Airplane Impact on Nuclear Power plants

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ABSTRACT

A short report on investigations of nuclear power plants under airplane attack is given. It concerns the modeling of planes with regard to mass and stiffness, the relevant plane velocity and finally the determination of load-time functions. The necessary analysis of the concrete containment structure is shortly addressed. Finally a proposal for a structure to keep planes from such building structures is discussed.

KEY WORDS: terror, airplane, attack, nuclear power plants, concrete, investigation, protection, structure

INTRODUCTION

In Germany since about ten years nuclear power plants have been designed also against the unintended collision of a Phantom fighter plane with such a structure. The author has been engaged in this type of problems for many years as a member of the German safety committee (RSK). To confirm computations of appropriate design loads even a one to one experiment has been carried out in a joint Japanese-US research project at Albuquerque New Mexico. Meanwhile new problems have come up now with the world wide danger of a terror attack by traffic planes. In public as well in relevant bodies [1, 2, 3, 5 ] this problem is discussed. The question is raised:

• is such an attack possible,
• with what result and
• how can it avoided if necessary.

With regard to the first question one can say in principle yes. With regard to the second one the authors is sure that containments designed against a phantom fighter plane will withstand such an attack. There are however many others in the world with a quite different containment-layout, which are at least until now not investigated. This statement however does not anticipate the general conclusion that such power plants in general would be heavily damaged. It is not only the containment structure which has to be considered but also the surrounding terrain, adjacent buildings and structural obstacles in the neighborhood etc. which may reduce or hinder catastrophic effects.

With regard to the third question one has to state that all classical passive means are relevant and should be used, such as controlling passengers at the airport, controlling the air space etc. However such measures are of different quality at the airports in different countries.

As a new method also the downing of attacking traffic planes by military fighter planes is under consideration. However the available time to bring a fighter plane into the air is too long. A passenger plane flying up to more than 700 km/ph needs only several minutes to deviate sufficiently from his allowed route to hit its aim at least in small countries. One also has to regard the immense consequences which would result from a wrong decision of the commander in charge.

Permanent military installations like canons or similar weapons with the necessary personal at the plant are expensive and raise the consequences already mentioned.

Also influencing a plane's course from outside may be mentioned. The flying personal however stated already that they will never accept that small deviations from there allowed route may lead to an automatic destruction of their planes, without any change of the pilots to intervene.

As in the meantime planes fly automatically to an aim fixed by coordinates also bad visibility caused by weather conditions or other means to influence visibility are probably not very effective.

As of course some existing power plants are not able to resist the acting loads, also passive technical devices to keep the plane from the buildings have been discussed such as rope systems, earth walls etc.

The Forces acting at a rigid Containment Structure

In principle it is well known how the forces exerted to structure in case of an airplane impact have to be determined. One has to model the structure and the plane by a "mass-spring-system" (Fig.5). However the relevant differential equation of impulse conservation shows clearly that the deformation of the concrete wall may be neglected compared to that of the hitting plane. So only the mass-spring system of the plane has to be considered. In doing so one at first has to select a choice of relevant planes with regard to the frequency of their use (Fig.1, 2, 3). Of interest are their following parameters:

• mass distribution
• stiffness characteristics and velocity
Fig. 1 Airbus 320

Fig. 2 Boeing 747

Fig. 3 Airbus 340/600
The plane's mass distribution is clearly defined, while the stiffness modelling (Fig. 4) of the many different sections within a plane is very difficult. One has to regard first an elastic behaviour which is limited by a buckling force, a plastic part and finally a compaction.

Of interest is the maximum velocity of the plane and its vertical angle of approach, which is different from the maximum speed at impact, as the latter depends also on the micro terrain situation, on the building arrangement i.e. on the structures around the critical one. To lay down the relevant parameters needs of course some kind of a probabilistic or a subjective decision. The rest is just the mathematical algorithm and the appropriate Finite Element code.

![Fig. 4 Model for sectional stiffness](image)

![Fig. 5. Principle mechanical model however with an unrealistic rough mapping](image)

![Fig. 6 The moment when the wings reach the building surface. The wings start to bend near the fuselage and, the innermost engines begin to separate from the wings.](image)
A rather good first and fast approximation of a load-time function (Fig.8) can be gained using the following well known Riera-Model, which was published already in 1968 [4] and used for the Phantom investigations many years ago [5] (Fig.7).

Starting with the equation of impulse conservation,

\[
F = \frac{\partial}{\partial t}[mv] = \frac{\partial v}{\partial t} + \frac{\partial m}{\partial t} v
\]

where \( m = \) mass \quad \( F = \) pressure
\( t = \) time \quad \( v = \) velocity

one finds that in control space 1 (Fig.7) mass \( m_{11} \) does not contribute to the force \( F \), as its derivative is zero as well as its velocity. The mass \( m_{12} \) however changes in time, what results in a force

\[
\rho A v^2(t)
\]

Mass \( m_2 \) contributes with the buckling force \( F_{buck} \) of the approaching, not yet destroyed rest of the tube. So the sum of all horizontal forces is finally

\[
F = \rho A(x) v^2(t) + F_{buck}
\]

As the second term is rather small compared to the first one, the force acting on a rigid target is more or less determined by the mass flowing into control space 1, when one approximately assumes that the speed \( v_2 \) is constant.

Fig. 7 Riera Model

Fig. 8 A principle example of load – time functions for big traffic airplanes, the details of which depend on the afore mentioned selected parameters
A separate problem is, that hard masses (Fig. 9, 10), different from the soft structural main parts of the plane have to be studied separately. If e.g. the nose of the plane touches a structure, the engines with their hard turbine axes may be torn out of the rest of the plane and hit the structure separately as a hard missile which may penetrate the containment due to generated high local shear forces shear.

**Fig. 9 Front wheels folded up**

**Fig. 10 Part of the landing gear**

**THE CONCRETE STRUCTURE**

In principle the investigation of the concrete structure is a routine task. The only problem, which arises, is the question how the acting force has to be applied to the concrete surface. (Fig.12.). What is the shape of the acting force? This is an important question. Investigations, done years ago at the author's laboratory, showed clearly that the failure mode of a reinforced shell or plate depends on the shape of the impacting body and its stiffness. At medium speed and low stiffness a bending mode failure may occur. Ring shaped loads on a thick plate with high speed loading may however may lead to a shear failure (Fig. 11). In a specific situation a final answer can only be given if the concrete structure with its reinforcement and the plane is realistically modeled in a nonlinear FE-analysis.

**Fig. 11 Penetration cone**
The mechanical Principle of the proposed Structure

It is obvious that all types of systems cantilevering from the soil surface up to a height of 50 to 100 m cannot hardly resist the relevant loads of hundreds of MN’s by bending with reasonable expenses. It seems therefore more reasonable to activate the inertia forces of a heavy mass on top of a simple support which can destroy an attacking airplane by contact force (Fig.13). Of course the created remnants of structure and plane must be led down to bottom in front of the containment in a controlled manner.

A usual beam cantilever beam needs much expensive flexural strength concentrated at the bottom of the systems. The proposed one however consists mainly of a rather cheap, heavy mass on top of an arbitrary supporting device. This "heavy mass" needs only a minimum strength, which has to guarantees that no dangerous, secondary missiles are produced.
The design of a protective structure

The proposed design consists of a heavy concrete structure with an upper and lower deck and intermediate vertical separation walls in about a 15m distance. Deviation shields (Fig.14, 15, 16) are attached to the latter. They are to hinder hard plane fragments produced at the destruction process of the plane as e.g. turbine axles or the shown landing gear to meet the containment. These concrete shields create the main parts of the heavy mass. Only a small percentage of reinforcement is necessary to keep fracture remnants together after collision.

As tension members steel ropes are led within the structure's legs (Fig.15). The latter may be of concrete or in case of lacking space also of steel. They have to be designed just to carry the vertical loads of the concrete structure, wind loads etc at normal life time conditions. They may be arranged in a distance of about 20 to 60 m. An impact very low above ground is not possible.

The necessary maximum height is about 50 to 60 m. It depends on the maximum inclination angle of the incoming plane, the height of the containment, and the horizontal distance to the structure. Investigations have shown that in many cases only a total length of less than 100 m, straight or curved, is sufficient (Fig.14). The upper vertical shield walls with a horizontal distance of approximately 15m between the upper and lower deck distribute the plane's impulse to an active length of about 60 m at a collision.

The positive aspects of such a structure in case of nuclear powerplants are:

- It is a passive acting type of structures. Its erection process is easy and often used for usual bridge structures. Many different erection methods, experience and scaffolding systems are available.
- In many cases it has to have only a short length, as the containment building is usually surrounded by a number of auxiliary buildings. They already protect the containment to a high extent (Fig. 14).
- One of the main advantages is that due to its separation from existing structures its erection process does not influence the electricity production. Even it has to be placed partly in a space occupied by a secondary building, the foundation of one of the legs can easily by arranged through it, using e.g. small steel columns as a support.
- Even an arrangement of the structure in water, at plants closed to a river or the sea, is easily possible via an abutment pier (Fig.16).

The costs have been shown to be very low with regard to the investments for the already existing building structures. As a passive concrete structure it needs nearly no costs for maintenance.
SUMMARY

The present discussion of terror attacks on power plants led to first rough investigations and discussions. There are such which may be declared to be safe without further detailed investigations, while in several countries plants have to be investigated more in detail depending on their different original design philosophies.

At first the actual attack situation is shortly discussed including active means to avoid such situations already by general safety measures. Then the general methods to cheque building structure with regard to their relevant strength are discussed. They result from the strategies developed already years ago, when the design loads for containments against the Phantom fighter planes were developed. These principal methods are shortly addressed.

In addition to already presented protection measures, if necessary, finally a passive structure is discussed. It consists of a heavy mass in a reasonable height, which is to collide with an attacking airplane. The latter will be destroyed, thereby exchanging its impulse with this mass. The fragments are brought down to bottom in a controlled manner by means of gravity and attached steel ropes. First numerical investigations have been done to cheque a realisation.

REFERENCES: