

Regarding thrust-producing engines, discuss the dilemma between performance versus...



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Performance Assignment Aim This assignment will discuss performance, efficiency and the effect of engine designs on these characteristics.

Performance and Efficiency Performance refers to the overall characteristics of an aircraft including straight and level flight, climb and range (Dole and Lewis, 2000). Performance is influenced by factors including weight, available thrust, altitude and aerodynamics of the aircraft. Efficiency refers to the range or endurance of an aircraft per unit of fuel, known as specific fuel consumption (SFC), or fuel flow per pound of thrust (Dole and Lewis, 2000). Important factors are the thrust to weight ratio of the engine, fuel consumption and the aerodynamic characteristics of the aircraft (Dole and Lewis, 2000). Overall engine efficiency is cycle efficiency x propulsion efficiency (Hunecke, 2010). Propulsion efficiency (η_p) = $2/(1+c/v)$ where c is exhaust speed and v is aircraft speed. Thus, maximum efficiency is achieved in a balanced equation. Looking at the equation, at takeoff, c exceeds v and thus η_p is low and as V increases η_p will increase however, to extend endurance, c is reduced (power reduction), once again affecting efficiency. In considering overall efficiency, propulsion efficiency must also be considered in relation the aircraft itself. One such method is the Oswald efficiency factor (FAA, 2001) whereby: $C_D = C_{D0} + (C_L)^2 / e AR$ where: C_D is the overall drag coefficient, C_{D0} is the zero-lift drag coefficient, C_L is the aircraft lift coefficient, is the aircraft circumference-to-diameter ratio e is the Oswald efficiency number, and AR is the aspect ratio. (FAA, 2001). From this equation in conjunction with the propulsion equation can be seen the multiplicity of factors that affect efficiency. The dilemma in performance versus efficiency arises from both design and operating environment. For

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example, a fighter jet may have low efficiency (a high SFC) however, the aircraft performance is high. Designers would attempt to maximise payload, time on station, manoeuvrability and speed to intercept (FAA, 2001). With respect to operating environment, aircraft efficiency is increased at higher altitudes as less fuel is used (drag is decreased) however, as air density decreases with altitude, thrust performance is decreased as incident airflow is less (Dole and Lewis, 2000). Management of the later is demonstrated by operating techniques such as stepped climb that provide the optimal range (performance) for SFC (efficiency). An increase in performance does not necessarily equate to an increase in efficiency. An inverse relationship normally exists. There are considerable trade-offs between the two and designers aim to achieve a balance relative to the aircrafts intended role.

Engine Designs Engine designs have increased the efficiency of engines through design modifications including to combustion chambers, compressors, turbines and air intakes. Examples of different engine designs and advances include (Mattingly, J., Heiser, W. and Pratt, D., 2003) (Hunecke, 2010) (Cumpsty, 2003); Development of turbofan engines to increase efficiency at higher speed. Development of turbojets over earlier piston engines to increase efficiency. Axial flow instead of centrifugal compressors for smaller diameter engine housings to improve performance. Use of reverse thrust technology to decrease stopping distances. Use of after-burners to increase acceleration performance. Use of carbon-fibre turbine blades to decrease heat energy loss and weight thereby improving performance and efficiency. Advances in fuel nozzle designs such as de Laval nozzle to increase efficiency. Use of multi-stage turbines with each stage

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operating at its optimal efficiency. References Cumpsty, Nicholas. (2003). Jet Propulsion (2nd ed.). Cambridge, UK: Cambridge University Press. Dole, Charles. E. and Lewis. James. E. (2000). Flight Theory and Aerodynamics: A Practical Guide for Operational Safety (2nd ed.). New York: Wiley-Interscience. Federal Aviation Administration (FAA). (2001). Aerodynamics for Naval Aviators. Newcastle, WA: Aviation Supplies & Academics, Inc. Hunecke, Klaus. (2010). Jet Engines: Fundamentals of Theory, Design and Operation. Wiltshire, UK: Crowood Press. Mattingly, J., Heiser, W. and Pratt, D. (2003). Aircraft Engine Design. Reston, VA: AIAA Education.