A Change in the Global Conditions of the Aerospace Industry

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The concept of flying has been something that humans have been trying to grasp for centuries. Throughout history, there have been many attempts to fly. However, it was not until the Wright brothers took flight in an airplane that humanity reached a major turning point. Within a century of the Wright brothers' achievement, the concept of flight had been well established and feats unimaginable to previous generations had been accomplished. Humans not only learned how to fly but they learned to fly faster than the speed of sounds. They learned to fly higher than the boundaries of earth and land on the moon. But as with all things in life, there are trade-offs that must be made. The trade-off for the achievements of humanity was the burning of fossil-fuels and emission of carbon dioxide, which have had a detrimental effect on the climate. With climate issues continuing to worsen, there has been a large shift towards hybrid electric and fully electric aircraft. The discussion will research the potential implications of hybrid electric aircraft. The study will focus on the future market, current progress, advantages, and potential dangers of the push toward a fully electric aviation industry. All-electric aircraft can reduce the environmental impact of aviation (Schäfer et al., 2018). The benefits and potential for all electric aircraft are immense, however, there are many hidden issues regarding fully electric aircraft such as dangers in battery technology. This topic will affect not only the aerospace industry but also the general population as we move toward an unknown future. The topic is aimed toward helping both the aerospace industry and the general person look at the topic at a more neutral stance rather than the positive light the media usually shows.

Background/Significance

Airplanes and aerial transportation have been widely used since its inception and continues to grow. Every day, FAA's Air Traffic Organization (ATO) provides service to more than 45,000 flights and 2.9 million airline passengers across more than 29 million square miles of airspace (Federal Aviation Administration, 2022). This coupled with the fact that the FAA handles 16,405,000 flights yearly and about 45,000 flights daily show just how important aerial travel is. Around 2.4% of global CO2 emissions comes from aviation (Timperley, 2020). At face value 2.4% may seem like a small number however considering this is a global statistic and the fact that developed nations use air travel far more than undeveloped nations this percentage truly poses a danger. In fact, the richest half (countries) are responsible for 90% of air travel CO2 emissions (Ritchie, 2020).

The introduction of hybridization in the aerospace industry is looking to decrease and eventually eliminate all carbon emissions. Hybridization in its simplest form involves the use of a mix of alternative energy sources and traditional (fossil fuel) sources to power aircraft. There 5 major types of hybrid electric configurations: series, parallel, series-parallel, turbo electric, and full electric. The 5 types of configurations are names of how the traditional and electrical system work together to produce propulsion for an aircraft. Hybridization will have immense implications on the future of the aerospace industry, both good and bad. It is important to understand the changes that will be brought by the introduction of a new era of aerial travel. The implications of these changes will have drastic effects in many areas, not only just those who use aerial travel.

Methodology

To understand the implications of hybrid electric aircraft it is important to understand that this change starts from the needs of society. Hybrid electric aircraft is a result of the needs of society to decrease carbon emissions and increase air travel efficiency. Once Hybrid electric aircraft is in use it will then affect society over time. There will most likely be a decrease in carbon emissions for the nations utilizing this technology but also other potential global effects. To effectively understand this topic a vast range of literature will be studied. It is important to first establish an understanding of what hybrid electric aircraft. It is then imperative to study the current state of hybrid electric technology which also has implications on how it affects society. Finally, the limitations of hybrid electric aircraft play a large role in how it currently affects society and how that role may change over time as those limitations are overcome. These key areas will provide the groundwork of knowledge that explain the societal implications of this technology.

Results and Discussion

Hybrid Electric Aircraft

Hybrid electric aircraft are aircrafts that utilize a mixture between traditional gas power and electric power. Usually, the electric power comes from some form of stored energy in the form of a battery and traditional power comes from the burning of fossil fuels. As of 2023 there are no hybrid electric or full electric aircraft in full commercial use. The closest aircraft to commercial viability is the Ampaire Eel. Ampaire expects it to be the first electrified regional aircraft to enter commercial service (certification in 2024) and the first in a series of larger Ampaire hybrid-electric aircraft that will lead a transition to sustainable aviation (Ampaire, 2022). There are also many hybrid electric and full electric aircraft that are planned for the future which will be reviewed in the current and future progress portion of the paper. There are companies that are heavily investing in hybrid technologies including but not limited to Boeing, Airbus, Embraer, Rolls-Royce, Siemens, and NASA. The goal of the companies is to reduce their carbon emissions and improve fuel economy. In fact, some companies such as Rolls-Royce are committed to fully eliminating carbon emissions. All new products will be compatible with net zero operations by 2030 and all products compatible by 2050 (Rolls Royce, 2022). Which means Rolls Royce intends to have all their products emitting zero emissions by 2050. All of this suggests the steady increase in use of hybrid electric and full electric aircraft in the near future.

An important concept in understanding hybrid electric aircraft is the idea of technology readiness level (TRL), which will be used to explain many concepts later in the paper. Technology readiness level is a method for estimating how close technology is to commercial viability used by NASA. It is a scale from 1 to 9 with 1 being the least ready for commercial viability and 9 being the most commercial viability. Generally, TRL 1-3 mark the conceptual design phase. TRL 4-5 mark the component design and testing phase. TRL 6-7 means a working protype has been made along with field tests. TRL 8 means the technology has been flight tested. TRL 9 means the technology is commercially viable. Based on the examples given in the later portion of the paper, most hybrid electric aircraft fall somewhere between a TRL of 1 and 6.

Current and Future Progress

As mentioned before there are no aircraft that are fully in commercial use. However, there are many aircraft that are planned for the near and distant future. At technology readiness level of 6-7 is the E-Fan X, which is a joint venture between Airbus, Siemens, and Rolls Royce.

At a TRL of 6-7 the project had a prototype demonstration and was quite close to test readiness. The goal for the venture was to create a commercial aircraft for 50-100 passengers with 25% emission (Airbus, 2020). However, during the pandemic the program was cancelled and is currently in an unknown status. At TRL of 5-6 there is currently the Zunum Aero, a start-up between Boeing and Jetblue. The aim of the project was to develop a 12 passenger HEP (Hybrid electric propulsion) aircraft. The project has declared many key statistics such as possible cruise speeds, flight range, and takeoff distance. However, the status of the project is unknown as the company faces financial troubles. At the conceptual level there are many projects at the TRL of 3-4 such as NASA's N3-x, which is a hybrid wing body concept with hydrogen-fueled turbogenerators. The concept design has 14 EM-driven propellors on the trailing edge of the aircraft. The idea is to re-energize the boundary layer while reducing fuel burn. The concept boasts a 70% fuel burn reduction when compared to the Boeing 777 (NASA, 2022). The projected entry into service is in the 2040s. At TRL of 2-3 there are many conceptual designs that are in their preliminary stage. Companies such as Pipistrel and NASA are looking to combine known aerodynamic concepts with power generation methods to create hybrid systems. All improvements in the hybrid electric propulsion category look to combine internal combustion engines with some form of electric power generation or usage. As research and experimentation continues it is likely that projects at TRL of 5 and up may have some form of application at the commercial level by 2040s.

Developments in aircraft design and system integration primarily look to change the overall structure of the aircraft and where engines are placed. Research into various wing shapes and fuselage shapes is common. For example, designs can look to decrease fuel consumption by improving aerodynamic capabilities such as drag or boundary layer reduction. A prominent example of a project that looks to further research aircraft design includes NASA's Double bubble, which tries to use a box wing design to decrease boundary layer and utilize the shape of the fuselage to generate lift. As various aircraft configurations are being researched, various materials are also being studied. Aerospace as a field is largely affected by research into lighter and stronger materials. Material research often has a large effect on aircraft configurations and system integration.

Limitations

There are various factors limiting the implementation of hybrid electric and full electric aircrafts. The development of electrical systems and energy storage systems are one of the few factors that heavily hinder the progress in hybridization. Developments in electrical machines look to improve not only electric propulsion but also communication systems and other auxiliary systems. Improvements in electrical systems look to decrease electrical resistance and over all weight. Some current ventures include research into superconducting materials which decrease circuit resistance and weight (Rendón et al, 2021). This will help increase efficiency which is a main concern for electric propulsion. Another improvement involves using liquid hydrogen and liquid neon, which are very difficult to incorporate, but if done properly, would see a reduction of electrical machine weight by 70% (Rendón et al, 2021). Many concepts on hybridization are limited by the realistic constraints. The most prominent restraint is that batteries simply cannot provide enough power for the duration of time necessary to make them commercially viable. Limitations in battery technology mean electric planes' batteries are still far less efficient than jet fuel (DeGeurin, 2021). This is a problem we see in electric road vehicles as well since gas engines still provide greater driving range compared to that of an electric engine. However, as new methods of energy storage and energy usage are being studied, the possibility for hybrid electric and fully electric configurations increases greatly. Batteries have around 50 times lower specific energy than liquid fuels and also do not decrease in weight as more power is used. Research into high density lithium-ion is being done by various companies but would still need considerable increase in storage and power output to be viable in aircraft usage. Other areas of interest are lithium-air and lithium-sulfur batteries which both look to increase specific energy in some way. Other areas of interest include supercapacitors which are known to be highly efficient, have long cycle life (15+ years) and can be charged rapidly (Rendón et al, 2021). However, supercapacitors have low energy density which currently prevents them from use. Finally, solar power is a topic that often appears when energy storage and batteries are the topic. The use of Solar power is being investigated by companies such as Airbus, Boeing, and NASA, however there are many realistic constraints such as low power output and energy storage. Studies in energy storage and output show a promising trend. Once batteries can store and output the necessary power for aircraft, they may be seen in fully electric jets on a smaller scale.

Societal Implications

Hybrid electric aircraft will have an indisputable effect on society in the future. Passengers of hybrid electric aircraft will enjoy a great number of benefits including but not limited to noise reduction, general comfort, and potentially reduced air travel costs. Countries utilizing hybrid electric aircraft will see an overall decrease in carbon emissions and air pollution. Over time this will may cause a decrease in fossil fuel usage in the aerospace industry. However, this affect only applies to the developed nations using hybrid electric aircraft. As mentioned before aircraft and air travel is dominated by developed nations. In some ways air transportation is an indicator of how developed a nation is. On the one hand, it is a factor of progress as it facilitates transportation within extended countries or countries without good land transportation infrastructure and it connects the country with the rest of the world. On the other hand, it is an indicator of development as its volume clearly depends on the level of economic activity as well as on the affluence of the population (Bourguignon & Darpeix, 2016). Developing nations are continuing to grow at a steady pace. This will more than likely cause an increase in the nations carbon footprint and total pollution. This was seen in recent history as developed nations attempted to decrease their overall pollution and carbon footprint, they were overtaken by developing nations which continued to increase pollution and emissions. This was the case with China. As China continued to develop at a rapid pace it quickly overtook the US in greenhouse gas emission. In 2006, China overtook the US as the world’s biggest emitter of carbon dioxide (CO2). In 2019, the last year before the pandemic hit, China’s greenhouse gas emissions were nearly 2.5 times that of the US (Regan et al, 2021). The same principle can be applied to air transportation. Developing nations are not at the state where they can viably consider using hybrid electric aircraft of their own since they do not have many of the necessary facilities, research, and resources to do so. They will instead be relegated to using fossil fuel-based aircraft as they continue to develop. The shift into hybridization marks a point where developed nations will decrease emissions but may ultimately not cause a shift in total global emissions due to the increase in air transportation in developing nations. This ultimately will result in a situation where devolved nations will enjoy many of the benefits of hybrid electric aircraft, where else developing nations will not.

The potential global issues between developed and developing issues does not end with only the introduction of hybrid electric aircraft. Battery creation and disposal, which was a topic discussed earlier in the paper, also pose a potential danger for developed nations. The mining of minerals that are used in batteries disproportionally causes more danger to developing nations. More than half of the world's lithium resources lies beneath the salt flats in the Andean regions of Argentina, Bolivia, and Chile, where indigenous quinoa farmers and llama herders must now compete with miners for water in one of the world's driest regions. Nearly 50% of world cobalt reserves are in the Democratic Republic of the Congo, which accounts for over two-thirds of global production of the mineral. About 20% of cobalt sourced from the central African nation comes from artisanal mines, where some 40,000 children work in extremely dangerous conditions, according to UNICEF, the UN's children's agency (UNCTAD, 2020). Gaining materials to make batteries also means putting pressure on developing nations to output materials that developing countries don't necessarily have the safety regulations to properly mine. Mining for these materials improperly also poses an immense danger for the local landscape, as improper maintenance can cause pollution, landscape contamination, amongst many other dangers. Much like the creation of batteries, the disposal poses a threat to developing nations as well. It is a known fact that developed nations ship their plastic waste to developing nations for recycling. In fact, Last year, the equivalent of 68,000 shipping containers of American plastic recycling were exported from the US to developing countries that mismanage more than 70% of their own plastic waste (McCormick et al, 2019). A similar picture can be painted for waste caused by hybrid electric aircraft. Once the lifecycle of equipment such as batteries runs out, they may very well be shipped to developing nations. This also poses dangers such as pollution and contamination since developing nations most likely do not have the proper facilities and information to properly use or dispose of the materials. Finally, some may suggest utilizing a utilitarian approach is best for these issues since the benefits of the majority outweigh the minority. However, when looking at the topic from a neutral point of view, it is difficult to say that as of 2023 the very few developed nations able to implement this technology are in the majority. In fact, the countries able to use hybrid electric technology are in the minority and may potentially cause a disproportionate amount of danger for other nations.

Potential Solutions

Despite all of this, there may be a potential solution. As mentioned before there is much research being conducted to decrease the overall cost and increase efficiency for hybrid electric and full electric aircraft. There may be a point in the future where hybrid electric aircraft are cheaper to produce than their gas engine counterparts. This will take vast improvements in many key areas and a willingness from developed nations to share the technology. This would mean developing nations no longer need to use gas turbine-based aircraft but can directly transition into using hybrid electric and full electric aircraft to meet their air transportation needs. Rather than seeing a stagnation or increase in global emissions there would be an overall decrease in total global emissions. This would also mean that developing nations will invest in the proper facilities and tools to properly mine, dispose, and recycle battery technology. This will benefit both a developed and developing nation since the developed nation will continue getting the necessary raw materials to batteries and the developing nation will have the proper systems in place to safely mine these materials. This will of course take some time. There are still many limitations of hybrid electric aircraft that keeps this scenario from being a reality, but it is possible as research into this technology continues making breakthroughs.

It is important to note that the initial purpose of using hybrid electric aircraft was due to society's needs to reduce pollution and emissions. The needs of society are what shaped and created hybrid electric aircraft, but over time it will be the effects of hybrid electric aircraft that shape society. As mentioned before, hybrid electric aircraft will decrease emissions for the countries that utilize it. However, once fully implemented, hybrid electric technology will potentially have other unintended consequences over time on a global scale. These global effects are what will shape global politics and differences between societies that can and cannot use hybrid electric aircraft. These global effects don't have to be negative, but at the current trajectory these negatives are the reality. The evidence studied throughout this paper suggests that hybrid electric aircraft will have many positive effects but also many potential negative effects. If the world wants to break or alter this momentum, there will need to be a greater consideration in these negative factors.

Finally, despite the discussion of the many potential dangers of hybrid electric aircraft, it is still a necessity. If developed nations were not making a transition towards hybrid electric aircraft, then there would be a rapid increase in total global emissions. The purpose of shedding light on many of the potential issues is not to suggest that the implementation of hybrid electric aircraft is a negative change. The purpose is to show that the change is as positive as it may initially seem. The takeaway of this research should not be to stop the progress towards hybrid electric aircraft. Rather, the takeaway should be that to take this from a good to great change many factors still need to be considered and many issues still need to be solved.

Conclusion

The introduction of hybridization will have consequences for not only the aerospace industry but also the world. It is undeniable that the implementation of hybrid electric aircraft is an overall positive change. However, there are many factors to consider when accounting for global factors. The change can be very good considering the potential to eliminate carbon emission and decrease overall energy consumption. It can also be harmful when considering the many unknown factors such as battery disposal and mining for battery materials. There is still a great deal of uncertainty regarding the matter, especially matters that concern the ethics of hybrid electric technology. It is important to consider both the benefits and potential dangers when looking into the future not only for ourselves but also others. There is still much more research to be done to gain a better understanding of the shift. The purpose of this research was to attain a general base of knowledge regarding hybridization, rather than being a comprehensive study. Hybridization is only the next milestone, there will be many milestones that follow, if technology continues to develop at a similar rate. It is important to continue looking at these changes in a neutral matter to truly ensure a sustainable future.

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