Mini-Project 3

Configuration Aerodynamics AE4802

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This project uses some visuals and calculations to help us understand the performance of a small, single-engine aircraft of given properties (Table I), to which I will hitherto refer as "Larry."

Table I: Properties of our aircraft, Larry

Weight	32,000 lbs
Span	65 ft
AR	7
Oswald efficiency number	0.8
Parasite drag	0.0270
Cl max	1.3 (with flaps up)
Engine	1 JT8D engine

Problem 1

Figure 1 shows a skymap of rate of climb for Larry. The red hatched line corresponds to the limit of Larry's flight envelope constrained by Cl_{max}. The blue hatched line corresponds to the limit of Larry's flight envelope constrained by maximum specific power = 0. The green contours show rate of climb.

Rate of climb was calculated using eq 1.

(Eq1) $$ROC = V sin\theta = \frac{P_{avail} - P_{req}}{W}$$

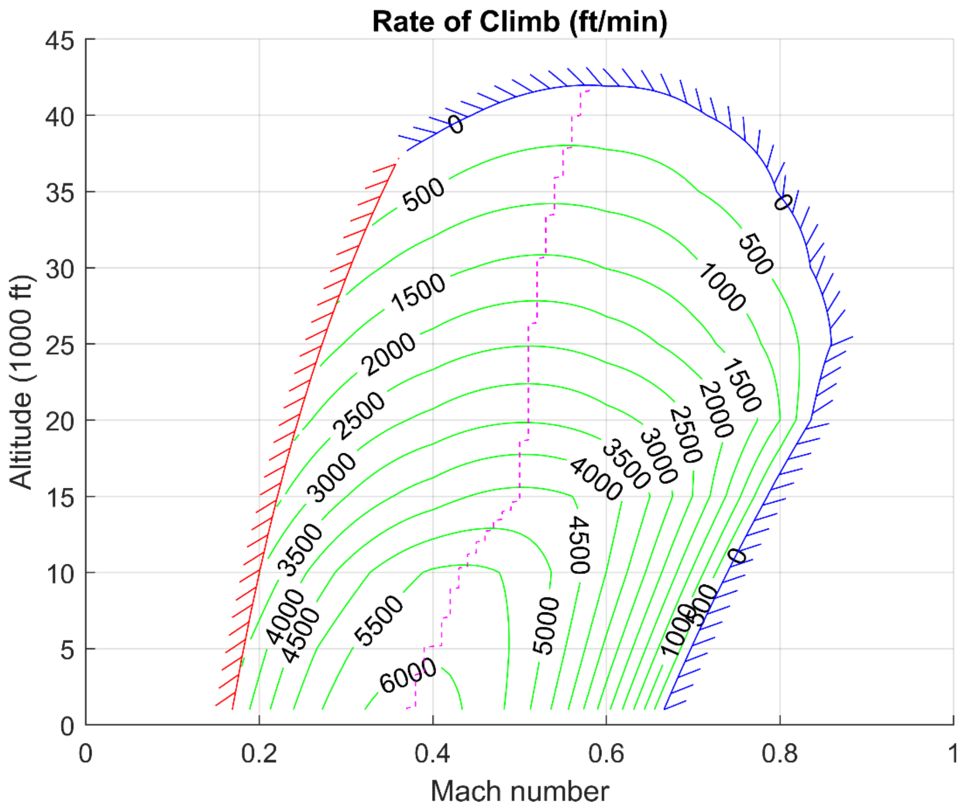

Figure 1: Skymap of ROC for our Aircraft

Figure 1 illustrates that Rate of Climb lowers with altitude, but also has a maximum somewhere between the limits of the flight envelope.

(Eq2)
$$Time\ to\ climb_{min} = ROC_{max}$$

The dotted magenta line on Figure 1 shows the path corresponding to the minimum time to climb. The individual points were calculated using Equation 2 by finding the maximum ROC for a given altitude. It looks like as altitude increases, the minimum time to climb increases with Mach number. At a high altitude a minimum time to climb is possible only at a higher speed and at a lower altitude, it is necessary to lower the speed to achieve a minimum time to climb.

Problem 2

Let's say that Larry has an unforeseen accident and loses its only engine at 10,000 ft. Eq 3 gives the range for a gliding aircraft at steady, level flight.

(Eq3)
$$R_{glide} = h\left(\frac{L}{D}\right)$$

This equation assumes a constant h (which is not the case) and forgoes the steps of integrating to find the changing conditions of Cl that leads to a change in Cd, a process necessary to capture the reality of changing density with altitude. However, because the altitude starts at 10,000 ft, which is not so significantly high, the assumption still can make for some preliminary and interesting data.

Figure 2 shows the curve that results when comparing glide range to initial velocity. In order to achieve the maximum range of 26 nautical miles, an initial velocity of 178 knots is necessary.

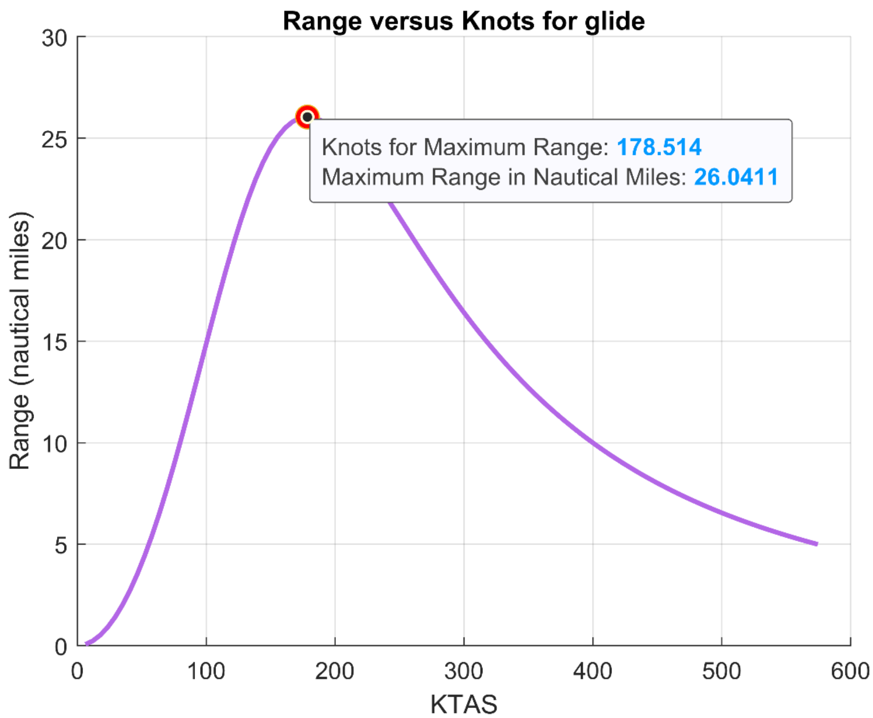

Figure 2: Range versus KTAS at a glide at an altitude of 10,000 ft

Let us now compare range to time aloft. Equation 4 shows that this requires dividing the equation for range by velocity.

(Eq4)
$$Time\ aloft = \frac{h\left(\frac{L}{D}\right)}{V}$$

Figure 3 shows that a maximum time aloft of 9 minutes can be achieved at 138 knots. This is a different speed than allows for our maximum range. If I were a pilot, I'm not sure which I would prefer: more time aloft in order to make decisions, or more range in order to get to safety. I assume that if I were in this situation, there would be many more factors involved, including available landing locations, speed at which I would need to land, etc. etc.

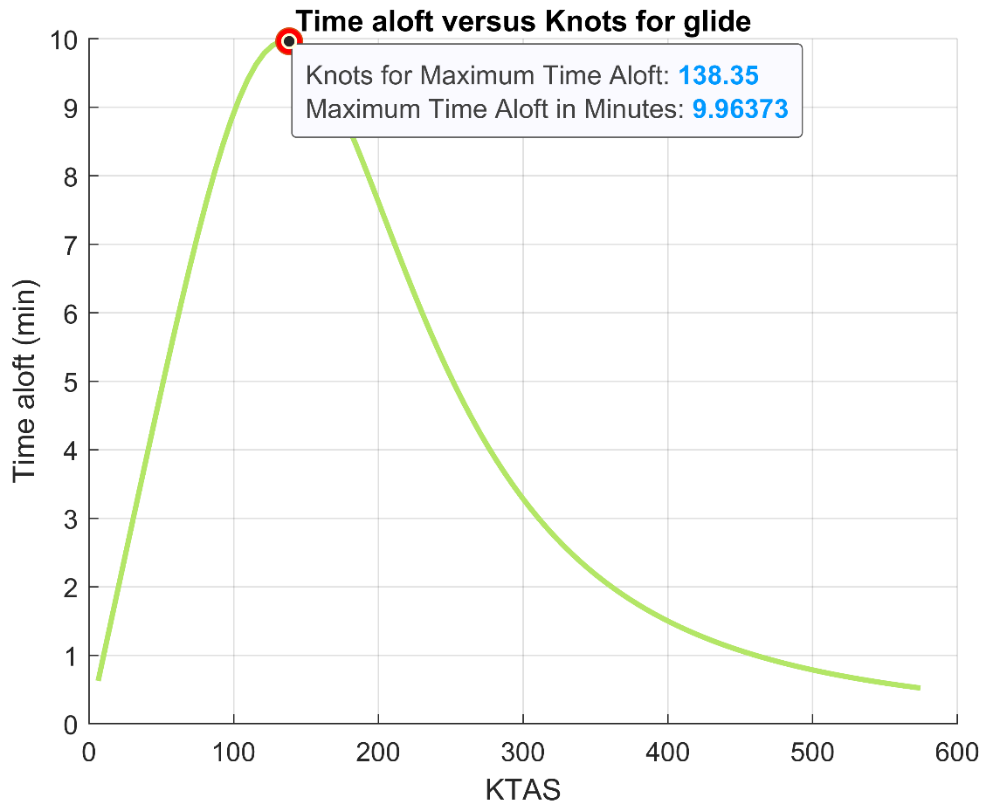

Figure 3: Time aloft vs. KTAS for gliding flight at 10,000 ft.

Problem 3

Larry has a maximum load factor of 3.5 g's. This means that Larry's structural limit prohibits the aircraft from maneuvering in such a way that 3.5 g's of load is applied to her airframe. Figure 4 shows the structural limit as a purple line on the V-n diagram.

There is another limitation on load factor, and that is the limit of maximum Cl. I calculated the load factor corresponding to maximum Cl using equation 5. Figure 4 shows this curve in a green line.

(Eq5)

$$n_{maxstall} = \frac{1}{2W}\rho_\infty V_\infty^2 SCl_{max}$$

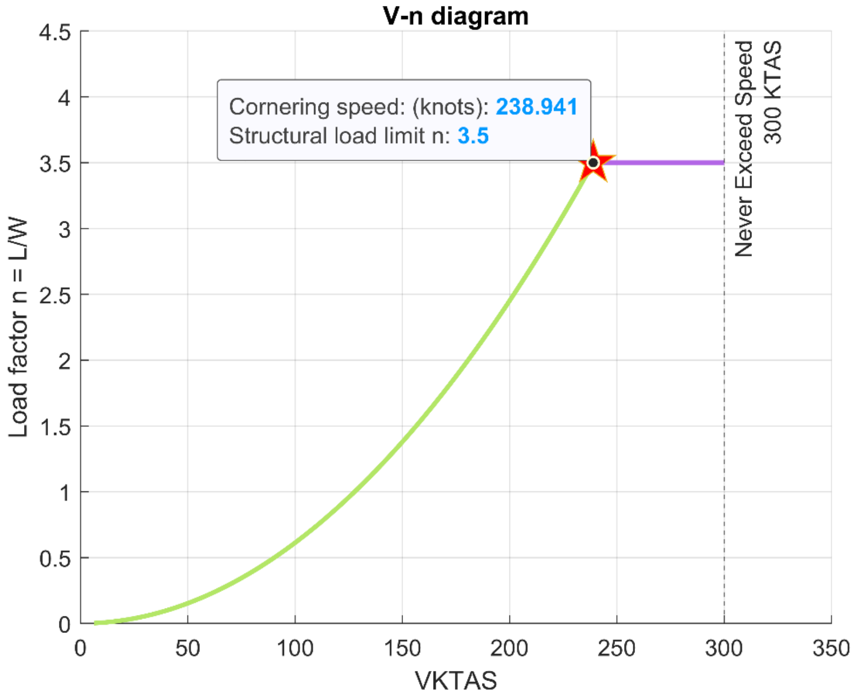

Figure 4: A V-n diagram for Larry

(The black dotted line shows the given speed at which to not exceed of 300 KTAS.)

The cornering speed is around **239 knots**. This is the fastest speed at which a turn can be accomplished without hitting the limits for structure and aerodynamics given. This number was found by solving for velocity in Equation 5 using the maximum load limit of 3.5 g's.

At this cornering speed, the level turn radius is around **1505 ft** and the turn rate is around **920 deg/min**.

In order to find the load factor limit defined by maximum thrust, I used Equation 6.

$$n = \left\{ \frac{\frac{1}{2}\rho_\infty V_\infty^2}{K(W/S)} \left[\left(\frac{T}{W}\right) - \frac{1}{2}\rho_\infty V_\infty^2 \frac{C_{D,0}}{(W/S)} \right] \right\}^{\frac{1}{2}}$$

(Eq6)

To find K, I used the Oswald efficiency given and AR given. For the thrust, I used the JT8D engine deck provided with the power code set to 50. Figure 5 shows the curve for the limit on load factor that corresponds to maximum thrust from Larry's single engine.

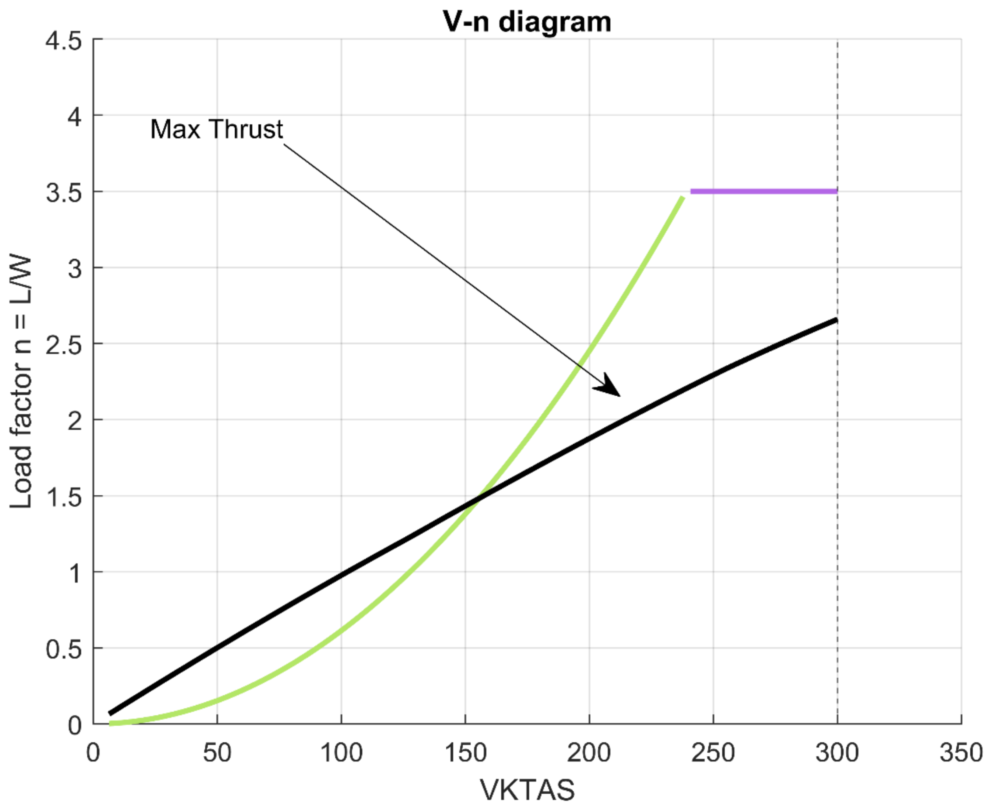

Figure 5: V-n diagram showing the addition of the Max Thrust curve for n as a black line.

Figure 5 shows that the limit for making a steady level turn is defined by Cl_max when under 150 KTAS, but between 150 and 300 VTAS, the load factor limit is defined by the maximum output of Larry's single engine. There is no danger in reaching Larry's structural load limit of 3.5 g's when accounting for load limit that corresponds to maximum thrust.