Flywheels – a 'Goldilocks solution' for aircraft emissions

Author: **Jonathan Firbank**

Passenger planes use thrust engines to 'taxi' on the ground from airport gate to the runway, which creates a large amount of emissions on the ground in a very short time. A collaboration between the University of Malta (UM) and the University of Nottingham Ningbo, China is working towards a solution to this problem. ***Jonathan Firbank*** *explores the subject following an interview with* ***Dr Robert Camilleri****.*

If you drive, you might have noticed that you burn more fuel when you are moving slowly. Urban driving, with all the traffic, red lights, and awkward corners does even more damage to your fuel than it does to your nerves. Your car's engine is most efficient around 60mph, in its highest gear. As the gears go lower and the cars go slower, more fuel is wasted.

Now imagine that car was hundreds of times heavier. And imagine that its engines were designed to be efficient at 600mph instead of 60, powerful enough to catapult it through the air over vast distances. Then imagine how inefficient its fuel consumption would be if it was stuck in traffic, starting and stopping, trundling around at the frustrating speeds of urban driving. The amount of wasted fuel would be staggering, a financial and environmental disaster. This is the reality of an aircraft taxiing on the ground.

Transport is responsible for approximately 16% of greenhouse gas emissions, with aviation contributing about 2%. Though this portion is relatively small, in the last four decades, the industry has steadily grown at 5% per annum. A bright future for conventional aviation is no such thing for the environment unless new technologies can curb its impact on climate change.

The problem hasn't gone unnoticed. For decades, research has been directed towards airplane fuel efficiency, with the industry leaning towards hydrogen power, hybrid engines, and increased electrification. Now, eyes move to the situation on the ground. An aircraft might only spend up to 10 minutes taxiing before a flight, but in that time, the engines (which are optimised for flight) can consume around 200kg of fuel. This problem is radically compounded in Europe.

Within the EU, the emergence of budget airlines like Ryanair and Easyjet operate aircraft for multiple short flights a day, vastly increasing the percentage of time moving on the ground (in comparison to transcontinental flights). The EU has legislated that aircraft taxiing must become emissions free by 2030. If this is achieved, it would clearly curb carbon emissions without limiting air travel in the region. But how it can be achieved has been decidedly less clear.

THE GOLDILOCKS DILEMMA

KERS-Air and REACTIVE, two international research projects, are trying to tackle this problem of ground aircraft pollution. The initiatives are headed by Dr Robert Camilleri (Institute of Aerospace Technologies, UM) and Prof. He Zang (University of Nottingham Ningbo, China). They are

research collaborations that also incorporate Medavia Ltd. (a Mediterranean aviation company) with the support of COMAC (a Chinese commercial aircraft corporation). As KERS-Air conducted preliminary research, it became clear that many solutions supporting zero-emission taxiing would generate new problems. Using an environmentally friendly tow truck to move planes would place a lot of new vehicles into an already busy space, creating a logistical nightmare as tow trucks were assigned to each aircraft. On the other hand, on-board solutions such as installing electrical motors at the aircraft's wheels needs a lot of electricity, which needs to come from the plane's Auxiliary Power Unit (APU), which was not designed for that. Upgrading the APU would be an expensive prospect and would add a large weight (which needs to be carried in flight) that would increase greenhouse gas emissions, offsetting the benefits on the ground. A workable proposal would need to weigh no more than the fuel currently used in taxiing.

KERS-Air proposed a more elegant solution. When a plane hits the runway, a vast amount of energy is expended, as the aircraft's brakes work to slow down an enormous weight travelling at high speed. If this energy was captured and stored temporarily, recycling it could provide a green form of propulsion. Similar ideas have been deployed in Formula 1 (F1). As F1 racers have become more electronic, they have incorporated systems that briefly recover and store energy as they brake around corners, then release it to reaccelerate. A less romantic example of the tech is found in the UK in 'soft hybrid' buses, which need to continually stop and start.

Simply upscaling existing technology is not an option. Storing the massive energy from a landing aircraft is not comparable and requires a novel energy storage solution. While batteries can store a substantial amount of energy, they cannot store it fast enough without suffering degradation. Additionally, reliability and long service life are key in aviation, so batteries were not an option. Conversely, supercapacitors can store energy extremely quickly, but they cannot store enough (unless there were so many that their weight penalised flight). This created a 'Goldilocks dilemma'. KERS-Air needed tech that was 'just right', sitting squarely between batteries and supercapacitors in both power and energy density.

The answer was a flywheel energy storage device, which has never been developed for aircraft before. A flywheel acts like a mechanical battery. It can store energy quickly and can increase storage capacity by simply increasing the speed of its rotation. Flywheels have been around for a long time, made out of steel, and relatively slow; KERS-Air is developing a much needed upgrade with unique geometry from composite materials. In its third and final year, KERS-Air is currently investigating the energy transfer between various components and developing a proof of concept. Meanwhile, the follow-up project, REACTIVE, is developing a prototype of the novel flywheel. The University of Nottingham Ningbo is focusing on developing the system's motor, while UM is focused on the flywheel itself. The challenges for the former is that it requires a slow speed but a high torque, while the flywheel demands far less torque but extraordinary speeds of around 60,000rpm.

REACTIVE represents a collaboration between governments as well as academic bodies, with Malta and China providing matching funding to UM and Nottingham Ningbo. The project is also supported by the Commercial

For a new, green technology to succeed, it doesn't just need to be economically viable, it needs to be economically preferable.

Dr Robert Camilleri
Photo by James Moffett

Aircraft Corporation of China. COMAC is a state-owned company poised to become a big player in aviation, as the Chinese Communist Party seeks to compete with Western companies currently dominating the space.

But for Camilleri, 'the international aspect of the project is what really makes it interesting to work on. It allows people with expertise in very specific fields to connect. This kind of collaboration is really where the thrill is.'

THE ECONOMICS OF CHANGE

Last year's Global Climate Change Conference was saturated with pro-fossil fuel lobbyists and produced little more than lip service. It vindicated cynics; the upper echelons of politics and industry aren't fans of climate change, but they prefer it to losing money. For a new, green technology to succeed, it doesn't just need to be economically viable, it needs to be economically preferable.

A key part of the research was a 'techno-economic analysis' investigating how the KERS system could benefit a company's bottom line. Camilleri acknowledges that long distance flights don't spend enough time taxiing to warrant the cost of upgrading. Instead, the tech should be targeted at airlines that use the same plane for multiple short flights every day, spending far longer on the ground. Budget airlines like Ryanair or Easyjet operate such business models. Their frequent use of the aircraft and large fleet make them major polluters in the EU. Their impact is as big as major European cities. Here, the KERS tech would have a much greater impact but would have to be fitted retroactively to existing aircraft. A passenger plane might have a service life of half a century; if green technology was only built into new aircraft, it would have little impact on climate change. As such, the KERS system is planned to be as independent as possible, totally separate from aircrafts' existing electrical system. This will facilitate retrofitting and reduce costs.

When it comes to budget airlines, money is paramount, meaning retrofitting aircraft with KERS technology would need to be affordable. It is estimated that the KERS upgrade could cost around €500,000 per aircraft, a cost that seems massive but that would be quickly recouped by fuel savings. The techno-economic analysis showed that the current taxiing process costs Ryanair around 75 million euro a year and Easyjet around 30 million euro a year, which should make KERS an extremely attractive investment. But especially during a global crisis, the radically short-term business strategies employed in budget aviation may not tolerate the up-front cost. Regulation is the answer to this problem.

'Legislation will become very important. In addition to the 2030 deadline for emissions-free taxiing, there are countries like France that are strong on regulating carbon emissions. They will implement penalties on older, polluting aircraft, creating an expense for airlines that want access to France. This will get the ball rolling for change,' explains Camilleri.

The 2030 deadline for emissions-free taxiing may result in airlines waiting till 2029 to make a change. But if just a few countries act early imposing bans, fines, or taxes, the budget airline business model would work against itself as the same planes are used for every route. Hopefully, airlines will see that green tech like the KERSair/REACTIVE flywheel is the cheaper option. After all, Goldilocks didn't only eat the bear's food because it was 'just right'. She ate it because it was free.

KERS-air (R&I-2017-005-T) is financed by the Malta Council for Science & Technology, for and on behalf of the Foundation for Science and Technology, through the FUSION: R&I Technology Development Programme.

REACTIVE is funded by the Malta Council for Science and Technology through the Sino-Malta Fund 2020 (Science and Technology Cooperation).