SAE INTERNATIONAL

AEROSPACE INFORMATION REPORT

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The Effect of Installation Power Losses on the Overall Performance of a Helicopter

RATIONALE

AIR5642 has been reaffirmed to comply with the SAE Five-Year Review policy.

INTRODUCTION

The engine installation on most helicopters will inevitably result in some loss of power when comparing the installed performance of the engine with the specification level for an engine run on a test bench. These losses are the result of a variety of mechanisms which are described in detail in ARP1702. In addition to these basic losses, there are additional sources of loss associated with the installation of specific items of equipment, such as intake sand filters, additional electrical generators, hydraulic pumps and infra red suppressors. It is important to understand the impact of these losses on the overall performance of the helicopter so that basic aircraft mission performance is not unnecessarily sacrificed and to ensure that the final combination of helicopter, engine and mission specific equipment will allow the mission performance objectives to be satisfied.

1. SCOPE:

The purpose of this SAE Aerospace Information Report (AIR) is to illustrate the effect of installation power losses on the performance of a helicopter. Installation power losses result from a variety of sources, some associated directly with the basic engine installation, and some coming from the installation of specific items of aircraft mission specific equipment. Close attention must be paid to the accurate measurement of these losses so that the correct aircraft performance is calculated.

Installation power losses inevitably result in a reduction in the overall performance of the aircraft. In some cases, careful attention to detail will allow specific elements of the overall loss to be reduced with immediate benefit for the mission performance of the aircraft. When considering items of equipment that affect the engine, it is important to understand the effect these will have on overall aircraft performance to ensure that mission capability is not unduly compromised. Alternatively, a clear understanding of these effects at the aircraft design stage may have an influence on the initial choice of engine size to ensure that mission performance targets are subsequently met. This report aims to give a general understanding of the effect of installation power losses on helicopter performance by the use of a set of example calculations.

2. REFERENCES:

1. “Helicopter Performance, Stability and Control”, RA Prouty, PWS Engineering, 1986

2. “Aerodynamics of V/STOL flight”, BW McCormick, Academic Press, 1967

3. INSTALLATION POWER LOSS MECHANISMS AND THEIR EFFECT ON ENGINE PERFORMANCE:

This section briefly reviews the loss mechanisms that can affect the installed performance of the engine and gives some typical relationships between the value of the loss and its consequent effect on engine power and specific fuel consumption (SFC). Clearly, the responses of individual engine types to specific loss mechanisms will differ and the actual losses will have to be obtained from the engine manufacturer's performance specification or customer deck. The response of engines will also differ depending on the way in which they are rated. Most loss mechanisms will reduce available power for temperature limited engines whereas some will yield no apparent loss for speed limited engines.

The basic installation losses may be considered under the following headings:

a. Inlet Total Pressure Loss: This has a powerful effect on engine performance with 1% pressure loss being typically worth 2% power loss for a given engine gas temperature. For a given power the engine would have to run to a higher gas temperature and this tends to offset some of the effect on SFC. Typically 1% pressure loss will cause a 1% worsening of SFC at a given power.

b. Inlet Temperature Rise: This can result from exhaust gas ingestion, anti-icing air discharge and ingestion of hot zone air through leaks in the inlet ducting. This problem will tend to be worse for a front drive engine installation that places the engine behind the rotor gearbox and therefore makes it more liable to ingest hot air from this source. A general rate of exchange is that 1 °C temperature rise will cause between 1/2% and 1% loss of power at a given gas temperature. Again, the effect on SFC at a power is less marked and would only amount to between 1/4 to 1/2% SFC degradation for a 1 °C temperature rise.

c. Compressor Air Bleed: This is used for cabin heating, air conditioning, engine inlet anti-icing, etc. On most engines bleed air extraction is quite costly, but the precise relationship between bleed flow and power loss will be dependent on the location of the bleed ports on the engine compressor. As an example 1% bleed flow taken from compressor delivery can cost 2 to 3% power for a given engine gas temperature. The effect on SFC is less marked because of the offsetting effect of the increased gas temperature at a given power. A 1% bleed flow taken from compressor delivery will cost between 1 and 1.5% SFC for a given power.

3. (Continued):

d. Exhaust System Pressure Loss: The aircraft tailpipe may impose a higher back pressure on the engine than the referee tailpipe. This may result from a less effective geometry giving reduced static pressure recovery and from the need to provide energy to power an ejector to entrain additional air for bay cooling purposes. As a general rule a 1% pressure loss will cause a 1% loss of power and a 1% increase in SFC.

e. Mechanical Power Offtake: Mechanical power may be extracted from either the gas generator rotor or power turbine drive train in order to power a variety of accessories such as electrical generators, hydraulic pumps, cooling fans, etc. Power extraction from the gas generator shaft is generally more expensive than that taken from the power turbine.

4. POWER LOSSES ASSOCIATED WITH VARIOUS TYPES OF EQUIPMENT:

The losses discussed above can apply to any aircraft in its standard configuration. For many helicopters, both military and civil, it may be necessary to add items of mission specific equipment when carrying out certain missions. These additional items of equipment will often affect the power available to the helicopter and will therefore adversely affect aircraft performance.

Some examples of equipment that can degrade the performance of the power plant on the helicopter are given below.

a. Intake Sand Filter: This will usually impose additional intake losses on the engine and these will have the same effect, only more severe, as the standard aircraft intake pressure losses discussed above. In addition it will usually be necessary to provide some means of scavenging the extracted sand and dust from the intake filter. This may take the form of a mechanically powered fan, compressor or turbine bleed air powered ejector or exhaust gas powered ejector. All of these scavenge mechanisms will further reduce the power available to the helicopter.

b. Additional Power Offtakes: These may be required to power additional electrical generation or to provide the drive to hydraulic pumps associated with heavy duty winches. The effect on engine performance will be as discussed above for mechanical power extraction.

c. Infra Red Suppression: This will give rise to additional exhaust pressure losses resulting from the mixing of the engine exhaust with ambient air to reduce the plume temperature. The effect on engine performance will be as discussed above for exhaust system pressure losses.

The geometry of the exhaust pipe can account for some thrust benefit. If the exit area is changed, as part of the IR suppressor design, the thrust due to the engine could be changed.