Final Report Summary - RETAX (Rotorcraft Electric Taxiing)

Executive Summary:

In the view of meeting the ACARE goals and radically reducing the impact of air transport on the environment, one concept being investigated is to move towards electrical aircraft.

Innovative solutions and breakthrough technologies will have to demonstrate overall increase of efficiency and reduction of undesirable emissions.

The current trend to evolve towards electrically controlled and actuated aircraft is an ongoing process. These electric systems are lighter, thus enabling to achieve significant savings in fuel consumption. Other advantages include reduced maintenance costs and easier monitoring.

On-board electrical systems are very common in the entire airplane. Electrical taxiing is just another electrifiable function; electrical braking or electrical flying controls are other examples.

Electric taxiing is an alternative method of maneuvering rotorcraft on ground, without any spinning from the rotor.

The main advantages identified consist of:

- Suppressing noise on ground generated by the high speed turning rotor
- Improving ground personnel safety by suppressing main and tail rotor rotation
- Reducing fuel consumption during taxiing, using an efficient motion system
- Allowing autonomous on ground movement, even backward without external means

This technology is based on an electrically-powered motorized wheel integrated within the landing gear, relying on an electrical energy source.

Electric ground taxiing offer an improve solution, which enables to reach simultaneously extended autonomy with the helicopter, noise and emission reduction, increasing safety on the airport.

With the RETAX project, feasibility has been demonstrated, using intrinsically safe and efficient solutions for rotorcraft autonomous taxiing on ground, minimizing the overall weight of the system, based on an electrically-powered motorized wheel, integrated within the landing gear.
This has been done through testing of a complete manufacture landing gear for heavy rotorcraft including motorized wheel, and reaching a TRL4 level, demonstrating the confidence in the solution. The full system has been tested on a face to face and dyno test-bed. The critical safety aspects have been demonstrated as well, related to the undesired events.

This feasibility demonstration of electrically driven rotorcraft ground taxiiing in accordance with Clean Sky electrification objectives will be a significant step towards greener rotorcraft operations, bringing this technology closer to the market.

Project Context and Objectives:

In the view of meeting the ACARE goals and radically reducing the impact of air transport on the environment, one concept being investigated is to move towards electrical aircraft.

Innovative solutions and breakthrough technologies will have to demonstrate overall increase of efficiency and reduction of undesirable emissions.

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On-board electrical systems are very common in the entire airplane. Electrical taxiiing is just another electrifiable function; electrical braking or electrical flying controls are other examples.

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Even if it does already exist for automotive application, or is being investigated through research project for aircraft, no demonstrator for helicopter taxiiing has been produced until now.

The main differences between rotorcraft and aircraft compared to automobile are:

- For automobile, the system is used all the time, with no extra weight as it replaces other energy modes
- For aeronautic application, taxiiing speed needed is very low compared to the maximum speed being required for a car
- Take-off and landing lead to new requirements in terms of shocks and acceleration.

Even if aircraft and rotorcraft seem to be quite similar for taxiiing use, there are specific challenges for rotorcraft:

- Horizontal take off speed could be more than 300 km/h for aircraft, and zero for rotorcraft
- The actual taxiiing cycle is not well known for rotorcraft as for aircraft
- For commercial aircraft the trips are planned and taxiing phase well known. For helicopter trips this is not the case, typical use cycles have to be defined.
- Safety issues are different and this could lead to different solutions.
- For rotorcraft there is tighter weight constraint due to the lower absolute mass and the higher sensitivity

The goal of RETAX is to explore intrinsically safe and efficient solutions for rotorcraft autonomous taxiing on ground, minimizing the overall weight of the system, based on an electrically-powered motorized wheel, integrated within the landing gear. Subsequently the goal is to select the most promising solution and develop it into a technical demonstrator to be tested.

The RETAX study has been divided into three phases in order to reach the above mentioned objectives:

- Preliminary study, to complete the set of sizing requirements, analyzes ground taxiing cycles and proposes a selection of possible technical concepts and architecture. The most suitable solution has been selected during the Preliminary Design Review (PDR), based on a matrix presentation.

- Detailed analysis of technology implementation and performance of the intended solution, and modelling of components. The global system has been detailed, tuning precisely the final solution in order to reach the best compromise.

- Manufacturing the demonstrator developed in the precedent phase. After the test of the individual components, the complete system has been assembled and tested in order to demonstrate the intended performance and the fulfilment of the requirement.

An extrapolation study has been conducted as well for medium size rotorcraft.

The former experience of Michelin in electric-drive solutions for motorized cars, busses and aircraft has been used and translated into rotorcraft electric taxiing system. A high level of integration and performance has to be reached in order to achieve an optimal solution.

Electric ground taxiing offer an improve solution, which enables to reach simultaneously extended autonomy with the helicopter, noise and emission reduction, increasing safety on the airport. But feasibility had to be demonstrated.

Project Results:

The results from the RETAX project will be described through the different phases, up to the real testing of a solution for autonomous taxiing on ground, based on an electrically-powered motorized wheel.

Preliminary study

At first the operating conditions and cycle to achieve as reference for the project have been defined, for the complete operation cycle.

This is related to the following phase: Maneuver (in and out), Taxiing (in and out), Take off, Flight, and Landing.

This takes in account also the performance to achieve, with a clear set of the requirements that needs to be fulfilled.

The output is a complete reference operating cycle per day, allowing the solution evaluation on a real life basis.

In parallel the constraints related to rotorcraft definition and integration, the safety and maintainability aspect, and the special
focus on weight reduction have been integrated. The environment related to landing gear geometry, in order to have a realistic solution for heavy rotorcraft. The cable lengths have been estimated based on actual rotorcraft, in order to make a realistic evaluation, in term of weight, loss and demonstrate the application with realistic constraints.

Different solutions have been evaluated at macro level to define electrical motorized wheel solutions based on:

- Rotorcraft definition and integration
- Environmental requirements
- Performance
- Operating conditions and Cycles
- Maintainability and reliability
- Weight
- Safety.

Heavy rotorcraft (12 tons) has been chosen as baseline. The solution to power the electrical motor will be based on high voltage power supply, and this electrical power supply will be available without rotor turning.

This can be done with APU, or with Turbine disconnected from the rotor during taxiing phase. For maneuver phase, external battery will be used.

The solutions evaluation has been conducted, to provide at the end 3 solutions for power network, and 3 solutions for mechanical integration.

A matrix for solution evaluation has been provided, allowing Eurocopter to choose the best solution for further analysis and modelisation.

The main results from the preliminary study:

- Motorized wheel solutions are feasible taking in account rotorcraft integration constraints, operating conditions and available power supply for taxiing phase. Performance can be achieved with existing integration constraint.
- Maneuvre phase using external battery for power supply is realistic, and could be considered as an interesting solution on the future, avoiding the use of a tug. The size of the battery is compatible with the foreseen use.
- Important driver for the solution is to be able to cope with rolling landing at high speed, and to be able to use backward motion for maneuver phase, if needed. These sizing cases are integrated for the proposed solutions.
- For the chosen reference cycle, electric taxiing will generate weight saving, as added weight for the system is lighter than the reduction in mass of fuel consumption.

Detailed analysis and modelisation

Once the concept has been chosen after the preliminary study, the detailed analysis and further development of this new concept has started.

The solution has been validated in detail, in order to define clearly the different components and sub-system.

The systems that are being investigated are different depending if we consider demonstration, study or future application.

For the design choice for this new solution, optimization has been conducted taking in account the different constraints, as available volume for the system or global system definition. Several loop of optimization have been performed on the list...
below to optimize the weight of the complete system:

- Gear box ratio and reduction stage choice
- Gear box type evaluation (planetary or //)
- Gear teeth choice (module, width, angle)
- Bearings choice.
- Gear teeth choice (module, width, angle)
- Casing design
- Casing optimization (constraint, deformation, cooling, lubrication)
- High speed motor choice
- Electronic choice
- Wiring and connector choice

The complete solution is based on existing landing gear and extrapolated brake to cope with the weight and performance of the rotorcraft.

The brake integration is not part of the project, but this was very important to integrate volume in order to have enough space allowance for brake integration on the future.

The different elements concern for the detailed analysis:

- Rotorcraft Power / battery supply: the solution for battery is not dependant on the chosen solution, and the solution that was evaluated before is directly applicable to this solution, as it is not link to the solution choice. For power supply during taxiing, a DC power source is considered, and that’s what will be used for testing for the demonstrator.
- The double inverter air cooled including DC power switching has been evaluated, and complement paper study has been asked focus on two subjects: Electronic air cooling and connectors interface, and EMC filter finalization with optimize elements. The goal is to have a more accurate view on what would be the solution for future real application. This will be done in parallel with the adaptation of the existing double inverter water cooled, that will be used for demonstrator testing.
- The motors wire and connector have been investigated regarding the different localisation and use. If some parts are quite similar to existing solution, this is not the case for wire with movement, high voltage and external to the rotorcraft. For these the solution used for demonstration will be based on solution already tested through intensive testing for automotive application.
- The traction motor used has been optimized for this dedicated cycle, evaluating different architecture and size, optimizing the global weight of the system, in particular link to the related wire and inverter.
- The gearbox including the engagement / disengagement system, is designed specifically for the actual geometry and the specific cycle. Different trade of have been made to optimize the gearbox link to the other constituent of the system. The output of the gearbox powers directly the wheel itself. The final solution is a multiple stage high efficiency air-cooled gearbox, The complete modelisation of the system has been conducted related to electromechanical, energetic and thermal design. This model has been encapsulated in order to be provided to Eurocopter.

The inputs of the powertrain model are mainly: torque set point, actual speed, DC bus voltage, cooling temperature, max DC bus current

And the outputs are the parameter that will be useful for simulation of the system: realised torque, max available torque, derating rate, motor losses, inverter losses, actual DC bus current, motor current, motor winding temperature, cable temperature.

The most demanding thermal cycle for the system related to power and losses have been evaluated related to real use of the
system. This cycle has been used to evaluate component losses, winding and cable temperature.

Different option had been foreseen for electric power. As the system won’t be separated from the rest of the electrical power, it is very important not to generate perturbation on the rotorcraft.

Dedicated testing has been launched regarding EMC test:

- Current ripple, on system relatively similar to the final solution.
- Conducted RF interference, with the collaboration of an external society. The tests were done first with industrial common mode filters. These tests have been reproduced using dedicated material in order to choose the best component for the application. This was done after the CDR, to have more accurate numbers in term of weight and volume for the filter.

The main results for the detailed analysis and modelisation:

- The complete solution has been detailed, modelized and simulated.
- A solidworks 3D model of the system has been provided to Eurocopter, allowing the integration inside the rotorcraft.
- A functional modelling of the components, including thermal constraints has been provided to Eurocopter on Matlab Simulink. This model is based on simulation and test on real system, similar to the one that will be developed.
- The global added weight for the system itself compare to the existing solution is less than the reduction in fuel consumption. Electric Taxing could generate weight saving!!

Manufacturing and testing of the demonstrator

The small adjustments to design according to feedback coming out of the CDR have been conducted first, to be integrated to the final solution.

The changes that were needed related to the mechanical part were mainly necessary to improve maintainability of the system, avoiding needing special maintenance level to take care of the system (reduction from maintenance level 3 to level 2, avoiding the opening of the system.

For inverter, complements regarding EMC have been done, and modification on the electronic design for air-cooled solution. These investigations on cooling system are focus on weight improvement of the system.

Once the final solution had been completed, all the detailed 2D drawing have been drafted and checked, taking in account a fine optimisation of each part, in order to gain weight.

The manufacture of the parts has been conducted according to the planning, allowing the assembly of the individual components and tests.

The main individual tests are related to:

- Motor testing
- Gearbox testing

In parallel the test bench have been adapted, in order to test the demonstrator according to the defined requirements.

The manufacturing for the different parts were compliant to the drawing.
Mounting of the system has been done as planned, without deviation compared to the foreseen solution.

No modification has been needed for the complete solution.

The physically complete demonstrator adapted to a simplified landing gear has been delivered on time, including the possibility to mounting on the different test bench.

The testing of the complete demonstrator has been performed through different steps:

- Safety demonstration
- Performances demonstration
- Endurance testing

The demonstration of compliance of the system with the safety requirements has been conducted mainly on the dyno test bench.

The positive results have demonstrated the full compliance of the system to avoid wheel jamming and to allow medium speed rolling take off, and high speed rolling landing.

The demonstration of compliance of the system with the main performance requirements has been performed on the face to face test bench, with a torque meter between the 2 systems.

The main specifications have been demonstrated based on the Retax maneuver cycle and Retax taxiing cycle, associated to specifics tests for focus performance.

All these performance requirements are related to the real use of a 12 tons rotorcraft.

The endurance testing has been performed based on the defined taxiing cycle, under the same conditions. The tests have been conducted on the face to face test bench as well.

During the timing of the project, it has been possible to achieve the equivalent distance on wheel of 1750 km, corresponding to around 1600 FH.

During this test, the electrical values and temperatures have been continually checked, and the gearbox has been regularly open for visual check.

After this endurance testing, no alteration of the motor or gearbox has been detected.

The main results for the Manufacturing and testing of the demonstrator:

- Designed solution is fully adapted to manufacturing and assembling of the system.
- Based on the Eurocopter specifications for heavy rotorcraft, all the different tests have been successively passed, related to:
  - Performance
  - Taxiing and Maneuver Environmental
  - Electric Power Supply
  - Safety and integrity
- The weight for complete system is in line with the target value
- The demonstrator illustrates the feasibility of the integration of the electric taxiing on a real heavy rotorcraft environment.
Extrapolation study of system design for medium weight rotorcraft

- This extrapolation has been done adapting the key data to the performances for a medium weight rotorcraft with the available power and voltage, and the design constraints. The solution is based on the prototype technology used for the heavy rotorcraft, reduced to fit with the smaller size rotorcraft specifications, off course this one is done at macro level compare to the other solution
- On the principle, the solution designed for a 12 tons rotorcraft is applicable to the 6 tons rotorcraft. Taking in account the same cycle and the same constraints of use (max speed, slope, power supply...) the major effect is the reduction of the max torque at start, which is being proportional to the mass.
- For this extrapolation, the first solution has been designed for the main landing gear. The nose landing gear has been explored as well afterwards, relaxing some constraints (traction on snow).

The main results for the extrapolation study for medium weight rotorcraft:

- The integration of a motorized wheel for taxiing a 6 tons rotorcraft is feasible, and provides many advantages, as for the heavy rotorcraft
- The choice of the solution on the nose or main landing gear is really dependent from integration constraint. For piloting function and traction availability, the main landing gear would be the preferred solution. Nevertheless, integration constraint could lead to use the nose landing gear. It is very important to consider the integration of the motorized wheel on the initial design, to avoid conflict with other system, as with the braking system for example.
- The performances for this particular application are actually not in line with the expectation, due to two main reasons:
  o The available power supply is limited.
  o The low voltage implies the need of a DCDC convertor.
This is not related to the RETAX system itself.

This extrapolation gives a first view of the feasible solutions, as a first step, but if the first application of the RETAX solution would be on a medium weight rotorcraft, a complete study would be needed, with a system entirely integrated, and fully designed for that solution.

Conclusion

- The RETAX solution has been analyze and test in detail with promising results in term of performance achievement and safety features related to undesired events. RETAX demonstrator proves the technical viability and effectiveness of such electrically driven rotorcraft ground taxiing. A TRL4 has been reached.
- The global system for the heavy rotorcraft represents an added weight smaller than the fuel consumption reduction estimated around 80 kg for the foreseen cycle. CO2 reduction represent around 200 tons/year/rotorcraft.
- If the first application would be the 6 tons rotorcraft, a complete study would be needed. The importance of the adapted power supply and integration has been demonstrated.
- Michelin is fully aware that the implementation of electrical taxiing on rotorcraft is a big step in innovation. Every aspect needs to be addressed in order to reach the necessary acceptance by the stakeholder – customers, crews, maintenance etc.
- Many details have been addressed in the present RETAX study, but this is a first step toward introduction of this technology on the aerospace market.

With the RETAX project, feasibility has been demonstrated, using intrinsically safe and efficient solutions for rotorcraft autonomous taxiing on ground, minimizing the overall weight of the system, based on an electrically-powered motorized wheel, integrated within the landing gear. This has been done through testing of a complete manufacture landing gear including motorized wheel.
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Potential Impact:

The potential impacts of the RETAX project are listed below:

- Improved international competitiveness of the European helicopter industry
- Optimal employment opportunities in this industry by means of existing job anchorage and new job creation in Europe
- Reduction of fuel consumption and thus CO2 emission during taxiing phase of operation, in line with the Clean Sky JTI objectives concerning the greening of air transport
- Reduction of noise emissions at heliports and at other landing and take-off sites for helicopters
- Reduction of wear of mechanical parts, especially the rotor tilting mechanism, and suppressing a mode of use for which the rotor is not designed for. In cases where substantial ground taxiing is used, this could have an impact on the incident frequency due to rotor wear.
- Possible elimination of the tug or tractor vehicle used in heliports to manoeuvre the helicopter
- Increasing effective range of the helicopter, in case where the fuel consumption savings during taxiing are higher than the fuel consumption penalty caused by the added weight of the system.
- Increased flexibility of operation on the ground (autonomous maneuver and taxiing, movement when limited noise is allowed)
- Improving ground personnel safety (rotor not spinning).
- Contribution to the electrification of the helicopter by means of replacement of hydraulically or pneumatic systems by electrical systems thus reducing weight and increasing reliability and efficiency

RETAX impact on EU Competitiveness

The efficient and functional integration of e-drive capabilities into the landing gear of a medium size or heavy rotorcraft would strongly contribute to EU competitiveness. In Europe the main other player besides market leader Eurocopter is AgustaWestland. European industry is strongly committed to the greening of vertical lift aircraft, which is demonstrated by various large budget R&D projects as well as by the launch of a variety of new or upgraded products which are more fuel efficient than the products they replace. The rotorcraft market is dominated by few players that compete strongly; besides the aforementioned European players, USA based Bell and Sikorsky are important on the global market. To these established players, some newcomers are growing fast, especially in Asia, at the moment still often working under licence of one of the established US or EU players.

Helicopters are major investments, and most of them are acquired by professional operators that seek above all reliable performance at minimal cost. As each helicopter is such a major investment, the model is often customized for a specific client, especially if such a client purchases several units at once. The final choice of supplier is thus also affected by such supplier’s capability to offer tailored functionality. One of the concerns that operators of rotorcraft have is the safety on the ground, especially when the rotor is spinning.

Another important argument related to options on the helicopter is that they could be chosen not only because they are needed, but also because it could be an important argument to sell the rotorcraft on the future.

Mid-sized and heavy rotorcraft are too heavy to handle by hand or by hand-operated powered tug; they are thus mostly manoeuvred on the ground using larger tugs (tractors) for some initial positioning, followed by rotor-powered ground taxiing for subsequent manoeuvring. Due to the safety concerns regarding rotor-powered ground taxiing, most pilots opt for limited manoeuvring on the ground, taking off as soon as possible and then orienting the helicopter in flight. Of course, in many
locations, tugs (tractors) are not available, limiting the options to either ground-taxiing using rotor thrust, or hover-taxiing at very low altitude; both options statistically result in accidents more frequently than most other situations.

RETAX e-driven landing gear wheels also would impact on the amount of maintenance required for the rotor tilting mechanism and the main thrust bearing that carries the main load from the rotor lift forces. This part of the rotor bearing mechanism suffers more than normal in ground taxiing operation mode, and such loads would be avoided if the helicopter were to use e-driven ground taxiing.

Helicopters offer substantial flexibility in choosing take-off and landing spots. One of the reasons why helicopters are used is exactly this: flexibility. However, this flexibility means that helicopters can land in places not completely prepared as heliports. It is especially such places that can be accident prone, as the circumstances are less controlled and often site safety officers are more required to improvise safe procedures for boarding and disembarking of passengers. Especially in such improvised landing spots, taxiing tractors or tugs are not available, resulting in either the need to refrain from ground taxiing altogether, or to employ rotor driven ground taxiing. If a helicopter would have an on-board e-driven taxiing system, then it could operate with much higher safety on such improvised landing or take-off spots.

Finally, one should take into account that rotor-powered ground taxiing only allows for forward movement of the helicopter, due to the tilting mechanism limitations on helicopters. Taxiing in reverse (backwards) is not possible at all using rotor powered taxiing. This means that while tractor or tug powered taxiing does allow for movements in all directions, this is not the case for rotor-powered ground taxiing. Thus the RETAX project will have a positive impact on the manoeuvrability of rotorcraft especially in those situations or locations where tractors or tugs are not available. In general, one can establish that e-driven ground taxiing capability will make operation of helicopters more flexible on the ground, allowing for cost savings regarding safety measures (less safety officers or other safety resources required while increasing actual safety), allowing for faster manoeuvring on the ground (reduced turnaround times) and for simplification of safety protocols related to ground taxiing.

The factors mentioned above are likely to make a helicopter with an e-drive system more competitive in the global market scene.

Retax impact on EU employment

The competitiveness of the EU industry directly results in EU jobs being maintained in Europe. Currently, the helicopter manufacturing and maintenance industry in Europe employs some 15.000 people in Eurocopter and 7.000 in AgustaWestland, plus maintenance and subsystem suppliers like Messier Bugatti; in total some 35.000 people which will all benefit from EU helicopters offering functionalities that make such helicopters more attractive to the marketplace.

Retax impact on CO2 reduction and energy transition

In the overall picture of CO2 emission sources, helicopters really are a very minor part of the total transport related emissions. Also in terms of fuel consumed, the helicopter operation part is a minimal part of all transport fuel consumption. Still, regardless of the small percentage of the total CO2 emissions, policies are developed (and will be implemented within the next few years) which put pressure on helicopter emissions.

Rules are evolving regarding CO2 trading, related to the weight or CO2 per year, to decide what type of rotorcraft will be affected.

This development in which helicopter operators will be obliged to purchase emission allowances to cover their CO2 emissions will further drive CO2 reduction investments by helicopter operators.
It is very interesting that the use of the motorized wheel for taxiing, without rotor turning, will generate fuel savings. For the foreseen operating cycle for a heavy rotorcraft, the savings will represent around 246 kg of fuel per day, or 64 tons per year per rotorcraft.

The weight saving for the cycle is higher than the added weight for the RETAX system.

The CO2 equivalent saving represents around 200 tons per year per rotorcraft!!

(3.15 grams of CO2 generated per gram of kerosene)

And electric taxiing could generate weight saving.

One should take here into consideration that helicopters are still very exclusive vehicles; less than 2000 per year are sold. For this reason, the fuel consumption impact of the RETAX will not have any significant impact on CO2 emissions in the world.

RETAX impact on quality of life

The ability to taxi a helicopter on the ground with limited engine power being used can help to minimize the noise generated by helicopters during take-off and landing. This noise is most negatively perceived if it is related to a fixed location where helicopters take-off and land often, like a heliport as found near airports, near hospitals, mountain rescue bases or traffic police or coast guard heliports.

The most important source of noise from helicopters is in fact the rotors; these produce most of the noise emitted, while the engines themselves produce only a less-propagating higher-frequency noise that does not carry as far as the typical main rotor noise.

In ground idle with two turbine and rotor turning, an heavy rotorcraft can be expected to radiate noise levels of approximately 100 to 110 dB(A) for an observer at a distance of 16 meter. The associated 8-hour working day exposure and peak pressure levels for this type of aircraft meet European regulation 2003/10/EC concerning safety and health requirements for workers wearing hearing protection. However, significant improvement in the working conditions around helicopters during ground operations can be achieved by having only one turbine in idle without rotor turning. The real measurements of the value were not possible in the scope of this study.

The reduction of noise during ground manoeuvring is not only relevant for those who live near heliports, it is perhaps most important for those who work on these heliports. Besides reducing the noise pressure on these professionals, the reduction of this noise pressure also helps to reduce stress levels and increases the possibilities for verbal communication on the ground, which both increases working conditions and ground operations safety.

RETAX impact on safety

Statistics show that over half of all helicopter accidents involve ground operation or take-off / landing procedures. The international IHST has set an 80% accident incidence reduction target by 2016, and achieving this internationally agreed target will require all safety improvements available to the helicopter operation community.

The e-driven taxiing will avoid accident-prone situations, which are nowadays sometimes unavoidable during helicopter operation in practice.
• The spinning main rotor (and tail rotor) is a source of great risk, especially when operating around un-experienced or untrained passengers. Ground taxiing can be done without the rotor in operation, substantially reducing the risk of accidents involving ground personnel being hit by the rotor, or accidents where the rotor hits other objects.

• The air displacement created by the rotor also generates risk with regard to light objects or sand being blown upwards into the air, which can result in such objects getting caught in the rotor blades, which can damage the rotor but can also result in accidents for bystanders.

• In addition, non-powered landing gear wheels can get ‘locked’ in a position perpendicular to the thrust of the rotor, which is referred to as wheel-lock. When this happens, the only way to make the helicopter manoeuvrable again is by manually (or with a powered tractor or tug) moving the wheel, which requires ground personnel to approach the wheel, creating a risk situation. An e-driven landing gear wheel would make such a ground crew intervention obsolete, reducing the amount of risky situations that can occur during take-off and ground taxiing.

During the last decade, in the world some 550 helicopter accidents were reported per year, of which more than half occurred during take-off or landing procedures. Helicopter accident incidence is 9.1 per 100,000 hours of flight, compared to 0.175 accidents per 100,000 hours of flight for normal aircraft (International Helicopter Safety Team, www.ihst.org).

In fact, when looking at the flight phase distribution of accidents, one can conclude that taxiing only represents a minor share of all accidents (5 accidents, all non-fatal); however when combined with landing (78 accidents) and take-off (46 accidents) these three phases together cover about half of the incidents (source: EHEST European helicopter accident analysis report 2000-2005)

Even though we may conclude from this data that taxiing is not the most risky flight phase, this should not be interpreted as a limited potential for safety improvement to be allocated to e-driven taxiing. At present, ground taxiing is not done a lot with helicopters, and exactly because of this fact, few accidents happen in this phase. One can however safely assume that the availability of safe ground taxiing functionality would allow for a reduction of the amount of accidents in adjacent flight phases (landing and take-off) as the helicopter pilot could execute manoeuvres on the ground which today are executed near-ground (air-taxiing).

Dissemination activities

The overall project during these 26 months achieved the goal to demonstrate the feasibility of the electrical taxiing without rotor turning. The complete work to be able to get a real demonstrator at the end generated more work than initially foreseen.

As this feasibility demonstration was a real goal of the study, trades-off have been made, in order to be able to focus on the real goal.

The available working hours, have been dedicated mainly to this feasibility demonstration, and it was agreed to reduce the dissemination actions to the minimum, using the web site as center point for the communication around the project.

The other important point is that we are used to communicate about factual value already demonstrated, and for the RETAX project we ended with the endurance test in November 2013...

A presentation around the RETAX project has been done during the Cleansky communication general meeting, on November 2012.

Exploitation of results

The different testing conducted on the heavy rotorcraft and the extrapolation study for the motorized wheel is a first step
towards greener rotorcraft operations.

The next step will be the integration of the solution into the complete rotorcraft, taking in account the following point that need to be demonstrated:

- Power supply available for taxiing compatible with the function in term of voltage and amount of power
- Possibility on the rotorcraft to have available power through the APU or turbine, without rotor turning
- Pilot work load acceptable related to the necessity to start the turbine just before take-off, and to stop it just after landing (including preheating or precooling time)
- Reliability of the start of the turbine just before takeoff.
- Piloting function of the system, with adequate man machine interface.
- Demonstration of the system on real environmental conditions

Before going further, it is really important to validate the points that needs to be demonstrated, especially the one that are not directly linked to the follow-up on this electrical motorized wheel, but are more related to the rotorcraft itself, as for example the start of the turbine.

For these questions to be solved it’s important to have a synergy with the aircraft activities around electrical taxiing, as part of the difficulties and solutions are the same.

The estimation of the number of rotorcraft to be considered for this taxiing application is hard to evaluate, but a first attempt could be done:

Based on an acceptable rate of the solution of 30%, the potential market for the RETAX solution would be:

Global market for medium and heavy weight rotorcraft with taxiing option:

Around 100 machines / year

Remark: the acceptable rate could be different if the RETAX solution is asked by part of the customers. It could be the same as for the windlass that is not needed by many customers, but is very useful to sell the rotorcraft, and often taken as option.

Further customer assessment in order to validate the acceptable rate for the solution will be needed, once the higher TRL will have been reached.

List of Websites:

www.retax-project.org

www.retax-project.com

**Related information**

| Result In Brief | The silence of taxiing rotorcraft |