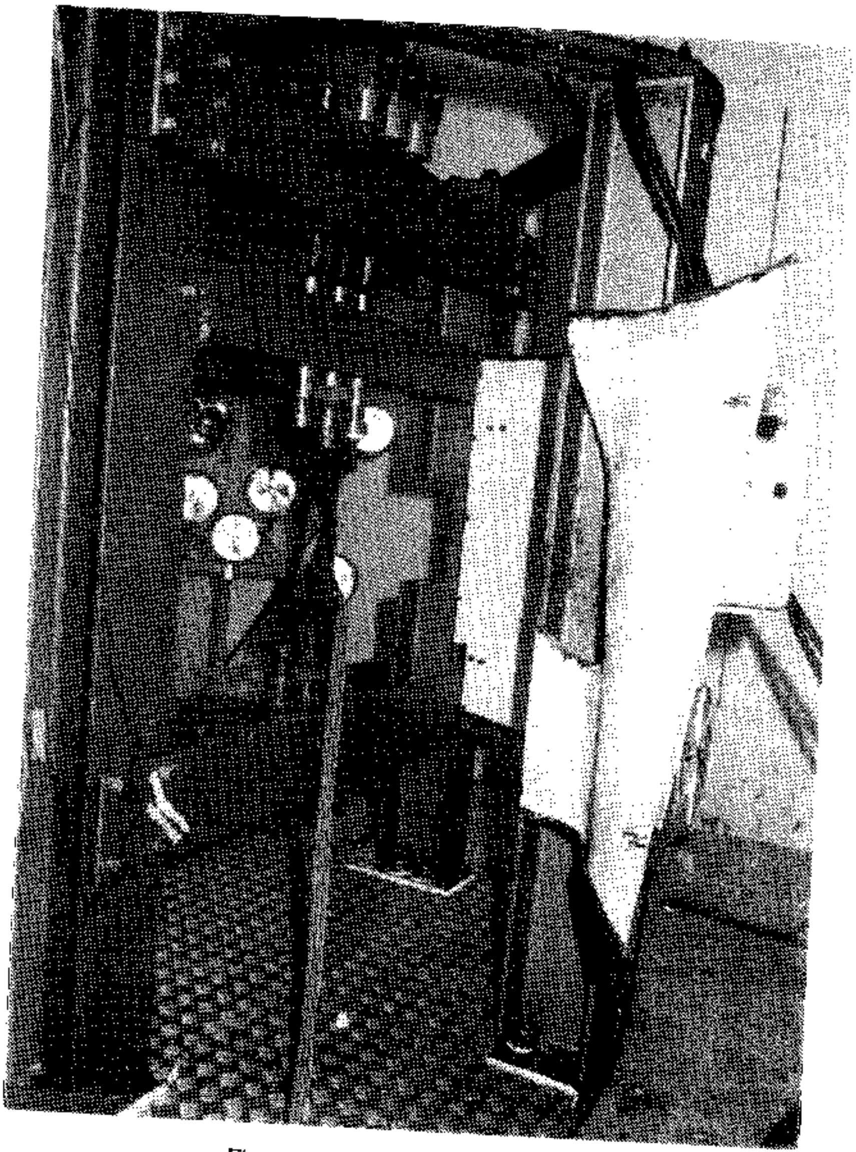

Figure 3 : BLADE SUPPORT
(Photo CEPr 88-1856)

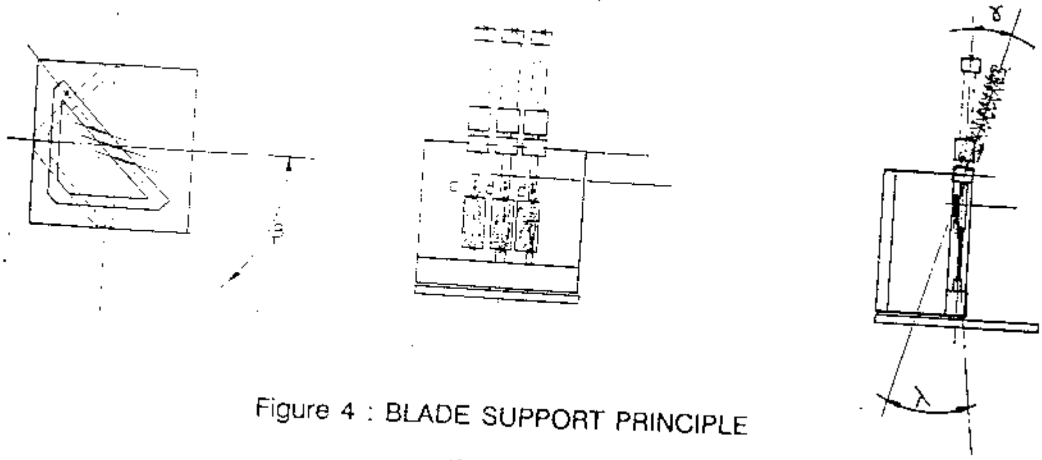

Figure 4 : BLADE SUPPORT PRINCIPLE

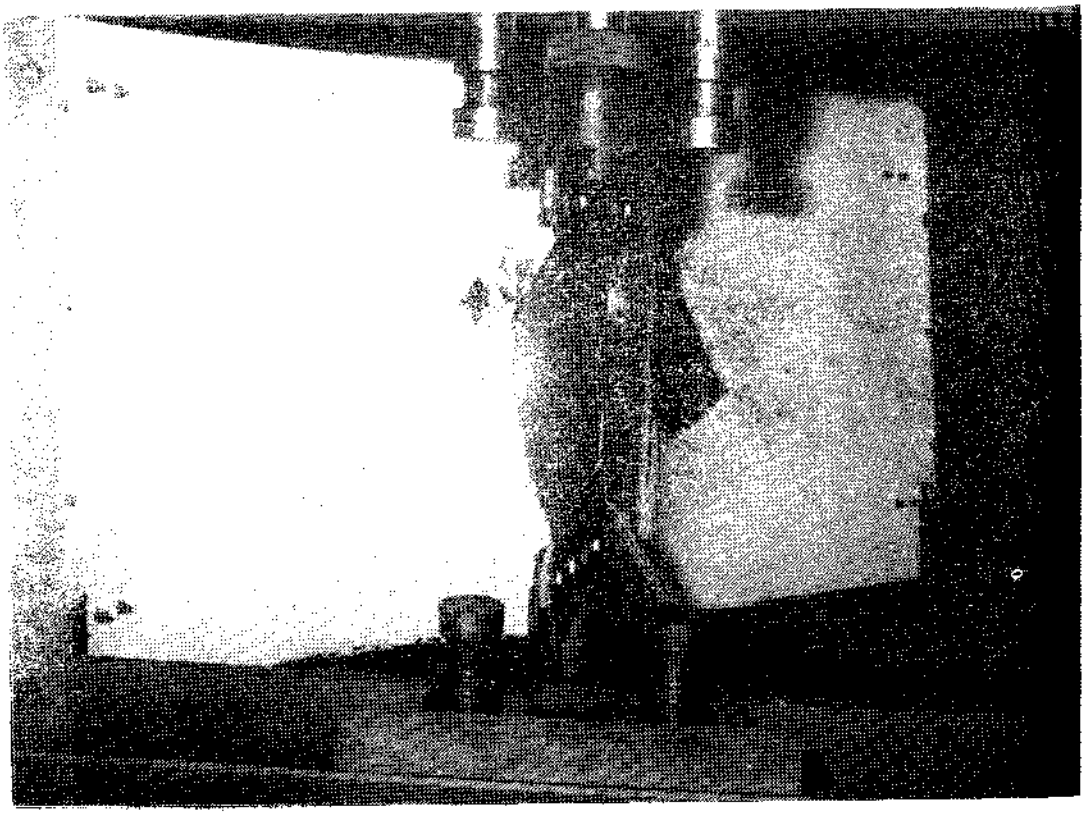

Figure 5 : SHOT RESULT EXEMPLE

PR

CEPr
ler foreign objec

Those
therefore new te

All the
FOD testing tea

Test c
introduce in the
between test co