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Analysis of Fuel Consumption for Cruising Flight of Cessna 172 Based on Speed Variations

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ABSTRACT

This research investigates the correlation between cruise speed, fuel consumption, and propeller efficiency in the Cessna 172 aircraft during actual flight conditions. The study involved five test flights conducted at different cruise speeds: 87.7, 90.8, 98.4, 105.3, and 113.5 knots, each flown over 100 nautical miles at 5,000 feet altitude. Fuel consumption was calculated by comparing initial and final fuel levels, revealing that actual usage consistently exceeded the Pilot Operating Handbook (POH) estimates. For instance, at 87.7 knots, actual fuel consumption was 39.61 L/hr, significantly higher than the POH value of 21.26 L/hr. Propeller efficiency peaked at lower speeds (0.828 at 87.7 knots) and declined at higher speeds (0.628 at 113.5 knots), indicating reduced aerodynamic performance. These findings underscore the importance of selecting optimal cruise speeds to enhance fuel efficiency, reduce operational costs, and extend aircraft lifespan. The study provides practical insights for pilots and operators aiming to optimize light aircraft performance in real-world operations.

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INTRODUCTION

Aircraft play a critical role in modern public transportation, offering speed and accessibility. However, over time, aircraft experience structural fatigue and system degradation, leading to a decline in performance. Therefore, regular and proper maintenance is essential to sustain safe and efficient operations [10]. One of the key performance factors affected by these degradations is fuel efficiency, especially in piston-engine aircraft commonly used in general aviation, such as the Cessna 172 [11]. The Cessna 172 is favored for its stability and ease of handling, making it a popular choice for flight training and short-distance operations.

Fuel efficiency is a vital consideration in both economic and environmental terms. The International Civil Aviation Organization (ICAO) has emphasized the importance of optimizing fuel use in aircraft operations to minimize environmental impact and operational costs [8]. Efforts to improve operational efficiency at airports, including taxiing and cruise phases, are central to overall sustainability goals [1]. Although the Cessna 172's Pilot Operating Handbook (POH) provides standardized fuel consumption data [6], real-world performance often diverges due to variations in engine condition, propeller efficiency, and atmospheric factors [13]. Studies involving other aircraft such as the King Air B200 and Boeing B737-800 NG have also shown that flight profiles and operational styles significantly influence fuel consumption [5][7].

This study aims to examine the relationship between cruise speed and actual fuel consumption in the Cessna 172, and to evaluate how deviations from POH expectations influence propeller efficiency and operational performance. By doing so, it seeks to provide a more accurate reference for flight planning, contribute to the understanding of small aircraft efficiency, and offer guidance for improving fuel economy through optimal cruise speed selection. Influence of malfunctions, and fuel efficiency is vital to maintaining the optimal operation of the aircraft.

METHODS

The study began with a literature review to understand key concepts in aircraft fuel efficiency, propeller aerodynamics, and relevant calculation techniques, drawing on both academic sources and regulatory guidance [8][11][13]. Additionally, interpolation techniques were applied to estimate POH fuel values at intermediate conditions, following numerical methods similar to those described by Pratama et al. [12]. The method consisted of several well-defined steps as illustrated in the flowchart Figure 1.

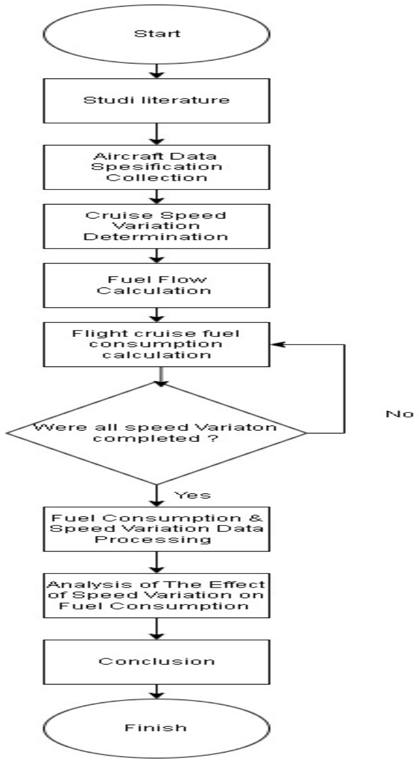

Figure 2. Research Flowchart

Subsequently, technical specifications of the Cessna 172—such as aircraft weight, engine power, propeller configuration, wing area, and aerodynamic characteristics—were gathered from the Pilot Operating Handbook (POH) [6]. Based on the aircraft's operational parameters, five cruise speed targets were selected: 87.7, 90.8, 98.4, 105.3, and 113.5 knots. These speed intervals were chosen to represent a wide range from low to high cruising speeds within the aircraft's safe operating envelope.

Flight tests were conducted for each selected speed over a fixed distance of 100 nautical miles at a constant altitude of 5,000 feet. During each flight, fuel consumption was recorded by measuring the difference between the initial and final fuel levels displayed on the onboard indicators. The formula used was

$$\text{Fuel Consumption (L)} = \text{Initial Fuel (L)} - \text{Final Fuel (L)} \quad (1)$$

From this, the actual fuel flow rate was calculated by dividing the consumed fuel by the total flight time in hours:

$$Fuel\ flow\left(\frac{L}{hr}\right) = \frac{Fuel\ Consumend\ (L)}{Flight\ Time(hr)} \quad (2)$$

To determine the propeller efficiency, several aerodynamic parameters were calculated. The lift coefficient was determined using

$$Cl = \frac{L}{\frac{1}{2}\rho V^2 S} \quad (3)$$

Next, the drag coefficient was calculated using the drag polar equation:

$$Cd = Cd_0 + k(CL)^2 \quad (4)$$

Because the aircraft was assumed to be in steady-level flight with constant weight, drag was considered equal to thrust, calculated as:

$$D = \frac{1}{2} \times \rho V^2 SCd \quad (5)$$

The available engine power was calculated by multiplying the rated power output by the percentage of brake horsepower (BHP) in use:

$$P_a = \%\text{BHP x Engine Rated Power (W)} \tag{6}$$

Finally, propeller efficiency was computed using:

$$\eta = \frac{T \times V}{Pa} \tag{7}$$

where T represents thrust and V is true airspeed.

All computed values including fuel flow and propeller efficiency were compiled into Tables and visualized using graphs to identify patterns. Actual flight results were compared with POH performance estimates to assess discrepancies and performance degradation. Although this study emphasized trend analysis through visualization, it did not employ formal statistical tools such as confidence intervals or hypothesis testing. Incorporating statistical validation is recommended for future research to improve the reliability of the findings.

RESULT AND DISCUSSION

3.1 Fuel Indicator Data Recording

The amount of fuel consumption recorded during five flight sessions with varying speeds is presented in Table 1. This data was collected to analyze the relationship between cruise speed and fuel requirements, which will later be used in the discussion of the research results. Fuel consumption was obtained by calculating the initial fuel before the cruise flight phase and subtracting the final fuel after the cruise flight phase was completed, as shown in the following equation.

$$\text{Fuel quantity} = \mathit{Initial\ fuel} - \mathit{Final\ fuel}$$
$$\mathit{Fuel\ quantity} = 159.1 - 126.3 = 32.8 \text{ Liters}$$

Table 1 Amount of Fuel Consumption

No	TAS (Kn)	Rpm	Travel Time (min)	Fuel Consumption (L)
1	113.5	2530	53	32.8
2	105.3	2430	57	38.4
3	98.4	2360	61	40.5
4	90.8	2260	66	41.7
5	87.7	2160	68	44.9

From the Table above, it is evident that there are differences in the amount of fuel that is needed. From here, we can then calculate the exact numbers of fuel flow during flight.

3.2 Calculation of Cruise Fuel Consumption

There will be two fuel flows that needs to be calculated, the actual fuel flow and the POH fuel flow.

3.2.1 Actual Fuel Flow Calculation

The actual fuel flow is acquired from calculating the flight from *Pondok Cabe* to *Bandung* with the distance of 100 Nm and in the altitude of 5000 ft for 5 times in varying speeds with intial fuel weight of 159.1 liters. The calculation and the result are as follows:

$$\mathit{Fuel\ flow} = \frac{32.8}{0.8833333} = 37.13 \text{ lt/jam}$$

Table 2 Actual Fuel Flow

No	TAS (Kn)	Rpm	Time Travel (min)	Fuel Flow (lt/hour)
1	113.5	2530	53	37.13207547

2	105.3	2430	57	40.42105263
3	98.4	2360	61	39.83606557
4	90.8	2260	66	37.90909091
5	87.7	2160	68	39.61764706

3.2.2 POH Fuel Flow Calculation

PRESSURE ALTITUDE FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2000	2500	---	---	---	76	114	8.5	72	114	8.1
	2400	72	110	8.1	69	109	7.7	65	108	7.3
	2300	65	104	7.3	62	103	6.9	59	102	6.6
	2200	58	99	6.6	55	97	6.3	53	96	6.1
	2100	52	92	6.0	50	91	5.8	48	89	5.7
4000	2550	---	---	---	76	117	8.5	72	116	8.1
	2500	77	115	8.6	73	114	8.1	69	113	7.7
	2400	69	109	7.8	65	108	7.3	62	107	7.0
	2300	62	104	7.0	59	102	6.6	57	101	6.4
	2200	56	98	6.3	54	96	6.1	51	94	5.9
	2100	51	91	5.8	48	89	5.7	47	88	5.5
6000	2600	---	---	---	77	119	8.6	72	118	8.1
	2500	73	114	8.2	69	113	7.8	66	112	7.4
	2400	66	108	7.4	63	107	7.0	60	106	6.7
	2300	60	103	6.7	57	101	6.4	55	99	6.2
	2200	54	96	6.1	52	95	5.9	50	92	5.8
	2100	49	90	5.7	47	88	5.5	46	86	5.5
8000	2650	---	---	---	77	121	8.6	73	120	8.1
	2600	77	119	8.7	73	118	8.2	69	117	7.8
	2500	70	113	7.8	66	112	7.4	63	111	7.1
	2400	63	108	7.1	60	106	6.7	58	104	6.5
	2300	57	101	6.4	55	100	6.2	53	97	6.0
	2200	52	95	6.0	50	93	5.8	49	91	5.7

Figure 2 POH Fuel Flow Data

With the actual fuel flow acquired, the calculation of the POH fuel flow based on the data from Figure 2 using interpolation equation in 5000 ft in the standard temperature column is:

$$\mathrm{Y} = \mathrm{Y1} + \frac{\mathrm{X} - \mathrm{X1}}{\mathrm{X2} - \mathrm{X1}}(\mathrm{Y2} - \mathrm{Y1})$$

$$\mathrm{Y} = 48 + \frac{5000 - 4000}{6000 - 4000}(47 - 48) = 47.5$$

Table 4 POH Fuel Flow

Altitude	RPM	BHP	KTAS	GPH	Lt/hour
5000	2100	47.8	88.8	5.6	21.16
	2200	53	95.5	6	22.68
	2300	58	101.5	6.5	24.57
	2400	64	107.5	7.15	27.02
	2500	71	113.5	8.45	31.94

3.3 Efficiency Calculation

With the data acquired, it is necessary to then calculate the efficiency. It is done by using the actual fuel flow along with the POH fuel flow that has been calculated previously. However, a conversion needs to be done, from mass to weight and from knot to meter per second.

Mass to weight conversion:

$$\begin{aligned} \mathrm{W} &= \mathrm{m} \times \mathrm{g} \\ &= 943.1\ \mathrm{Kg} \times 9{,}8 \mathrm{m/s^2} \\ &= 9242.38\ \mathrm{N} \end{aligned}$$

Knot to meter per second conversion:

$$\begin{aligned} \mathrm{V} &= V_{kt} \times \mathrm{m/s} \\ &= 87.7\ \mathrm{Knot} \times 0.514\ \mathrm{m/s} \\ &= 45.0778\ \mathrm{m/s} \end{aligned}$$

After acquiring the numbers, we then can calculate the propeller efficiency. However, we need to do it in steps, starting from the lift coefficient, drag coefficient, drag, and efficiency.

Lift coefficient calculation:

$$Cl = \frac{L}{\frac{1}{2}\rho V^2 S}$$

$$Cl = \frac{9242{,}38}{\frac{1}{2}\times 1{,}225\times(45{,}0778)^2\times 16{,}2} = 0.458392$$

Drag polar is then used to calculate the drag coefficient:

$$Cd = Cd_0 + k(CL)^2$$

$$Cd = 0{,}033 + 0{,}035(0.45839)2^2$$

$$= 0.040354$$

Since the flights are carrying the same weight, so drag equals thrust, which means:

$$D = \frac{1}{2}\times \rho V^2 SCd$$

$$D = \frac{1}{2}\times 1.225\times(45.0778)^2\times 16.2\times 0.040354$$

$$= 813.648 \text{ N}$$

To know the propeller efficiency, the plane's power is needed, but it needs to be converted to Joule/sec and multiplied with %BHP in Table 3, resulting in:

$$\text{Pa} = 160 \text{ Hp} = 119312 \text{ watt}$$

$$\text{P} = \%\text{BHP} = 0.478\times \text{Pa}$$

$$\text{Pa} = 0.478\times 119312$$

$$= 57031.1 \text{ watt}$$

Efficiency calculation:

$$\eta = \frac{T\times V}{Pa}$$

$$\eta = \frac{813.648\times 45.0778}{57031.14}$$

$$= 0.643113$$

From the calculations above the propeller efficiency then can be calculated, resulting in:

Table 5 Propeller Efficiency

m	S	rho	v (m/s)	W (N)	CL	CD	D (N)	T	Pa	Efficiency
943.1	16.2	1.225	45.0778	9242.38	0.458392	0.040354	813.648	813.648	57031.14	0.643113
943.1	16.2	1.225	47	9242.38	0.427627	0.0394	851.5656	851.5656	63235.36	0.628503
943.1	16.2	1.225	50.7832	9242.38	0.361179	0.037566	961.2878	961.2878	69200.96	0.705442
943.1	16.2	1.225	54	9242.38	0.317965	0.036539	1062.076	1062.076	77552.8	0.741224
943.1	16.2	1.225	58	9242.38	0.273681	0.035622	1202.962	1202.962	84711.52	0.828454

The calculations of the fuel flows are making it apparent that there are differences in the numbers. Table and graph are provided make it easier to read.

Table 6 Fuel Flow Comparison

KTAS	Fuel Flow (POH)	TAS	Fuel Flow (Actual)
88.5	21.16	87.7	39.61764706
95.5	22.68	90.8	37.90909091
101.5	24.57	98.4	39.83606557
107.5	27.02	105.3	40.42105263
113.5	31.94	113.5	37.13207547

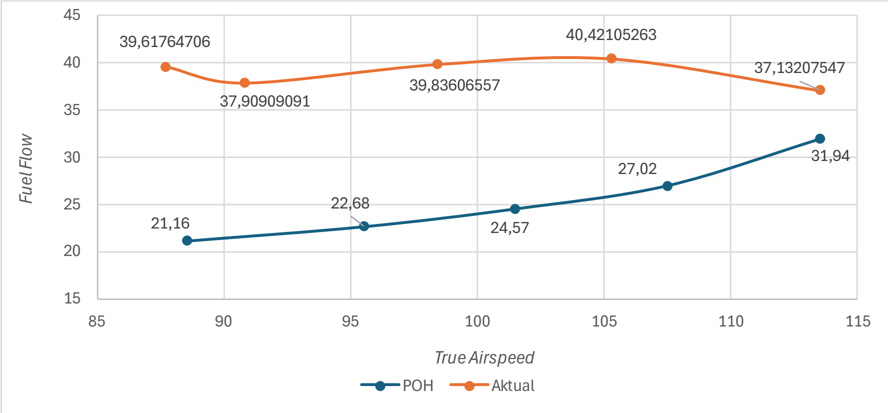

Figure 3 Comparison Graph between Actual Fuel Flow and POH Fuel Flow

The graph in Figure 3 showed that there is an indication of performance difference between the actual fuel flow that is higher than the POH, this might also show that on high performance condition, fuel efficiency in actual condition is lower compared to the POH. For example, at 87.7 knots the actual fuel flow is 39.61 lt/hour, while the POH at 88.8 knots is only 21.16 lt/hour. This can be caused from numerous causes, such as machine condition, temperature, and air pressure.

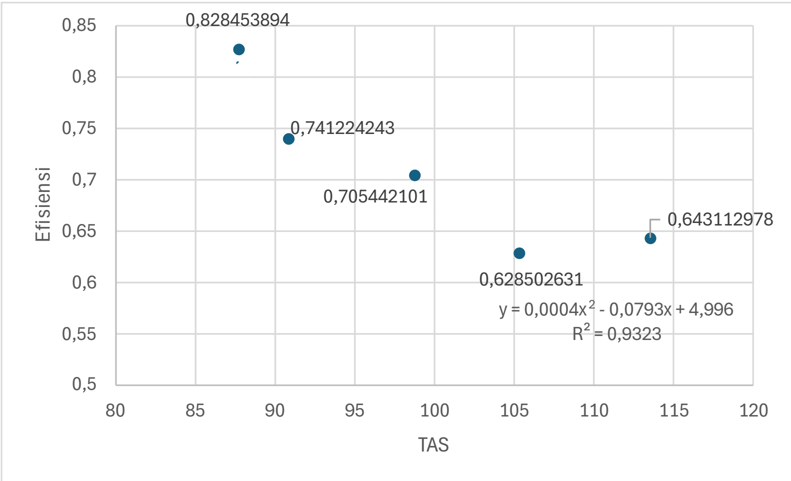

Figure 4 Propeller Efficiency Graph

From Figure 4 where we see the correlation between propeller efficiency and true airspeed, we can see that propeller efficiency decreases along with the increase of true airspeed. At the speed of 87.8 knots for example, the propeller efficiency is at its highest its optimal efficiency, in 82.8%. When the true air speed increases up until 100 knots, the propeller efficiency gradually decreases into its lowest, 62.8%. This is actually not uncommon because Cessna 172 is usually used for short-distances flight with high fuel efficiency needs. Because of this, the propeller is in its peak performance during low-speed flight and will experience decrease when used in high-speed flight.

The results indicate that actual fuel consumption is consistently higher than POH estimates, which aligns with previous findings in larger aircraft models like the Boeing B737-800 NG [5] and turboprop aircraft like the King Air B200 [7]. Similar discrepancies in flight performance modeling have been highlighted in studies on piston-engine aircraft and the interpretation of POH data [13]. Other research on multirotor cruise efficiency under varying wind conditions has demonstrated that optimal cruise airspeed selection plays a crucial role in overall system efficiency, especially in urban air mobility contexts [4]. The influence of human factors and decision-making in uncontrolled airspace, as discussed by Haberkorn [3], may also partially explain deviations in pilot-managed cruise conditions. Additionally, control system design and flight stability, such as those explored by Sukandi in longitudinal motion control [2], may offer further insight into operational variance under real-flight conditions.

CONCLUSION

This research demonstrates that the actual cruise fuel consumption of the Cessna 172 significantly exceeds the estimates provided in the Pilot Operating Handbook (POH), indicating a notable decrease in operational efficiency under real-world conditions. The study also finds that propeller efficiency is highest at lower cruise speeds and declines as the aircraft's speed increases, suggesting that the Cessna 172 is aerodynamically optimized for lower-speed operations. Furthermore, the observed discrepancies between expected and actual performance are likely influenced by several operational factors, including engine wear, ambient temperature, and altitude. These findings emphasize the importance of selecting optimal cruise speeds to balance fuel efficiency and performance. Future studies are encouraged to expand this analysis to different aircraft models and to consider environmental variables under more controlled conditions for a more comprehensive understanding of aircraft efficiency.

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