An airbag application for the ALAR incidences for the Passenger Aircrafts

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ABSTRACT

The airbag system can be designed to reduce the damage on the fuselage during an Approach and Landing Accident Reduction (ALAR) situations as well as ditching in the water for the transcontinental flights. Minimum hull damage protects the passengers in deep waters. *A preliminary investigation for this end is performed in this paper.* A simple model under 10000 elements is used to investigate the problem. The findings of the LS-DYNA finite element simulation are reported in this paper. It also shows a filtering effect on the impact pulse on the structure. The spikes on the deceleration pulse can create injury to the occupants. The airbag filters the pulse thus reducing various injuries to the occupant apart from hull protection. The most useful feature is its automatic deployment at the most critical moment. This is also useful for the small and mid-size aircrafts to survive various ALAR incidences. It saves life as well as property in case of the small crafts.

PROBLEM STATEMENT

The passenger aircrafts are subjected to ALAR environment due to various reasons. There is also a possibility of ditching of the aircraft in the transcontinental flights. The hull integrity is an important issue for such situations. The proposal in this paper is to add a system of airbag and tether that could absorb certain percentage of the impact energy without having a peak deceleration pulse that could injure the occupant under all circumstances. The problem is considered under various situations such as rigid floor, on the water with flat (calm) condition or in hogging or sagging conditions.

APPROACH

A simple finite element model is setup to show the effect of the airbag contribution to the impact. The model stiffness is tweaked to be within the elastic plastic range. The mass and stiffness are altered to obtain a reasonable model for the current analysis. A set of five bags in a row are assembled to form the airbag system. They were evenly spaced and tethered together. The system is also tethered to the fuselage to obtain a reasonable constraint. There are eight different models analyzed and compared. The finite element analysis is performed using LS_DYNA and

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the results are shown with the LS_POST. The fluid is simulated using the fluid element present in the program. The hogging and sagging are the most severe support conditions for the structure in the water surface. They were simulated in this current analysis. The configuration of the proposed external airbag system is shown in the following figure 1.

Figure 1: The configuration of the external airbag system.

The representative finite element model of the system is shown below in Figure 2.

Figure 2: A representative model with airbag attachment for the analysis purposes.

The floor is simulated with the rigid material. Figure 2 shows an unpackaged folded airbag system finite element model. The bags are tethered togather and to the structure. The airbag is a multichambered system to provide enough reaction forces. The analysis is performed on the cylindrical section of the structure. The front bag needs to be designed for the aerodynamic stability. The finite element model is currently focused on showing the advantage of adding the bags to the system. The vertical decent velocity is kept to a value of Vz = 25.0 ft/sec.

Abrrupt Landing on Rigid Floors without airbags:

The finite element model used to simulate the structure and the event of abrubt landing onto the rigid surface is shown in the following figure 3.

Figure 3: The simulated results of the drop test for the condensed fuselage onto the rigid floor are shown in the figure.

The peak plastic strain for the structure is around 8.165% This structure is without any airbag system. The same model when added with the airbag system reduces the plastic strain levels to within 2% starin which is the limit for the structure to stay without any damage.

Abrrupt Landing on Rigid Floors with airbags:

The abrrupt landing of the aircraft on rigid terrain invariably leads to a very high level of damage and fatality. This can be avoided by having a proper energy absorbing systems in place and deployeable at a very short notice. One such configuration is proposed in this section. An array of five airbags with three fold system each was used in this investigation. The bags were tethered to each other as well as to the fuselage. The deformation plotof the analysis is shown in the following figures.

Figure 4: Airbag simulation of the fuselage impact on the rigid floor.

Figure 5: Simulation on the fuselage impact with airbag on the rigid floor plastic strain contour.

The above picture shows the peak value of plastic strain on the fuselage to be 0.128% when the airbag is deployed. There is a reduction in plastic starin from 8.7% to 0.128%. This makes a difference to the structure, it moves from elastic deformation to permanent plastic deformation which happens beyond 2% strain. Another important contribution to the impact is that it reduces the deceleration pulse that can cause the hip injury to the occupant. This is one of the main reason for using the airbag system compare to the other types of energy absorption systems proposed by others. The deceleration pulse is observed for all the cases at a node located at the center station top of the keel rib of the hull. It is at the node number 29596 or 29594 in some cases.

Figure 6: The deceleration pulse for the structure without airbag impact on the rigid floor.

The deceleration pulse for the fuselage on the rigid floor without any airbag generates a spike of 50g. The three folded airbag system is used to study the damage on the hull. The deployment of the airbag depends on the depth of the gap between the hull and the floor. It has to deployed not too soon as well as not too late. Too soon will give various aerodynamic effects and too late will reduce the effect of deployment and energy absorption. Here the two conditions are studied where in one condition the airbag is fully deployed and in the other the partial deployment occur before the touch down. The models of the two conditions are shown in the figure 7.

Fully Deployed Condition
Partially Deployed Condition

Gap = 11.4 inch

Gap = 8.5 inch

Figure 7: The two states of the three fold airbag deployment configuration.

Figure 8: The deceleration pulse for the structure with 3fold airbag impact on to the rigid floor.

A fully deployed condition for the airbag before impact is obtained with a 11.5 inch gap between the fuselage and the ground. Under this condition a deceleration value of 13g is experienced.

Figure 8a: The deceleration pulse for the structure with 3fold airbag for a partially deployed condition impact on to rigid floor.

The 8.5 inch gap between the floor and the fuselage provides a partially deployed condition at the time of impact. A deceleration pulse of 26g is experienced. This deceleration process as experienced near the passenger seat would be less than half of what is experienced at the observed location of node 29596, which is located at the upper end of the bottom ribs for the center station. *The rigid floor impact on the passenger without any airbag would be approximately 26G. The 3fold fully deployed airbag condition reduces the deceleration peak to 6G, where the partial bag experiences a value of 13G.* Thus a safe deceleration peaks are experienced which can avoid hip injury and other shock trauma for the passenger.

We need to further investigate this ALAR issue in various ditching conditions. The fuselage is subjected to different surface conditions of water such as flat, sagging and hogging. These three situations of the ditching conditions of the structure are analyzed for with-bag and without-bag condition. Also the fluid is modelled in two different methods, such as the conventional formulation as well as the SPH formulation. Hence the twelve different cases where analyzed and presented. In the conventional method, where the solid elements were treated as the fluid, gives a stiffer solution without the realistic surface effects. *The surface effects are more closely captured by the SPH method*. But it provides a more softer solution than the real situation.

Ditching in Calm waters using Conventional method and sph method:

Conventional method:

Ditching in calm waters is shown in the following analysis. In this method the fluid is modelled as conventional hexa elements with fluid properties. Due to element restriction, the fluid is modelled with two segments of fine and coarse mesh. One segment in contact with the structure is modelled with fine mesh and the other segment with very coarse mesh. The two segments were connected togather by the friction contact with friction value of 1.0, this sticks togather without having to connect the meshes. This method of modelling is very suitable for the

Figure 9: The finite element model with fluid elements to simulate the ditching event in calm water (Flat fluid surface) condition.

studying of the fuselage structure with such a coarse mesh. It gives a conservative values for the fuselage stresses and strains.

The fuselage plastic strain contour is plotted in the following figure 10. The peak plastic strain is well within 1.5%. The disadvantage of this method is that it does not show the local deformation of the fluid surface. But it gives a very good upper bound estimate for the stresses and strain on the fuselage. To show the surface effects of the fluid a SPH method of analysis was used to model the fluid.

Figure 10: Effective plastic strain contour on the structure for the ditching in calm water analysis without the airbag system is shown in the figure.

The fuselage has a deformation of 1.5% as compared to 8.7% on the rigid floor. Hence the loading on the fuselage is much softer in water than on the rigid floors.

Figure 11: The deceleration pulse of the fuselage impact to flat fluid without airbag is shown in this figure.

A 140g pulse was observed without the bag on the calm water surfacein the conventional model.

Sph model:

To study the effects of the fluid structure interaction the sph model is used. The fluid is modelled as small spherical particle. A fine mesh is placed at the surface and a coarse mesh is used at the bottom. The same fluid properties are used as in the above model. The structure is subjected to a velocity of 25 ft/sec. The results are shown in the following figures.

Figure 12: SPH model for a calm water ditching of the fuselage without bag.

Figure 12a: Z-deceleration pulse for a calm water ditching of the fuselage without bag in SPH method.

The surface effects are well captured in this formulation. The plastic strains on the fuselage are very small. The surface effects does not increase the deceleration pulse on the fuselage. The deceleration pulse of 140g was observed with the conventional method and 10g was observed with the SPH method. This was as expected due to the modelling of the surface effects by the SPH method.

Ditching in Calm waters using Conventional method with airbag attached to the fuselage:

The fuselage model is added with an arrey of 3 fold airbag and tether. This system is subjected to the fluid in calm weather condition. The structure is subjected to a velocity of 25 ft/sec. The results of the event is given below.

Figure 13: The Ditching event with airbag deployment in the calm water.

Figure 14: The plastic strain contour on the hull for the ditching analysis with the airbag system.

The fuselage is subjected to an effective plastic strain of 1.2% in the flat fluid surface with airbag analysis. This gives the upper bound starin values for the fuselage. It remains well within the yield limit.

Ditching in Calm waters using SPH method with airbag attached to the fuselage:

The fuselage with the airbag ditching condition onto the calm water surface is simlated with the SPH method. This is done to capture the surface effects of the fluid. The deformation plot is shown in the following Figure 15.

Figure 15: The deformation plot of the fuselage detching with airbag deployment.

Compare to the deformation plot in Figure12 without airbag and the figure 15 with airbag shows a considerable surface perturbation due to the deployment of the bag.

Conventional Fluide element	SPH modelling

Figure 16: The deceleration pulse for the hull with airbag system in Conventional and SPH modelling on to flat fluid.

Figure 17: The velocity profile for the hull with airbag system.

Also it can be observed the deployment of airbag increases the downward velocity then it starts reducing due to resistance of the fluid. This shows a suction effect generated by the airbag deployment. The deceleration pulse between the SPH model and the conventional model were shown Figure 16. This shows the difference of modelling the surface effects. The comparison between the with and without bag show that the max deceleration pulse of 13g for both the cases in the SPH model. The difference between them were considerable such as 140g and 13g in the conventional model. This is due to the fluid surface was poorly represented in the conventional model as compared to the SPH method.

Ditching in waters with hogging surface condition using Conventional method without airbag:

Figure 18: Ditching event with hogging surface condition.

Figure 19: The plastic strain contour for the hull subjected to hogging surface without airbag systems.

The effective plastic strain on the hull without airbag was found to be 1.2%. The SPH model was shown below.

Figure 20: Deformation plot of the ditching under hogging condition.

Figure 20a: The velocity plot of the model in the hogging condition.

The plot shows a steady decrease of velocity without any reversal (suction condition) as found on the model with the airbag.

Figure 20b: The decelaration pulse for the hull without bag on to the hogging surface with SPH simulation is shown in the figure.

Ditching in waters with hogging surface condition using Conventional method with airbag:

The following setup shows a simulation of the structure with the bag in the hogging surface condition.

Figure 21: The ditching event with the hogging surface condition with airbag.

Ditching in waters with hogging surface condition using SPH method with airbag:

The model is analyzed with the SPH method to capute the surface effects in ditching condition . This enhanced modelling reduces the stresses on the fuselage components. As well as the surface deformations are captured to a very high level of accuracy. Even a very large conventional model may not produce this quality of deformation results.

Figure 22: The deceleration pulse for hogging surface with airbag SPH model.

Figure 23: The plastic strain contour for the hull in the hogging surface

Figure 24: The deceleration pulse for the hull in the hogging surface without any airbag systems.

Figure 25: The deceleration pulse for the hull in the hogging condition with the airbag systems.

Ditching in water under Sagging condition using Conventional method:

The next set of simulation shows the structure with and without airbag systems in the sagging surface condition.

Figure 26: The sagging surface condition for the ditching model without the airbag.

Figure 27: The plastic strain contour for the hull without airbag systems in sagging condition.

Figure 28: The Z-deceleration of the hull for sagging condition surface without airbag in SPH model.

Figure 29: The sagging surface condition for the ditching model with airbag systems.

Figure 30: The plastic strain contour for the the hull with airbag systems in sagging condition

Figure 31: The deceleration pulse for the hull in the sagging surface without any airbag systems.

Figure 32: The deceleration pulse for the hull in the sagging surface with airbag systems.

Figure 33: The Z-deceleration for the hull with sagging surface condition in SPH model.

	Rigid Floor	Rigid Floor With bag	Flat Fluid	Flat Fluid with bag	Sag Surface	Sag Surface with bag	Hog Surface	Hog Surface with bag
Conv Model deceleration in ft/sec^2	1500	400 to -400	5000 to -15000	0 to -15000	40	20 to -10	0 to -15000	0 to -15000
SPH Model deceleration in ft/sec^2			300 to -800 (34g)	300 to -300 (18.6g)	900 to -600 (46.5g)	200 to -150 (11g)	400 to -300 (22g)	400 to -800 (38g)
Eff. Plastic Strain in %	8.165%	0.128%	1.5%	1.2%	0.4%	0.005%	1.2%	1.1%

Table 1: The peaks of the deceleration pulse observed at node 29596 located at the lower mid section of the fuselage are shown in the table

The analysis show that the airbag deployment does not help the aircraft ditching in water. It is a good option for landing the craft on the ground. It reduces the permanent damage on the fuselage as well as dampens the vertical deceleration to increase the occupant safety. The SPH model has a lower values on the vertical deceleration pulse than the conventional FEM model due to its surface effects are modelled well in the SPH method.

RESULTS

The finite element analysis performed in the paper shows various significant results. The simulation of the ALAR event in the most condensed form shows various destructive results such as the hull gets a permanent damage and the deceleration pulse has several peaks of high value which can be harmful to the occupant. The results were tabulated in the table 1. The results in the table clearly show that the strain on the hull reduces for all the cases than the problem case where the hull gets damaged for the given impact condition. The second observation is that the system is subjected to significant reduction of the deceleration pulse due to airbag deployment, which improves the occupant protection in this sort of situation. The airbag is useful only for the cases of the hull impacting the land. It does not have much influence on the impact on the water. Hence the airbag can be deployed on the land condition and not on the water condition due to the reasons of maneuverability.

RECOMMENDATIONS

Thus the investigation shows that the addition of the airbag system greatly improves the chances of having an undamaged hull with a minimized or softened deceleration pulse. Both increase the occupant safety index for the given ALAR and ditching conditions. The front end of the airbag system needs to be designed for the aerodynamic conditions. The stream lined bag tends to minimize the drag on the aerodynamic flow as well as the stability of the craft will not be offset. An umbrella shaped airbag can be designed to handle this situation.

CONCLUSION

The analysis shows that the stiffness to mass ratio of the hull determines the deformation characteristics in this type of impact. A stiff model is chosen to demonstrate the airbag influence on the structure. The model did demonstrate a desired level of performance. The airbag deployment demonstrates a reduction in hull damage and smoothing of the hull deceleration pulse, which reduces various occupant injuries. It also reveals for the given hull configuration of stiffness to mass ratio, the deployment of the airbag is well suited for the landing on the ground and it is not very much required for the landing on the water condition. Hence the deployment can be manually aborted for the water landing.

FUTURE WORK

A more detailed and fine model can help us solve in determining the size of the bags and the tether required to keep them together. Once the bag is designed its packaging, triggering mechanisms and other logistics issues can be addressed.

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