There has been consolidation in the number of self-taxi systems down to three main projects. Two use motorised wheels, while the third uses a modified tractor towing tug. With the first of these systems due to enter service, more of their economic benefits are coming clear.

The progress of self-taxi systems

Fuel has been the most significant operating cost for airlines in recent years. As oil prices have continued to rise, airlines have looked for new ways to improve efficiencies and lower their fuel bills.

Self-taxi systems are a development that could cut aircraft fuel consumption. Other indirect benefits include time savings, lower maintenance costs and reduced CO_2 emissions.

The main concept behind self-taxi solutions is to move an aircraft between the runway and the airport gate without using aircraft engines. With a self-taxi system, engines need only be started and run for the minimum time necessary for warm-up before departure. Engines can be shut down immediately after landing, provided that thrust reversers have not been used, or shut down after a minimal cool-down period if reversers have been used.

Suppliers

There are three competing self-taxi solutions with realistic aims of entering service in the next three to four years: WheelTug; Honeywell/Safran's joint venture electric green taxi system; and IAI's TaxiBot.

WheelTug

The WheelTug solution involves installing electric motors in each of the aircraft's two nose wheels. These allow the aircraft to back up from the stand and move forward without using the engines. Electrical power for the motors is supplied by the auxiliary power unit (APU). A dedicated cockpit panel provides the interface for the pilots to control the system. The added weight of the WheelTug solution is about 300lbs.

An important element of the WheelTug business model is that there will be no upfront capital expenditure requirement for airlines. Before the system enters service WheelTug will agree lease contracts with individual operators. This will identify the estimated savings the airline will make from using the WheelTug system. The equipment will be supplied free of charge in return for lease payments totalling half of those savings.

"Airlines want to see a return on investment (ROI) within two or three years. By supplying the equipment for free in return for half of the savings realised, they can achieve an instant return," claims Isaiah Cox, chief executive officer, WheelTug.

Initially WheelTug will be available for 737NG and A320 family aircraft. Versions for the MD-80, 757, regional jets and even widebody aircraft could be launched in the future based on demonstrated airline interest.

WheelTug currently has 549 reserved delivery slots with 10 airlines, including KLM and El Al. At the beginning of June it announced a slot purchase agreement with Air Berlin for 110 delivery slots across its 737 and A320 family fleets. "We are currently estimating entry into service during the third quarter of 2014 although this is a rolling timeframe," says Cox. "We are waiting for aircraft manufacturers to supply the data we need to expedite WheelTug's development and certification."

Honeywell/Safran

The electric green taxi system is the result of a 50/50 joint venture partnership between Honeywell and Safran. It draws upon Honeywell's experience in avionics, electric power systems and APU integration and Safran's electric power systems and landing gear expertise.

The electric green taxi system is based on integrating electric motors into an aircraft's main landing gear. These move the aircraft using power from the APU's generator.

"Wheel actuator assemblies will be mounted and integrated into both main landing gear legs. The assemblies consist of an electric motor, clutch assembly, wheel interface and a reduction gearbox," explains Brian Wenig, vice president, electric green taxi system, at Honeywell. "One outer main wheel on each leg will be powered by the electric motors."

A cockpit interface will give pilots control over speed and direction while taxiing. A demonstration version of the system is undergoing in-depth testing using a dedicated A320. The current test version adds about 700lbs to an aircraft, but Honeywell/Safran are focused on reducing the weight for the full production model.

The electric green taxi system is aimed solely at narrowbody aircraft, including the 737 and A320 family, the Embraer E-Jets, the Bombardier C-series and Comac's C919. "We are targeting entry into service on single aisle platforms by the end of 2016," says Wenig. There are no plans to adapt the system for larger or widebodied aircraft.

There is no official word yet from Honeywell/Safran on the likely cost of their taxi system, but they claim a high level of interest from airlines.

IAI

IAI has taken a different approach to the self-taxi problem. Rather than focusing on aircraft-installed devices, it has come up with a modified tractor tug solution.

TaxiBot is a modified towbarless tug vehicle that is controlled from the flightdeck, and can transport an aircraft to and from a runway without the use of engines. Pilots control the vehicle's traction, braking and steering. The aircraft's nose wheels sit on a turret at the back of the vehicle. The pilots use the

Conventional aircraft taxiing incurs many different costs, as well as having several other indirect effects on issues such as aircraft turnaround times and noise emissions at airports.

steering tiller on the flightdeck to make directional adjustments, as they would with a conventional taxi situation. These steering inputs turn the turret on the TaxiBot, which turns the wheels on the tug vehicle to steer in the required direction.

TaxiBot vehicles are powered by hybrid diesel/electric engines. Sensors on the TaxiBot detect when pressure has been applied to the aircraft's mainwheel brakes, and reduce the tug's power to slow down. On taxi-out a TaxiBot vehicle will move an aircraft to a holding point off the runway where it can start its engines. The TaxiBot will then be disconnected and driven back to the terminal area.

For taxi-in a TaxiBot will need to be connected to an aircraft at a point away from the runway before moving it to the gate. The aircraft will still need to run its APU during TaxiBot operation.

There will be two main types of TaxiBot, for narrowbodies and widebodies.

The narrowbody (NB) version will be certified for A320 family aircraft in early 2014. Certification for 737NG family aircraft is expected to take place soon afterwards. Other narrowbody types for which IAI plan future TaxiBot certification include the 757, and MD-80 and -90 families.

"The widebody (WB) TaxiBot will be officially certified for Airbus and Boeing aircraft from mid-2015," says Moshe Ararat, business development and marketing, IAI LAHAV. "It will have capability for A330, A340, A380, 767, 777, 747 and MD-11 aircraft."

IAI plans to display the TaxiBot at June's Paris Air Show. Following this Lufthansa Leos will test three NB TaxiBot vehicles in a typical daily operational environment with Lufthansa's 737 fleet at Frankfurt airport in July 2013.

Benefits for airlines

The main potential benefits of self-taxi systems for airlines are: a reduction in fuel burn; time savings; lower maintenance costs; and a reduced environmental impact. Those operators that spend the most time taxiing will benefit most. This includes airlines with high average daily flight cycles, such as low-cost carriers and regional operators. It also includes those airlines operating from congested airports with long taxi times.

Taxi Fuel

Existing conventional methods involve using one or more engines to taxi an aircraft between the runway and the terminal gate. At some large or congested airports the taxi time per flight cycle and subsequent fuel burn can be considerable.

All three self-taxi solutions under development claim to reduce fuel burn during taxi. Although the aircraft's APU needs to be run during taxi for all three solutions, this will burn far less fuel than using the engines.

For a typical 737NG or A320 family aircraft, WheelTug claims its system will reduce taxi fuel costs by $180 per cycle from dual engine taxi, and by $110 per cycle from single engine taxi.

The Honeywell/Safran electric green taxi system is being developed to target 4% reductions in complete block fuel.

IAI claims that TaxiBot could reduce the amount of fuel burned on the ground during taxi by 80-85% for all aircraft.

Time

"Fuel savings are still the main justification for electric taxi systems, but time savings are where it starts to get interesting" says Cox.

The greatest time savings are likely to be achieved by installed electric motor systems, because there is no need to wait for tractor tug availability, connection, pushback and disconnection. For 737NG or A320 aircraft WheelTug claims that its self-taxi system can save an average of 150 seconds per departure when compared to a towbar tractor, and 130 seconds when compared to a lift tug.

A more significant turnaround time saving could be achieved by what WheelTug refers to as the WheelTug Twist ™. This is based on the capability to taxi on to the stand and rotate the aircraft safely without the need for engines and the subsequent risk of jet blast. The aircraft can then be parked side on to the gate, making the front and rear exits equally accessible. This could speed up enplaning and deplaning.

All three self-taxi systems will provide a turnaround time benefit of several minutes by avoiding the need to wait at the gate for the aircraft's engines to warm up.

WheelTug claims that its self-taxi system could save up to 17.5 minutes per turnaround. Over the course of a day this may be significant enough to allow an airline to increase utilisation and add an additional rotation to its schedule. The Honeywell/Safran system might provide similar capability. TaxiBot will save several minutes by removing the need for engine warm-up at the gate but it will still require time for tugs to be connected. It is also unlikely that the TaxiBot could provide the manoeuvrability required to rotate the aircraft at the gate to allow for equal access to the front and rear exits.

Aircraft maintenance

The ability to move an aircraft between a runway and the airport gate area without the use of engines will also reduce engine running time. This could lead to longer removal intervals and lower maintenance costs.

Moving away from the apron area with engines off also reduces the risk of engine foreign object damage.

Brake wear should also be reduced by self-taxi systems. WheelTug claims that in conventional taxiing 30% of brake wear

It was announced in June 2013 that Air Berlin had reserved 110 delivery slots for WheelTug's self-taxi system for its 737 and A320 fleets. This takes Wheeltug's total reserved delivery slots to 549 across 10 airlines.

occurs on taxi-out, and 5% during taxi-in. It estimates that for an NB aircraft operating an average of 4.5 cycles per day, the e-taxi system could save $19,200 a year in carbon brake costs.

Environment

Carbon emissions are reduced through the use of self-taxi equipment, because less fuel is burned. "Using the electric green taxi system could reduce CO2 and NOx emissions during taxi by more than 50%," claims Wenig.

Taxiing to and from the terminal area without engines will also reduce noise levels. WheelTug points out that this may be useful at airports with strict noise curfews. Such curfews will often dictate the time that the first engines can be powered up in the morning. By using self-taxi systems airlines can begin moving their aircraft on to the taxiway before the curfew lifts, so they can take off minutes after the curfew expires. WheelTug claims that this efficiency gain could allow for five to 10 additional peak morning take-off slots, worth up to $3 million at congested international airports.

Aircraft-installed v tractor tug solutions

Both the installed electric motor and tractor tug solutions have their advantages, with potential reductions in fuel burn, maintenance costs, turnaround times, and environmental emissions.

Installed electric motor self-taxi systems will add structural weight to an aircraft. They can also, however, reduce the amount of contingency or margin taxi fuel that is carried for taxi purposes. Installed self-taxi systems can be considered weight-neutral when the amount of 'just in case' fuel loaded for taxiing is equal to the combined weight of the self-taxi hardware and the fuel burnt by the APU during taxi.

TaxiBot will bring similar weight savings in terms of reduced contingency requirements. It also has the benefit of not adding structural weight during flight, because it involves no modifications to the aircraft. This means that TaxiBot users could have lower overall block fuel burn.

There have been questions as to whether installed self-taxi systems will require more power than that provided by standard APUs. Both WheelTug and Honeywell/Safran claim that this is not the case, and that APU modifications will not be necessary.

The installed systems developed by WheelTug and Honeywell/Safran offer greater autonomy than TaxiBot. This is because the aircraft is not dependent on an airport having the appropriate tractor tugs for self-taxi purposes.

WheelTug and the electric green taxi system are also more likely to save time on turnarounds. Aircraft using installed electric motors can taxi away from the stand without needing to wait for tug vehicles to become available and then be connected to an aircraft.

Another benefit of the installed self-taxi systems is that they will not require changes to airport infrastructure. For TaxiBot operations it might be necessary to adjust infrastructure to allow for the tug vehicles to be hooked and unhooked in remote areas of the airfield.

"I believe there is a market for both the installed and TaxiBot approaches," says Wenig. "Installed electric motor solutions are more suited to single aisle aircraft, while TaxiBot is potentially more suited to larger WBs."

NLG vs MLG installed systems

The two installed electric motor systems under development have taken different approaches to the self-taxi concept. WheelTug decided to focus on a nose landing gear (NLG) solution, while Honeywell/Safran chose to develop a main landing gear (MLG) system. Both approaches could have their advantages.

The WheelTug solution looks as though it will add less weight to the aircraft. It is estimated to weigh 300lbs, compared to a current test system weight of 700lbs for the electric green taxi system. This difference could lead to aircraft with WheelTug installed burning less fuel in flight.

"The main reason for developing the electric green taxi system using the main gear is the greater traction that this affords over the nose gear," claims Wenig. "On current NB aircraft, only 7-8% of the weight is distributed on the nose gear."

The improved traction resulting from a main gear-based system has two chief advantages. The first is the acceleration characteristics during taxi. Using the electric green taxi system, an aircraft will be able to go from 0-20 knots in 90 seconds. The second main benefit is that the electric green taxi system will be operationally capable in all weather conditions, including in snow and rain when surface friction is reduced," says Wenig. In some weather conditions the level of traction provided by a nose wheel taxi system may not be sufficient to move an aircraft.

"There is no question that a main gear system will have better traction," admits Cox. "Even though our dispatch reliability is aimed at 99.8%, there will be situations where the WheelTug will not be used for all ground movements. Our goal is commercial value. To cover 100% of the operational envelope would require a longer certification process and a less commercially attractive solution," adds Cox.

WheelTug's main aim is to provide a cost-effective solution that can be used in at least 95% of situations.

Aircraft brakes and anti-skid sensors are installed in the main landing gear. WheelTug claims that installing electric motors in close proximity to these systems could cause problems.

Wheeltug's self-taxi system is based on installing electric motors in the aircraft's nosewheel. By supplying the equipment free-of-charge in return for half of the savings realised by an operator, WheelTug hopes its system will provide an instant return on investment.

According to WheelTug, heat from an aircraft's brakes could limit the life of a self-taxi system's electric motor, and potentially require the installation of a cooling system. Conversely WheelTug claims that heat from a taxi system's motors could prevent an aircraft's brakes from cooling as quickly. WheelTug suggests that this could lead to aircraft needing to wait longer for brakes to cool, which could undermine any turnaround time savings promised by an installed electric taxi system.

Cox also points to the potential certification complications of positioning the electric motors of a self-taxi system in close proximity to an aircraft's anti-skid sensors. "Anti-skid sensors are safety-critical systems. There will need to be proof that the taxi system's motors do not interfere with these anti-lock devices, which probably involves challenges like rejected take-off (RTO) tests."

By installing the electric motors of its e-taxi system in the nose wheels, WheelTug can avoid the potential technical complications associated with brakes and anti-skid sensors. WheelTug also believes that the design of its nose wheel will make it easier to install and remove than competing MLG solutions. Cox claims that WheelTug can be installed in two shifts, equivalent to 100 man-hours.

The airport perspective

For airport operators there are potential apron efficiency, safety and environmental benefits to be gained from aircraft using self-taxi technology.

Testing of WheelTug's e-taxi system took place at Prague Airport in 2012. "Using installed electric motor taxi technology such as WheelTug can save about three minutes on push-back. This is the time it usually takes to disconnect a tractor tug and prepare to taxi," explains Libor Kurzweil, director of quality, safety and process management, at Prague Airport. "Prague airport used simulation software tools to investigate differences between movements of conventional aircraft versus those equipped with WheelTug. We estimate that apron throughput could be 2.7% higher when aircraft use WheelTug, because of the shorter turnarounds."

"Self-taxi systems may help to reduce the noise and pollution footprint from an airport operation, both within the airport perimeter and in the close vicinity," continues Kurzweil. "Claims that e-taxi solutions like WheelTug can help operators move aircraft earlier at airports with noise curfews are not clear cut. It will depend upon the individual airport and local conditions. The use of WheelTug may not get around curfew restrictions relating to engine start-up, since a running APU is still considered to be an aircraft engine."

Kurzweil believes that there are more advantages to installed systems rather than the robotic tractor tug approach. "From the airport operator's perspective, the installed systems look better. Taxiing with the use of electric motors in the aircraft's wheels does not require any new infrastructure or totally new procedures. New procedures are needed for robotic tugs, and possibly even new infrastructure, to allow areas for the safe unhooking of tugs near the runway. With the robot, you only transfer the tug disconnect problem to another area of the airport."

The airline perspective

easyJet has been working with Honeywell/Safran during the development of the electric green taxi system, although it has not yet ordered the system or tested it on its own aircraft.

"We supplied Honeywell/Safran with a lot of operational data in order to determine realistic predictions for cost savings and other benefits from adopting the electric green taxi system," says Ian Davies, head of maintenance and engineering, at easyJet. "We are enthusiastic about the system and the benefits it could realise."

One question levelled at self-taxi systems is the potential for increased maintenance costs due to increased APU usage. Davies does not see this as a defining issue. "We already use the APU for engine air starts," he explains. "easyJet uses single engine taxi procedures during which the APU is running. Installing the electric green taxi system on our fleet would not alter our APU usage."

Despite the positives, Davies points out a number of important issues to consider before adopting the electric green taxi system. "The system will add extra weight to the aircraft. The golden rule is that every extra 100kg you add to an aircraft can cost you 3% more on in-flight fuel burn. Adopting the system would also require a big capital investment," adds Davies.

Summary

Self-taxi systems have the potential to improve airline cost and operational efficiencies. The first systems are currently estimated to enter service in 2014. All three self-taxi systems under development have the potential to reduce taxi fuel burn, environmental emissions and maintenance costs.

TaxiBot benefits from adding no weight to an aircraft, so it will not impact in-flight fuel burn. WheelTug and Honeywell/Safran's electric green taxi system are likely to provide greater autonomy and faster turnaround time. AC

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