NEW FLOATATION DEVICES TO AVOID HELICOPTERS' TOTAL INVERSION AFTER CAPSIZE

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ABSTRACT

Additional floatation devices in order to prevent the total inversion of the helicopter after a capsize event are presented in this article. Two solutions are studied: foam-filled cowling panels attached to the upper fairing of the helicopter, and floats placed above the cabin walls. The efficiency of the systems is investigated by means of model tests, and the technical feasibility is studied for the Super Puma EC225.

Keywords: *Helicopter ditching, capsize, crashworthiness*

1. INTRODUCTION

Helicopters operating over water should be equipped with an Emergency Floatation System (EFS) in order to ensure the passengers' safe escape in life rafts. It consists in 2 or 4 inflatable floats which are deployed when ditching in order to ensure that the helicopter remains up-right in the water during the evacuation time. However, due to its high centre of gravity, the helicopter can capsize. In this case, drowning has been identified in previous studies to be the main cause of death (CAA paper 2005/06 on helicopter ditching and crashworthiness, reports DOT/FAT/CT-92/13 and DOT/FAT/CT-92/14).

In order to prevent it, researches are conducted on the possible addition of EFS in the upper part of the helicopter. With it, the capsized helicopter does not float totally inverted, but with an inclined position allowing the escape on one side, and guarantying an important presence of air inside the cabin.

In 1995, 10 solutions have been proposed and analysed in a BMT Offshore report. Three of them were retained and tested in model basin for the helicopter Westland EH101 (figure 1 to 3).

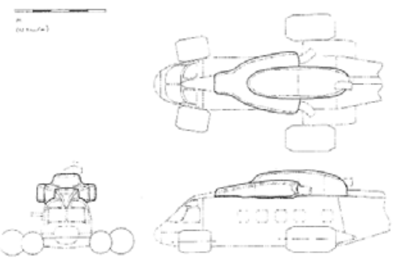

Figure 1. Foam-filled engine cowling panels.

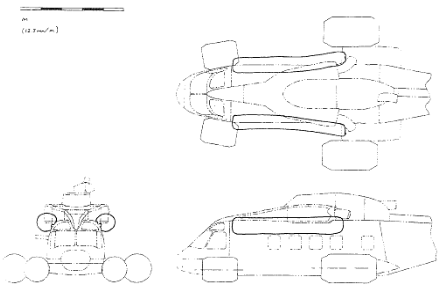

Figure 2. Long buoyancy bags along upper cabine.

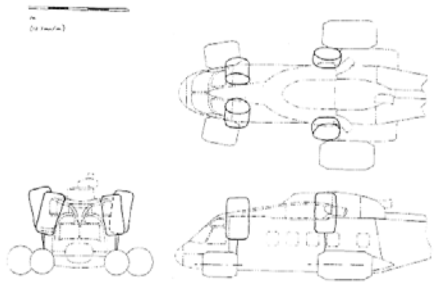

Figure 3. Tethered inflatable floatation units.

The first two solutions were found to provide the best results in terms of evacuation possibilities. Their design is studied here for the EC225 since it is the most common helicopter operating in the North Sea offshore industry.

2. DESIGN OF AN ADDITIONAL EFS

2.1 Design objectives

For the side-floating concept (without standard EFS failure), the design objective should be for the helicopter to have all its windows on one side above the water level with the lowest part of the window (the top if the helicopter is rolled more than 90°) at water level, and the air gap has to be sufficient for a full load of passengers. This is illustrated in figure 4.

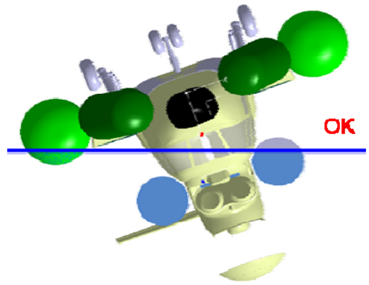

Figure 4. Illustration of the design objective.

2.2 Hypothesis of the study

When designing the standard EFS, a special care is paid to the watertight elements in the lowest part of the structure. For the additional EFS, the watertight elements in the upper part should be identified. For the EC225, approximately 1500L have been found, especially in the main gear box, the upper panels and hydraulics elements in this zone. It does not include the blades volume since they can break during the capsize process.

The most critical mass and centre of gravity configurations should be identified. The lightest helicopter load case, with the highest centre of gravity (AV3) and the one at maximum mass (AV1) will be studied. For the heaviest aircraft, the passengers mass is subtracted. The righting moment curves for both configurations are plotted in figure 5.

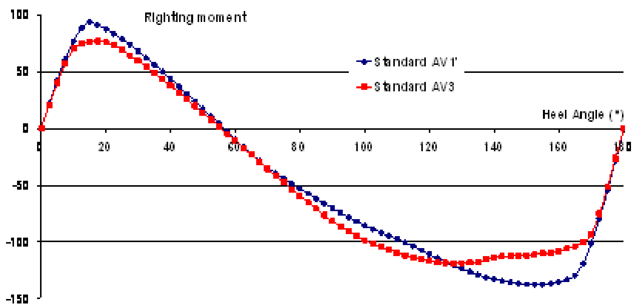

Figure 5. Righting moment curves for the heaviest (red) and lightest (blue) mass configurations.

3. STUDIED SOLUTIONS

The addition of only foam filled cowling panels could not lead to the wanted inclined equilibrium position. As a consequence, mixed solutions between foam filled cowling panels and cabin wall floats have been selected for model testing. Two of them present additional buoyant elements only on one side of the helicopter.

Six different configurations have been identified for model testing:

C1. Helicopter with no additional buoyancy (for comparison)

C2. Upper floats on one side of the helicopter. Floats volume = 4600L

C3. Upper floats on both sides of the helicopter. Floats volume = 7550L

C4. Upper floats on both sides of the helicopter. Floats volume = 6660L

C5. Foam filled cowling panels + floats on one side. Volume = 5490L

C6. Foam filled cowling panels + floats on both sides. Volume = 7520L

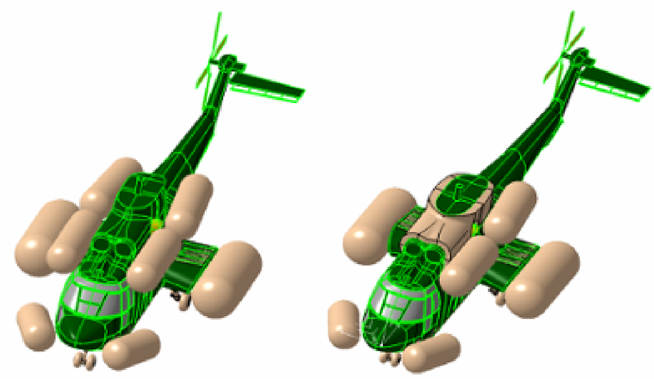

Figure 6. EFS configurations 3 (left) and 5 (right).

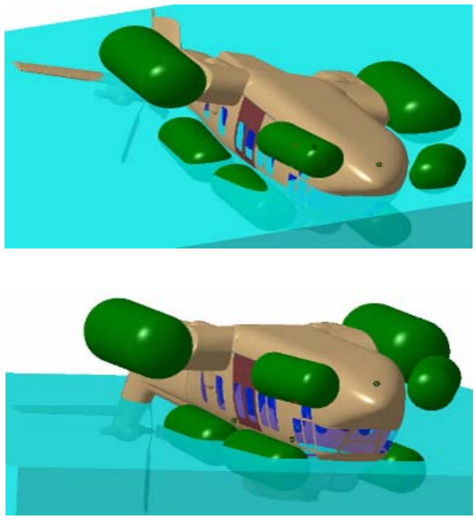

Figure 7. EFS configurations C3. Equilibrium positions for load cases AV1 (top) and AV3 (bottom).

For each configuration, the equilibrium position of the capsized helicopter is found for a heel angle between 150° and 160° for the load case AV1. For the lightest load case AV3, if there are floats on both sides, the buoyancy produced by the only additional EFS is sufficient to make the helicopter floating, as illustrated in figure 7 for the EFS configuration C3.

The stability of these positions is evaluated through the righting moment curves. For non-symmetric position of the floats, they should be plotted between -180° and 180°. Anti-symmetric solutions present the advantage to have only one “capsized” equilibrium position. No oscillation between two positions is there possible, whereas it can happen for the symmetric configurations. This is illustrated by righting moment curves, plotted in figure 8 for EFS configurations C5 and C6 (load case AV1).

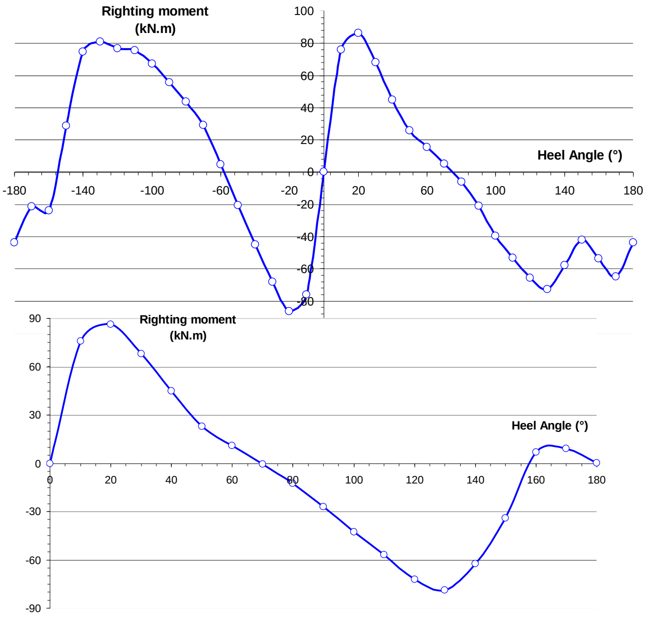

Figure 8. Righting moment curves for EFS configuration 5 (top) and 6 (bottom).

4. MODEL TESTS

4.1 Experimental set-up

Model tests of the 6 presented configurations were performed at scale 1:14, in irregular waves (JONSWAP spectra, sea sates 3 and 5). The objective was to evaluate the stability of the inverted inclined positions, and the possibility for the passengers to escape.

Foam was placed inside the model in order to correctly represent the inherent buoyancy of the helicopter in its up-right position as well as in the inverted position. Blades were not modelled.

The model was inverted prior to launch the waves, the water having penetrated in all the floodable parts. It was orientated perpendicularly to the waves' propagation direction, with the emerged windows facing and opposed to the incoming waves. Tests were performed with closed and open doors in order to evaluate the influence of the water sloshing inside the cabin.

2 videos cameras, mounted on the carriage, followed registered the helicopter motion. After each run, an evaluation of the water level on the windows was done. The windows were numbered as shown in figure 9.

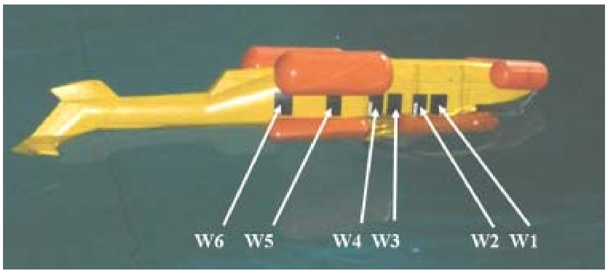

Figure 9. Inverted model in waves.

4.2 Results

The following conclusions could be drawn from the model tests:

- Windows W1 and W2 are the mot commonly submerged due to the position of the helicopter with its nose down in the water. Conversely, windows W5 and W6 have been found to be the driest in waves.

- When the windows above the waterline face the oncoming waves, they can be submerged directly by the waves when they arrive. When the windows above the waterline are opposed to the incoming waves, they can be submerged just after a wave crest. There, the helicopter move down and the water can pass between the floats and the fuselage and submerge the windows.

  For the asymmetrical configurations C2 and C5, the highest percentages of the windows that have been submerged

during the run is greater with windows above the waterline opposed to the wave. For the symmetrical configuration C3 and C6, the percentage is greater with windows above the waterline facing the waves. No significant difference was observed for configuration C4.
The differences between both positions were found in all the cases to be little.

- All the configurations showed a good efficiency for the lightest helicopter (load case AV3)

- Configuration 4 (symmetrical floats) has been found to be unstable i.e. the helicopter can go from one inclined position to the symmetrical one on the other side.

- Configurations with buoyancy attached to the cowling panels have been found to be the most efficient with respect to stability and windows above the waterline. At equivalent total buoyancy, this is due to the fact that the buoyant elements are in these cases further from the centre of gravity.

- Configurations C5 and C6 showed their ability even with a damaged float i.e. a float with reduced volume corresponding to the puncture of one compartment.

- The doors' opening has not been found to be an issue for the behaviour of the inverted helicopter.

4.3 "Crash" cases

If the ditching is not controlled, there is higher possibility to damage the standard floats at the impact. In those cases, the upper EFS could provide buoyancy redundancy and passengers escape remain possible.

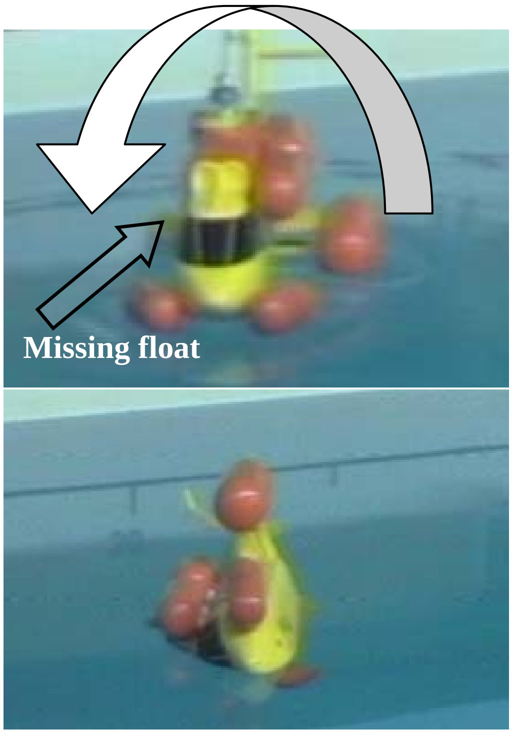

Figure 10. Impact without one the standard rear starboard float for configuration C5.

To reproduce those scenarii, tests have been performed for configurations C5 and C6 dropping the model without one of the rear standard floats. The model was then tested in waves to observe the behaviour of those positions.

For configuration C5, removing the standard rear starboard float, the helicopter stabilises with a heel angle of about 90° with all the port windows clear (figure 10). Approximately half the cabin is above the waterline. Once in waves, the windows are periodically submerged by the water, but the helicopter remains in this 90° position.

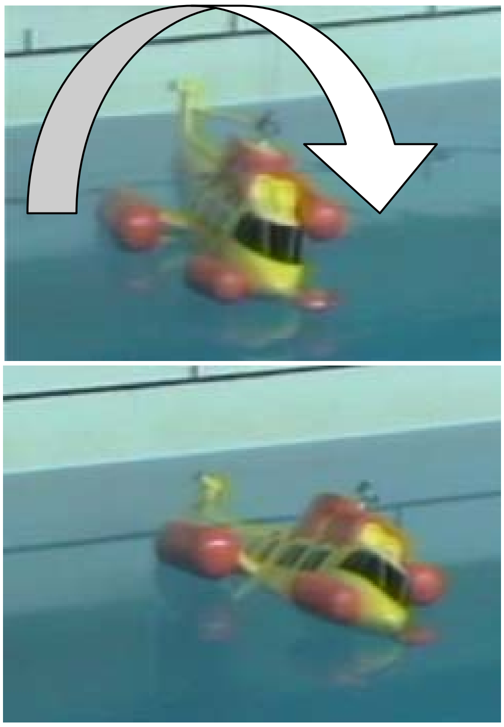

Figure 11. Impact without one the standard rear port float for configuration 5.

Removing the port rear starboard float (figure 11), the helicopter stabilises with a heel angle of about 45° with all the starboard windows clear. Approximately half the cabin is above the waterline. As for the previous configuration, in waves, the windows are periodically submerged, but the helicopter remains in the same position.

For configuration 6, due to the symmetry of the upper floats, to remove the port or starboard side float is equivalent. The result is similar to the previous case for configuration C5; the helicopter stabilises with approximately a heel angle of 45° and remains in this position in waves, with the windows periodically submerged.

Both configurations C5 and C6 presents acceptable floatation levels when one of the standard float is removed, showing the gain obtained by providing buoyancy redundancy. However, configuration C6 stabilises at a 45° position with more airspace in the cabin than the 90° position, whatever the side of the removed float. In waves, the windows are submerged, but the helicopter stays in a position for which egress would be possible.

5. TECHNICAL FEASIBILITY

The identified constraints for the integration of such EFS on a EC225 are the following:

- Temperatures
- Interaction with blades
- Emergency exits clear
- Aerodynamics impact
- Inadvertent deployment
- Compatibility with other equipments
- Fixation and loads on the structure
- Location of the bottles
- Access to the upper deck
- Fairings opening
- Retro-fit

5.1 Position and size of the floats

In the case of the EC225, the engines nozzles are located on both sides of the helicopter, longitudinally near the rotor position, as illustrated in figure 12. For this reason, two floats are necessary on each side of the helicopter.

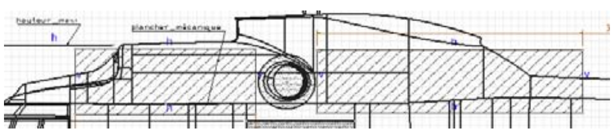

Figure 12. Nozzle location on an EC225.

Then, the floats should not block the exits nor interact with the blades. This gives a spatial delimitation for the floats. It is more restrictive in the front part of the helicopter. This is why the upper EFS lacks of buoyancy in the front part and once inverted, the helicopter tends to nose down in the water.

5.2 Proposed positioning of the upper floats

Figure 13 shows a proposed technical solution for the positioning of the upper floats.

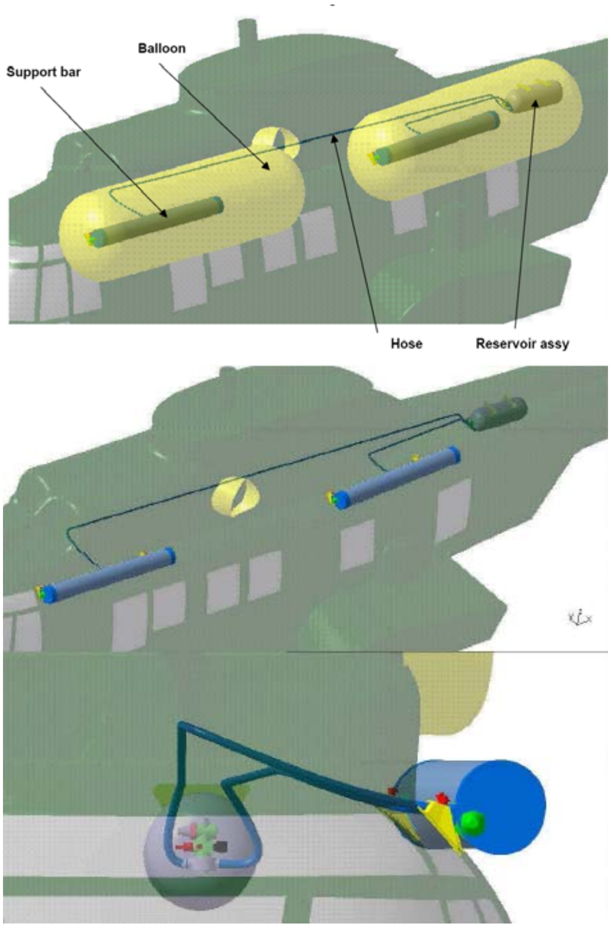

Figure 13. Integration of upper EFS on a EC225.

The system should be removable in order to be compatible with the opening of the cowling panels and should have the necessary degrees of freedom to allow retrofit.

5.3 Temperature constraint

The usual environmental conditions for qualification of EFS equipment range from -40°C to +70°C in operation and -55°C to +85°C in storage. In the region of the engine nozzle, temperatures up to 200°C can be found.

No standard floats currently installed on Eurocopter rotorcrafts are able to sustain those temperatures.

The main path toward a solution would be in defining/developing a float fabric that could handle the temperature requirements. Others studies could be lead in different ways:

- Thermal protection for packed EFS
- Thermal protection for inflated EFS
- Float fabric able to handle high temperatures in packed configuration
- Float fabric able to handle high temperatures when float inflated

5.4 Aerodynamic impact

The installation of upper floats would lead, from an aerodynamics point of view, to a mass impact of 100kg, or a range penalty of 50km.

Concerning the foam filled cowling panels, complementary studies are needed since the shape of the panels influences the rotor efficiency.

5.5 Mass impact

For the configurations C5 and C6, the mass impact has been evaluated to 150kg for the asymmetric floats configuration, and 200kg for the symmetric floats configuration.

These values do not take into account the possible resort to new materials for the floats that could increase the total mass impact of the system.

5.6 Deployment

The inflation of additional EFS could be done at three different moments: in flight, after ditching or after capsize. It could be done manually or automatically via water sensors.

The consequence of inadvertent deployment of the upper floats on the safety of the helicopter must consider the effects on helicopter handling qualities, stability and control and the further consequences of a float becoming detached and/or torn and subsequent entanglement with flight control components or rotating parts. More over, the possible burn of the floats should be envisaged in this case. Since no elements are today available to conclude on the effect of an unintentional deployment of the upper floats while flying, an inadvertent deployment must be considered a catastrophic event. Consequently, a 10-9 probability of inadvertent deployment should be the design and certification objective.

5.7 Other compatibility issues

The technical solution proposed for the upper floats is incompatible with the hoist installation, and does not allow a complete opening of the upper fairings. An improvement of the installation is needed to ensure theses compatibilities.

The life rafts in an EC225 are located in the winglets and can be activated through a handle in the cockpit, through a handle in the fuselage and directly on the liferaft container.

They are designed for the upright helicopter. If inverted with an inclined position, one liferaft is under the water level and the other one above the water. Their correct deployment is not guarantied. The one under water can be blocked while inflating; the one above the waterline could be inverted after deployment.

Tests at full scale should be performed in order to determinate the deployment of the life raft from the inverted helicopter.

Handles inside the cabin should be installed in order to facilitate passengers egress in the inclined position. A modelling of the cabin in the inclined position is needed to perform an ergonomic study of the evacuation for the selected configuration.

6. CONCLUSIONS & FUTURE WORKS

Among the different configurations of additional EFS for the EC225 presented in this work, the one preferred by EUROCOPTER is the configuration C6 i.e. the one with 1500L foam-filled cowling panels and two floats on each side. The reasons are the following:

- The model test campaign showed the better behaviour of the additional EFS configurations with foam-filled cowling panels together with symmetrical and asymmetrical floats.
- Floats in the upper part of the machine present risks due to the environment and the vicinity to the blades. The presence of foam filled cowling panel allows reducing the floats volume. The risks of floats damaged are therefore reduced.
- However, the foam-filled cowling panels can affect the engine and rotor performance. In this study, their thickness has been limited to 10cm.
- The symmetrical solution is preferred to the asymmetrical one for the following reasons:
  - Floats on one side have lower volume with a symmetrical configuration.
  - The inclined position with a symmetrical configuration is higher in the water, with more airspace inside the cabin.
  - An asymmetrical configuration implies that there is a different level of safety depending on the side of the helicopter.
  - Better redundancy in cases of water impact with floats damage with a symmetrical configuration.

The integration of additional EFS has been studied for the EC225, presenting a technical solution for cabin wall floats. The following conclusions can be drawn from the integration study:

- Temperature constraints need further developments to be solved. Emergency floatation balloon technologies compliant with the thermal constraints are not yet available.
- Safety analysis leads to a catastrophic event. It is a challenge to effectively reach 10-9 probability of inadvertent deployment.
- Weight penalty of additional EFS is greater than 2 passengers.
- A complete new design of the cowling panels and the gas exhaust would be mandatory, as well as the influence on the rotor performance.
- The presented implementation is not compatible with other equipments (hoist).

Further developments are needed in order to go ahead with the integration of additional EFS in the helicopter.

- Developments of new tissues fabric due to the high temperatures in the upper part of the helicopter
- An analysis, by modelling, of the interaction between the blades and the floats in the upper part of the helicopters at ditching.
- Evaluation of the blades' break possibility when the helicopter capsizes and the consequences for both standard and additional EFS.
- Aerodynamic study with the new cowling panels.
- Modelling of the inside of the cabin for ergonomic study of the egress in the inclined position.
- Life rafts deployment for both upright and inverted positions.

7. ACKNOWLEDMENTS

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