REPORT OF FINDINGS ON INTERNAL COMBUSTION ENGINE OF AN AIRCRAFT

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Executive Summary:

Team #3 is working on the Internal Combustion Engine (ICE) of the aircraft. The team is focusing on four key components of the Internal combustion engine which are as follows mechanism, combustion, efficiency and noise. The team's primary objective is to make the Internal Combustion Engine more efficient and environment friendly not only for the present but also for future generations.

The report relates to two important components when it comes to mechanism, propellers and crank mechanism. It includes implementing the traditional engine components to improve mechanical efficiency of the engine. Using the concept of the offset mechanism, the power loss can be reduced, and smooth acceleration designs can be obtained.

This document deals with the phenomenon of combustion that provides power to the engine. However, the combustion reaction also creates pollutants as a result of an incomplete reaction. The catalytic converters' role is to eliminate these pollutants before they reach the ambient air.

This report also discusses improving the overall efficiency of an aircraft's internal combustion engine. Compression ratio is one of the primary ways to improve fuel efficiency and as well as the fuel economy. The energies that are related to the aircraft's internal combustion engine are thrust, thermal energy, kinetic energy, and chemical energy.

In addition, this report discusses the issue of noise pollution from an aircraft's internal combustion engine. A design modification to the internal combustion engine that implements larger turbine fans reduces the noise produced by the engine. This report also explains the phenomenon of the *sonic boom*.

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1.0 Introduction:

Team#3’s research project lays emphasis on the Internal combustion engine of an aircraft for a rapidly changing world. The research relates with making air transport more affordable and environment friendly. This report will be focusing on the subtopics of mechanism, combustion, efficiency, and noise. The research questions related to mechanism are answered in section 2.0. Section 2.1 answer research questions associated with combustion of the engine. Section 2.2 discusses the research question describing different methods to improve the efficiency of an aircraft’s internal combustion engine. The research questions regarding the aircraft’s engine noise are answered in section 2.3 of this document. The glossary terms are in *italics* throughout the project report with their definitions appearing after the conclusion and the references can be found at the end of the document.

2.0 MECHANISM

2.0.1 Research Question #1: How does mechanical operation in an Internal combustion engine work?

PRINCIPLE: THRUST

The aircraft is a machine able to fly by gaining support from air. The aircraft encounters gravity by using either *static-lift* or the *dynamic-lift* of an *aerofoil*. It needs more than just lift to stay *aloft* in air. Aircrafts operate with the help of propellers which is based on the system of *propulsion*. A propeller converts *rotary motion* from an engine or power source into back and forth stream which enhances of rotation blades. In the working mechanism, a working fluid (fuel) is accelerated by the system, in reaction to this acceleration a force is produced. Pressure and *shear stress* are the only two ways nature exerts an *aerodynamic* force on an object [1].

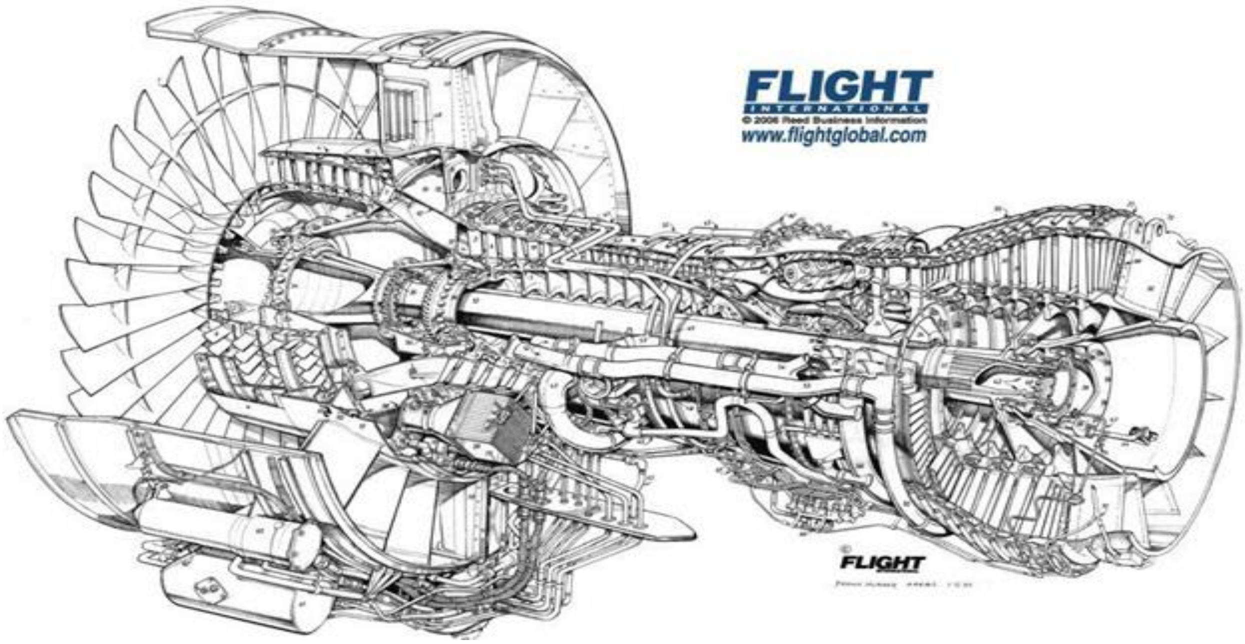

Figure 1: Propeller [1]

The *propellers* (Figure 1) generally have multiple blades, the shape leads to high air pressure on one surface and low air pressure on the other surface. *Thrust* provides forward motion needed to sustain lift and counter *drag*, it is also used to accelerate and maneuver the aircraft. Jets or rocket engines produce thrust by increasing the pressure inside the engine. The increased pressure in the jet or rocket engine exerts more force in a forward direction than the rear direction. Blades of an airplane propeller are designed in a similar fashion to the wings of an aircraft. The wings are often referred to as "aerofoils," are the propeller blades. Aerofoils are surfaces designed specially to manipulate the airflow around them to generate a directional force, different aerofoil cross-sectional shapes will affect the *lift coefficients* at different altitudes, affecting the propeller efficiencies under different conditions[2]. Just as the wings produce the force of lift (perpendicular to the wing) to lift the airplane through the air, airplane propellers produce a force of thrust (perpendicular to the propeller blades) to propel the aircraft through the air. Airplane propellers produce thrust in the following step-by step manner. Thrust is required to accelerate an airplane in a horizontal manner, and drag is produced as an opposing force, resisting the aircraft's forward motion. To accelerate, the thrust produced by airplane propellers must be greater than the drag produced. If the thrust and opposing force were to be equal, the airplane would be in a state of equilibrium, with no forward motion. That is how the propellers work in the aircraft engines.

It is important to understand what efficiency is when talking about aircrafts. The efficiency is the ratio between output power (Pout) and input power. For the input power it is the one generated by the motor (burning fuel) and the output power can be seen as the ability of the aircraft to produce a given thrust at a given speed[3].

(1) Efficiency=Pout/Pin [4]

The curve represented in Figure 2, demonstrates the *efficiency* of a propeller. J = v/nD, where v is the incoming airspeed (m/s), n is the rotational speed (rev/s) and D is the propeller's diameter

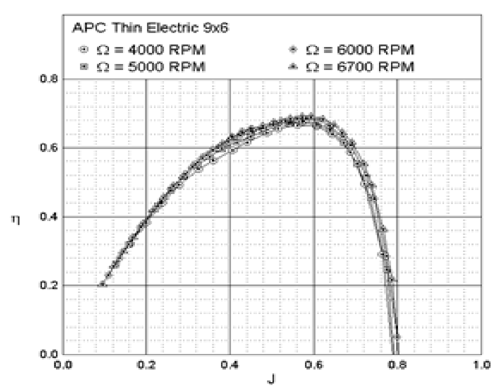

Figure 2: Curve demonstrating the efficiency [3]

(m). The advance ratio J can be seen, more or less, as an expression of the angle of attack of the blades[5].

Using Aluminium alloy blades increases the engine power. Propellers made of Kevlar or carbon fibre have a 10% increase in climb performance and 12% reduction in take off distance at *max gross weight*[5]. Increasing the number of propeller blades will have a huge impact on efficiency of the engine since using a propeller with more blades will perform better as it distributes its power and thrust more evenly in its wake and there is reduction in drag which is the resistance offered to the flow of the aircraft.

2.0.2 Research Question#2: How does the crank mechanism in an Internal combustion engine of an aircraft work?

PRINCIPLE: TORQUE

Engines like the Internal Combustion Engine work with a *piston-cylinder* assembly produce power to enhance movement of wheels or propellers. A *crank* is an off-centre connection that provides energy to a rotating wheel or turbine. A crank is used in a piston-cylinder assembly to convert (back and forth motion) to (round and round motion)[6]. The conversion of the cylinder pressure to *torque* involves a complex set of steps.

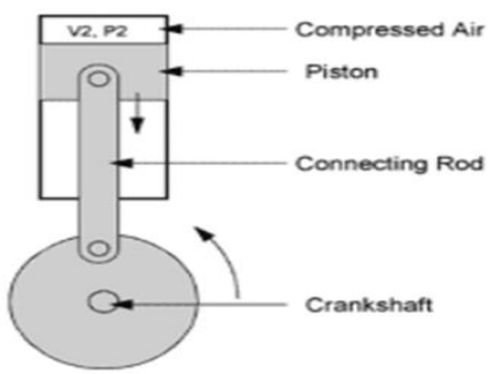

Figure 3: Crank Mechanism [7]

As seen in Figure 3, The torque is generated when the gas force obtained by burning of gas is applied at a distance from the crankshaft's axis of rotation.

(2) T = F * r * sin(theta) [7]

Where, T = torque

F = linear force

r = distance measured from the axis of rotation to where the linear force is applied

theta = the angle between F and r[8].

Periodically, variable *torsinal frequencies* make the propellers work and generate thrust which results in the aircraft being afloat.

In research it has been discovered that offset mechanisms are used to increase mechanical efficiency, therefore increase the net torque output. This can be done by reducing the line of contact between the piston and the cylinder inner lining which in turn reduces power loss due to friction and enhances smooth *acceleration* designs. Even increasing the *compression*, lighter moving parts of the engine, change in ignition timing would enhance a better engine performance. The procurement of the offset connecting rod is done in such a way that during *power stroke*, offset crank shaft is mutually perpendicular to the piston's axis enhancing maximum torque generation[9] . Generally, long connecting rods between piston-cylinder would reduce friction and promote faster return action by reducing the time for the *return stroke* since it's a cyclic process there by making the mechanism efficient and minimizing power loss. In the present day, it is described that the operation of a new crank–rod mechanism designed for generation of maximum torque is facilitated by decreasing the size of the engine, and by reducing the load on the shaft bearings which would also facilitate a higher efficiency of the working piston-cylinder assembly[10].

2.1 COMBUSTION

2.1.1 Research Question #1: What is combustion and what its products?

The main *combustion* reaction happens in the piston, where the fuel mixes with the incoming oxygen from the air. This *chemical reaction* generates a small explosion that moves the piston in order to start the engine's mechanisms. This also produces carbon dioxide, as well as water [11]. This reaction happens in *stoichiometric* proportions as the coefficients in front of the reactants show in reaction [11]. This means only specific amounts of reactants will be consumed during the combustion reaction. The ideal *air-fuel ratio*, also called the stoichiometric air-fuel ratio, for the combustion reaction for a gasoline engine is around 14.7:1, which means 14.7 kg of air is needed to burn 1 kg of fuel [11]. The *equivalence air-fuel ratio* λ will be a more useful coefficient to give an indication of the air-fuel mixture proportions relative to the stoichiometric air-fuel ratio. When $\lambda<1$ the amount of oxygen is insufficient to burn all the fuel. When $\lambda=1$ the amounts of fuel and oxygen in the mixture respect the ideal air-fuel ratio meaning all the oxygen and the fuel are consumed by the combustion reaction. Finally, when $\lambda >1$, the oxygen present exceeds the amount required to burn all the fuel [11]. The unreacted elements, such as unburned fuel (hydrocarbons), oxygen (O2), and other particles from the air that do not participate in the combustion reaction, which will mostly be nitrogen (N2), will be left in the engine. Given the high temperature conditions of the engine, these leftover elements will react together to form other pollutants, such as carbon monoxide (CO) and nitrogen oxide (NO) [12]. Figure 4 shows the influence of the equivalence air-fuel ratio on the pollutant formation.

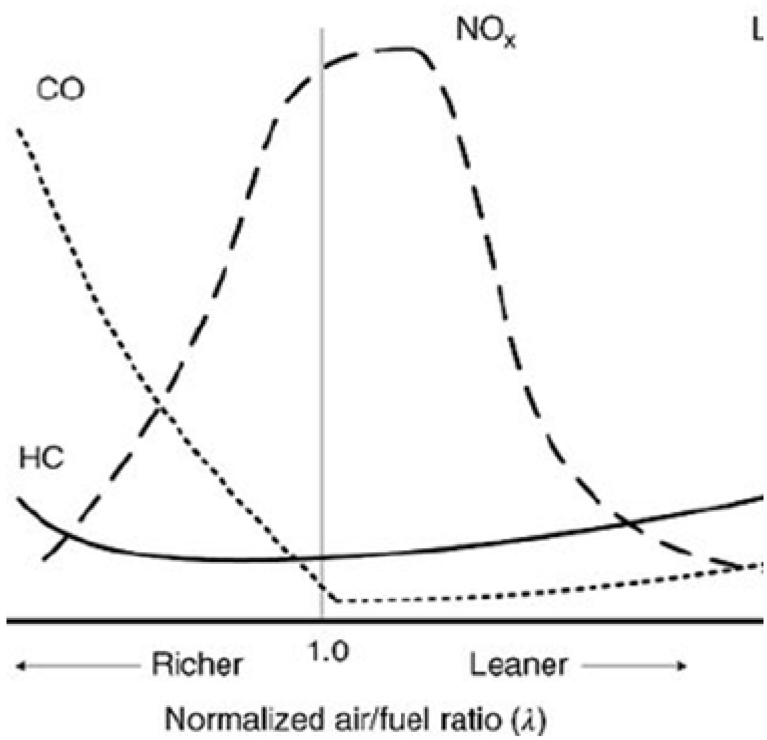

Figure 4: Pollutants formation (CO, NO, HC) with respect to the air-fuel ratio [13]

No tends to form during fuel-lean conditions (λ>1) where some oxygen is left unreacted and the amount of nitrogen is higher [14]. At temperatures above 1600 °C, the nitrogen and oxygen molecules (N2 and O2) dissociate themselves into nitrogen and oxygens atoms. This dissociation leads to a series of reactions between these atoms, also known as the extended *Zeldovich mechanism*, where NO is formed. The Zeldovich mechanism global reaction can be expressed as: [15]. The amount of NO formed by reaction (2) as a function of temperature and time [15]. The CO formation happens mostly in fuel-rich mixtures (λ <1) in the engine where there is a lower concentration of oxygen atoms leading to an incomplete combustion (see figure 4 above) [16]. Normally, the CO is oxidized by hydroxyl (OH) during an intermediate reaction, but that reaction never happens in fuel rich conditions and the CO remains [14]. In the case of hydrocarbons emissions, they are the unburned fuel components that did not react with the oxygen, which usually occurs in fuel-rich conditions (λ <1). Hydrocarbons also fail to react with oxygen at the cold-start of the engine or during warm-up phase, which is when the engine temperature is low [14].

2.1.2 Research Question #2: Which pollutants are produced by the engine and how are their emissions limited?

As the combustion reaction between the fuel (hydrocarbons) and the oxygen from the air do not fully react with each other, there is an excess of particles from unburned fuel (hydrocarbons HC) and particles from the air that react together and form pollutants, such as carbon monoxide (CO) and nitrogen oxides (NOx) [17]. The *catalytic converters'* purpose is to eliminate these pollutants by reacting with them and producing non-harmful particles to be emitted without affecting the main combustion reaction [17]. The most commonly used catalytic converter in the automotive industry is the three-way catalytic converter (TWC) that eliminates CO, NO and hydrocarbons by replacing them with carbon dioxide (CO2), nitrogen gas (N2), and water (H2O) [17]. The TWC eliminates the toxic particles through two phases. The first phase is a *reduction reaction* to separate the oxygen and nitrogen atoms to form N2 [18].

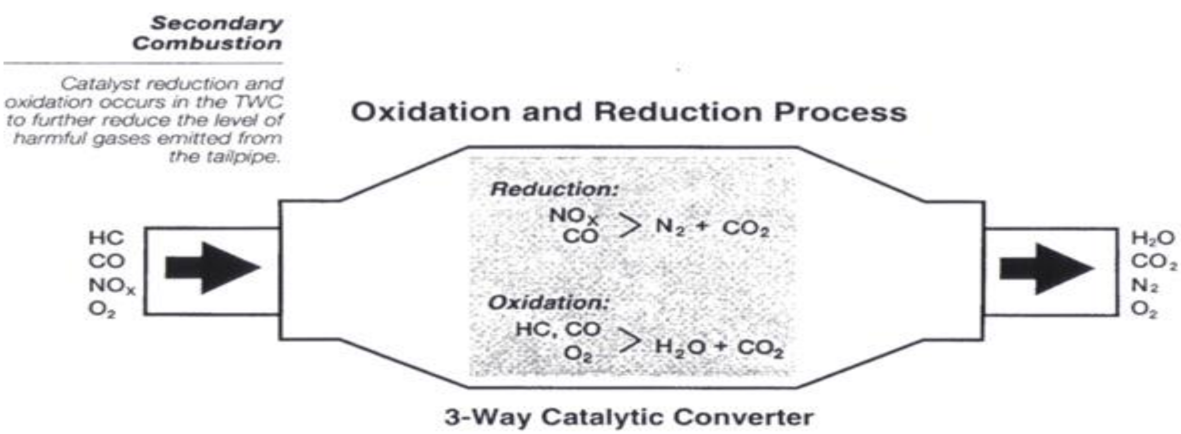

Figure 5: Simplified model of a three-way catalytic converter (TWC) [19]

The second phase is an *oxidation reaction* where the oxygen atoms are used to attach to the CO molecules to form CO2, as well as to react with the hydrocarbon molecules to form H2O and CO2 [18]. These reactions occur quicker at high temperatures; thus, the TWC becomes more efficient when it reaches higher temperatures (around 90% when the temperature reaches above 350 °C) [18].

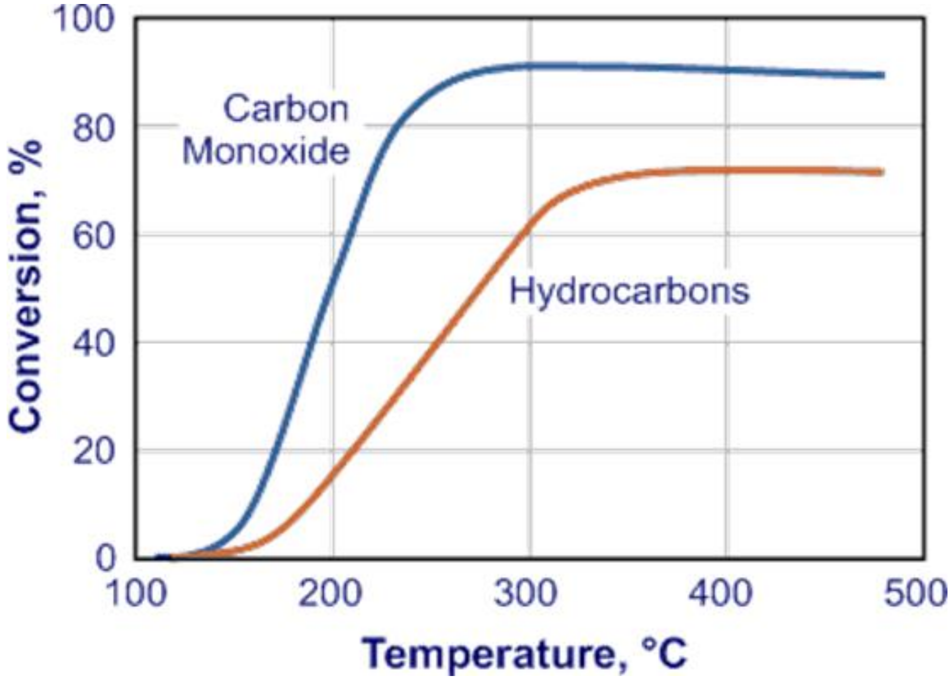

Figure 6: Conversion % of Carbon monoxide (CO) and hydrocarbons (HC) versus Temperature Graph [20**].**

However, the TWC reaches these temperatures very quickly after the engine starts. The TWC is placed in the exhaust system and has a ceramic honeycomb structure maximizing the surface area covered by the reactants to create as many reactions as possible; consequently, maximizing efficiency [17]. Ceramic is usually chosen over other materials (like metals) due to its low porosity and high strength [21]. Also, part of the TWC's composition are platinum-group metals (rare-earth metals) that are integrated onto the inner surface of the honeycomb structure. They are in contact with the incoming pollutants to optimize the reaction conditions for the reduction and oxidation phases. More specifically, the reducing structure has platinum and rhodium integrated, and the oxidizing structure has platinum and palladium [17]. Platinum-group metals are very good catalysts for oxidation and reduction reactions because they are oxidized faster than most metals (like iron). This means they easily attract oxygen atoms to deposit onto the inner surface of the catalytic converter in order to facilitate the separation of the nitrogen and oxygen atoms or to accelerate the oxidation of CO and hydrocarbons [21]. These reactions happen at a higher frequency when the temperature increases as Figure 6 shows.

2.2 EFFICIENCY

2.2.1 Findings of improving fuel efficiency of an aircraft's internal combustion engine

2.2.1.1 Improving fuel efficiency

Compression ratio in the *Gas turbine* is one of the primary ways to improve the fuel efficiency of an aircraft's engine [22]. It is also a well-known branch of thermodynamics, and the ratio of the volume inside a *cylinder* at the beginning and ending of a stroke; in addition to top and bottom of a cylinder. Making engines with a higher compression ratio to produce more *power output* can improve both the fuel efficiency and economy of an aircraft's internal combustion engine [22]. Fuel efficiency is part of how airlines determine tickets prices, so reducing the amount of fuel used would lead to lower prices.

2.2.1.2 Power outputs and gas turbine

One of the major types of an internal combustion engine is the gas turbine, which is widely used in most aircraft industries. The power output of the gas turbine can be very high, where both the weight and the *volume* are minimized [23]. This suggests that cutting down the weight everywhere possibly makes the aircraft more efficient. Having lightweight food carts is one of the simplest ways to reduce weight onboard. Along with reducing weight, minimizing the heat loss also plays an important role in improving the fuel efficiency [23].

2.2.1.3 Gas turbine configuration

Figure 7 as shown below, illustrates the main components of gas turbine. Combustion air goes inside the turbine through the *compressor* where the *pressure* is raised, and the *work* is produced to operate the compressor [23]. To pass the air through the turbine, the turbine inlet temperature must be less than 1227 determined by the blade material. It is important to note that developing the turbine blades that can resist higher temperatures would result in increasing the power output for the gas turbine, which is similar as compression ratio [23][24, p.1]. This proposes that increasing the temperature is one of the key mechanisms in raising engine performance.

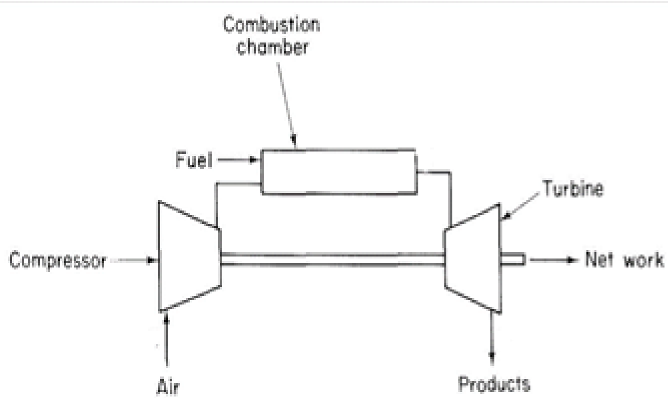

Figure 7: Gas turbine engine components [23]

2.2.1.4 Related Research

Yuh and Tohru conducted a research in 2005 on the effect of higher compression ratio engines. The results show that the *fuel consumption* was improved by 1-3% [22]. This research shows that developing engines with higher compression ratios has a positive impact on overall fuel efficiency.

2.2.2 Findings of investigating factors affecting efficiency of an aircraft's internal combustion engine

2.2.2.1 Energies breakdown

Energy conversion is the process of changing energy from one form to another. Following energies that relate to the internal combustion engine are *thrust*, *thermal energy*, mechanical work, *kinetic energy*, and *chemical energy* [25]. Figure 8 shows an overall energy breakdown for an aircraft turbofan. The figure displays that approximately 30% of the *potential energy* is useful in the aircraft, whereas about 67% of the energy is *irreversible* [25]. This exemplifies that if a flight from Ottawa to Toronto requires 4500 litres of fuel, only 1350 litres of fuel will be useful to the aircraft while the rest of fuel is burned in warm up before taking off, during take-off, and climb-out etc.

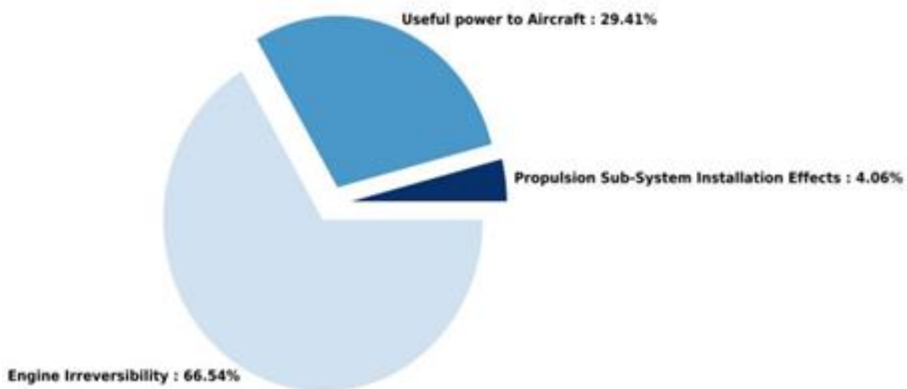

Figure 8: Total energy breakdown of a turbofan inside an engine [25]

2.2.2.2 Breakdown of specific energies divided into groups

Figure 9 shows the breakdown of specific lost energies that are divided into different sources of groups in the engine irreversibilities breakdown [25]. Four percent of the energy is lost due to the installation of the engine in terms of the weight of the aircraft added and *drag force* generated by the aircraft. Nearly one-third of the energy loss is mostly thermal energy that leaves the engine in the form of hot *exhaust gases* [25]. These hot exhaust gases released in the form of greenhouse gas emissions have a major impact on climate change, which may cause serious health hazards and environmental pollution.

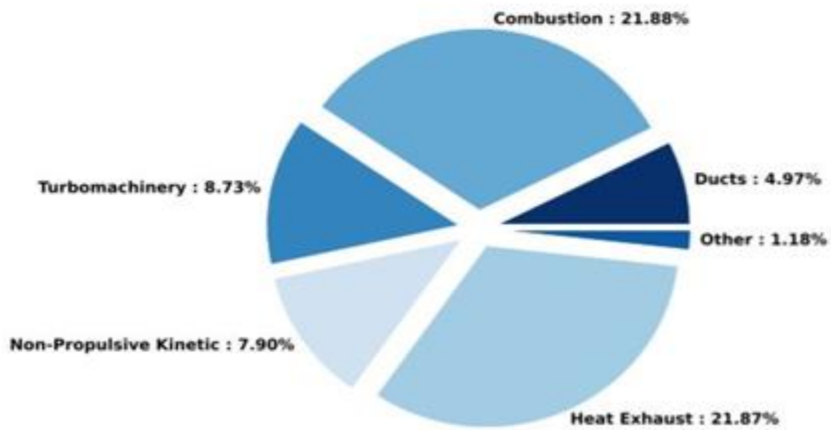

Figure 9: Irreversibilities energies breakdown [25]

2.2.2.3 Energy transformation

A combustion engine is a device that transforms chemical energy stored in the form of heat energy and transfer part of this heat energy into mechanical work [26][27]. Figure 10 below illustrates a simple model of the internal combustion engine where a combustion process is carried out inside. If the loss of thermal energy is less in that process, it should relate to the high thermal efficiency that would improves the overall efficiency of the aircraft's internal combustion engine. [27].

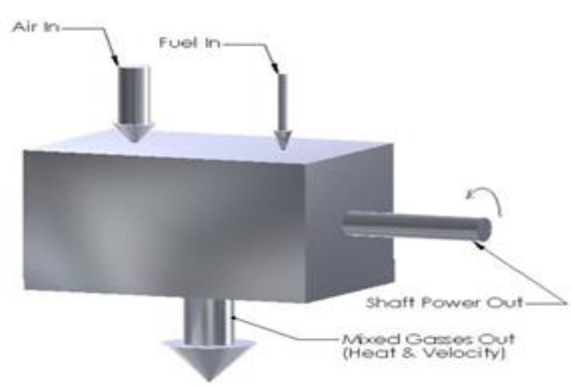

Figure 10: Model that represents an aircraft's internal combustion engine [27]

2.2.2.4 Piston role in energy loss

The main function of *piston* is to seal the combustion chamber to minimize energy loss [26][27]. However, two-thirds of the fuel's energy is lost in the process of converting chemical energy into mechanical energy to run the aircraft. Some of the power that is produced by the engine is also lost in making the pistons go up and down and pumping the air through the engine. The equation to measure energy irreversibility of the system is shown in Equation 3 below [25]. The total amount of energy that is not reversible can be calculated with the help of this equation.

$$I^*_{system} = \frac{\sum jI_j}{E_{x,total\ input}} \tag{3}$$

[25] p6 Where is the total energy irreversibility of the system, is the sum of each energy component, and is the total input of energy.

2.3 NOISE

2.3.1 Findings of research question one: the ways to reduce noise pollution by the internal combustion engine

2.3.1.1 Sources of noise pollution in the internal combustion engine

Noise pollution is the propagation of noise with a harmful impact on the hearing of humans and animals. In an aircraft, a popular source of noise pollution comes from the following scenario. The aircraft is traveling down the airport runway, gathering *velocity*, as it is about to take off the ground. A *high-pitched* whining noise is produced [28]. This *noise pollution* is being produced as a result of large air waves getting pulled in to the engine by its rapidly rotating turbine fans [28]. Another source of *noise pollution* from within the internal combustion engine is its exhaust *valve*. A *low-pitched* rumble is created when exhaust fumes are being released through this *valve* [28].

2.3.1.2 Engine turbine fan configuration

The first engineering principle that answers research question one is frequency. An effective way of reducing noise levels originating from the turbine fans is to rework the current design of the internal combustion engine by implementing larger turbine fans into the engine [28]. The original turbine fans turn at a very fast frequency of 4000 rotations per minute. The faster the turning speeds of the fans, the more air waves get pulled into the engine, and the more intense the *noise pollution* produced becomes. The larger fans possess more weight than the original fans and turn at a slower rate. These larger turbine fans will therefore reduce the noise pollution production of the engine.

A separate set of design modifications to the engine can be made to reduce noise pollution originating from the exhaust value. The modification entails implementing of sound-absorptive enclosures; These enclosures are known as *mufflers* [29]. Mufflers are a part of the engine exhaust system that serve to muffle the sounds coming from the engine [29].

2.3.1.3 Active noise control

Until the aircraft manufacturers are able to incorporate the engine turbine fan configuration into modern aircraft, active noise control is a another, more feasible, way to protect people onboard an aircraft from the harmful impact of noise pollution. Frequency is also utilized in the active noise control. Active noise control is a contingency plan formulated by a group of aerospace experts [28]. Active noise control involves producing a *sound field* as the mirror image of the offending sound [28]. A sensor such as a microphone, *accelerometer*, or other device picks up the annoying sound and relays the signal to an electronic controller, which drives an *electromagnetic* vibration generator to produce the opposing sound. Figure 11, as show below, illustrates the concept of the active noise control.

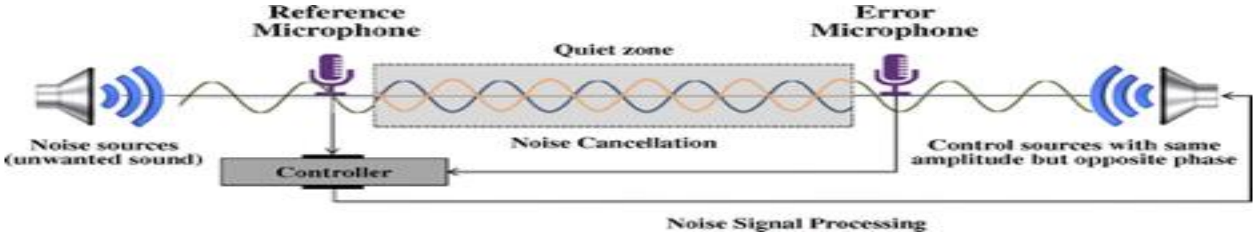

Figure 11: Active Noise Control Visualization [30]

This active noise cancels out the disturbance, with the net result that the sound is significantly reduced. One consumer product that does employ active noise control is headphones typically used by the pilots themselves and being made readily available to the public to ensure a quiet flight for passengers and flight crew [28].

2.3.2 Findings of research question two: the sonic boom and its effects on the aircraft pilot and passengers

2.3.2.1 The sonic boom

The engineering principle that answers the second research question is pressure. It is very likely that a sonic boom causes damage to the human nervous system. A *sonic boom* is a situation whereby an aircraft flying at *supersonic speed* and compiles pressurized energy sound waves called *shockwaves* along its body frame and a kinetic energy build up begins [31]. These *shockwaves* are at their most powerful at tip of the aircraft. Once this energy buildup has attained a certain threshold energy level, the aircraft is then able to break through the *sound barrier*. As soon as the aircraft breaks through the sound barrier, there is a sudden “explosion” of sound as a result of several simultaneous collisions between the *shockwaves* at this supersonic speed. This “explosion” of the *shock waves* is what’s called the sonic boom [32].

The figure shown below demonstrates the propagation, range, and effect of a sonic boom.

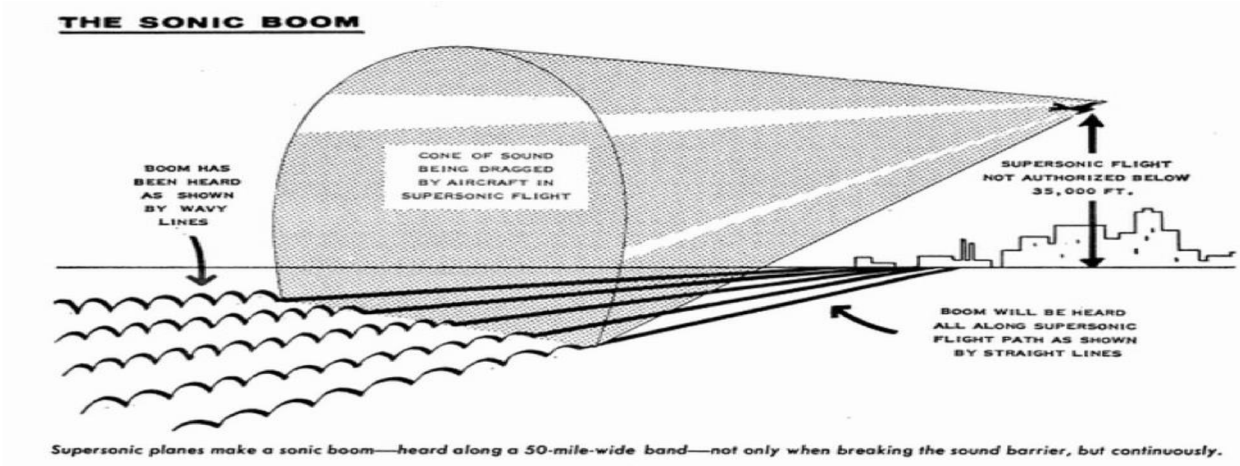

Figure 12: Sonic Boom Visualization [33]

2.3.2.2 Electric field generating device

There are many ideas from experts in the field of aerospace engineering on how to prevent the *sonic boom* from happening. 30 years ago, a set of Russian engineers made a claim that that they could quiet the sonic boom without having to make any modifications to the aircraft body frame [31]. The Russian engineers proposed the installation of electric field generating device in the airplane's nose [31]. The introduction of the *electric field* serves the purpose of counterbalancing the s*hockwave* buildup. The pressurized energy *ions* and electrons from the shockwaves interact with the electric already containing positively charged *ions* and negatively charged *electrons* [31]. This reaction produced large quantities of *plasma*. Plasma is a hot ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons [31]. *Plasma* is a neutral energy entity and so will not form a buildup of its own.

3.0 Report Conclusion

The report explains the workings of an internal combustion engine of the aircraft by looking at four different important aspects: mechanism, combustion, efficiency, and noise. The implementation of the necessary measures will improve the overall efficiency of the ICE, which will be beneficial to society. The report also discusses the traditional Internal Combustion Engine and the drawbacks of the pre-existing engine design.

The mechanical efficiency of the propellers and the crank mechanism can be improved in internal combustion engines. This would lead to conservation of energy, which would lead to minimal power loss, facilitating better engine performance. The combustion reaction and its products were defined and explained using chemical reactions to understand how pollutants are formed in the engine. The pollutants produced by the combustion reaction of the ICE were mentioned and the mechanism behind the elimination of the pollutants by catalytic converters was explained. The engineering principle of thermodynamics was also used to focus on improving the internal combustion engine's fuel efficiency. The report also focuses on factors affecting aircraft's engine efficiency which was answered by using the engineering principle of energy conversion. Fuel efficiency can be improved through compression ratio. The report also discusses the ways noise pollution from the internal combustion engine could be reduced and also highlights the effects of the sonic boom on passengers.

The goal of Team#3's report is to reduce the price of air tickets, making it more fuel efficient which would in return make air transport cost effective. Team#3 believes that the research work of this project would be valuable to the rapidly changing world. Team#3 acknowledges the opportunity to present this report and looks forward to receiving feedback. For any questions regarding the report or if there is a need for any further explanation, please feel free to contact the team at (613) 123-4567.

Glossary

Acceleration: Increase in magnitude of velocity of a moving body [34].

Accelerometer: An electromechanical device used to measure dynamic acceleration forces, detect movement or vibrations in sound waves, and relay the signals to a controller [35].

Aerodynamic: Relating or using aerodynamics [36].

Aerofoil: A structure with curved surfaces designed to give the most favourable ratio of lift to drag in flight, used as the basic form of the wings and fins of most aircrafts [37].

Air quality: It refers to level of pollutants in the air [38].

Airflow: flow of air caused by an aircraft [39].

Air-fuel ratio (AFR): Ratio between the mass of oxygen by the mass of fuel[40].

Aloft: In the air [41].

Catalytic Converter: A device with a monolith structure converting pollutants such as nitrogen oxide (NO), carbon monoxide (CO), and hydrocarbons (HC) to carbon dioxide (CO2), water (H2O), and nitrogen gas (N2) [42].

Chemical energy: Energy that is stored in chemical substance [43].

Chemical Reaction: A chemical process where two molecules (or reactants) come in contact to form (a) new molecule(s) [44].

Combustion: A chemical process where a substance is burned (generates heat) when in contact with another substance (usually oxygen) [45].

Compression: The reduction in volume of a fuel mixture in an Internal Combustion Engine before ignition [46].

Compressor: A machine for compressing the gases, especially air [47].

Crank: A mechanical part which is used to convert linear motion into rotatory motion [48].

Cylinder: A part in which a piston travel [49].

Drag: Pull along forcefully [50].

Drag force: Force that is acting opposite the aircraft motion through the air [51].

Dynamic-lift: The force produced by air moving over a specially shaped surface. Aerodynamic lift acts in a direction perpendicular to the direction in which the air is moving [52].

Efficiency: Quantifies level of performance. Complete usage of least amount of input resulting in highest amount of output [53].

Electric field: A region around a charged particle or object within which a force would be exerted on other charged particles or objects [54].

Electromagnetic: Relates to electromagnetic force, which is where both electricity and magnetism operate as different manifestations in the same phenomenon[55].

Electron: A very small piece of matter and energy that is negatively charged while moving at close to the speed of light. Its symbol is e^-[56].

Energy conversion: Process of changing one form of energy to another [57]

Equivalence air-fuel ratio: Ratio between the actual AFR and the stoichiometric (ideal) AFR [40].

Exhaust gases: Gas emitted from the engine when the fuel is burned [58].

Fuel consumption: Amount of fuel mode of transportation uses to travel a particular distance at a particular speed [59].

Fuel efficiency: : Energy released during fuel combustion that is converted in some type of useful energy [60].

Gas turbine: It is a type of internal combustion engine [61].

High-pitched: Sounds come from sounds that vibrate very fast and give off very sharp, irritating tones to the eardrum [62].

Ion: An atom or molecule with a net positive electric charge due to the loss or insufficient number of electrons in its makeup [63].

Irreversible: Energy that is not reversable [64].

Kinetic energy: Energy of anything that is in motion [65].

Lift-coefficient: A dimensionless coefficient that relates the lift generated by a lifting body to the fluid density around the body, the fluid velocity and an associated reference area [66].

Low-pitched: Sounds come from sounds that vibrate slowly [67].

Maximum gross weight: The maximum allowable weight of the fully loaded vehicle, including liquids, passengers, cargo and the tongue weight of an aircraft [68].

Mechanism: A process, technique, or system conceived with the aim of achieving a certain result or set of results [69].

Noise pollution: The release of harmful or annoying levels of noise that affect human life [70].

Oxidation Reaction: Chemical reaction where a substance loses an electron when reacting with another substance [71].

Piston: It consists of a cylindrical body that either move by or move against a fluid [72].

Piston Cylinder: Sliding cylinder with a closed head (the piston) that is moved reciprocally in a slightly larger cylindrical chamber (the cylinder) by or against pressure of a fluid, as in an engine or pump [73].

Plasma: An ionized gas consisting of positive ions and free electrons in equal proportions resulting in more or less no overall electric charge, typically at low pressures (as in the upper atmosphere and in fluorescent lamps) or at very high temperatures (as in stars and nuclear fusion reactors) [74].

Potential energy: Energy stored in an object at rest [75].

Power output: Amount of power produced [76].

Power stroke: The stage of the cycle of an Internal Combustion Engine in which the piston is driven out by the expansion of gases [77].

Pressure: Force being applied on an object [78].

Propellers: A device that consists of central hub with radiating blades which spin and facilitate movement [79].

Propulsion: Source of mechanical power driving an object forward [80].

Reduction Reaction: Chemical reaction where a substance gains an electron when reacting with another substance [71].

Return stroke: Reciprocating motion [81].

Rotatory motion: The act of rotating as if on an axis [82].

Sheer Stress: External force acting on surface parallel to the slope [83].

Shockwave: A sharp change of pressure in a narrow region traveling through a medium, especially air, caused by explosion or by a body moving faster than sound [84].

Sonic boom: A loud explosive noise caused by the shock wave from an aircraft traveling faster than the speed of sound [85].

Sound barrier: A reference to an aircraft reaching the speed of sound. It represents a resistive force that presents aircrafts travelling at supersonic speed to achieve greater speeds. The sound barrier is said to be “broken” when breaks through the force restraint by this force and this action gives rise to the sonic boom [86].

Sound field: The dispersion of sound energy within given boundaries [87].

Static-lift: It is the stable lift of an aircraft in the longitudinal plane under steady flight conditions [52].

Stoichiometric: Defines the proportions of the amount of reactants where a chemical reaction is complete (all the reactants are consumed) [40].

Supersonic speed: A rate of travel of an object that exceeds the speed of sound. This speed is approximately 344 miles/second. It is also known by a more technical term as Mach 1 [88].

Thermal energy: Energy present in a system at a temperature [89].

Thermodynamics: It describes a relation between heat and work [90].

Thrust: To push with a force [91].

Torque: Force that produces rotation [92].

Torsinal frequencies: Twisting in a certain repetitive manner [93].

Turbine: A machine that produces power and in a shape of wheel or rotor [94].

Velocity: The speed of an object in a given direction [95].

Volume: Spaced occupied measured by cubic units [96].

Work: Transferring of energy from one place to another [97].

Zeldovich Mechanism: Series of chemical reactions between atomic nitrogen (N) and oxygen (O) leading to the formation of nitrogen oxide (NO) [98].

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