HELICOPTER TRANSPORTATION AS A SLING LOAD WITH ANOTHER ROTORCRAFT: DYNAMIC BEHAVIOR STUDY AND STABILIZING PARACHUTE SIZING

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Abstract

This paper details a novel methodology for determining parachute dimensions to ensure stable sling load operations between two rotorcrafts. We present a comprehensive approach encompassing analytical and multibody dynamic modelling to address the critical challenge of maintaining stability during this complex operation. Initially, we analytically evaluated the neutral yaw static stability of the carried helicopter fuselage, vertical tail, and parachute, establishing an initial parachute area estimation. Subsequently, a single-degree-of-freedom dynamic system (yaw motion only) was employed to validate these results. A detailed multibody model simulating the complete system – including the carrier and transported rotorcrafts with the stabilizing parachute – was developed to account for environmental factors, cable lengths, and inter-axis coupling effects. Furthermore, the dynamic behavior of the transported helicopter without the parachute was assessed. Finally, structural load calculations, adhering to CS-29.865 (Ref. 1), were performed to determine the forces acting on the system, ensuring safe operational parameters.

1. NOTATION

Symbols

α	Angle of attack, deg
β	Angle of sideslip, deg
θ_1	Rope Angle, deg
θ_2	A/C Angle, deg
ρ	Air Density, kg/m^3
Ψ	Psi, Yaw Attitude, deg
Cn	Aerodynamic Yaw Moment Coefficient
C_y	Lateral Aerodynamic Coefficient
e	Distance from transporting rope attachment point to barycenter, m
F_a	Aerodynamic force, N
I_{xx}	A/C roll inertia, kg m^2
l	Rope Length, m
L	Reference Length, m
m	A/C mass, kg
Mz	Yaw Moment, Nm
S	Reference Surface, m^2
$S(t)$	Transporting A/C motion, m
V	Airspeed, m/s

Acronyms:

1-DOF	One Degree of Freedom
AoA	Angle of Attack
CD	Aerodynamic Drag Coefficient
CFD	Computational Fluid Dynamic
CL	Aerodynamic Lift Coefficient
CM	Aerodynamic Moment Coefficient
CS	Certification Specifications
FPA	Flat Plate Area
HC	(Transported) Helicopter
HD	Density Altitude
HT	Horizontal Tailplane
IAS	Indicated Airspeed

ISA	International Standard Atmosphere
RC	Rotorcraft Carrier
SFBM	Shear Force and Bending Moment
SL	Sea Level
VT	Vertical Tail
WRT	With Respect To

2. INTRODUCTION

In the event of a critical helicopter failure, rapid recovery and return-to-service are paramount. While conventional rescue methods often rely on ground support and specialized equipment, a potentially viable strategy involves utilizing a second rotorcraft to transport the damaged one as a sling load.

This scenario, though complex, presents an avenue for retrieving damaged vehicles to facilitate essential repairs and return to service. While the dynamics of other external load item transportation is a topic widely explored in the literature, the peculiar case discussed in this paper has not been previously tackled accordingly to authors' best knowledge.

This paper investigates the dynamic behavior and stabilization requirements associated with such "sling load" operation, specifically focusing on the sizing of a stabilizing parachute and the structural load analysis of the transported helicopter.

To facilitate this unconventional transport, a significant reduction in the carried helicopter aerodynamic profile is necessary. This involves the strategic removal of critical components including the main and tail rotor blades, as well as essential aerodynamic surfaces such as the tailplane and a portion of the vertical fin. Furthermore, the connection mechanism between the two rotorcrafts necessitates the utilization of the main rotor hub for cable attachment, and the vertical tail is employed for the parachute deployment system.

This complex process introduces several unique challenges. The potential dynamic instability of both the carrier and transported helicopters presents a primary concern. Moreover, the transported helicopter's structural components, not originally designed for sling-load operations, are subjected to unprecedented stress levels. Therefore, this study addresses these issues through a multi-disciplinary approach. Specifically, we illustrate a robust methodology for determining the optimal size of a stabilizing parachute designed to mitigate oscillations during transportation. Simultaneously, we conduct a dynamic behavior analysis of the transported helicopter without the stabilizing parachute. Finally, we assess the structural loads experienced by the transported helicopter components according to the CS-29.865 (Ref. 1) standard, providing critical data for component design and ensuring structural integrity during the sling load operation.

3. TRANSPORTATION CONFIGURATION

3.1. Helicopter's Configuration

This section details the specific configuration adopted for the transported helicopter (HC), a critical element enabling its transportability as a sling load utilizing another rotorcraft. The core principle behind this configuration is ensuring a safe transportation and the integration of a dedicated support system for the stabilizing parachute.

The transported helicopter's transportability in flight is enabled by a radical simplification of its primary flight components. Specifically, the main and tail rotor blades are entirely removed. The rotor hub, acting as a robust anchor point, is utilized to connect a high-strength cable to the rotorcraft carrier (RC).

Furthermore, the horizontal tailplane and part of the vertical fin trailing edge have been removed (reducing its functionality of about 50%) in order to create a dedicated support system to accommodate the installation of the stabilizing parachute.

The configuration can be seen in Figure 1.

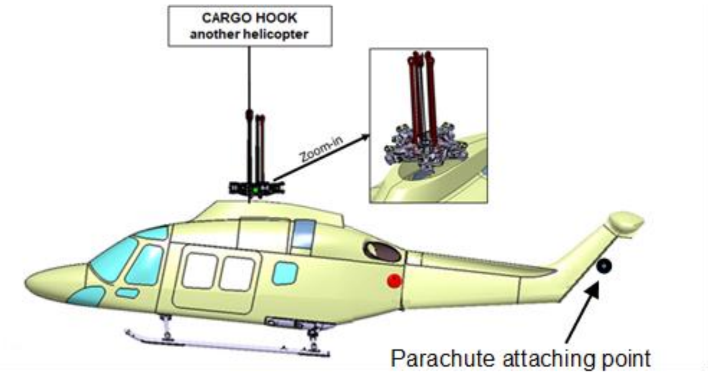


Figure 1 Helicopter's configuration for transportation as a sling load.

3.2. Aerodynamic Assessment for Cables Length

In order to evaluate the interference developed downstream of the transported helicopter, and therefore the actual dynamic pressure acting on the directional parachute, a CFD simulation is performed considering the configuration described in the previous subsection.

The computational domain is composed by a surface mesh of about 4M elements (maximum size of 30mm for non-lifting surfaces, and 20mm for lifting surfaces), and the volume mesh of 8 prism layers with a 40% last ratio growth model (10M cells), employing a Wall Function approach, plus a hexahedral/tetrahedral volume mesh (inner domain 40M cells; outer domain 2M cells). The domain, shown in Figure 2, is represented by a cubic volume which, in turn, includes a spherical subdomain, a non-conformal interface connecting the two fluid zones.

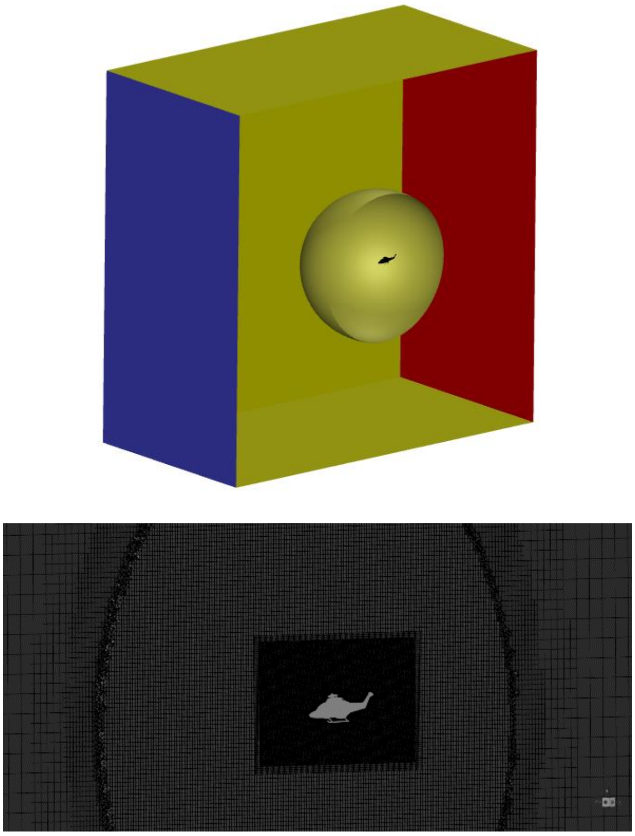


Figure 2 CFD Domain and Mesh.

The Reynolds-Averaged Navier-Stokes (RANS) equations are solved using Ansys Fluent 2023R2, employing the k-ω SST (Shear Stress Transport) two-equation turbulence model. Pressure and velocity were coupled, and second-order upwind schemes were applied to discretize variables such as density, momentum, and energy. The fluid was modeled as an ideal gas with viscosity described by Sutherland's law.

The CFD simulation condition performed for the Cable Length sizing is: $V = 100kts$, $\alpha = 0deg$, $\beta = 0deg$.

Figure 3 shows velocity streamlines and YZ section planes located at three different distances from the helicopter. Scanplane contours highlights the loss of dynamic pressure caused by the wake arising from the fuselage body. The parachute cable, therefore, will be sized with a length equal to the distance for which a reduction in dynamic pressure in the parachute area is considered acceptable (e.g. Figure 3 (bottom) represents a $q_{loss} = 0.95$) (Ref. 2).

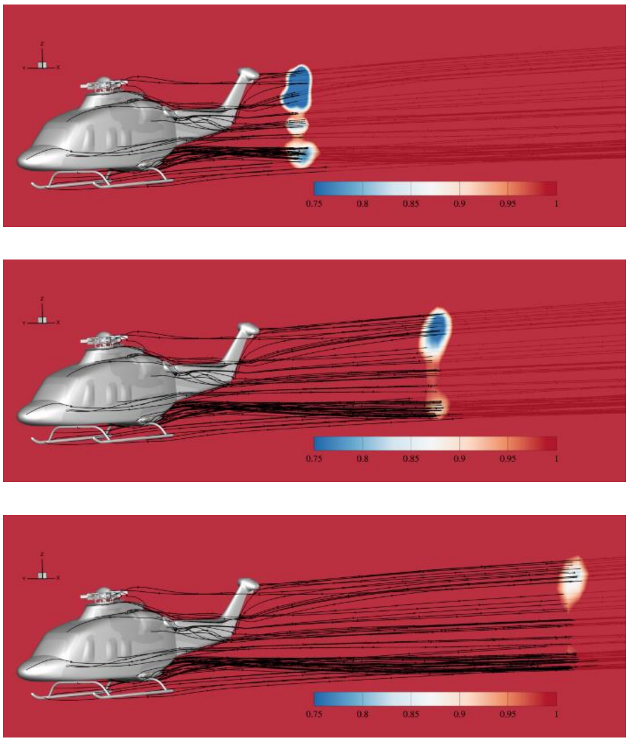


Figure 3 Streamlines Velocity and Dynamic Pressure Scan plane per Distance from the Helicopter.

3.3. Parachute Modelling

Since the major effect of the parachute, due to its intrinsic characteristics, is to provide drag (which in this case has a stabilization function), it has been modelled as an FPA (Flat Plate Area). Therefore, it has been assumed to be representative to assign zero values for any AoA for CL and CM, while the CD has a value equal to one or almost one. In fact, over a range of AoA between ±8 deg, the CD assumes the value of 0.95. This phenomenon has been estimated from aerodynamic investigation and it is due to the transported HC fuselage interference on the parachute, which decreases the dynamic pressure acting on the FPA of ~5%, as described in Section 3.2.

4. STABILIZING PARACHUTE SIZING

4.1. Neutral Yaw Static Stability Assessment

An initial estimation of parachute area can be achieved through a neutral yaw static stability assessment, considering only the transported helicopter's system. For the specific configuration of the HC and its associated degraded vertical fin, a simple approach dictates that static neutral yaw stability is achieved by setting to zero the sum of all yaw moments Mz. This is represented by the equation:

$$M_{z\,FUS} + M_{z\,FIN} + M_{z\,CHUTE} = 0$$

Where Mz represents the yaw moment, and is calculated as (Ref. 3):

$$M_z = \frac{1}{2}\rho V^2 L\, S\, Cn;$$

Here, ρ is the air density, V is the free stream velocity, L is the moment arm, S is the aerodynamic reference surface, and Cn is the aerodynamic yaw moment coefficient. L, S and Cn are referred to the body considered (HC fuselage, vertical fin and the parachute).

This equation provides a foundation for the initial parachute area sizing. In fact, given that all other parameters are known, the parachute area is the only variable remaining to be determined.

To facilitate this analysis, a local aerodynamic linearization of the HC fuselage and vertical fin was employed, as detailed in Figure 4 and Figure 5. This linearization enables a simplified analysis of the aerodynamic forces and moments acting on the aircraft during static conditions. The subsequent calculation of the parachute area then proceeds based on this linearized representation.

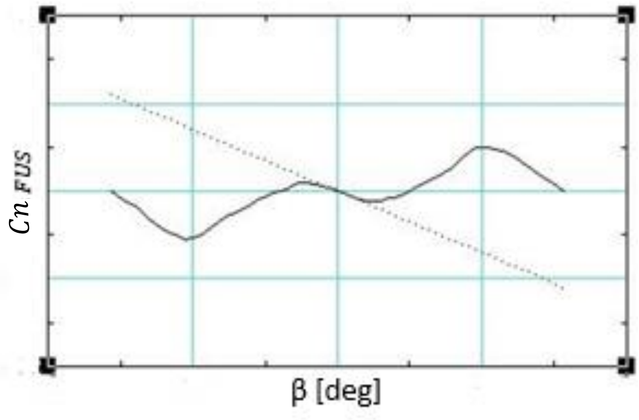


Figure 4 Yaw Moment Aerodynamic Coefficient Linearization for HC Fuselage

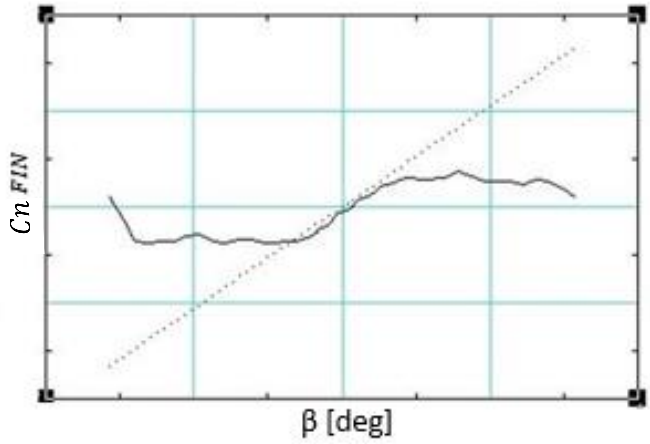


Figure 5 Yaw Moment Aerodynamic Coefficient Linearization for HC Vertical fin

4.2. 1-DOF Model Building and Outcomes

To assess the validity of the obtained result of Section 4.1, a second-order dynamic system model was built, representing the helicopter-parachute system and considering only the yaw attitude DOF (Figure 6). This model aims to capture the following key aspects of the dynamics (Ref. 4):

- the inertial behavior of the helicopter regarding yaw,
- the yaw moment generated by the fuselage aerodynamics,
- the stabilizing effect of the vertical tail within the lateral plane,
- the stabilizing contribution of the parachute in the lateral plane.

Also, aerodynamics of vertical tail and fuselage have been fully considered (without the linearization of Section 4.1).

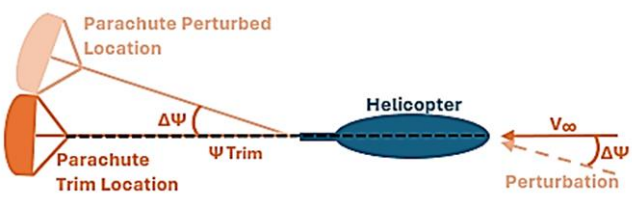


Figure 6 Graphical representation of 1DOF Model building

The 1-DOF model has been built using FLIGHTLAB software, which is a Finite Element, Component based, selective fidelity air vehicle modelling, and simulation tool developed by ART© (Advanced Rotorcraft Technology, Inc.) (ref. 5).

The system has been implemented into the modelling tool following the multibody approach.

The 1-degree-of-freedom model has been tested using a 30 ft/s lateral gust as prescribed by Ref. 6 at an operational speed of 80 kIAS at ISA SL. As illustrated in Figure 7, the parachute FPA derived through the neutral yaw static stability method (Section 4.1) demonstrated sufficient stabilization authority for the system analyzed.

The plot illustrates the time evolution of sideslip angle and yaw attitude angle during the simulation. It can be noticed that the system was initialized in a trim condition and then subjected to an impulsive 30 ft/s lateral wind gust at t = 30 s, demonstrating dynamic stabilization with acceptable oscillations.

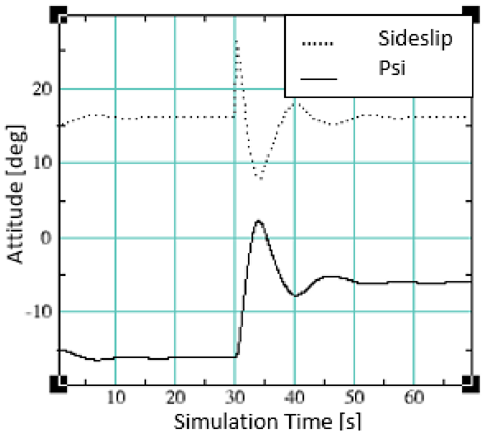


Figure 7: Neutral Yaw Static Stability Parachute FPA Tested with 30 ft/s Wind Gust @80 kIAS ISA SL Using 1DOF Model.

Given the intended role of this initial FPA value as a preliminary estimation for the multibody model, a comprehensive validation of the FPA was not pursued.

The main outcome obtained with this 1DOF evaluation is that moment equilibrium calculations (Section 4.1) provided an adequate basis for establishing an initial guess FPA value for subsequent multibody model assessments, obviating the necessity for constructing a 1DOF model for this specific validation or considering aerodynamic forces without linearization.

It is important to note, however, that this analysis does not account for ambient or coupling effects between axes, as well as interactions between the rotorcraft carrier and the transported platform, factors which could influence the accuracy of the target parameter, which is the stabilizing parachute FPA.

4.3. Complete Multibody Model Building

The primary objective of this part of the study is to simulate key environmental factors that can influence parachute performance, including altitude, temperature, and variations in chord lengths as well as coupling effects (as discussed in Section 4.2).

The analysis begins with the definition of a rotorcraft carrier (RC) model, properly designed to represent the helicopter accurately in both static and dynamic simulation conditions. Subsequently, the complete system – comprising the RC, the transported helicopter (HC), and the parachute – was built in FLIGHTLAB as a double pendulum system (illustrated in Figure 8).

Specifically:

- The transported helicopter (HC) was modelled in line with Section 3.1. The length of the connecting rope between the HC and parachute was determined based on aerodynamic assessments (Section 3.2), to ensure a minimum dynamic pressure of 95%.
- The RC was connected to the HC transported via rope, with a cable length at least 20% greater than the HC-Parachute connection length. This geometric extension was implemented to mitigate the risk of parachute interception during transport. The rationale for this approach is based on maintaining a sufficient separation between the parachute and the RC.

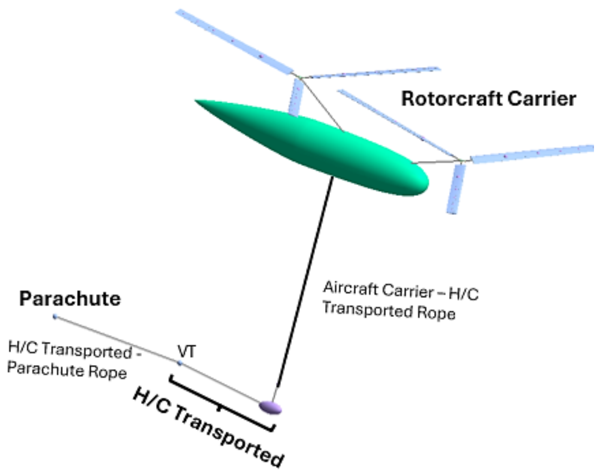


Figure 8 Multibody Model Building for Transportation with Stabilizing Parachute

To effectively model the connection between two rotorcrafts, we employed a single elastic cable segment. The choice of a single segment is justified by the substantial difference in the mass carried compared to the one of the cable.

In fact, the HC weight is significantly higher wrt the rope weight, indicating that the cable will experience an almost uniform tension distribution throughout its length. Therefore, we can reasonably assume that the tension along the cable is approximately constant, allowing for a simplified analysis.

Then, the cable between the HC and stabilizing parachute was modelled as a rigid displacement element. This simplification was enforced considering the inherent functionality of the parachute – namely, its ability to stabilize the HC via drag force – which allows for the assumption of constant cable tension throughout the simulation.

To facilitate dynamic modelling as a pendulum, hinges were introduced to permit rotational movement around the theta and psi axes in body frame. Rotation around the parachute itself (phi axis) was deemed negligible because of the parachute axial symmetry, and therefore excluded from the model. These components were interconnected, linking the hinges to both the parachute cable and the vertical fin.

4.4. Complete Multibody Model Simulations

Following model definition, a series of simulations were performed to determine optimal parachute dimensions for the transported helicopter operational environment and to assess the impact of operational variations.

These variations are:

- A range of parachute FPAs (from the value found in Section 4.1 up to double that value) were implemented within the simulation model.
- Simulations were conducted at speeds up to 100 knots equivalent airspeed (KEAS), representing a typical Vne for cargo hook operations.
- Weight configurations for the transported HC were analyzed (maximum, medium and minimum HC weights were taken into account).
- Three different atmospheric conditions were imposed, representing ISA SL, 5000 ft HD and 10000 ft HD.
- Three variations of the RC – HC connecting chord length (18 ft, 60 ft, and 100 ft) were simulated.

The simulations employed three distinct methodologies to account for a comprehensive range of potential dynamic effects encountered during flight:

- Free dynamic response analysis, from a defined initial condition disturbance.
- Dynamic response to impulsive lateral wind gusts (±30 ft/s).
- Forward acceleration profiles ranging from 0 to 40, 60, 80, and 100 kIAS.

4.5. Complete Multibody Model Remarkable Results

First, an initial assessment was performed selecting the optimal FPA for the stabilizer parachute. A configuration exhibiting minimal drag was prioritized, while simultaneously ensuring the stability of the transported helicopter across a range of operational conditions.

It has to be noticed that lower FPA values result in increased heading and yaw angles for the HC, implying more overall draggy configurations, while excessively large FPA values yield a drag contribution disproportionate to the achieved stabilization effect.

The drag effect was estimated based on the RC-HC swing angle, which is directly influenced by dynamic pressure and so, also by drag (which increases in absolute value with the increase in dynamic pressure).

As illustrated in Figure 9, a FPA value approximately 40% greater than the initial equilibrium-of-moments derived FPA (Section 4.1) yielded the most effective stabilization.

In fact, the first FPA value, obtained in Section 4.1 and validated through a 1-DOF model, was insufficient when incorporated in the complete multibody model. Also, the FPA 80% greater than the one found with the 1-DOF model has similar stabilization wrt the 40% bigger but is globally draggier (the swing angle is higher).

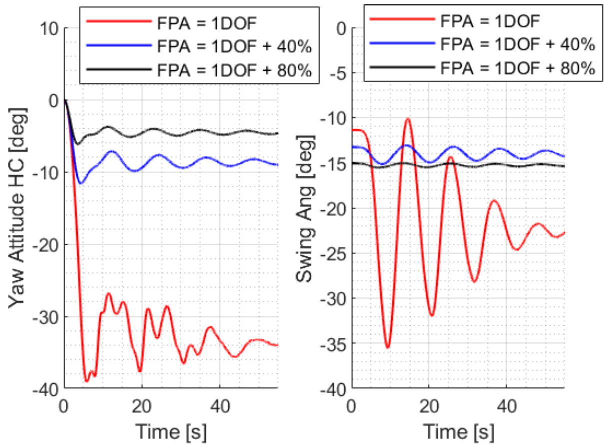


Figure 9 Free Dynamic Response of Three Different FPA Parachute Values @ 100kIAS

Once the FPA value has been chosen (1-DOF+40%), further investigations, already anticipated in Section 4.4, have been done, assessing the influence of weight, velocity, altitude, and chord length.

These parameters were found to exert negligible effects on parachute stabilization once the FPA value ensured the stability of the HC, as it can be seen in Figure 10, Figure 11 and Figure 12, which show some of the main outcomes of conducted sensitivity analysis.

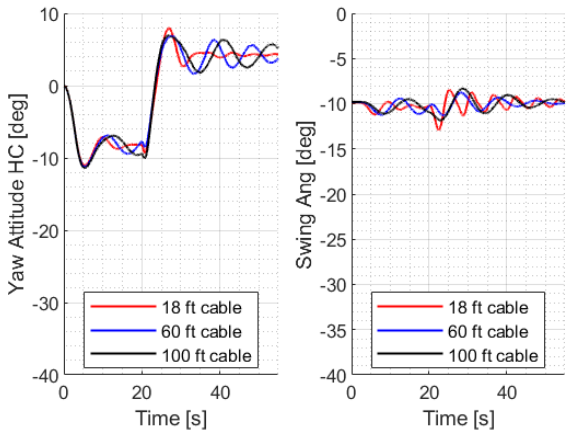


Figure 10 Cable Lengths Sensitivity (Between HC and RC) Tested with a Continuous 30 ft/s Wind Gust Starting at 20s, @100 kIAS

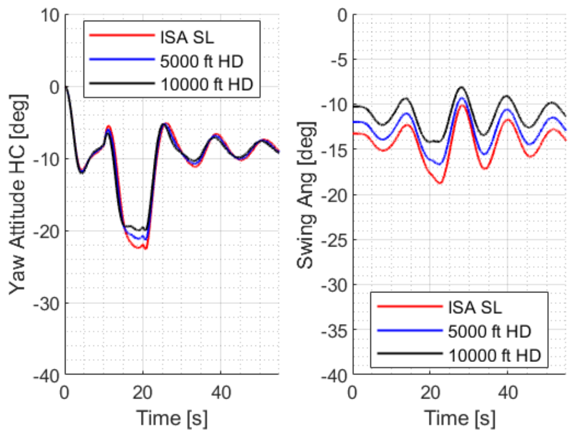


Figure 11 Ambient Conditions Sensitivity Tested with an Impulsive 10s Wind Gust of 30 ft/s, @100 kIAS

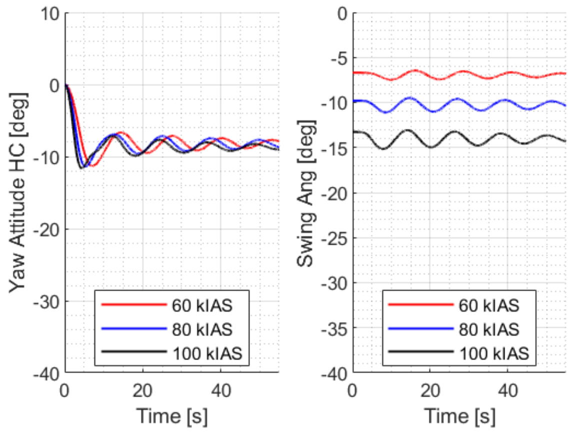


Figure 12 Airspeed Sensitivity Tested with a Free Dynamic Response to Initial Condition Disturbance

Finally, the impact of coupling effects was investigated. To determine whether the FPA augmentation (wrt the 1-DOF case) was driven by inter-axis coupling of the transported system (H/C + chute) or by carrier – transported rotorcrafts coupling, the dynamic behavior of the rotorcraft carrier was frozen – all accelerations were set to zero, leaving the rotorcraft free to move only at constant velocity. Analysis revealed that incorporating the complete multibody model did not significantly alter the stabilization performance, suggesting that inter-axis coupling parachute-HC represents the dominant driver for increased FPA values, while the one between the two rotorcrafts is negligible.

This can be seen in Figure 13 which compares the free dynamic response of the system for both cases (rotorcraft carrier dynamics free and frozen), demonstrating that negligible differences are involved.

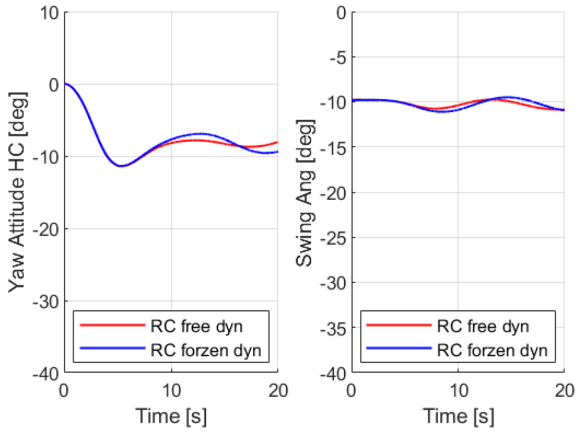


Figure 13 Free Dynamic Response @100kIAS with rotorcraft carrier dynamics free and frozen

5. TRANSPORTATION WITHOUT STABILIZING PARACHUTE

Finally, transportation was conducted without the stabilizing parachute to assess the necessity of this dynamic stabilization element.

5.1. Structure of the Model

The model was developed based on a pendulum approximation, mirroring the methodology presented in Section 4.3.

The model is based on the following assumptions:

- the connection between the rotorcraft carrier and the HC transported is represented by a cable;
- the complete horizontal and vertical tails were maintained. The inclusion of these elements, in the absence of a parachute, was deemed critical to ensure maximum stability during the simulation.
- MR and TR are removed as for the case of Section 4.3.

As for Section 4.3, the cable connecting the RC with the HC has been modelled as a single elastic cable segment.

The multibody model built is graphically presented in Figure 14.

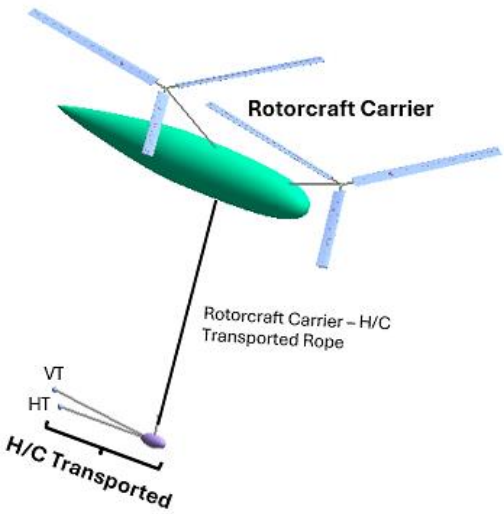


Figure 14 Multibody model building for transportation without stabilizing parachute

5.2. Simulations Conducted

Due to the inherently unstable nature of HC transportation without a stabilizing parachute, simulations were performed utilizing a frontal wind ramp, increasing from 0 knots to a range of 20-40-60-80 knots (Figure 15). This approach aimed to realistically replicate a controlled low-acceleration transport scenario.

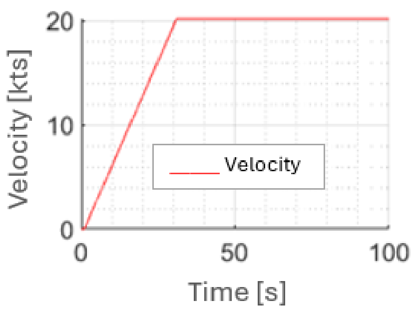


Figure 15 Wind Ramp Example

Also, an additional transported HC fuselage have been tested in order to evaluate the dependency of the sling load dynamic developed during the transportation on the HC fuselage aerodynamic characteristics.

5.3. Analysis Main Outcomes

Two transported HC have been considered (HC1 and HC2), knowing, from company experience, that HC1 is more dynamically stable wrt HC2.

This behavior has been confirmed even with the simulations performed in this section, in fact HC1 exhibits significantly greater dynamic stability compared to HC2:

- At flight conditions up to 20 kIAS, both helicopters demonstrate a convergent dynamic behavior, as visualized in Figure 16. However, maintaining stable transport under these conditions requires careful piloting due to the inherent instability of the aerodynamic characteristics of the rotorcrafts.
- At 30 kIAS, HC1 continues to maintain a convergent dynamic response, whereas HC2 displays a diverging trend, implying transportation without a stabilizing parachute inadvisable (Figure 17).
- For speeds exceeding 30 kIAS, both helicopters exhibit a rapidly divergent dynamic behavior (Figure 18).

Consequently, these results suggest that stable transportation without utilizing a stabilizing parachute is feasible but constrained to very low airspeed regimes determined by helicopter fuselage aerodynamics properties. In fact, the upper limit of these achievable speeds remains dependent on this aerodynamic influence.

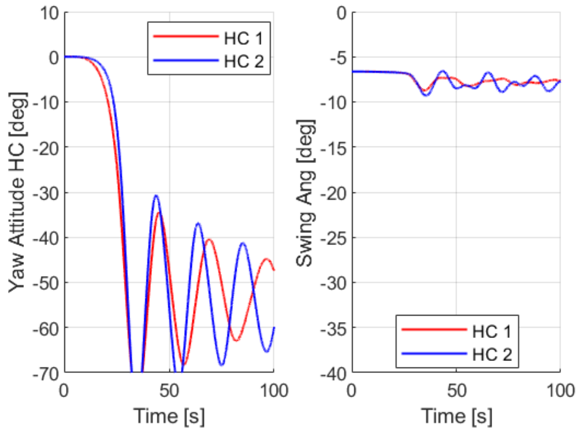


Figure 16 Forward acceleration up to 20 kIAS comparing HC1 and HC2

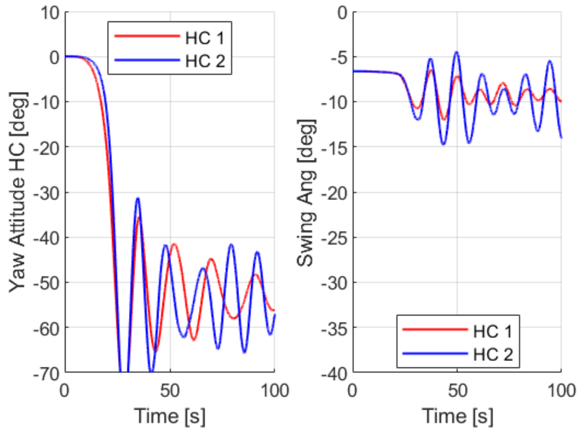


Figure 17 Forward acceleration up to 30 kIAS comparing HC1 and HC2

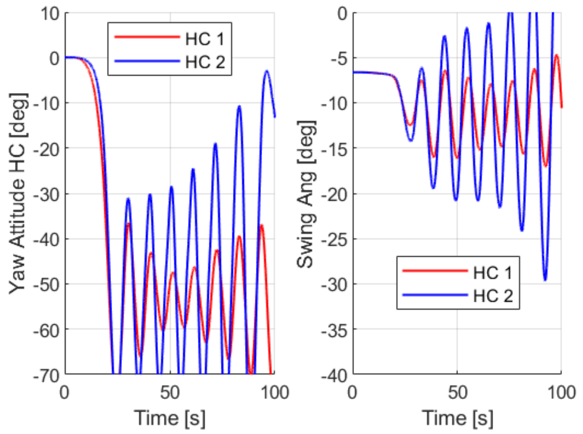


Figure 18 Forward acceleration up to 40 kIAS comparing HC1 and HC2

6. STATIC LOAD ASSESSMENT FOR THE PRIMARY STRUCTURE

The static load evaluation of the carried helicopter airframe was performed by combining the following distinct load cases:

Aerodynamic Loads

Computed using the enveloping values of angle of attack (α) and sideslip (β) derived from evaluations of Section 4.5.

Parachute Loads

Drag forces, derived from the parachute data detailed in Section 3.3 (FPA + 40%), were mapped onto the structural attachment points for the load analysis.

Mast Attachment Loads

In accordance with CS-29.865 (Ref. 1), nine orientations were considered: one vertical and eight equally spaced azimuthal positions at 45° intervals in the horizontal (XY) plane, each inclined 30° from the mast's vertical axis. A vertical load factor N_z was superimposed on all cases to account for dynamic amplification during transport.

Mass and Inertia-Induced Loads

Inertial forces resulting from the above external loads were calculated. The mass properties of the airframe were used to determine the corresponding inertia loads.

The resulting Shear Force and Bending Moments (SFBM), depicted in Figure 19 and Figure 20, highlights critical aspects in this analysis.

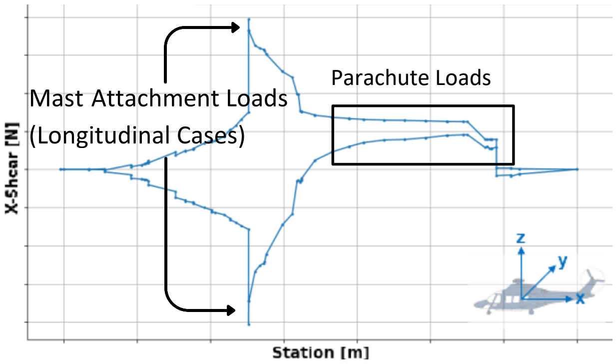


Figure 19: Longitudinal Limit Shear (X Shear)

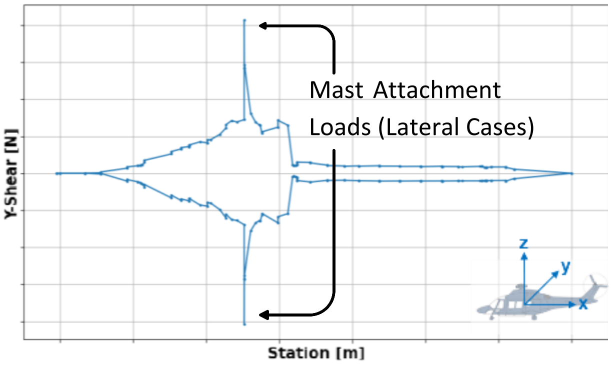
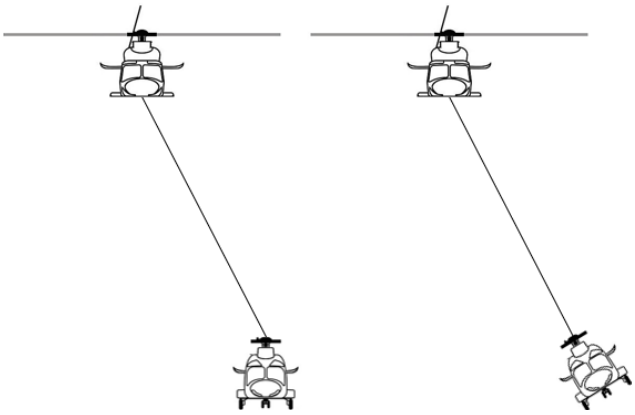


Figure 20: Lateral Limit Shear (Y Shear)

The loads generated by the parachute act primarily along the X shear direction, introducing force to which the primary structure has not been previously subjected. The dynamic pressure is the principal parameter affecting this force—specifically, airspeed and air density. A reduction in either variable directly contributes to mitigating this load. Notably, the loads form the helicopter mast attachment points do not raise concerns in terms of X shear stress.

In contrast, the Y shear SFBM present a more critical scenario. The loads induced by the attachment points of the mast introduce forces that, again, have no precedent in the helicopter's prior structural loading history, and their magnitude significantly exceeds those considered in earlier analyses.

The application of CS-29.865 (Ref. 1) as a reference for these load cases introduces notable limitations. The regulation was developed to address scenarios involving the transporting helicopter, not the underslung configuration. As a result, it leads to unrealistic loading conditions—most critically in the Y shear direction. Figure 21(a) illustrates the position of the transported helicopter at the initial moment of the lateral displacement of the upper helicopter. In contrast, Figure 21(b) depicts the configuration reached shortly thereafter, once the system stabilizes under the combined effects of inertial and aerodynamic forces, aligning itself along the direction of the towing line.



(a) (b)

Figure 21: Graphical representations of lateral system response

To support this assessment, a model was developed to simulate the maximum lateral angle differentials, with particular focus on scenarios in which the transporting rotorcraft is hovering and undergoes a sudden lateral motion. In this model, the parachute is assumed to have no influence on the system dynamics. The simplified representation of the system is shown in Figure 22.

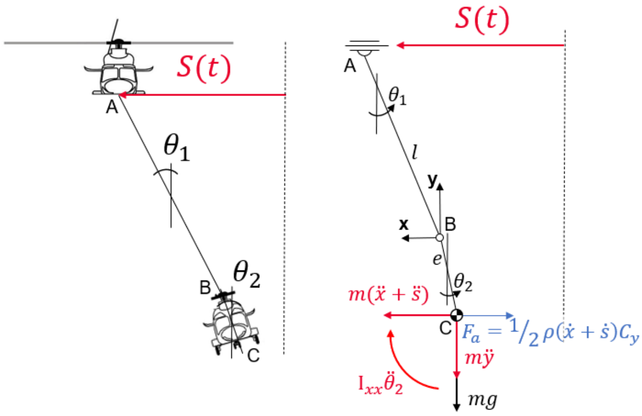


Figure 22: Analytical model of lateral response

The system's response to a sudden motion input S(t), illustrated in Figure 23, confirms that the 30° angular offset prescribed by CS-29.865 is overly conservative. The loads at the mast tends to be in the axial direction. This analysis suggests that a reduced lateral angle would still ensure an adequate safety margin without leading to structural overdesign. Consequently, design efforts could be more effectively focused on adopting a conservative vertical load factor N_z.

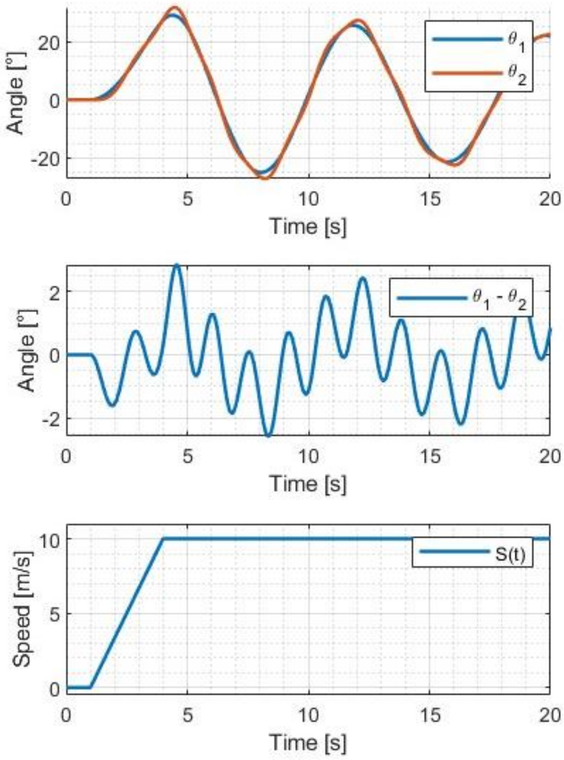


Figure 23 Response to a sudden lateral movement S(t) of the transporting rotorcraft

7. CONCLUSIONS

The developed methodology ensures stable sling load operations between two rotorcrafts yielding the following key findings:

1. Initial Parachute Area Estimation: Initial analytical assessments of neutral yaw static stability provided an initial guess of parachute area; however, this value was found to be significantly underestimated.

2. Validation with 1-DOF Dynamic Modeling: A single degree of freedom dynamic system corroborated the initial static stability analysis; however, this value was found to be significantly underestimated.

3. Inter-Axis Coupling as a Key Factor: The inter-axis coupling of the transported system (HC with parachute) substantially increases the required parachute area compared to scenarios assuming zero net yaw moment (Mz) equilibrium or the simplified 1-DOF analysis.

4. Dominance of Dynamic Pressure: A comprehensive multibody dynamic model, accounting for transported helicopter weight, airspeed, altitude, cable length, demonstrated that these factors exert negligible influence on parachute stabilization once an adequate parachute area was found. Dynamic pressure emerged as the primary player on stability.

5. Optimal Parachute Area Selection: The optimal parachute area should prioritize drag minimization while ensuring sufficient stability. Drag estimation can be achieved through analysis of sling load swing angle.

6. Transportation Without Stabilizing Parachute: The utilization of the transported rotorcraft as a self-stabilizing system is limited to low speeds – approximately up to 20-30 knots – and depends heavily on the aerodynamic characteristics of the transported fuselage. Careful operational pilot handling is recommended.

7. Loads on the Transported Aircraft: The loads transmitted to the mast of the transported aircraft, specifically at the attachment points, are predominantly axial

in nature, as the helicopter tends to follow the rope's swing angle more closely.

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