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Performance Tests of Cessna 172S Magnetos Under Various Thermal Conditions

Muhammad Nur Cahyo Hidayat Nasrullah[1], Sabam Danny Sulung[2], Untung Lestari Nur Wibowo[3] Ikhwanul Qiram[4]
[1,2,3]Indonesian Civial Pilot Academy, Banyuwangi, Indonesia
[4]Department of Mechanical Engineering, PGRI Banyuwangi University, Indonesia

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ABSTRACT

Magneto serves as the ignition source in the combustion process of piston aircraft engines. Typically, spark-ignition aircraft like the Cessna 172SP are equipped with two ignition systems (dual magnetos). Dual magnetos are installed so that if one system fails, the aircraft can still continue its flight. During the engine startup process, the magneto plays a significant role as the ignition source for the initial combustion before the aircraft engine comes to life. In the case experienced by pilots at the Indonesian Civil Pilot Academy Banyuwangi, starting the engine became challenging when the aircraft had been previously used for a flight. Therefore, this research is conducted to address the underlying causes of this issue. The parameters examined in this research include outside air temperature (OAT), Cylinder Head Temperature (CHT), and Exhaust Gas Temperature (EGT). Data were collected regarding the duration of the engine startup process. The duration time for starting the engine was found to be the highest at an exhaust gas temperature of 135 °F, a cylinder head temperature of 180 °F, and an outside air temperature of 35 °F, with a duration time of 6.8 seconds. Conversely, the shortest engine startup duration was observed at an exhaust gas temperature of 75 °F, a cylinder head temperature of 75 °F, and an outside air temperature of 26 °F, resulting in a duration time of 1.6 seconds.

Corresponding Author:

Ikhwanul Qiram,
Department of Mechanical Engineering,
PGRI Banyuwangi University,
Jl. Ikan Tongkol No.22, Kertosari,
Banyuwangi District, Banyuwangi Regency, East Java 68416.
Email: ikhwanulqiram@gmail.com

1. INTRODUCTION

This research aims to delve deeper and broaden the understanding of the very important role of the ignition system in piston aircraft engines, which significantly affects the combustion process (Finkelberg et al., 2019). Optimal ignition is a key element for achieving efficient combustion, which in turn not only improves the stability of the combustion process, but also reduces vibrations that can occur in the engine (Czarnigowski & Jakliński, 2019). The most common ignition system used in piston aircraft engines is the spark ignition system. Spark ignition was chosen because of its reliability, as well as its high power ratio despite its relatively low weight (Xiaogang et al., 2020; Yu et al., 2021). The reliability of this system is key in ensuring that the aircraft can maintain optimal performance throughout the duration of the flight.

Piston aircraft engines are designed with great complexity to ensure that the aircraft is able to achieve a high ratio of power to weight. The use of these piston engines is a highly prioritized option to allow the aircraft to remain light in weight, yet still have plenty of power (Czarnigowski & Jakliński, 2019). In this highly complex piston aircraft engine, the magneto is a component that has a very vital role. The magneto is responsible for generating the spark required to ignite the fuel and air mixture in the engine cylinder. Typically, each aircraft is equipped with two magnetos as a safety measure, so that if one malfunctions, the aircraft can still continue its flight. The magneto functions as an AC current generator that is driven by engine rotation. This unique component uses permanent magnets as an energy source, so it does not rely on other power sources such as batteries or alternators (Jerlăianu et al., 2020).

The use of permanent magnets in magneto is gaining popularity due to their unique and favorable properties. However, the impact of elevated temperatures is becoming a frequent problem and requires special attention from researchers (Luo et al., 2022; Mohammadi et al., 2014; Wrobel, Mellor, et al., 2015). An increase in temperature can have a significant impact on the performance of permanent magnets, as revealed in a study by Lee et al. who found that irreversible demagnetization of permanent magnets can occur, in part due to an increase in engine operating temperature (Lee et al., 2015). Moreover, temperature can also affect power loss and iron loss in generators operated by permanent magnets (Wrobel, Staton, et al., 2015)

The field conditions that formed the background for this study were when pilots of the Cessna 172S aircraft at the Indonesian Civil Pilot Academy Banyuwangi reported consistent difficulties when starting the engine, especially when the aircraft had previously been used in flight. The special condition of this Cessna aircraft, which only utilizes an air-cooled cooling system, suggests that the taxiing, landing and previous use processes can have an impact on the temperature of various components, including the magneto. Therefore, using the in-situ data collection method, this study attempts to explore this phenomenon of difficulty in the starting process, and look for possible links between thermal influences and the time taken to start the engine (Mirza et al., 2016). With a deeper understanding of the role of temperature in magneto performance, this research is expected to provide crucial insights to address the challenges faced by Cessna 172S pilots at the Indonesian Civil Pilot Academy Banyuwangi and improve overall flight safety.

2. RESEARCH METHOD

2.1 Thinking framework

This research process began with field observations when the author encountered problems in the engine start process (Mirza et al., 2016). Engine start difficulties are found when the pilot will carry out flying in the second or third period. In addition, engine start difficulties also occur when technicians perform post flight which requires moving the aircraft to the parking stand before entering the hangar. From this observation, the author tries to describe how the temperature impact on magneto performance. The hypothesis in this study is that the magneto is less able to supply sparks into the engine. So that in the process of the first time the engine is carried out the combustion process, the ignition given is not maximized. From this research, the indicators shown are outside air temperature (OAT), Cylinder Head Temperature (CHT) and Exhaust Gas Temperature (EGT).

Data on outside air temperature (OAT), Cylinder Head Temperature (CHT) and Exhaust Gas Temperature (EGT) then become a reference for taking other parameters. The next parameters taken are Voltage, Ampere and duration during the engine start process from four aircraft samples. from the results of this test, conclusions are then drawn to be analyzed using existing literature. The following Figure 1 shows the thinking framework in this research.

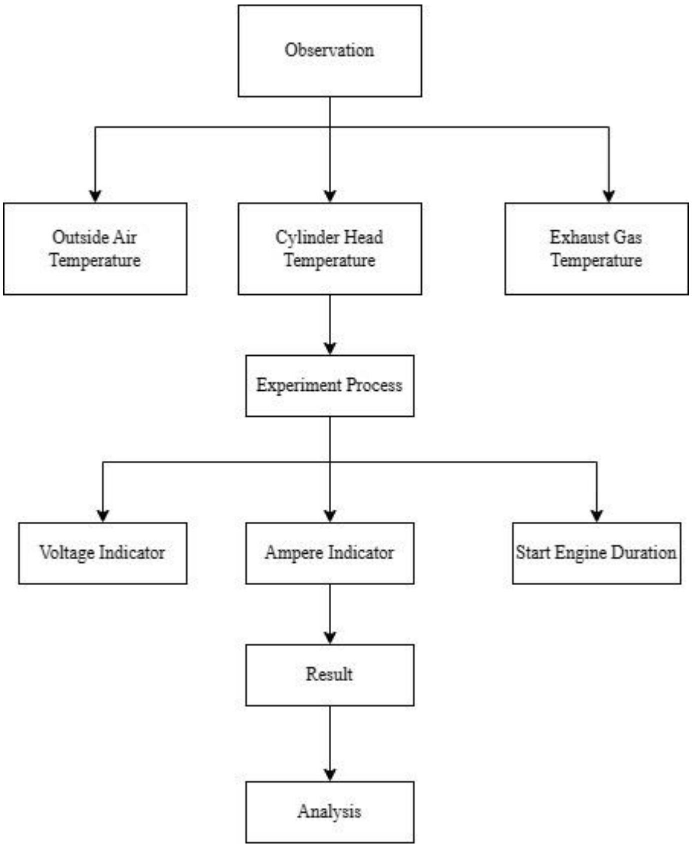

Figure 1. Thinking framework.

2.2. Testing the starting engine process time

The test data is seen by knowing the time it takes for the engine to start after starting the engine. Indicators that must be met include outside air temperature (OAT). OAT measures the temperature around the aircraft, so it can be interpreted as the outside temperature when the test takes place. OAT data is obtained in order to compare how the starting process on the aircraft if carried out at high temperatures and low temperatures. Next is the exhaust gas temperature (EGT). The EGT parameter on the Cessna 172s aircraft engine is the exhaust gas temperature value. This parameter must also be adjusted by comparing low and high EGT temperatures. Low EGT temperature is obtained when the aircraft is first started. Starting is first done per day at 23.00 universal time (UTC) to 24.00 universal time (UTC). Then for the high temperature taken after the aircraft landing, approximately five minutes from engine shut off.

In addition to EGT, the next parameter to be recorded is cylinder head temperature (CHT). The CHT value is taken from the engine instrument found on the Garmin Display Unit (GDU). The CHT value needs to be known because it can indicate that the aircraft engine being tested is in a post-combustion state. So if the CHT recorded is large, then the data listed belongs to the aircraft that has carried out the flight. Integration of data from these three parameters will provide a more comprehensive picture of the impact of temperature on the engine starting process of the Cessna 172S aircraft under various conditions. Analysis of this data will support a better understanding of aircraft engine starting performance in relation to temperature factors. For better understanding, a schematic diagram is shown in Figure 2.

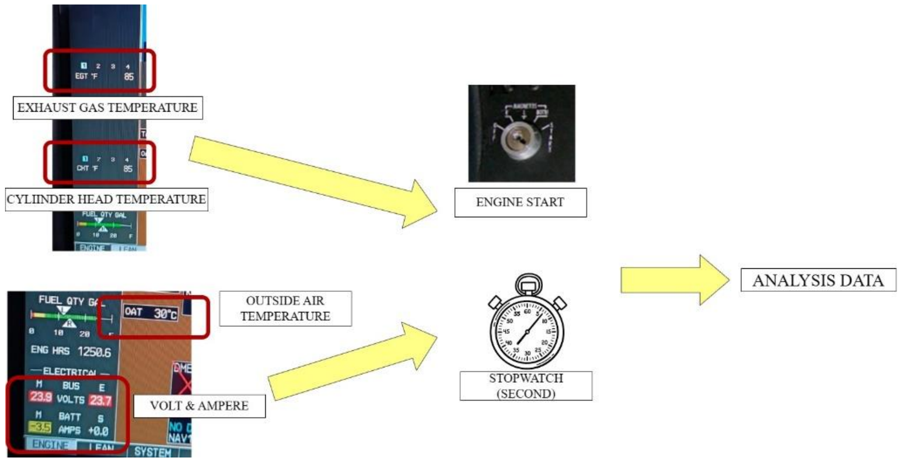

Figure 2. Schematic diagram.

3. RESULTS AND DISCUSSIONS

This research was conducted directly on the 172S Cessna aircraft. the data taken is realtime data at the time of testing. The purpose of this research is to find out how the impact of various temperature parameters on the magneto engine. The test was carried out by taking data on the starting time as the the aircraft first started flight or preflight. Data taken on engine start duration at several variations of temperature parameters can be found in Table 1.

NO.	Exhaust Gas Temperature (°F)	Cylinder Head Temperatur (°F)	Outside Air Temperature (°C)	Voltage Output (VOLT)	Ampere Output (AMP)	Starting Duration (second)
1	105	120	42	6,8	-0,5	5,4
2	100	105	42	4,8	-2	6
3	135	180	35	3,7	-2,5	6,8
4	100	100	34	3,1	-1,5	4,8
5	75	75	25	2,3	-1,5	2,3
6	75	75	26	2,2	-2	1,6
7	75	75	27	3,6	-1,8	2
8	75	75	26	2,9	-1,5	1,8

Table 1. starting duration (second) at temperature variation.

It can be seen that, the greater the temperature value at outside air temperature (OAT), cylinder head temperature (CHT) and exhaust gas temperature (EGT) causes the duration of the engine starting process to be longer. The duration value of engine starting time is obtained at exhaust gas temperature 135 °F, cylinder head temperature 180 °F and outside air temperature 35 °F. the highest engine starting time duration value is at 6.8 seconds. While the lowest engine start duration value is at exhaust gas temperature 75 °F, cylinder head temperature 75 °F and outside air temperature 26 °F. The engine start duration value is 1.6 seconds. From the existing data, it can be seen that temperature affects the duration of engine start time. Engine starting conditions that take a long time can have a damaging effect on the starter components on the aircraft.

Engine start on a Cessna 172S aircraft is the process of starting the engine to operate from a shut down state. This process is done by cranking the propeller which is assisted by a sky tech starter connected to the flywheel (Wild, 2018). The flywheel is connected to the crankshaft which then starts the four stroke engine cycle on the powering lycoming engine on the Cessna 172S aircraft (Mcclelland, 1971). This four stroke then powers the aircraft to turn the propeller. However, before the propeller is actually rotated the engine must sustainably go through this cranking process. The success of the cranking process is influenced by engine ignition. Ignition on the Cessna 172S is provided by a magneto which is a kind of generator rotated by the propeller. Magneto uses permanent magnets as an energy source, so it does not require an external power source such as a battery or alternator. Two magnetos are usually used in an aircraft as a safety measure, so that if one malfunctions, the aircraft can still continue the flight with the other magneto.

However, in the case of engine starting, magneto has a very important role to be able to start the engine. The four stroke cycle process in the engine is one of the ignition processes. In the engine starting process, it is expected that even the slowest rotation must be able to produce combustion that can provoke propeller rotation. The engine starting process is called successful if the propeller rotation is stable. This is indicated by the process of four cylinders taking turns burning. In the process, the magneto is responsible for generating the spark that is needed to start the aircraft engine by igniting the fuel and air mixture in the engine cylinders (Czarnigowski & Jakliński, 2019; Sulung et al., 2023). The reliability of this ignition is critical to flight safety, and this is why the influence of temperature on the magneto is so great. When the ambient temperature rises, especially during aircraft operations in air with extreme heat conditions, the permanent magnets used in the magneto can demagnetize. This demagnetization results in the loss of the permanent magnets' ability to maintain the strong magnetic field required to create a consistent spark. As a result, aircraft engine ignition can become less reliable, potentially disrupting the aircraft engine starting process and threatening flight safety.

In addition to demagnetization issues, high temperatures can also reduce the coercivity of permanent magnet materials. Coercivity is the ability of a material to maintain magnetization in the presence of an external magnetic field (Kruiver et al., 2001). At high temperatures, coercivity is reduced, and this can make permanent magnets more susceptible to loss of their magnetic properties (Li et al., 2020). As a result, in-flight ignition systems can become less efficient and can affect the speed and reliability of engine starting. This is evidenced in Figure 2 where the engine starting time will decrease along with the temperature values at outside air temperature (OAT), cylinder head temperature (CHT) and exhaust gas temperature (EGT). The sparks generated by the magneto are highly dependent on the magnetic field generated. A strong magnetic field will create a consistent and strong spark, which will ignite the fuel and air mixture in the engine cylinder. However, if the magnetic properties of the permanent magnet material in the magneto are affected by high temperatures, the magnetic field generated will weaken, and this can result in sparks that cannot properly perform the combustion process in the engine (Wrobel, Mellor, et al., 2015).

Molecularly, the effect of temperature on magnetic properties can be explained through changes in the behavior of atoms and molecules in materials. At elevated temperatures, the kinetic energy of atoms and molecules increases, resulting in more intensive and random movements. Temperature can be considered as a measure of the thermal energy possessed by the atoms and molecules in the material. The higher the temperature, the greater the kinetic energy possessed by the particles. Atoms and molecules in materials have magnetic moments, known as magnetic dipoles. These magnetic dipoles are the result of the individual magnetic moments possessed by the atoms or molecules. At low temperatures, these magnetic moments tend to orient more uniformly, creating a strong magnetic field within the material. Therefore, materials can exhibit strong magnetic properties at low temperatures. However, at high temperatures, random movement and thermal energy can affect the orientation of these magnetic moments. Atoms and molecules can fluctuate in their orientation randomly due to the effects of heat causing the magnetic moments to change dynamically (Gauyacq et al., 2012). As a result, the magnetic field generated by the material may become weaker or even disappear completely when the temperature reaches a very high level.

4. CONCLUSION

This research describes how temperature affects performance. This research explores how ambient temperature, especially high temperature, affects the performance of the engine starting process in aircraft. The results show that high temperatures have a negative impact on the performance of the aircraft engine starting process, especially with regard to engine ignition. The main influence lies in reducing the reliability of the ignition generated by the magneto. The magneto is an AC generator that uses a permanent magnet system. The influence of temperature causes changes in the magnetic properties of the permanent magnets in the magneto. This has important implications for flight safety, as reliable ignition performance is critical in the engine starting process and flight.

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