Proceedings of the Cranfield Multi-Strand Conference: Creating Wealth Through Research and Innovation (CMC 2008): Cranfield University, 6-7 May 2008, Pages 244-254.

Characterising the level of crashworthiness for impacts on hard ground and water surfaces for a metallic helicopter under floor structure: What lessons can be learned?

K. Hughes

Crashworthiness, Impact and Structural Mechanics Group (CISM),
School of Engineering, Cranfield University, Cranfield, BEDS, MK43 0AL, UK

Abstract

Helicopters are seen by the petroleum industry as the only viable way of transportation between on and offshore platforms. At present, there exists no certification requirement to ensure a high level of survivability in the event of a water impact. Within the literature, there exists a body of information related to the post crash analysis of accident data, which supports the finding that a conventional metallic under floor design performs poorly during a water impact, in relation to the transmission of water pressure and the absorption of energy.

In order to characterise this behaviour, this paper concerns the crashworthiness of helicopters to two extremes in loading, namely hard ground and water surfaces, for an impact speed of 8ms^{-1}, for a simple box-beam construction common to metallic helicopters. The experimental findings were used to validate finite element simulations, with a view for assessing the level of crashworthiness currently offered, together with identifying potential design improvements. To improve the level of crashworthiness, careful redesign of frames, joints and skin is required, together with developing a passive next generation floor that can cater for both hard surface and water impacts, by being able to degrade its localised strength, depending upon the type of surface encountered.

1. Introduction

The earliest recorded work that investigates the effects of a man made object impacting on water can be traced back to 1929, where Von Karman developed the first theoretical model to calculate the forces encountered during rigid seaplane floats impacting onto water [1]. This approach utilised the concept of added mass, which was a difficult parameter to quantify, but provided a good starting point for developing understanding in this field, which was subsequently extended and adopted during later works.

In the early days of helicopter crashworthiness development, a small cross-section of experimental data was available. Typically, these were reviewed by separate agencies and the information was generally fragmented, making it difficult to identify potential design improvements, or amend current regulations.

This problem was first addressed in 1986 by providing a historical review of civil helicopter accidents occurring between 1974 and 1978, which was later followed by a review of US Navy and Army accidents in the same year [2, 3]. This was again reviewed in 1993 for helicopter ditchings onto water that occurred between 1982 and 1989. This was performed in two phases, where part I dealt with the analysis of the impact and post impact conditions [4], and part II provided an assessment of the structural response on occupant injury, the identification of ways of alleviating injury, together with an evaluation of current numerical techniques for modelling impacts onto water [5]. Several full-scale helicopter drop tests have also been performed in recent years in order to provide a greater understanding of the phenomena associated with fluid-structure interactions [6-9].

This research has identified that the water environment poses a unique design case, for which conventional designs perform poorly, in terms of transmitting the water pressure and the absorption of energy. The poor transmission of these loads, coupled with a high failure strength of the surrounding structure, means that frame collapse does not occur and high forces and accelerations are passed through the airframe. This in turn can lead to the distortion of the passenger floor and preventing the energy absorbing seats from operating effectively, through to the jamming or loss of the doors. A more serious problem concerns loss in floatation capability if skin integrity fails and the resulting internal damage that will occur.

This paper concerns the crashworthiness of helicopters onto water and provides a complete section-by-section analysis of a representative sub floor section that was dropped as part of an EU project (*CAST*, whose aim was to develop simulation tools and a design methodology that will permit cost effective design and entry into service of crashworthy helicopters for impacts onto both ground and water [9].

This paper is split into two parts, with the first providing a description of the test facilities, the choice of boundary conditions and the instrumentation applied to the structure, and the second part will provide a detailed classification of the different failure modes observed. The assessment of the crashworthy response will enable limitations to be identified, which will have a profound impact on future metallic helicopter design and significantly improve occupant survivability during an impact on water. For further information, the reader is directed towards reference [10].

2. Helicopter crashworthiness

Due to the facilities available within CAST, a novel and dedicated instrumented experimental campaign was performed to investigate water impact phenomena, ranging from material and joint testing, right through to helicopter sub structure and full-scale helicopter drop tests onto hard and water surfaces. A Westland WG30 helicopter was supplied by Agusta-Westland, as this airframe was considered to be typical of a metallic design. Two sections of floor were cut from the main passenger section, which saw the aft section sent to the water impact facility at CIRA, Italy, and the forward section to Eurocopter Deutschland who performed the hard surface drop test, as shown in figure 1.

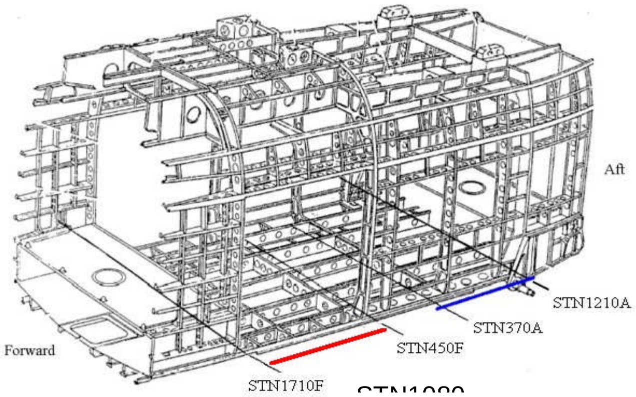

Figure 1 Location of the component sub floors in relation to the main passenger section of the WG30

3. Hard surface drop test

This section of floor was cut between STN1710F and 450F, which is located in the forward part of the main passenger section and corresponds to the full width of the port and starboard doors. This component weighed 44kg and was 2.25m wide, 1.26m long and 0.165m high. This section was chosen to investigate the damage that occurs where the main lift frames are directly attached, together with incorporating the influence of at least one other major cross-member. The floor is primarily constructed from aluminium 2014-T6, whilst the passenger floor is constructed from a fibrelam composite.

The floor was dropped via a guided descent at 8ms^{-1}, to which a 1 ton ballast plate was added. Instrumentation included eight accelerometers positioned on the main longitudinal frames, together with strain gauges and three force transducers. The main features of damage can be found in figure 2, where the passenger floor has been removed for clarity. As can be seen, all the frames contribute to energy absorption, as failure in the form of hinge lines in both transverse and longitudinal frames is observed. The skin plays no part in the energy absorbing process. Good agreement was obtained for the locations of frame collapse and force-time histories with the numerical results. The existing structure is capable of absorbing the impact energy, but achieves this in an inefficient manner due to the limited use of the available stroke.

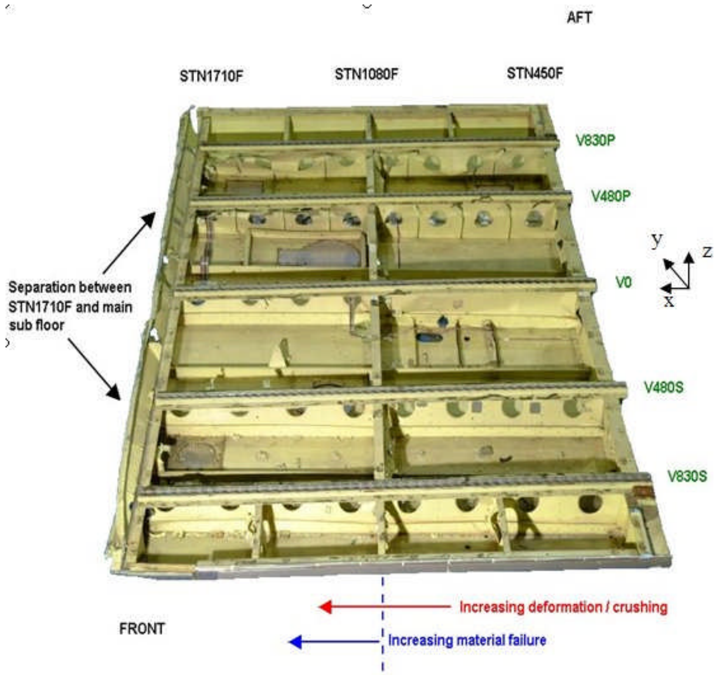

Figure 2 Overall view of the post test specimen, where the floor has been removed for clarity

4. Water drop test

This under floor construction is based upon simple box-beams and was cut between STN370A and 1210A, resulting in a floor with a mass of 41 kg, with dimensions 2170mm wide, 970mm long and 163mm high. An 8ms^{-1} guided descent was performed via a trolley assembly, to which ballast of 600kg was applied through 18 seat rail attachment points in order to represent the lift frames, seats and passengers.

The post impact specimen can be found in figure 3, where the passenger floor has been removed for clarity. As can be seen, the floor retains its global integrity, as the main longitudinal frames remain undamaged, with the skin deflecting quite significantly in between these longitudinal frames. There are two main locations of skin and rivet failure, which would result in the ingress of water and the resulting secondary damage. The curved end sections remain relatively undamaged, as their shape minimises loading at these locations, due to the redirection of the water.

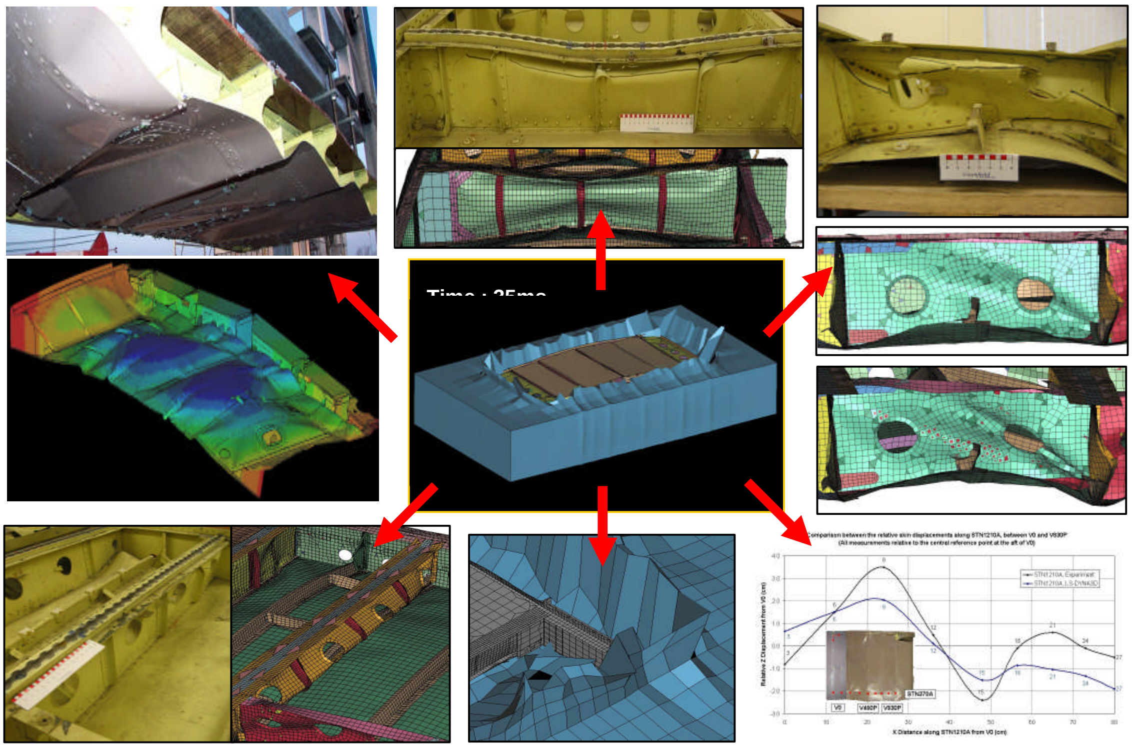

Figure 3 The finite element analysis allowed detailed comparisons with experiment for hinge location, skin deformation and collapsed height of the frames

To recreate numerically, a purely Lagrangian approach was used. The code was able to predict a representative response when compared to test, as good agreement for limited frame collapse, the deflections of the skin (within 10% of test), together with the locations of potential skin failure. Limited joint collapse is predicted, which is also consistent with test. The skin deflects in-between the frames, causing localised material and rivet failure, in the form of tensile pull-out from the surrounding frames.

4. Design Limitations

The key issues for developing helicopter crashworthiness for impacts on both hard ground and water surfaces depend upon developing a passive energy absorbing structure that incorporates the following recommendations;

a. Reduce failure strength of the existing design

The first observation concerns limited utilisation of the available frame stroke, so consideration should be given to frame construction to ensure progressive collapse through the careful selection of geometry, material type and possible inclusion of a trigger, and the second is through the redesign of the joints, as progressive joint failure will be critical in order to allow for increased and controlled frame collapse.

The current metallic design has been developed based upon hard ground crash regulations, so the structure has been designed to collapse at relatively higher loads than are typically encountered during a water impact, which are insufficient to trigger frame collapse. Reducing the failure strength of the existing design is a difficult engineering problem, as if the strength of the structure is too low, this will result in a degradation in performance during a hard surface impact.

b. Development of skin

During a water impact, the dominant membrane behaviour of the skin is the only mechanism to transfer the water pressure to other energy absorbing components. Therefore, skin integrity is essential if the loads generated are to be transferred to enable frame collapse to occur, without the skin failing. This in turn will increase the floatation capabilities and post impact survivability for the occupants. Therefore, the deflection of the skin needs to be encouraged, as this forms a significant passive energy absorber during an impact on water. This will require a move away from conventional metallic skins towards the use of composite materials.

5. Conclusions

The experimental and numerical results have demonstrated that a water impact is a critical design scenario, where crash requirements from both hard and soft surfaces must be taken into account during the preliminary design phase.

To improve the crashworthy response on water requires an improvement in the membrane behaviour of the skin in order to utilise the infinite stroke offered by the water, together with incorporating a dual failure mode capability for the surrounding structure that can degrade its strength depending upon the type of surface impacted. This will lead to a next generation under floor structure that offers improved crash protection for occupants and crew.

6. References

[1] Von Karman, Th. The impact of seaplane floats during landing, NACA Technical Note 321, October 1929

[2] Coltman, J.W., Neri, L.M., Analysis of US civil rotorcraft accidents for development of improved design criteria, National specialists meeting on crashworthy design of rotorcraft, American Helicopter Society, 1986

[3] Coltman, J.W., Domzalski, L., Arndt, S.M., Evaluation of the crash environment for US Navy helicopters……the hazards and Navy response, National specialists meeting on crashworthy design of rotorcraft, American Helicopter Society, Atlanta, Georgia, 1986

[4] Chen, C.C.T., Muller, M., Fogary, K.M., Rotorcraft ditchings and water related impacts that occurred from 1982 to 1989 – Phase I, US Department of Transportation, FAA Technical Center, Atlantic City, DOT/FAA/CT-92/13, October, 1993

[5] Muller, M., Rotorcraft ditchings and water related impacts that occurred from 1982 to 1989 – Phase II, US Department of Transportation, FAA Technical Center, Atlantic City, DOT/FAA/CT-92/14, October, 1993

[6] Fasanella, E.L., Jackson, K.E., Lyle, K.H., Finite element simulation of a full scale crash test of a composite helicopter, AHS 56th Annual Forum, Virginia, USA, 2000

[7] Wittlin, G., Smith, M., Sareen, A., Richards, M., Airframe water impact analysis using a combined MSC/DYTRAN – DRI/KRASH approach, AHS 53rd Annual Forum, Virginia Beach, Virginia, April 29- May 1, 1997

[8] Wittlin, G., Schultz, M., Smith, M.R., Rotary wing aircraft water impact test and analyses correlation, AHS 56th Annual Forum, Virginia, USA, May 2-4, 2000

[9] CAST – Crashworthiness of Helicopters onto Water – Design of Structures using Advanced Simulation Tools, funded by the European Community under the "Competitive and Sustainable Growth" programme (Contract G4RD-CT1999-0172), 2000-2003.

[10] Hughes, K, Application of improved Lagrangian techniques for helicopter crashworthiness on water. *Phd Thesis*, Cranfield University, 2005

Characterising the level of crashworthiness for impacts on hard ground and water surfaces for a metallic helicopter under floor structure: What lessons can be learned?

Hughes, Kevin

2008-05-07T00:00:00Z

http://dspace.lib.cranfield.ac.uk/handle/1826/5671