

Bird and Tyre Impact Analysis on Landing Gear

Claire Mercier
Messier-Bugatti-Dowty

ABSTRACT

As part of the aircraft certification process, landing gear has to be certified against particular risks such as bird and tyre impact cases.

According to international aviation regulations, it has to be demonstrated that the landing gear is designed to ensure the capability for continued safe flight and landing after bird impact or after tyre impact resulting from wheel or tyre failure.

Structural parts such as the down-lock mechanism must be validated against these requirements since their structural integrity is essential to ensure landing gear down-locking for landing and subsequent on ground movement.

Recently, MESSIER-BUGATTI-DOWTY has been involved in the development of explicit analysis in support of bird and tyre impact justification.

A model of the down-lock mechanism has been developed and a full scale test has been set up in order to demonstrate the validity of the analysis.

Two extensive test campaigns have been performed considering bird and tyre impact cases using highly instrumented components to record strains and displacements on impacted parts.

Based on a comparison to the test results, the modelling of bird and tyre projectiles has been validated. The computed displacements and strains in the down-lock mechanism have also been favourably compared with experimental evidence.

Based on these results, a model of the complete landing gear has been built in order to take into account the effect of landing gear stiffness and to re run analysis in the complete landing gear environment.

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INTRODUCTION

The analysis of particular risks has for some time been of concern and interest and has come under greater scrutiny in recent years from the Aircraft Manufacturers and the Airworthiness Authorities, where particular well publicised in service events have highlighted the concerns.

According to international regulation, particular risks are defined as those events or influences, which are outside the systems concerned. Bird strike, and wheel and tyre failure are part of these particular risks.

As part of the certification process, these events are the subject of a specific study in order to ensure the safety of the system in case of such exceptional events.

Based on the definition of bird and tyre impact cases, a trajectory analysis is first performed. The impact cases are studied in respect to the landing gear and the possible impacted parts are identified.

Once the trajectory analysis is made and possible impacted parts are determined, further structural analysis must be performed on each concerned part unless requirements indicate that the loss of some particular part is not critical.

Historically, MESSIER-BUGATTI-DOWTY used, in line with standard industrial practice, a simple approach based on the conservation of energy principle to compute the loads induced by both the tyre and bird impacts.

These loads were then applied on analytical beam models to compute the stresses in the structure and to determine safety margins.

In recent developments, in order to take account of the dynamic effect of such impacts with greater accuracy, MESSIER-BUGATTI-DOWTY has developed a new methodology to support bird and tyre impact analysis.

This methodology is based on explicit time integration analyses, run with LS-DYNA code.

IMPACT CASES DEFINITION

Bird Strike

According to international regulation, the aeroplane and its equipments must be designed to assure capability of continued safe flight and landing after impact with a 4 lb bird.

The bird impact cases are defined by the bird geometry to be considered, approximated by a cylinder form, and by the impact conditions such as impact velocity and impact angle.

The impact conditions are driven by the aircraft speed and attitude; the bird being considered having a negligible speed in respect to the aircraft. Typically, the impact speed considered for bird impact cases on commercial aeroplanes landing gears is around 150 m.s^{-1} , which corresponds to the maximum speed to be considered while landing gears are extended.

The impact angles to be considered are defined by the angle of attack and sideslip of the aircraft as illustrated in [Figure 1](#).

Bird strike events have been reported during take-off run or landing roll when the aircraft is on-ground, and during flight phases when the aircraft is off-ground.

In current study, the landing gear is considered in extended position and unloaded (off-ground). On-ground impact cases are considered covered by this study as they should occur at lower speed.

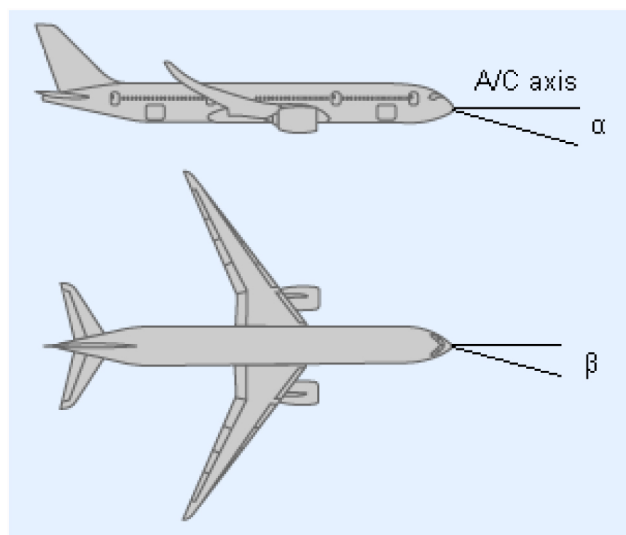


Figure 1. Impact angle - Angle of attack and sideslip

Wheel and Tyre Failure

The Wheel and Tyre Failure events considered in the particular risks analysis are of different types:

- Tread Shed which is a projection of tyre debris resulting from a tyre burst as the aircraft is in contact with the ground,
- Flailing tread which is a rotation of a strip of loose tread with the wheel,

- Wheel Rim Release which corresponds to a projection of rim debris,

- Tyre Burst which corresponds to a tyre explosion without projection of tyre debris.

The wheel and tyre failure cases are defined by the speed and angle of ejection of the tyre debris and by the tyre debris definition. The four different scenarios are illustrated in [Figure 2](#).

In respect with the tyre debris projection study, the tread shed cases are considered as the most critical for landing gear structural parts. The tread shed analyses only are documented in this paper.

The maximum debris velocity to consider in tread shed analysis is equal to the maximum rated speed of the tyre, which is typically around 105 m.s^{-1} for commercial aircraft.

Tread shed debris is only assumed to occur when the wheels are in contact with the ground. The landing gear is considered in extended position with a shock absorber compressed at static stroke.

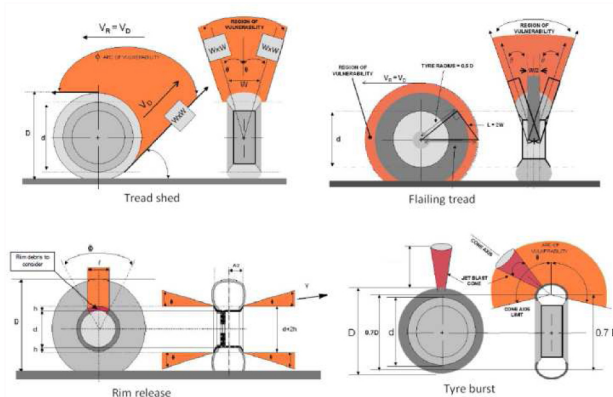


Figure 2. Illustrations of Wheel and Tyre Failure

Trajectory Analysis

Considering bird and tyre impact cases definition, trajectory analyses have been performed in order to identify the critical parts subjected to impact cases and the associated impact conditions.

The bird strike trajectory analysis is performed considering a simple cylinder form representative of the bird ([Figure 3](#)).

In the tread shed analysis, edge-on impact cases and flat-on impact cases have been considered as illustrated in [Figure 4](#).

This trajectory analysis highlights that the down-lock mechanism composed by the lock-links, down-lock springs and unlock actuator may be struck by bird strike or tread sheds.

It is also demonstrated by this trajectory analysis that no tyre impact has to be considered on unlock actuator since unlock actuator is protected by the lock-links for such event.

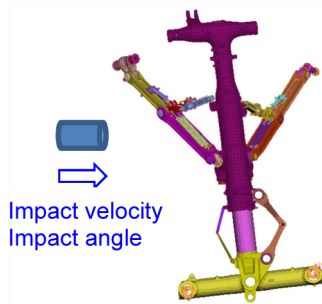


Figure 3. Bird impact cases - Trajectory analysis

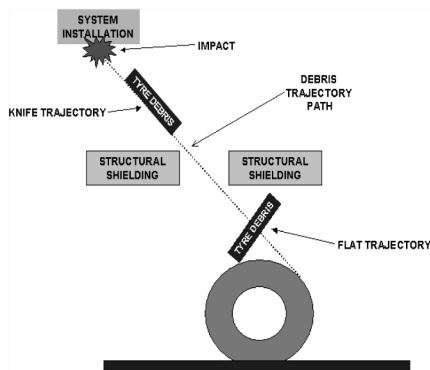


Figure 4. Tread Shed Impact Cases - Trajectory Analysis

MODELLING

Structural Modelling

The landing gear is a complex mechanism that includes non linearities, contact elements at joints and friction assumptions.

The model must represent the behaviour of the lock-links, unlock actuator, down-lock springs and associated components.

This leads to an extremely complex model that incorporates a number of features that require some understanding (e.g. pin joints and hence assumptions about friction, foreshortening loads, etc) and inherent risks to successful modelling.

For preliminary analysis, the lock-links subsystem has been modelled considering as a first assumption some rigid conditions at the attachment points.

The model was then completed with test rig modelling and joint modelling for correlation analysis.

The structural elements such as lock-links and unlock actuator are modelled with HEXA solid mesh (8nodes) as illustrated in [Figure 5](#) and [Figure 6](#). Elasto-plastic material laws are used for the impacted parts.

The damping effect of oil contained in the unlock actuator is considered through a damping law defined as a function of the velocity.

Detailed modelling of the pins has also been considered in order to get representative stiffness of the assembly ([Figure 7](#)).

Down-lock springs are modelled with discrete elements.

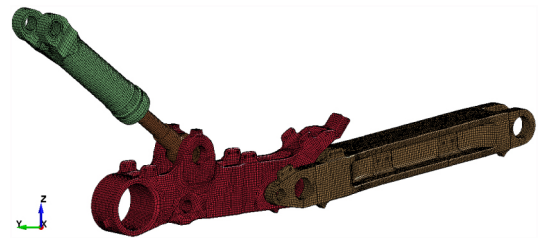


Figure 5. Lock-links and actuator solid mesh



Figure 6. Unlock actuator damping modelling

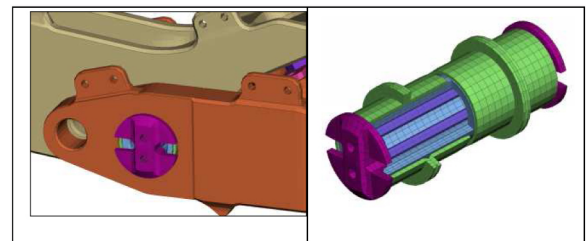


Figure 7. Pins modelling

Bird Impact Modelling

The bird model has been developed using SNECMA experience in engine fan blade impact modelling. The bird is modelled with SPH elements, typically used for simulating fluid flows.

Smoothed Particle Hydrodynamics (SPH) is a meshless formulation, and thus completely avoids the problems such as element distortion and hourglass modes. In the SPH formulation, the bird is discretized into a large number of interacting masses.

Field variables of a particle are computed through interpolation of the neighboring particles. The integral interpolant of any function can be written as:

$$f(x) = \int f(x')W(x - x', h)dx'$$