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Metallurgical Marvel: Lithium in Aerospace

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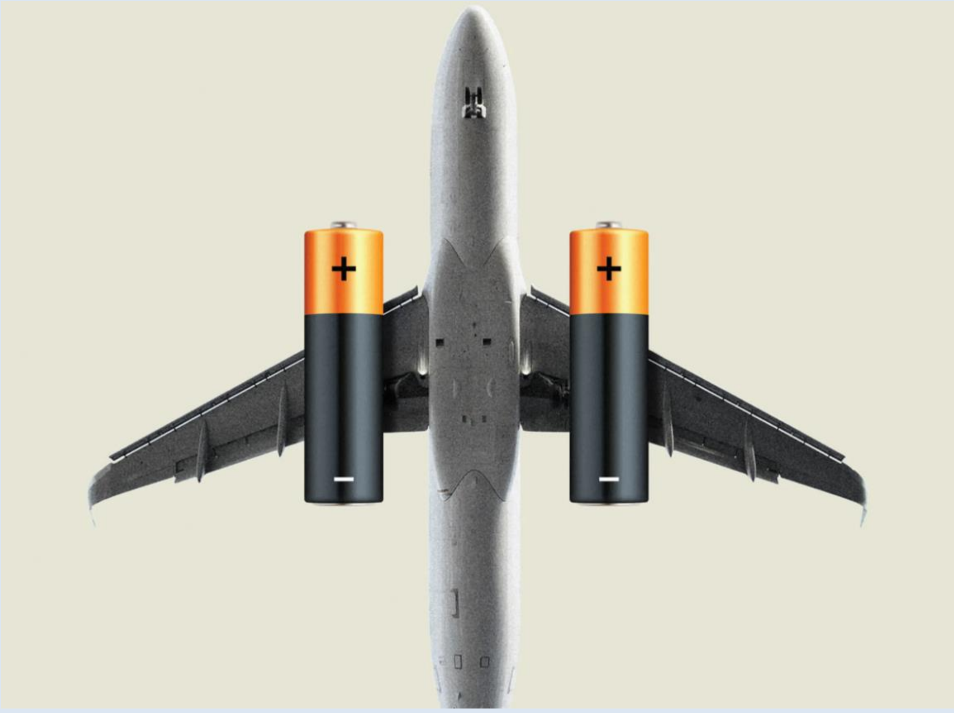

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Charting the rise of consumer electronics, lithium has fast established itself as the go-to material for batteries. Lithium-ion batteries have edged out nickel-cadmium batteries due to their higher energy density,[1] low self-discharge[2] and no memory effect.[3] Hindustan Aeronautics Limited (HAL) became the first manufacturer to incorporate lithium-ion batteries into a military aircraft in Asia. HAL's Hindustan Turbo Trainer 40 (HTT-40) has already passed various tests, including dozens of safety checks, and HAL has already produced spares.[4] Is this the onset of the lithium revolution in aerospace?

Fuelless Fire and Aluminium Alloys: Lithium's Potential in Aerospace and Defence

Lithium-ion batteries have been a feature in defence for over a decade, from tactical radios, thermal imagers, ECM, ESM, and portable computing to military vehicles, boats, shelter applications, aircraft, and missiles. With thrice the energy density and a ten-year lifespan, military adoption has moved from early adoption to a mature growth phase. Even in 2004, a NATO dismounted soldier consumed approximately 500 Wh during a 3-day mission. Today, it is likely to double that consumption.

Along with the increase in gadgetry, the prevalent form of warfare has shifted towards urban engagement, wherein adversaries rely on civilian populations to fight back. In such settings, situational awareness is gained in disguise. Reliance on batteries has therefore increased, and a lithium-ion battery allows this silent watch to carry on for three times longer compared to a lead-acid battery used in most military vehicles.[5] In aviation, lithium-ion batteries serve as propulsive energy carriers for electric and hybrid aeroplanes. Increasingly, the aerospace industry is trying to move towards a cleaner flight, which requires higher energy density and capacity.[6]

Amidst the great revolution of lithium-ion batteries, it would be unjust to conflate the potential of lithium with that of lithium-ion batteries. Aluminium-lithium alloys have been a staple of aviation for more than half a century. Lithium, being the lightest metallic element, reduces the alloy's density and weight. Aluminium-lithium alloys also often include copper and zirconium. Every one per cent by weight of lithium added reduces the density by three per cent. In contrast to composite materials, aluminium-lithium alloys require less capital investment for the aircraft manufacturer. The cost easily offsets the more significant performance increment.

Aluminium-lithium alloys also offer incredibly high fatigue crack growth resistance, making them ideal for damage-tolerant structures like lower-wing surfaces. Even leading and trailing edges, access covers, seat tracks, and wing skins are made from aluminium-lithium alloys. For military aircraft, the main wing box, centre fuselage, and control surfaces benefit from these alloys. Aluminium-lithium alloys are fast substituting conventional aluminium alloys in helicopters, rockets, and satellite systems.[7]

The MiG 29's fuselage, fuel tanks, and cockpits employed alloy 1420. This alloy also formed the fuselage of various Soviet aircraft, including the Su-27, Tu-156, and Yak-38. Other alloys of aluminium and lithium have been relied on, notably in the Airbus A330 and A340 for leading edges and the C-17 Globemaster for its payload adapter.[8] The third-generation aluminium-lithium alloys feature in the bulkheads of the F-16,[9] the second stage of the Falcon 9 rocket, the Boeing 787[10] and the Airbus A380's extruded crossbeams, stringers, longitudinal beams, and seat rails.[11]

Lithium Logistics

Lithium, one of the three elements created in the Big Bang, is not as abundant as hydrogen and helium. It makes up a measly 0.002 per cent of the Earth's crust. It is still higher than tin, silver, gold, and platinum concentrations.[12]

With a newfound role for lithium in renewable energy, the demand is bound to increase compound by 25 per cent. To match, the production will have to go from about 0.54 million metric tonnes to 2.7 million metric tonnes, with greenfield and brownfield expansions to account for a further 0.6 million metric tons.[13]

The four countries with the largest lithium deposits are Chile (8 million tonnes), Australia (2.7 million tonnes), Argentina (2 million tonnes), and China (1 million tonnes). However, Australia has been the largest supplier globally, ahead of Chile, China, and Argentina. Australian lithium is mined from ores, while South American lithium is sourced from brine pools and brine deposits in the Salars (salt deserts). In Salars, the saltwater that contains lithium is sourced from underground lakes, and then evaporated. Further refining of the saline solution produces commercially viable lithium. Such intensive and water-guzzling extraction of lithium has upset the local communities. There have been reports of droughts threatening livestock and vegetation alike.[14]

India's Directorate of Atomic Minerals recently surveyed a slight stretch of land in the Mandya district in southern Karnataka. Researchers have estimated that there are about 14,000 tonnes of lithium reserves in the region.[15] This exploration is part of a nationwide push for lithium mining. Following the South American Salars, work is underway to extract lithium from the salty flatlands of Rajasthan and Gujarat and the mica belts of Odisha and Chhattisgarh. The Nagamangala Schist

Belt is another good site for lithium and other rare metals. India has also floated Khanij Bidesh India Limited (KABIL), which has signed an agreement with an Argentine firm.[16]

Lithium shall power the next generation in more than one way. For aerospace, lithium has the potential to unlock unprecedented possibilities, from alloys to electric and hybrid components.

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