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DISRUPTIVE AND EFFICIENT REAR FUSELAGE FOR DUAL USE HIGH SPEED ROTORCRAFTS.

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The RACER demonstrator (Rapid and Cost Effective Rotorcraft) is the answer from Airbus Helicopters to the need of High Speed Rotary-Wing Aircrafts. It is a Technological Demonstrator, in which are implemented a no minor quantity of innovations, RACER will perform its first flight by the end of 2023 within the European initiative of Clean Sky 2.

This paper will show the characteristics and developments of the RACER, as an advanced formula of Gyrodyne patented by Airbus Helicopters. A comparison will also be made between the solutions of the European competitors and the FVL (Future Vertical Lift) of USA. It will be made an introduction about its main features for developing dual operations, as well as mission performance, aerodynamics and structure. Moreover, a general description of the structural fuselage breakdown will be done, with special focus on the basic structural layout and the main component developed, manufactured and assembled in Spain: the rear fuselage.

The rear fuselage is a complex, disruptive and efficient airframe that plays a key role in the RACER, contributing to reinforce its dual nature. This fuselage includes several patents and innovative developments such as asymmetric transversal sections for the tail boom and double-tilted empennage in “H” configuration, which is pioneer in the implementation of Out of Autoclave (OoA) technologies for big dimensions and complexity (primary structure of the Empennage), also the implementation of the first primary structure (class 2 part) developed by Additive Manufacturing which will be the first item in this technology that ever has flight in Airbus Helicopters. The description of the main components of the rear fuselage will include information about the details of the design and production, testing and certification, in addition to the innovative challenges dealt as it has been already mentioned.

Key words: Gyrodyne, RACER, Disruptive, Efficient, OoA, Additive

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1. Introduction

1.1. Clean Sky 2

Clean Sky 2 (CS2) is the greatest European research program that develops innovative novelty technologies/solutions focused on to reduce the environmental impact of the aviation industry, improve the competitiveness of the sector and increase the efficiency of mobility.

The RACER is a Technological Demonstrator project, and it is developed by Airbus Helicopters, AH is leading a European consortium involving eight main partners (Core Partners) and eighteen secondary ones (partners), from thirteen different countries with more than forty participating entities (public and private).

1.2. Introduction to the High Speed Formula

The base of the RACER is a Gyrodyne —such concept has been matured by Airbus Helicopters through the X^3 [1] high speed demonstrator (Fig. 1 a and b)—, the architecture consists on: main rotor, wing, lateral propellers and “H” [2] tail unit (Fig. 1 c).

a) b) c)

Figure 1. a) Patent of Airbus Helicopters, b) X^3 demonstrator, c) RACER demonstrator.

The operating principle of this demonstrator is very simple and safe; the anti-torque is generated during hover by the differential thrust of the lateral propellers, thus is compensated the effect of the main rotor. When the speed is increased in order to move in forward flight, the anti-torque is passively generated by the vertical stabilizers geometry in addition to the active effect of the lateral pusher propellers. During cruise flight, both propellers generate forward thrust, while the wing and main rotor contribute with the 50% of the lift, each.

The transition process from hover to forward flight is simple and non-critical, in a complete different manner than the “Tilt Rotor” technology, and is done just by the inversion of the lateral starboard propeller pitch. The Main rotor unloading at forward flight is thanks to the wing, and its lifting action and as collateral effect of the wing installation is that the antitorque compensation need is reduced.

The high speed capabilities are achieved by avoiding high Mach numbers at the tip of the advancing blade as, most specially, the retracting blade stall. It is needed to reduce the main rotor rotation speed and thanks to the RACER Wing and lateral propellers, the lifting and trusting loads are reduced in the disc blades to the optimal ones in terms of forward flight. (Fig. 2).

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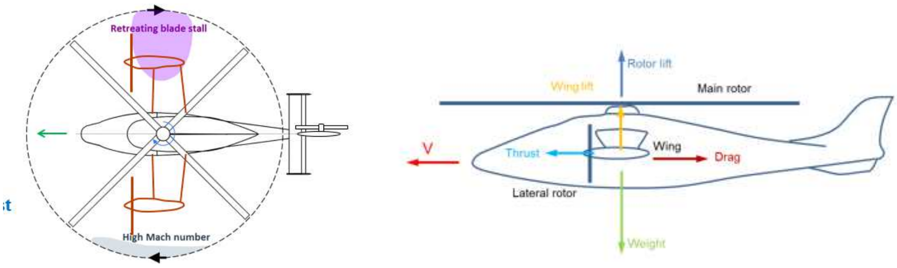

Figure 2. Gyrodyne Flight Physics-RACER rotorcraft.

The RACER objectives:

1) Give an answer to the “Mobility Gap” detected between the Fixed-Wing and Rotary-Wing aircrafts (Fig. 3).
2) Fly 50% faster than conventional rotorcrafts.
3) 15% fuel consumption savings, with operating costs/Nm≤25%.
4) Travel or cover twice times the distance of a conventional helicopter within the “Golden Hour”.
5) Modular formula to cover different MTOW ranges (Maximum Take Off Weight).

Applicability to EMS/SAR missions; Parapublic and Passenger Transport Missions

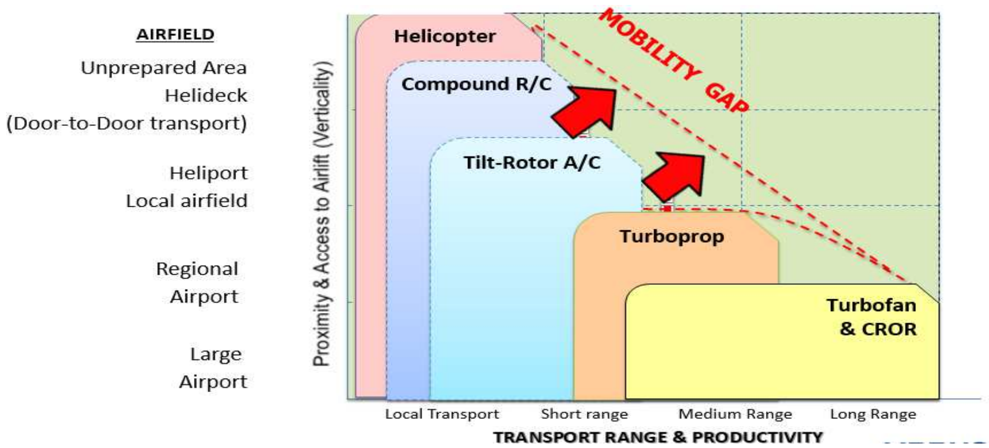

Figure 3.Mobility Gap.

1.3. FVL – Future Vertical Lift

High Speed on Rotary-Wing aircrafts is not a technological trend that only matters to Europe and its industry, also for other many countries such as: Russia, Japan, China and USA is interesting. In the case of the USA, a macro-program called FVL (Future Vertical Lift), focused on exploring the limits of the rotorcraft formulas and their different architectures and solutions, and is ongoing. This program has two main lines: FARA (Future Attack Reconnaissance Aircraft) and FLRAA (Future Long-Range Assault Aircraft) (Fig. 4).

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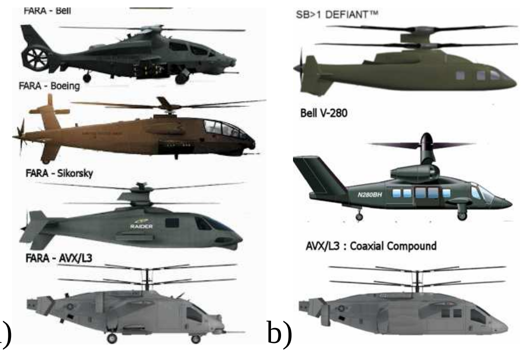

Figure 4.FVL: a) FARA and b) FLRAA challengers.

2. RACER (RApid Cost Effective Rotorcraft)

1.1. RACER Architecture

The general conception of the RACER is focused on reaching the efficiency in high speed flight, thanks to the stylized low cx fuselage, the fully retractable landing gear, aerodynamic cowlings and mast fairing, the biplane box wings with pusher propellers and finally the asymmetric rear fuselage with disruptive “H” shape empennage.

The helicopter's dynamic system consists of the main rotor, the main gear box, two engines and the two lateral pusher propellers with their lateral gearboxes and the drive shafts (Fig. 5). The main gearbox and both engines are positioned over the fuselage, in the typical engine deck of the H/Cs, with the engines just behind the main gearbox. The main gear box directly drives the main rotor mast and the two lateral shafts, which drive the pusher propellers via a lateral gearbox. The supercritical shafts [4] are housed into the upper wing box and the lateral gear boxes are mounted in a nacelle at the wing tip providing an optimal aerodynamic wing-to-wing connection in terms of drag and noise.

The allocation of the pusher propellers, just behind the wing, it provides to the aircraft an inherent safety feature, especially focus on hoisting operations and emergency exits, in which the lower wing acts as a physical barrier towards the lateral rotors [3]. Furthermore, the pusher propeller rotor disc is out of the cabin perimeter, and therefore the noise impact in the cabin is limited and also the risk of rotor propeller impact into the cabin due to a rotor explosion.

The innovative engines have an unique solution of running, the RACER can fly in forward flight just with only one engine on, while the second one is on standby mode, nevertheless and if needed by the crew, the second engine could be automatically on again providing high levels of power in accordance with the flight needs. This unique solution is called “eco-mode” by AH and Engine Manufacturer which will allow fuel savings in forward flight. It is estimated that for RACER and per NM flying at 180kts, up to 15% of fuel savings will be obtained, in comparison with the equivalent flight of an conventional helicopters at 130kts.

The wing is composed of an upper and a lower wings with a staggered layout from upper to lower wings. The wing is assembled to the main fuselage by two points and the connection between the upper and lower wings is performed in their tips using the pusher propeller location for that purpose. Thanks to this Wing implementation, which is an Airbus Helicopter Patent, the lateral drive shafts are installed in the upper wing center box and in the lower wing the main landing gear together its housing are placed [3]. The already said integration of the landing gear inside the lower wing gives the chance of install a short, light and simple with an easy retraction kinematics.

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The rearward position of the lower wing is simultaneously beneficial in terms of aeromechanics [3] and weight; it solution provides a substantial increase of the pitch stability of the helicopter, reducing the size and weight of the horizontal plane, and decreases its downwash interactions during low forward speeds. The pusher propellers contribute to that positive flag effect and allow the improvement of the dumping and directional stability of the demonstrator. The reduced wing plan shape and the mutual outboard wing overlap produces a main rotor download and as result of that, the improvement of the hover performances for the demonstrator. The rotation of the lateral rotors pusher discs is chosen in order to take advantage of the vortex generation within the nacelle [4], due to that, it is reduced the power needed for high-speed flight [5]. The allocation of the rotors behind the trailing edge has some drawbacks in terms of acoustic emission which is a linked to the distance between the lateral propellers and the main rotor disc.

The “H” form empennage presents a lower interaction with the wake airflow of the rotor head and the fuselage, whilst the double curvature of the Vertical Stabilizers minimizes the drag with respect to the horizontal plane of the tail [6], [7]. The Tail Boom has an asymmetric cross section design in order to use the downwash of the main rotor, aiming for additional passive anti-torque capabilities during hover, and the relative relief of the antitorque demand from the lateral propellers.

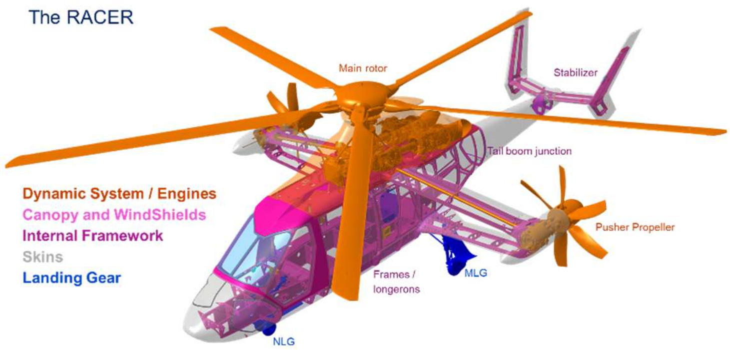

Figure 5. RACER Architecture.

1.2. RACER Rear Fuselage

The RACER Rear Fuselage is an Airframe development performed under the leadership of Airbus Helicopters España from 2013 until 2023, and it has been done into a collaborative project/framework with a Spanish consortium, in which participated several companies and technological centers, all of them internally leaded by Aernnova.

The RACER Rotorless Tail is splitted as follows (major parts): Tail Boom and Empennage, and its main hallmark is the absence of a conventional anti-torque tail rotor (Fig. 6a).

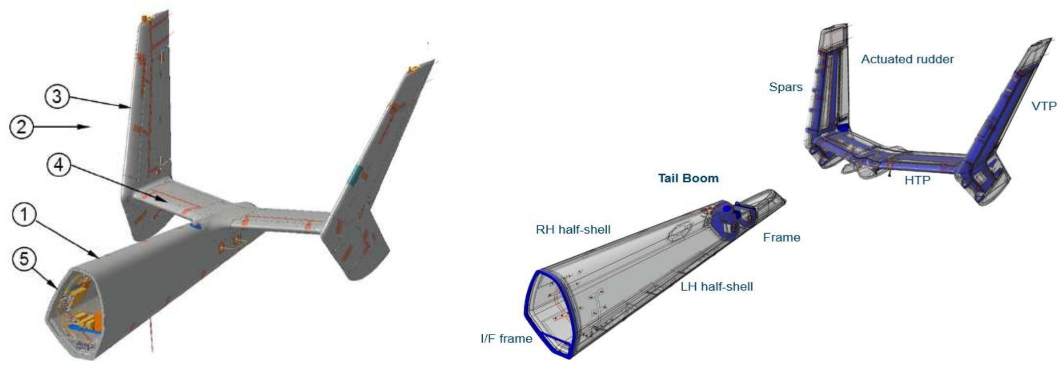

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Figure 6. RACER Rear Fuselage: a) Tail Boom description (TB) (1) Central Fuselage union (5), Empennage (2), Horizontal Stabilizer (HTP) (4) and Vertical Stabilizers (VTP) (3); b) General Architecture.

The tail boom is a composite-sandwich monocoque structure which is splitted into two parts (RH/LH tail boom skins). In order to secure the Tail Boom stiffening, several transversal structural elements (ribs) (Fig. 6) were designed and manufactured. This configuration is the best one in terms of Drag/Weight ratio. The Weight was one of the main development drivers for the Rotorless Tail, reaching a new level of weight standards for this MTOW Platform. In this line it was researched and developed different lightweight solutions, one of them was devoted to the optimization of the Tail Boom Skin Manufacturing process. Thanks to a specific sequential manufacturing process developed for Tail Boom skins, was feasible to save kilograms in this major structure. The Trade off was focus on the assessment of 5 honeycomb types, as well as all their combinations with 3 different adhesives, in addition to the different process steps too. The additional challenge for this brand new manufacturing process and lightweight solution was the Tail Boom shape and its dimensions (Fig. 7), critical were the Corners with Aggressive radii of both Tail Boom skins, especially the RH Tail Boom Skin. The transversal section of the TB is unique and asymmetric (not cambered) (Fig. 6b and 7a), since it has a curved part that is specifically designed to generate a transversal load with the effect of the main rotor downwash flow, thus inducing passively an anti-torque contribution [8], [9]; this allows to increase the efficiency during hover in approximately up to 10% (Fig.7b).

a) 

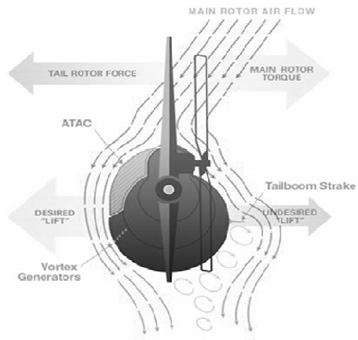
b) 

Figura 7. RACER Tail Boom- Transversal Section: a) Sandwich Inclusion Challenge in the corners, b) Asymmetric Transversal Section Working Principle.

The joint between the Empennage and the TB was an additional project challenge, due to the assembly of the Empennage is in the tip of the TB, and the area in which must to be performed this assembly is in an A4 paper sheet area. This location was selected for optimizing the aerodynamic efficiency and longitudinal stability of RACER. This union/joint between TB and Empennage is on ground movable joint (trimmability capacity) therefore is feasible to adjust the Empennage angle of attack, within a range of ±5º, in steps of 0.5º. It must be remarkable the high level of loads that this connection will have to transfer from Empennage to Fuselage and vice versa. Finally this challenge was performed by Airbus Helicopters España with the additional request of avoiding weight penalization. Thanks to this Empennage capability the selection of the final allocation of the Empennage will be easier than invest in CFDs and WTTs.

The Empennage architecture is an "H" configuration with a horizontal tail plane (HTP) and two double-tilted vertical stabilizers (VTP) (Fig. 6). The double tilting of the VTP with respect to the HTP, with its upper and lower parts with different dihedral and sweep angles, is the best solution in accordance with aerodynamic efficiency for high speed, nevertheless is a very complex structural and

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technological solution. The VTPs include an electrical actuator that can be used on flight to perform trimming settings.

The horizontal tail plane (HTP) is a structure composed of an integral torsion box (two spars, two closure ribs and two central ribs) and of two skins, everything designed and made with composite materials. The front part of the HTP is closed by leading edges, which are manufactured in monolithic composite materials, its dimensions and structural requirements (similar to the fix wing platforms due to the flight speeds) have been an additional challenge of the project.

The HTP torsion box is other of the project technological cornerstones, this item is the biggest RTM part (3.5m span) that ever has been developed and flight in Airbus Helicopters. Thanks to this technology the whole torsion box is manufactured in just one shoot (Fig. 8). The design and production of this part is conditioned by the complexity of its manufacturing tooling, the resin injection strategy, the preform design and layout and finally the demolding operations. All these listed parameters are crucial for success achievement with OoA processes.

Figure 8.HTP Torsion Box RTM

The Vertical Stabilizers rudders (also known as control surfaces) are designed and manufactured as RTM pieces with foam core integration, due to that, it was feasible the integration in just one manufacturing shoot, five elements that used to be manufactured separately and then assembled together.

The implementation in the RACER Rear Fuselage of additive manufacturing related parts (primary and secondary) were another of the challenges and technical cornerstones of the project, especially for primary structural parts. The Vertical Stabilizer Rudder Fittings (Fig. 9a) have been developed and manufactured in Titanium (Powder Bed Fusion PBF/Selective Laser Melting SLM), which is one of the first ever primary structural elements (Primary Structure Class 2) manufactured for helicopter which will fly in Airbus. Regarding the secondary structures or non-related parts, additive manufacturing has been applied to several fairings, tramps and access doors on both TB and the Empennage, with metal (Scalmalloy) and thermoplastic elements (ULTEM9085) (Fig. 9b).

a) 

b) 

Figure 9. Additive Manufacturing: a) Titanium fittings PBF/SLM; b) ULTEM Pieces

3. Results and discussion

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The structural test campaign performed by Airbus Helicopters España (AHE), was carried out at several levels of the test pyramid and it has been successfully completed. AHE has prepared all the documentation for the PtF (Permit to Fly) of the Rear Fuselage, in accordance with the requirements of the authorities. AHE will compare all the ground test campaign results with the flight test campaign ones, these activities are expected to be done during 2023-24.

AHE has delivered to the RACER assembly line the Rear Fuselage (October, 2021), which was integrated and assembled with the rest of the Rotorcraft airframe. AHE design was based on "plug and play" concept, therefore the rear fuselage was shipped in flyable use conditions.

4. Conclusions

The RACER is an European formula that is a reliable and feasible solution in order to give an answer to the future demand of high speed rotorcrafts for dual application purposes.

RACER is a simple and unique formula, with a lower operation costing and higher safety than other Rotary Wing high speed formulas.

Airbus España, as well as the most of the Spanish industry is leading the knowledge and technique for the development of innovative, disruptive and efficient rear fuselages.

Spain has been pioneer at the implementation of primary structure additive manufacturing on an aircraft.

The RACER could get to be a platform to explore high speed at the ambit of military.

Acknowledgment

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Finally, to my family, for all the time I have taken from them because of this project.

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