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Aircraft Emission and its Control

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Abstract: This paper proposes a basic knowledge about the emissionsfrom the aircrafts or aviation filed, to understand the emission formation and transformation, effect or impact of theseemissions and control or reductionapproaches of theseformedemissions. Nowadays the pollution effect of the emissionproductsfrom the aircraft are major concern to environmental protection. Therefore, itisrequired to establish a system whichlowers the emissionusing the modern emissionreductionapproach like Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) project, where the major effective pollutants like, Carbon Dioxide (CO_2) and in general like Hydrocarbons, Carbon Monoxide (CO), Nitrogen Oxide (NO_2), Sulphur Oxide (SO), Lead, Black Carbon, etc., are reduced. Here the effectiveness of reducing Carbon Dioxide (CO_2) pollutantisdiscussed.
Keywords: Emission, Carbon Dioxide (CO_2) and CORSIA.

I. Introduction

Aircraft Emission is nothing but an amount of gas, heat, etc. that is released out to atmosphere after combustion process or it can be said that the combustion products emitted from the engine due to burning of propellants. Emissions are in the form of vapours and gases which are emitted directly into an atmosphere which cause severe air pollution. Control of pollutant emission is a major factor in the design of modern combustion systems. Pollutants of concern include particulate matter, such as soot, fly ash, metal fumes, unburnt hydrocarbons, oxides of nitrogen, carbon monoxide and greenhouse gases like Nitrous oxide and Carbon di-oxide.

However, aircraft emissions are unusual, in that a significant proportion is emitted at certain altitudes. These emissions give rise to important environmental concerns regarding their global impact and their effect on local air quality at ground level. A comprehensive assessment concerning aviation's contribution to global atmospheric problems is contained in the "Special Report on Aviation and the Global Atmosphere", which was prepared at ICAO's request by the Intergovernmental Panel on Climate Change (IPCC) in collaboration with the Scientific Assessment Panel to the Montreal Protocol on Substances that Deplete the Ozone Layer and was published in 1999. [1]

It is estimated that airplanes could generate 43 gigatons of planet-warming pollution through 2050, consuming almost 5 percent of the world's remaining carbon budget, according to a new Center report. Aircraft emit staggering amounts of CO_2, the most prevalent manmade greenhouse gas. In fact, they currently account for some 11 percent of CO_2 emissions from U.S. transportation sources and 3 percent of the United States' total CO_2 emissions. [2]

II. Emission formation and Transformation

Aircraft pollutants generally transform in three different zones:

1. Immediately after exiting the combustor within the engine.
2. Downstream from the engine in the hot exhaust plume.
3. After emissions have cooled and mixed with the ambient atmosphere.

At the aircraft engine exit, hot combustion gases mix with ambient air to quickly cool the gas stream. Some gases, like heavy hydrocarbons, can condense under these conditions to form aerosol particles. In the exhaust plume, as emissions continue to cool, some molecules undergo chemical reactions producing other molecules that can also condense into particles. Small particles in the plume collide and form larger particles, although still microscopic in size. The resulting particulate matter in the plume can be solid or liquid and include carbon in the form of soot, inorganic salts (like ammonium nitrate and ammonium sulphate), and heavy hydrocarbons that condense into aerosol particles. [3]

III. Growth in Aircraft Emission

Aircraft emit carbon dioxide (CO_2) and other greenhouse gases. The focus here is on CO_2 emissions from passenger aviation. Emissions are measured by country and on a monthly basis. Data are from Amadeus IT Group in combination with ICAO emission factors. Due to the large numbers, the unit used here is MT (million tonnes). [4]

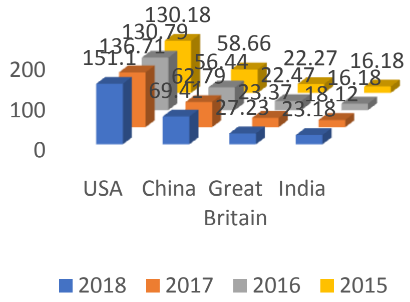

Table 1: Growth in AircraftEmission of CO_2

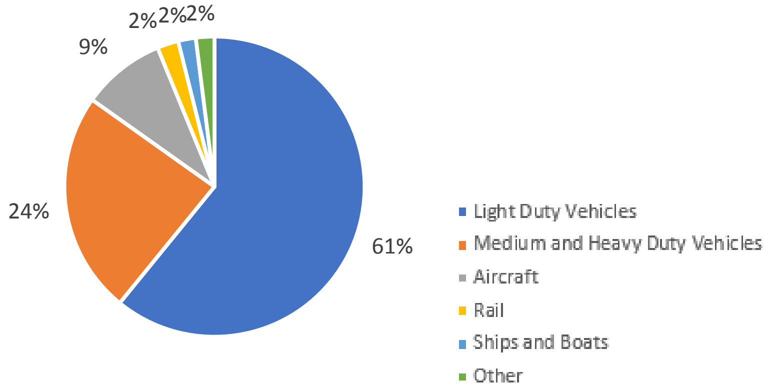

Table 2: U.S. Carbon Dioxide Emissions, by Transportation Source

From the Table 1 it is observed that the growth in aircraft emission of CO_2 is increasing rapidly in the USA from 2015 – 2018. When compared to other major countries like China, Great Britain and India, it is estimated that more than sum of these 3 major countries' is the USA in the records of aircraft emission.

Factors affecting the Emission formation:

- Type of fuel.
- Air composition.
- Combustion temperature.
- Air-fuel mixture proportion.
- Rate chemical reaction and other combustion parameters.

U.S. aviation is part of the increasingly interconnected global aviation sector, which makes up about 2 percent of global CO_2 emissions but is one of the fastest growing sources. From 1990 to 2010, global aircraft carbon dioxide emissions grew about 40 percent. If global aviation were a country, it would rank as the seventh largest carbon dioxide emitter, and U.S. aircraft emissions are 29 percent of all global aircraft emissions. Absent new policies, global aircraft emissions are projected to triple by 2050. [6]

IV. Emission Impacts

Aviation emissions affect both air quality and the global climate. Compared to other economic sectors, commercial aviation is a relatively small contributor to emissions of concern for both air quality and climate change. However, aviation emissions occur in the climatically sensitive upper troposphere and lower stratosphere where they may have a disproportionate impact on climate. They also occur at high altitudes where their impact may be felt at large distances away from where they are released. [3]

In attempting to aggregate and quantify the total climate impact of aircraft emissions the Intergovernmental Panel on Climate Change (IPCC) has estimated that aviation's total climate impact is some two to four times that of its direct CO_2 emissions alone. This is measured as radiative forcing. While there is uncertainty about the exact level of impact of NOx and water vapour, governments have accepted the broad scientific view that they do have an effect. Globally in 2005, aviation contributed "possibly as much as 4.9 percent of radiative forcing." [5]

There are three factors to consider in evaluating emissions' impacts:

1. The quantity and characteristics of emissions.
2. How sensitive environments and humans get exposed to them.
3. Their human health and environmental effects. [3]

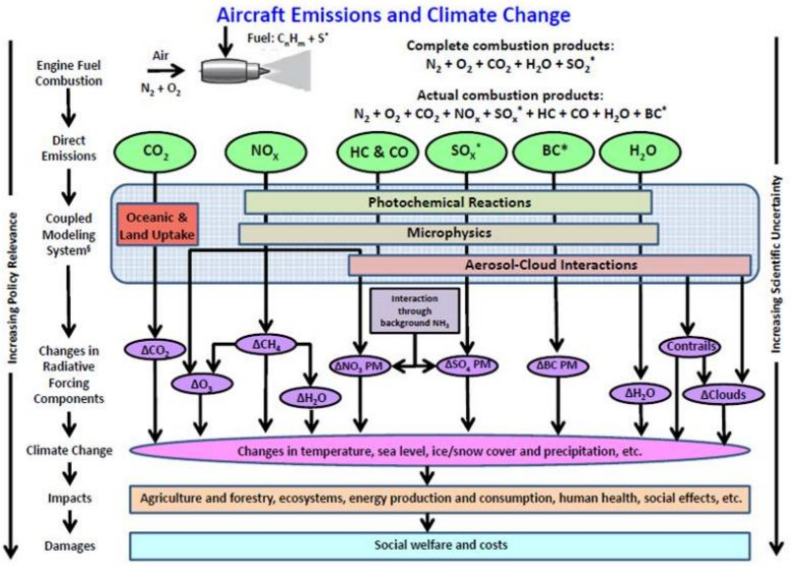

Figure 1: Schematic representation of emissions from aircraft combustion

Atmospheric and climate system interactions (e.g. chemical, microphysical, dynamical and radiative) of aircraft emissions remain poorly understood and require more research. Figure 1 is a graphical representation of the current understanding of the potential climate and social welfare impacts of emissions from aircraft combustion.

The Figure 1 also shows policy implications at various stages of these emissions, with increasing policy relevance downward. The formation of gases and particles that interact with radiation affect climate and air quality at the surface. Minimization of these products is therefore desirable. Mitigation options such as altering the routes to prevent formation of contrails, redesigning engine combustors with high bypass ratios to reduce temperatures to minimize formation of NOx, and reducing impurities such as sulphur in the fuel to minimize formation of particles are all examples of results of policy decisions to minimize climate impacts.[3]

Emission: CO_2

Description: Carbon dioxide is the product of complete combustion of hydrocarbon fuels like gasoline, jet fuel, and diesel. Carbon in fuel combines with oxygen in the air to produce CO_2.

Impact: Climate Change, Greenhouse effect, etc. [3]

V. Pollution Effects

Primary air pollutants (those formed directly from the source) and secondary pollutants (those formed via reactions involving primary pollutants in the atmosphere) affect our environment and Human health in many ways.

The following four principle effects of air pollutants in troposphere:

1. Altered properties of the atmosphere and precipitation.
2. Harm to vegetation.
3. Soiling and deterioration of materials.
4. Potential increase of morbidity and mortality in humans.

Altered properties of the atmosphere affecting local areas including reduced visibility, resulting from presence of carbon-based particulate matter, Sulphates, nitrates, organic compounds, nitrogen dioxide and carbon dioxide; reduced solar radiation; altered temperature and wind distributions. On a larger scale greenhouse gas may alter global climates.

Because of the difficulty of conducting research on human subjects, and the large number of uncontrolled variables, controversy exists in assessing the effects of pollution on human health. However, it is well known that pollutants can aggravate pre-existing respiratory ailments.

Secondary pollutants in photochemical smog causes eye irritation. These pollutants ozone, organic nitrates, oxygenated hydrocarbons and photochemical aerosol are formed primarily by reaction among nitic oxide and various hydrocarbons. Also, carbon-based particles may contain adsorbed carcinogens.

VI. Control Options

To reduce the environmental impact of aircraft three categories of action are required:
1. Research and monitoring are needed to establish the actual extent of emissions and their effects.
2. Policy options that mitigate environmental impacts need to be devised.
3. Mitigating policies have to be implemented through appropriate legislative and institutional frameworks.

Control options can be put into three categories:
1. Demand management
2. Operational change
3. Technological change

Implementation methods can be divided into intelligence and information, incentive and disincentive, regulation and investment. Table 3 sketches out a matrix of basic options and means of implementation with examples of particular measures. [7]

Options	Intelligence	Incentive	Regulation	Investment
Operations	flight planning models	fuel and emission taxes	bubble emission limits	global booking system
higher load factor	advanced booking; integrated flight planning	aircraft movement tax	ticket transfer permit	less seat spacing
shorter route	ATC			
lower altitude	optimum height		zone emission limits	
slower cruise		fuel and emission taxes		
less congestion	better ATC	aircraft movement tax		better ATC
Technology				
engine emission	information to operators and consumers	emission taxes	emission limits per unit thrust	more efficient, low emission engines
aircraft emission	information to operators and consumers	emission taxes	emission limits per seat.km	large aircraft optimised for passenger transport
Demand management	advertising and labelling			
passenger	advertising and labelling	passenger movement or distance tax		better local environment and holiday facilities
				telecommunications
				alternative modes
freight	economic information	freight tax		alternative modes
	advertising and labelling			localised production

Table 3: Some emission control options

VII. Carbon Dioxide CO_2 reducing strategies

Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA, is an emission mitigation approach for the global airline industry, developed by the International Civil Aviation Organization (ICAO). CORSIA addresses emissions from international air travel. The proposal has been described as "a delicate compromise between all involved in its elaboration." [8]

The main principles of the CORSIA market
- Carbon offsetting is the process through which a company or organization offsets its emissions of CO_2 by buying credits in the carbon market.

- These carbon credits are generated by setting up projects to reduce greenhouse gas emissions, in different parts of the planet and especially in developing countries.
- The international agreement CORSIA is the device through which ICAO aims to offset the growth of its emissions from 2020, based on that same year.
- Included in CORSIA are international flights, operating between the voluntary countries of the agreement in a first stage (2021-2026) and all countries in a second mandatory phase (2027-2035).
- Small Island Developing States, Least Developed Countries developed countries, landlocked developing countries, and countries whose air traffic represents less than 0.5% will be exempt from these obligations but may decide to participate voluntarily.

1. Each airline operator shall:
- Estimate its CO_2 emissions based on the fuel consumption achieved on the air routes including in the scope of CORSIA for a given year.
- Achieve third party verification for its emissions.
2. ICAO will collect all the emission data and estimate the growth in emissions for a given year compared to the baseline year 2020 (the growth factor).
3. By using the growth factor (%) each operator will be able to calculate the amount of CO_2 emissions to be offset:
   [Sector's growth factor for CO_2 emissions (%)] x [Operator's annual emissions] = [Annual volume of emissions to be offset (tCO_2)]
4. The operator will then have to purchase carbon credits equivalent to the volume of annual emissions to be offset. Each carbon credit corresponds to one tonne of CO_2 equivalent (tCO_2) reduced by an offsetting project. [9]

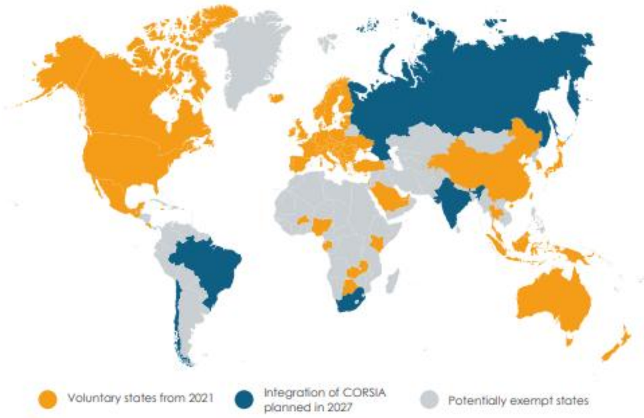

Table 4: The Countries Involved

- 87.7% of international aviation activity is covered by the agreement.
- 80% of post-2020 growth in GHC emissions is covered by the agreement.

The implementation CORSIA is imminent. Air operators must therefore prepare now to integrate these new mechanisms.

From 2018 the main activities for airlines will be to:
- Monitor fuel consumption and associated CO_2 emissions;
- Disclosure emissions that will be subject to third party verification;
- Implement mechanisms to reduce CO_2 emissions, improve the operational and technological performance of the sector's activities;
- Offset unavoidable emissions by purchasing carbon credits. [9]

CORSIA affords airlines flexibility to choose how to cut CO_2. They can:
- Fly more efficient aircraft.
- Use new technologies to set more efficient flightpaths and reduce delays.
- Use sustainable lower-carbon alternative fuels.
- Invest in emissions offsets within or outside of the aviation sector.

It is forecast that CORSIA will mitigate around 2.5 billion tonnes of CO2 and generate over USD 40 billion in climate finance between 2021 and 2035, which is an annual average of 164 million tonnes of CO_2.[9]

VIII. Conclusion

Aviation is a complex and vital industry serving not only the USA but also the entire world. It accounts for about 40% of aircraft pollution and is therefore a key country when considering control policies. Its speed and accessibility are well suited to modern society as globalization, technology development and just in time manufacturing transform the world. To maintain its central transportation role, aviation must ensure it can mitigate any environmental constraints that result from its operations. Aviation places a high premium on safety, which demands the incorporation of only proven and technically sound technologies to reduce environmental impacts. Aircraft are high cost and have a long-life span, requiring long lead times for new technologies to be widely incorporated in the fleet.

With the projected result from the CORSIA project, the CO_2 emission reduction of aircraft emission and its control techniques can be achieved with greater expectations towards the clean and green environment.

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