



AEROSPACE INFORMATION REPORT

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Rotorcraft Turboshaft Engine Idle Power Scheduling

RATIONALE

AIR4121 was originally drafted around 1998. It was first balloted by the committee in 2010 but remained unpublished. The document has been reviewed and updated for initial publication.

1. SCOPE

The purpose of this SAE Aerospace Information Report (AIR) is to provide rotorcraft and engine designers with a better understanding of turboshaft engine idle power characteristics and objectives to be considered in the design and integration process. For the purpose of this document, idle is the lowest suitable steady-state power setting, most commonly corresponding to a gas generator speed setting or range. In general, a lower engine idle setting is desired by the airframer to reduce noise, fuel consumption, and main rotor downwash when on the ground and to reduce the size requirement of a rotor brake system. In contrast, the engine manufacturer generally prefers a higher engine idle setting, as operation further away from the engine design speed involves more challenges in operability and mechanical design. A variety of rotorcraft and engine factors are described for consideration. Some typical engine power and torque trends are presented for illustrative purposes. The information contained herein may assist in the early design phase to result in a more optimum match between engine and rotorcraft requirements.

2. REFERENCES

2.1 Applicable Documents

There are no referenced publications specified herein.

2.2 Definitions

CRITICAL SPEED: A rotational speed that produces high vibratory strain energy in the engine or rotorcraft shafting in the presence of residual unbalance. Steady-state operation at or near this speed is undesirable, and engine or rotorcraft manuals may specify corresponding speed range(s) to avoid during operation.

DECOUPLED: An operating condition in which the engine output shaft is disengaged from the rotorcraft rotor system, characterized by zero output power. This condition is commonly encountered during autorotative flight, which can result from loss of engine power (power-off), or during maneuvers such as a rapid descent with engines operating (power-on), where main rotor speed is driven higher than engine output shaft speed. It can also occur on a multi-engine rotorcraft when engine throttles are set to different positions, causing one or more engines to become decoupled. It is also known as no-load or desynchronized operation.

FLIGHT: An engine operating control mode characterized by closed-loop governing to the nominal engine output shaft speed, whether on the ground or airborne. This mode is also known as FLY. Operation in FLIGHT at the minimum steady-state power setting (or minimum collective pitch) is casually known as flight idle; however, this term can be confusing because such operation also routinely occurs while on the ground.

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IDLE: An engine operating control mode characterized by operation at the minimum suitable self-sustaining steady-state power setting or throttle detent. Idle is most commonly defined by a physical or referred gas generator speed setting or range, sometimes as a schedule versus engine inlet temperature. For some engines or operating modes, idle may be defined as a power turbine or output shaft speed. Idle may also be effectively defined by a minimum fuel flow limit at certain conditions. Engine output shaft speed at idle is usually determined by the rotorcraft rotor system load because engine output power is too low to achieve governed main rotor speed. Idle is casually known as ground idle as it is primarily used during operation on the ground; however, this term can be confusing because idle operation may also be selected while airborne.

PERCENT OUTPUT POWER: Percent of normal engine takeoff power, which can be either rated takeoff or maximum continuous power depending on the manufacturer, at sea level static, standard day conditions.

PERCENT OUTPUT TORQUE: Percent of nominal engine output torque, which is typically based on torque at 100% output power and 100% speed. Other definitions of 100% torque may also be used, such as the rotorcraft main gearbox or transmission torque limit.

PERCENT POWER TURBINE SPEED: Percent of nominal engine power turbine or output shaft speed. Typical governed range is from 75% to 105%.

ROLL-BACK: An uncommanded or uncontrolled engine gas generator deceleration. Causes of roll-back include, but are not limited to, compressor stall, excessive customer bleed, and water ingestion. Roll-backs are typically not recoverable in the engine idle power region.

3. CONSIDERATIONS FOR SETTING ENGINE IDLE POWER

3.1 Overview of Engine Idle

Idle is the lowest suitable steady-state power setting most commonly defined by a gas generator speed setting or range. At the idle setting, the engine does not produce enough power to achieve governed output shaft speed, in which case the output shaft speed is determined by the load imposed by the rotorcraft rotor system. The primary purpose of idle is to provide a minimum power setting that reduces noise, fuel consumption, and main rotor downwash during ground operation. A period of idle operation is often required to allow pressurization of lubrication seals and for thermal stabilization of the engine before acceleration to high power operation. Engines are also generally required to run at idle for a given period of time immediately preceding shutdown to ensure a consistent, uniform temperature distribution within the engine to minimize adverse life impact to critical rotating parts.

Although it is less common than a gas generator speed definition, some engines define idle as a governed power turbine or output shaft speed. This approach can be implemented as a default idle definition or as a special control mode to ensure that a power turbine critical speed is avoided or to optimize generator operation. This idle mode may not be intended for use in flight as it may operate at a governed speed lower than the speed nominally used for flight (typically 100%). Because this type of idle mode is similar to speed governing in FLIGHT mode but at a lower rotor speed that may be incapable of supporting sustained flight, pilot awareness of the different governed speed is important to mitigate safety risks associated with potential confusion of idle and FLIGHT modes.

3.2 Rotorcraft and Engine Factors

Many factors can influence, or be influenced by, the engine idle power setting. These factors are associated with design, functional, operational, and safety aspects of the rotorcraft and engine. Some of these factors are listed in Table 1, which summarizes the advantages of scheduling the engine idle at a lower or higher power setting. A lower idle power setting has several advantages, which are generally attractive to the airframer. Conversely, a higher idle power setting is generally desirable to improve engine-related considerations.

Table 1 - Advantages of different idle power schedule levels

Advantages of Scheduling Lower Idle Power	Advantages of Scheduling Higher Idle Power
• Reduced rotorcraft rotor brake torque requirements • Reduced noise • Lower fuel consumption • Lower engine and rotorcraft rotor speeds possible, offering more flexibility to avoid critical speed range(s) • Reduced engine compartment heat load • More margin for main rotor blade droop stop design and operation	• Increased engine/customer bleed air and power extraction capabilities • Shorter time to accelerate to governed output shaft speed • Engine less likely to experience off-idle stalls and/or unrecoverable roll-back • Engine oil less likely to leak through seals • Improved engine compartment cooling capability with shaft-driven blowers or entrained air ejector systems

The following sections discuss these factors and associated considerations in more detail. If the rotorcraft is equipped with an auxiliary power unit, then consideration of some of these factors may change or be eliminated. For instance, an auxiliary power unit may provide bleed air or power generation capability, which could eliminate that burden from the engine.

3.2.1 Rotor Brake

Lower idle power will reduce the rotorcraft rotor brake torque required to stop and lock or hold the main rotor, which directly influences the design and size of the rotor brake. More power is required to stop a turning rotor than to hold a static rotor. Some rotorcraft applications require the ability to brake a turning rotor with at least one engine running at idle, in which case a lower engine idle power setting is especially preferred to reduce the heat load and wear on the rotor brake. Starting an engine to idle with the main rotor braked and/or power turbine rotor locked may also be a requirement for some rotorcraft. Engine upgrades on legacy rotorcraft may result in a higher idle power than what the original rotor brake system design can safely accommodate.

At idle, the engine characteristic may be such that exhaust temperature increases as gas generator speed decreases due to operation further away from the gas generator and power turbine aerodynamic design points, which are usually at a higher speed and/or power condition. Furthermore, power turbine speed is zero during rotor brake use, resulting in minimal temperature drop across the power turbine. Therefore, the exhaust temperature is essentially equivalent to the power turbine inlet temperature. Power turbine exit swirl angles may also be significantly different with the rotor brake engaged. The combination of exhaust gas temperature and swirl angle in this condition should be considered in the design of power turbine, lubrication system, and exhaust system components.

3.2.2 Noise

A lower idle power setting results in lower rotorcraft rotor speed, engine gas generator shaft speed, and engine exhaust velocity, which should all reduce the noise level at idle.

3.2.3 Fuel Consumption

A primary reason for operating at idle instead of FLIGHT during ground operation is to reduce fuel consumption. The lower fuel flow at idle can significantly reduce fuel burn during preflight checks and especially during extended ground operation, such as maintenance runs. A lower idle power setting will further reduce fuel consumption because the gas generator should be at a lower speed, which requires lower fuel flow.